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Improving warehouse control at Royal Vezet B.V.

A simulation study on dynamic warehouse processes

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“Change is the law of life.

And those who look only to the past or the present are certain to miss the future.”

John F. Kennedy

Management summary

For many years, Vezet has faced growth in turnover and production volume. The production facility in Warmenhuizen is recently expanded, new machines are bought and new products types are introduced, but the warehouse operations have not fully participated in this growth. So, Vezet encounter more often problems with storing products in the warehouse. The managers of Vezet decided that it is time to review the warehousing performances and to research the future requirements at warehouse level. In order to perform this research, we formulated the following research question:

> *"What improvements does Vezet B.V. require at the outbound processes (in terms of storage capacity and investments) to meet the current and future requirements in a way that the service level remains ensured?"*

We identified multiple topics which were relevant for warehousing, and concluded that the *volume utilization* and *location utilization* were the most important measures for the Vezet warehouses. In the EA-warehouse (managed by Dailycool), the main problem is related to the location utilization, while in the EAA-warehouse, the main problems are related to the volume utilization of individual locations. We created a model that is able to analyze the warehouse processes. This model helps us to acquire understanding about the warehouse operations.

In the EAA-warehouse, we have to deal with two events that require immediate attention. The introduction of new products and the switch of **X** products to the LVC, require changes in the current lay-out of the warehouse. Also, additional storage space for the LVC-products is required, which is urgently recommended to be located close to the alley at the COOP storage area. This is the only suitable location that can be used for storing these rollies. By the end of 2015, the LVC destination will be replaced by a new distribution center, the SFC. We concluded that these changes lead to storage problems, and that the best solution is to directly send these products to the SFC.

The production capacity of Vezet will also be expanded at the end of 2015, at the expense of the storage area of COOP. This intended expansion cannot occur before the switch from LVC to the SFC, because it leads to the outsourcing of the COOP activities due to space problems. This is not desired by the management. After the switch to the SFC, the COOP activities can be transferred to the current EAA-warehouse, because inventory of SFC-products is held in the SFC and not at Vezet.

In the EA-warehouse, we found patterns in the location utilization that enlarges the current problems. One important reason for these problems is that production and distribution in the EA-warehouse are currently not aligned. Therefore, we suggest that the order pickers in the EA-warehouse start at the same time as the production employees. This increases personnel costs, but ensures that the capacity of the warehouse does not have to be expanded until 20**XX**.

Also, we conducted a strategic analysis, which we used to analyze the future until 2025. We translated the model, we used before, into a simulation model which is able to simulate the future processes in the EA-warehouse. We include the tactical events (like the switch of **X** products from the RDC to the LVC) in the simulation model. This ensures that the model provides a realistic image of the future. There are two factors important for this analysis: the volume growth and the product range growth. Growth is expected for both factors, respectively **X** and **X** percent per year. From the simulation model, we see that serious warehouse space problems occur. This is presented in table 0-1. The daily production volume and the number of product types are input for the model. This enables us to simulate the warehouse processes in detail for the next years and to identify the

utilization rates and the number of problems. In the table, we see that the frequency of problems is already every five days. By the improvements we suggested, the frequency of problems will decrease shortly. However for the remaining years more problems must to be expected.

xx

Table 0-1: Simulation results EA-warehouse

In 20**XX**, an expansion of **X** percent of the current warehouse area is required. However, we recommend Vezet to be prepared for the future (2025) and expand the warehouse building by **xx** percent, which equals **X** square meters.

The warehouse processes and operations are currently well-considered, but face several problems. We made some suggestions to improve these processes for a short period. However, we expect the warehouse to be too small within a few years, and expansion is required.

Glossary

BT	Battery truck
DC	Distribution Center
EA-warehouse	Eindproduct,Artikelen warehouse (warehouse of Dailycool)
EAA-warehouse	Eindproduct,Artikelen,Assemblage warehouse (warehouse of Expedition)
FeFo	First-Expired First-out
JIT	Just-In-Time
KPI	Key Performance Indicator
LVC	National Fresh Center (Dutch: Landelijke Vers Centrale)
MPC	Manufacturing Planning and Control
RDC	Regional Distribution Center (Dutch: Regionaal Distributie Centrale)
Rolly	Half sized Euro pallet on wheels
SFC	Shared Fresh Center
SKU	Stock Keeping Unit
TSL	Temporary Shipping Location
Cooking convenience	Department at Vezet (Dutch: Kookgemak)
Meal convenience	Department at Vezet (Dutch: Maaltijdgemak)
Fruit Convenience	Department at Vezet (Dutch: Fruitgemak)

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1. Research design

To complete the study Industrial Engineering and Management – Production and Logistics Management at the University of Twente, students have to perform an assignment at a company. This master thesis provides an overview of the assignment done at Vezet B.V. in Warmenhuizen by the author. Section 1.1 describes the company profile including key figures, history and the departments involved in this research. In the following sections, the research proposal is presented, starting in section 1.2, which explains the project motivation. In section 1.3, the problem statements are explained, followed by the research objectives in section 1.4. Finally, the research questions and approach are presented in sections 1.5 and 1.6.

1.1. Company description

Royal Vezet B.V. (hereinafter referred to as Vezet) is the leading specialist in processing freshly chopped, ready to cook vegetables and fruits in the Netherlands. Each week an average of **XX** million kilograms of raw materials like onions, carrots and cauliflower is turned into products like *'Nasi en Bami groente',* '*Chinese Roerbakmix'* and *'Hutspot'*. Besides these items, Vezet also produces fruit salads, fresh pizzas, meals and large salads.

Vezet was founded in 1914 by three sauerkraut producing companies as '*Verenigde Zuurkoolbedrijven'* (VZ). In 1973, Vezet started producing for Albert Heijn, the Dutch retail supermarket. Albert Heijn is owned by the Dutch supermarket operator Royal Ahold N.V. and has the largest number of supermarket stores in the Netherlands. At that moment, the diversity in products was low, but volumes were rising. This was extended by the introduction of ready-to-cook lettuce in 1989 and stir-fry vegetables in 1994. Due to the introduction of new products like large salads in 2005, fruit salads in 2008 and fresh pizzas in 2012, as well as increasing volumes, the plant in Warmenhuizen required expansion, the latest was realized in 2013. Vezet became a co-maker in Supply Chain of Albert Heijn, which means that Vezet is responsible for the processes until the distribution centers of Albert Heijn, whereas Albert Heijn provides full information about sales and forecasts. Together, they deliver freshly chopped vegetables to consumers at high service levels and minimum costs. In 2013, more than **X** million units were sold to Albert Heijn. At this moment, the sales to Albert Heijn represent about **X** % of the total revenue of Vezet. The other sales consist of products for **X** COOP distribution centers (DCs) in Denmark, and small fruit snacks for Lekkerland and DeliXL. All activities combined resulted in a turnover of **X** million euro in 2013.

Production process

Consumers demand freshly cut vegetables and fruits to be as fresh as possible and with the highest quality, which has clear implications for the supply chain of Vezet. In figure 1.1, we present a general impression of the supply chain of fresh-cut vegetables and fruits at Vezet. From this figure, we see that the decoupling point of Vezet is in the distribution centre of Albert Heijn. This is a consequence of the agreements that Vezet and Albert Heijn have made. For a detailed version of the supply chain map, we refer to appendix D. In the remainder of this section, we describe the internal processes at the production facility in Warmenhuizen. We use an indication number for each process step, which corresponds with the same number in the lay-out of the plant (see figure 1.2).

The production process of freshly cut vegetables and fruits starts at the suppliers (for example, the field of the farmers). During the winter months, materials are mostly bought in the South-European countries, while in the summer most raw materials are bought locally. When these raw materials are needed for production at Vezet, the suppliers transport their products to the receiving docks (see 1).

The raw materials are stored at a raw-materials warehouse (see 3), from which they can easily be retrieved when needed for production.

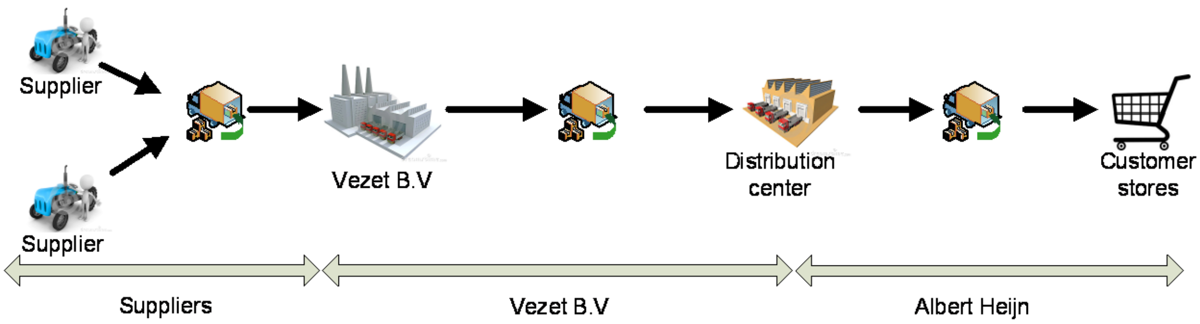

Figure 1-1: General impression of the supply chain for fresh-cut vegetables, including decoupling points.

When needed for production, the raw materials are taken from the raw materials inventory and transported to the preprocessing lines (see 4). At these lines, the products are washed, peeled and/or cut into smaller pieces. These products are temporarily stored in a warehouse in the factory (see 5). As soon as those semi-finished products are required for the next production step, they will be transported to the production lines.

Figure 1-2: Vezet lay-out (December 2014)

In December 2014, a wide range of products is produced at Vezet which can be divided into three divisions: *Cooking Convenience (see 6)*, *Fruit Convenience (see 7)* and *Meal Convenience* (including pizza production, see 8). The oldest and biggest division is *Cooking Convenience* with **X** production lines, which produces **X** different products like '*Boerenkool'* and '*Boerensoepgroenten'*. On average, this division produces more than **X** packages per week. The more recently introduced division, *Meal convenience* can produce **X** different products on **X** production lines, resulting in **X** packages per week on average. The last category, *Fruit convenience*, produces **X** packages per week and has **X** production lines.

Finished goods inventory

At the production lines, the products are sorted, mixed, weighted and finally put into packages. The packages are put into plastic crates and placed on a load carrier, i.e., a pallet or rolly. The number of crates stacked on a load carrier may vary, due to demand, dimensions of the crates or end-of-production-run. The finished products are then transported to the finished goods warehouse, which is either at Dailycool (9) or at Expedition (10 and 11).

In order to group products, the finished goods warehouses are divided into storage zones that contain a number of stack places. Eight zones can be identified, each has its own characteristics (see table 1-1). The location numbers are used by the software system and currently do not have specific meaning (e.g., zone 5 is currently not used). Dailycool is responsible for the zones 1 - 4, which contain high volume Albert Heijn products, stacked on pallets. These products need to be transported to the Regional Distribution centers (RDCs) of Albert Heijn. At the Expedition warehouse, four storage zones can be identified. Zone 7 and 9 contain special, low volume Albert Heijn products destined for the National Fresh Center (LVC) of Albert Heijn, zone 6 contains products for the COOP distribution centers in Denmark, and the last zone (8) consists of products for Albert Heijn supermarkets in Germany. Anno December 2014, the following zones are used:

Storage zone	Responsible	Type of products	Storage unit
1	Dailycool	High volume AH	Crates / Pallet
2	Dailycool	High volume AH	Crates / Pallet
3	Dailycool	High volume AH	Crates / Pallet
4	Dailycool	High volume AH	Crates / Pallet
6	Expedition	COOP/DeliXL/Znek	Carton boxes / Pallet
7	Expedition	Low volume AH	Crates / Rolly
8	Expedition	German AH	Crates / Rolly
9	Expedition	Low volume AH	Crates / Rolly

Table 1-1: Storage zone characteristics

Dailycool

For the storage of high volume finished goods, Vezet uses the services of an in-house 3PL provider: Dailycool. This company is part of '*Schot Groep*' and operates mainly for Vezet (**X** %), but also transports fresh products for other companies in order to spread costs and increase revenues. These extra transports only occur when Vezet does not need services of Dailycool. The work of Dailycool can be divided into four parts:

1) Storage and picking of the finished products in the in-house warehouse
2) Planning of the docks and trucks
3) Transportation of the finished products to the distribution centers of AH
4) Transportation of empty crates from the distribution centers to Vezet

The finished products destined for one of the RDCs of Albert Heijn, are put into crates and stacked on Euro pallets (100 * 120 cm). These pallets are moved to the warehouse of Dailycool, stored at a storage location and picked when needed. When a truck is fully loaded with products, it may be sent to one of the RDCs or it is moved to a temporary on-site parking location. The truck remains at this parking location until a driver is available and the time window for that RDC has opened. At the RDC (Zaandam, Pijnacker, Tilburg or Zwolle), the truck with finished products is unloaded and employees of the RDC move these products to the right storage location. Meanwhile, the truck is loaded with empty crates that are required for production at Vezet. Then, the truck is sent to Warmenhuizen. At the receiving area the empty crates are unloaded and can be used for a new production cycle.

When the finished goods storage of Dailycool (also called EA-warehouse) was built, it was designed as a possible production location, which means that this location is not really suitable for storage facilities. This can be seen by, for example: differences in heights of the location, number of pillars at inconvenient places and fire sprinklers that limit the stacking of pallets. Especially during rush hours, this results into a lack of stacking places. This is an undesirable situation, and can eventually lead to dangerous situations. In figure 1-3, we see a part of the storage location of Dailycool. The pallets are stacked on top of each other, and no racks are used, because it is assumed that this current way of working ensures easy retrieval and high productivity at low costs.

Figure 1-3: Pallets at Dailycool

The detailed lay-out of Dailycool is pictured in figure 1-4. There are three locations from which ingoing products can origin, two of these locations are: C*ooking* C*onvenience* and P*izza*- & *Fruit* C*onvenience* (see figure 1-2). The third location can be found at the docks/exit. It is, due to lay-out problems, not possible to transport the products of *Meal Convenience* internally, so these products are transported to the nearest dock at M*eal Convenience*, put into a truck and then transported to the warehouse of Dailycool.

A product, stored in the Dailycool warehouse, can always be found in the same zone, but within a zone, the products are stored randomly. There are certain restrictions for storing the products. A location can at most hold one kind of product, which means that 'Soepgroenten' can never be placed at the same location as 'Nasi en Bami groenten'. Moreover, a location cannot hold one type of product with different production dates. This means that the 'Maaltijdsalade Geitenkaas' produced today cannot be placed at the same location as the 'Maaltijdsalade Geitenkaas' produced yesterday. However, these products can be placed nearby each other, as long as this will not lead to order pick errors. These restrictions are implemented to assure that products are picked FEFO (First-Expired First-out) and to prevent mistakes. As soon as a storage location becomes empty, it can be used by another product.

Figure 1-4: Dailycool lay-out (December 2014)

Expedition

At the other finished goods operator, the Expedition department (see figure 1.5), we find a high variety of low volume products that are destined for the National Fresh Centre (LVC) of Albert Heijn in Nieuwegein. These products are stacked on rollies and therefore require a different storage method. It would have made more sense to store all products on the same storage unit (either pallet or rolly), but this is not possible because of crossdocking restrictions set by Albert Heijn. It is more convient to use rollies on small stores like AH-to-go shops, while large supermarkets can be supplied with pallets. In the storage facility of Expedition, also called EAA-warehouse, we see for example: AH-to-go products, meal salads and stews. Expedition has, in December 2014, two locations in the factory. The main location is the storage location of Albert Heijn products, in zone 7 and 9, which is pictured in Figure 1-6. The total available area at these locations is, including aisles, **X** square meters. Products can enter from two directions: *Cooking Convenience* or *Meal* & *Fruit Convenience*. These products are stacked on rollies and manually transported from its production location to their storage location.

Figure 1-5: Rollies at Expedition

Contrary to Dailycool, we see that dedicated storage is used at Expedition. This means that every product within Expedition has a fixed location. Expedition uses this way of storing, because it is less sensitive to errors and a high throughput can be accomplished (compared to random storage). A rolly is taken to its location within the zone and has to wait until the products are needed for distribution. As soon as a product is required for distribution, it can be picked. The rolly can now be transported to one of the two temporary shipping locations (TSL A or B). Rollies can be placed at the Temporary Shipping Locations (TSLs) and wait until a truck is available at the docks. This is necessary, because there are no sufficient docks at this side of the factory, i.e., only two docks can be used. These docks are used for inbound flows (i.e., clean empty crates), transportation of products from meal convenience to Dailycool and the outbound flow of Expedition.

The TSLs can be seen as an extended storage location, because when a product is picked, it remains at the TSL until the truck is available. This will enable the order picker to handle multiple distribution orders and pick rollies before the actual distribution time, leading to low inventory levels in the zones 7 and 9. The cycle times at the TSL vary between 30 minutes to 6 hours.

Figure 1-6: Expedition lay-out (December 2014)

The above figure corresponds with point 11 in figure 1-2 and represents a part of the Expedition activities. In figure 1-6, we can identify two separate areas (on the left the TSLs and on the right zone 7 & 9). The one on the right is used for the storage of the products, while the location on the left is a temporary extension of the storage location. This is originally meant as an alley used for transportation through the plant. Currently, the lane is used for both storage and transportation, causing dangerous situations.

The lay-out of this EAA-warehouse reveals that this location was not intended to be used for storing finished products. We can see in- and outgoing processes crossing, causing inefficient situations. Expedition was sent to this side of the plant, because of the increasing need for storage locations, and the inability to create enough space at the other side of the plant.

A part of the Expedition activities is still performed at the other side of the plant (point 10 in figure 1-2). These locations are denoted as zones 6 and 8. The lay-out of these zones can be found in figure 1-7. It can be seen that this location is between the Dailycool warehouse and the production line. The total available space for the operations including aisles is 200 m^2. At zone 6, the COOP products are handled, while zone 8 contains tables that are used to sort the German AH and Znek products. The COOP products are received, stacked and put to its temporary storage location (based on destination). The COOP trucks are only sent once a day to Denmark, at around 21:00 hours, and contain all COOP products made that day. So, the inventory level of COOP products is zero at night. The product volumes for the German Albert Heijn stores are very small, and the operations are performed manually. Anno December 2014, four Albert Heijn stores in Germany are served by Vezet.

Figure 1-7: Lay-out zone 6 & 8 (December 2014)

1.2. Project motivation

Vezet has faced an increase in yearly production volume and revenues. The most important segment for Vezet, *Cooking Convenience´* grew **X %**, while the whole market grew 63% in that same period. The two other segments have faced approximately the same growth rates. The company invested millions of Euros to increase production capacity, by buying new production lines and hiring extra personnel. Due to the focus on increasing and optimizing production lines, the logistic processes were undervalued for years. When looking at the warehouse activities at Vezet, we see examples of inefficient and sometimes dangerous situations. It may happen that products are temporarily lost, accidents occur or even wrong products are sent to the customer. We notice products stored at odd places in the factory, crossing in- and outbound flows and many reach truck movements. Both Dailycool and Expedition employees are currently complaining about the capacity of the storage locations and indicate that the problems have become more severe in the last years. We heard statements like: "*It is hard to do our job in the right way*", "*Our warehouse is too small*", "*We require a new warehouse*" and "*Sooner or later, a major accident will happen".*

We see that the rush hours are the most problematic, because the inventory position is very high at these moments. In this case, new products cannot be added to the inventory, because there is no storage location available. Currently, we do not know the frequency, the impact and the main causes of these rush hours. Vezet needs to acknowledge the current warehouse problems and implement solutions that solve these problems.

On top of that, we see similar problems at the production sites. New production lines are placed, while the available space is nearly zero. The required space is taken from the storage facilities, because there is no other space to take. So, while Dailycool and Expedition require more square meters to store the finished products, they are forced to do their operations on a smaller area.

For the next 5 – 10 years, more growth is expected for Vezet. This growth is mainly caused by expansion of the number of Albert Heijn stores, by opening new stores and the acquisition of several C1000-stores by Albert Heijn. Albert Heijn also wants to broaden the range of fresh products, which can be derived from the annual report of 'Royal Ahold N.V': "*Albert Heijn is completely revamping its fresh departments to be better than ever. The goal is to offer a delicious, high-quality assortment of relevant products – including more healthy and responsible products – that is inspiring and easy to shop"* (Ahold, 2013). This strategy also affects the operations at Vezet.

Increasing the production volume, the product range and number of production lines leads to even more warehouse problems. In order to facilitate the future growth and developments, we need to know the warehouse requirements for the next 5 - 10 years. Vezet needs understanding about these requirements and needs suggestions about the directions the stakeholders (Vezet, Dailycool and Expedition) have to follow.

1.3. Research objectives

Over **X** different types of products are produced every day and more than **X** consumer units are produced each week. In order to measure the performances, Vezet uses Key Performance Indicators (KPIs). The most important one is the '*service level',* which means that at least **X** % of the demand of Albert Heijn stores must be satisfied by Vezet. The extent to which the service levels are met determines financial bonus/malus consequences. For every research conducted at Vezet this service level is set as a restriction, meaning that the research may not lead to a decrease of the service level.

This research focuses on the requirements of outbound processes at Vezet. Especially during rush hours, we see problems at the storage locations, but are not able to acknowledge the size and nature of the problems. Management requires more information, an analysis of these problems and sustainable solutions, before any action can be taken. This research assignment has three objectives:

1) Identify the size and nature of the problems for the current and future outbound processes.
2) Find possible options to improve the current outbound processes.
3) Find possible options to meet the future requirements for the outbound processes.

To achieve the objective, a research question is formulated along with sub-questions, in order to structure and divide the research into workable parts. These questions are presented in the next section, followed by the research approach that clarifies how and when the research will be conducted.

1.4. Research questions

From the previous sections the following research question can be deduced:

> *"What improvements does Vezet B.V. require at the outbound processes (in terms of storage capacity and investments) to meet the current and future requirements in a way that the service level remains ensured?"*

The research question is divided into five smaller sub-questions. These sub-questions are explained in the following section and will be used to answer the research question in Chapter 7 '*Conclusions'*.

<u>Sub-question 1: 'What patterns in the outbound processes can be distinguished in the current situation at Expedition and Dailycool?'</u>

Fresh cut vegetables are fast moving products which must be transported to the customer as fast as possible. This has consequences for the outbound processes of Vezet. We have to know how the outbound processes at both storage locations are designed and how it performs. Vezet has currently little knowledge about the warehouse processes, since a strategic analysis of the warehouses has not been conducted so far. So, we use scientific literature to identify the main process characteristics at similar warehouse. This is used to measure the current warehouse processes at Vezet.

Sub-question 2: 'What is the magnitude of the operational warehouse problems and how can support be created for these problems at management and production level?

Knowledge about the warehouse processes at Vezet is not enough to identify the size of the storage problems. We have to apply these processes to the real capacity restrictions, like location sizes and number of locations. We cannot analyze these requirements at warehouse level due to complexity, stochasticity and a large number of other variables. There are three possibilities to analyze this type of problems, for example: 1) real-life case studies 2) mathematical calculations and 3) simulation programs. We have chosen to use a simulation program for this research, because it is an understandable, accurate way of analysis. Because of the high variability in the processes, we will use real data points as input. This enables us to test whether the simulation model is accurate, but also creates support from the employees. The model should show problems that are recognized by the employees. Because of the high variation in the processes, it is necessary to have sufficient support from the employees.

An accurate simulation model allows us to identify the frequency and the size of the problems. But since the number of real data points is limited, we need to create a general model that does not use real data points, but distribution functions. This enables us to review longer periods and identify structural issues. The results from this second model are compared with the first results in order to make sure that this model is valid. Then, the model and its performances will be shown to the management of Vezet to create support and understanding of the discovered problems.

Sub-question 3: 'Which factors can be distinguished to describe the future of warehousing processes at Expedition and Dailycool?'

Strategic warehouse problems cannot be solved within one year (e.g., designing a new warehouse is time-consuming). Therefore, a strategic warehouse plan for the next 5-10 years is needed. In order to make a strategic plan, it is necessary to identify the causes of growth and decline. These causes are described in scientific literature, which will be used as a baseline for making growth scenarios for Vezet. Unfortunately, strategic growth factors are not extensively described in the warehouse articles (Rouwenhorst et al., 2000). Hence, an extension is required to articles about strategic production, because growth scenarios in production will also affect storage facilities.

Within Vezet, the financial and commercial departments have already established expectations and scenarios for the next years. In order to understand these expectations, interviews need to be organized. The findings from these interviews are compared with literature, which results in a number of growth scenarios. The likelihood and realization of these scenarios will be discussed with the managers of the two departments.

Sub-question 4: 'Which problems arise from the growth scenarios and what are the consequences of these problems?'

The growth scenarios established in the previous sub-question are implemented in the simulation model. The general simulation model made in sub-question 2 is used to deal with, for example increasing production volumes and product ranges. This will provide understanding of utilization rates and how often capacity issues occur in the future scenario's. These problems are expressed in terms of requirements needed to solve these problems, like storage capacity needed for a single product and total capacity needed.

Sub-question 5: 'What solutions can be identified to avoid the problems from the growth scenarios, and how can these solutions be implemented?'

The problems found in sub-question 4 require solutions. These solutions are deduced from scientific literature, and combined with ideas from employees who encountered these problems. This leads to a number of solutions, which need to be analyzed for feasibility and desirability. Testing on feasibility is done by using the simulation model from the previous questions. In order to know the desirability of the solution, advantages and disadvantages must be identified and an implementation plan must be created. Solutions are selected by the most important KPIs of Vezet, investment costs and space requirements. Finally, these solutions are presented to the management of Vezet and Dailycool.

1.5. Problem approach

Since 2010, Vezet has faced difficulties with logistic processes and adapted a lot of solutions to improve the logistic operations. These solutions were not sustainable, because as soon as production required additional space for the introduction of a new machine, this space was taken from the storage locations. So, the warehouse operators faced an increase in production volume, but were restricted to use less square meters. This research creates and investigates structural solutions for the logistic and warehouse processes.

To clarify the steps to be taken in this research, we present the research structure in figure 1-8. A challenge of this research is data collection, because data about physical inventory levels is not available. That is why the physical inventory levels are deduced from production and pick data. The complication is that this information is deleted after 3 months, because it is not relevant anymore for Vezet. So, there is only a limited amount of real data that can be used in the simulation model. To identify patterns and abnormalities within the production and pick data, we use scientific literature.

In chapter 2, a framework is created from literature to structure this research. This framework provides understanding of the most described decisions taken in warehouse planning and control at operational, tactical and strategic level. This can also be used to describe alternatives for problems found at these levels.

There are three requirements set to the simulation model that is created for answering sub-question 2. Firstly, the model must be a realistic visualization of the situation, i.e., the model will account for influences like seasonal trends and shelf life of the finished goods. Secondly, the model needs to be understandable for every person involved. This means that everyone must be able to see similarities between the model and reality, with minimum explanation of the model. And thirdly, the model needs to measure process flows in a correct way, which means that the results from the simulation must be accurate and useful for the storage location managers. The simulation model will be created in the program 'Plant Simulation'. This is done because the program is able to fulfill the requirements set for the simulation.

The problem is complex, due to the large amount of data, involvement of two independently operating organizations and many stakeholders. Therefore, it is necessary to collect data and information in a clear and independent way. To get to know the organization, we start this research with two weeks at the factory (i.e., at the storage facilities of Expedition and Dailycool). This leads to an understanding of the warehousing processes for research perspective, and acceptation and understanding of the need for research amongst the employees.

Scope

The intention of the research is to improve and prepare Vezet at warehouse level for the current and future requirements. This only involves the storage of finished goods, because other storage facilities (e.g., raw materials and work-in-process), are handled in other parts of the factory and thus are not within the scope of this research.

As mentioned in section 1.1, Dailycool is an in-house 3PL-provider that has four functions. This research is limited to the warehouse function of Dailycool because this directly affects the production location in Warmenhuizen. Vezet has the responsibility to provide sufficient space to Dailycool to perform their operations, while Dailycool is responsible for the execution of the other functions.

To be able to make a strategic plan, a reasonable horizon must be chosen. A frequently used horizon for strategic decisions is 10 years (Baker & Canessa, 2009). This planning horizon is also used in this research, because some of the alternatives, presented in chapter 6, require multiple years of preparation before implementation (e.g., building a new warehouse).

The logistic costs that are made inside a warehouse are to a large extent already determined during the design phase (Rouwenhorst et al., 2000). Therefore, and due to time constrains of this research, only changes at strategic and tactical level are considered in the simulation model. We assume that the current ways of picking and stacking are continued in the forecasted horizon.

Deliverables
Vezet has focused on increasing productivity for years and has not been able to put sufficient effort in the organization of the logistical processes, which has led to inefficient processes and sometimes dangerous situations. For example, high handling times due to storage locations of Expedition at multiple locations in the factory and dangerous situations can occur due to crossing flows of in- and outbound products. Vezet has tried to come up with solutions and improvements for these logistical processes, but these were mostly temporary and not sustainable.

This research provides Vezet and Dailycool an understanding of the outbound processes, warehouse operations and their relation. Managers of Vezet will be able to look into specific events by using the analytical tools from this research, e.g., production and pick graphs and statistics from a certain period. This information will support managers when facing difficult decisions like the warehouse design.

Secondly, from the analysis of the current production, storage and order picking process, we derive the inventory position at the storage locations. Combined with the operational simulation model, we derive the storage requirements for the current situation. These requirements are used to formulate improvements for the current warehouse processes.

Finally, alternatives are offered to the management to deal with the storage problems that are found in the simulation model including the growth scenarios. To make these alternatives more practical, we offer the managers of Vezet and Dailycool a roadmap, which can be used for the practical implementation of these alternatives.

Research structure

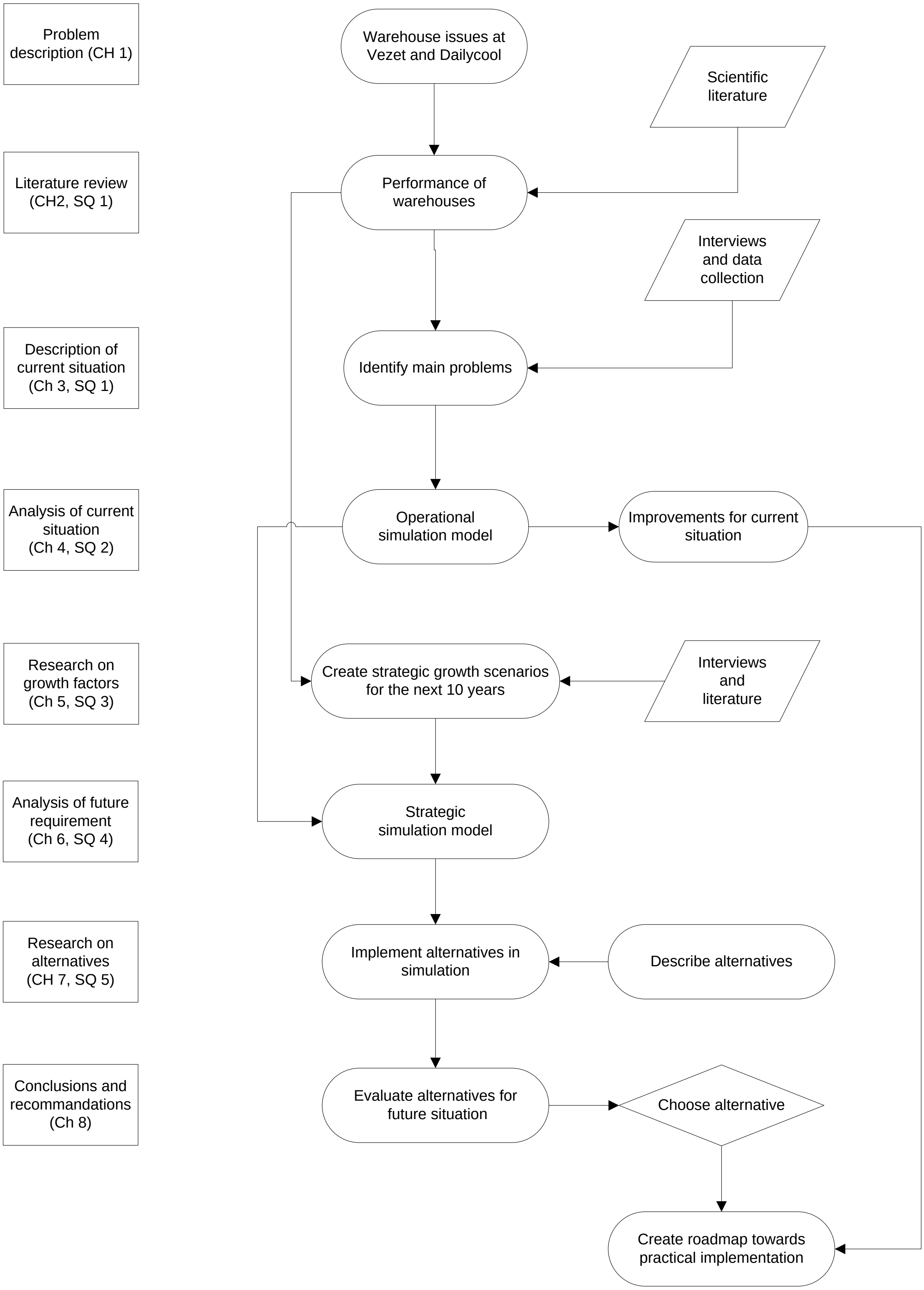

Figure 1-8: Research structure

2. Warehouse characteristics

The problems described in chapter 1, have a qualitative rather than a quantitative nature which makes it hard for the management deal with these problems. So in order to understand these possible problems, we need obtain information about how to analyze warehouse performances. This will be done by giving an analysis of scientific literature. The analysis is used to deduce KPIs that enable us to identify the performances of the Vezet warehouses.

In section 2.1, a general framework is introduced that is used to structure the research. The precise application of this framework in this research is explained in section 2.2. In the sections 2.3 – 2.5, we fill the framework with applications generated by a wide range of warehouse literature. We summarize the findings from this chapter, in section 2.6.

2.1. A generic framework for warehouse planning and control

A useful tool for structuring operations is a framework, focused on production and management decisions. The classical Manufacturing Planning and Control Frameworks have a specific orientation toward production, technological or material planning, but are inadequate in practice (Hans et al., 2012). Therefore the framework of Zijm (2000) is used, which is designed for integrated Manufacturing Planning and Control (MPC) in highly complex organizations. For a state-of-the-art overview in the literature of MPC, we refer to the paper of Hans (2012). The entire Manufacturing Planning and Control framework would be too broad and complex for this research, that is why this framework is applied to a specific area within the Manufacturing Planning and Control; warehouse operations.

Within the processes of managing operations, three decision stages can be distinguished: strategic, tactical and operational (Rouwenhorst et al., 2000). For instance, the choice of using different types of storage systems can be seen as strategic. A strategic decision is made for a number of years (more than 2 years) and cannot easily be changed, while a tactical decision is made for 1- 2 years. For example, a tactical decision is the number of the pick zones. Finally, the short-term decisions, on operational level, must be made, like the assignment of the docks. As explained in Rouwenhorst (2000), decisions taken at operational level affect the organization at a different level than decisions at strategic level.

Managerial areas

As shown in table 2-1, three managerial areas can be distinguished: Technological, Resource Capacity and Materials (for details about the choice for these areas, we refer to Zijm (2000), Hans et al. (2003), and Hans et al. (2012)).

The technological planning can be performed in different ways, but it is most often performed by the management and supply planners. Technological planning involves decisions making regarding protocols and reporting. These planning tools enable the stakeholders to review the current processes and define desirable processes.

The resource capacity and materials planning both analyze the resources used in the processes, but there is a difference between these. Resource capacity planning addresses the dimensions, planning, monitoring and control of renewable resources (i.e., resources that can be used multiple times like personnel, barcode scanners, reach trucks, docks, stacking places).

Material planning addresses the purchasing, storage and distribution of consumable products, like items produced in the factory, crates, pallets and labels.

Hierarchical Levels

At each of the four hierarchical levels different decisions are made, which are mostly influenced by the available time. Rouwenhorst et al. (2000) describe the strategic level as long term decisions made at a horizon of approximately five years. They pose questions on a number of processes, like do we need a separate reserve area or what type of storage system needs to be used? These strategic questions are related to a level in which it is not easy to change a decision after some time, because high investments are involved. Secondly, on tactical level decisions are made for the next two years. These decisions are, of course, bound by decisions made in the strategic level. It involves defining the number of pick zones or the selection of picking equipment. The remaining categories are the offline and online operational levels, both involve short term decisions related to the execution of the warehouse processes. The difference between these two types of decision making, is that within offline decision making, the decisions are made *in advance* while online decisions are made *reactive*, on unforeseen events.

	Technological Planning	Resource Capacity Planning	Materials Planning
Strategic	R & D, knowledge management	Strategic resource planning	Supply chain design, warehouse design
Tactical	Macro process planning	Project selection, rough cut capacity planning	Procurement and purchasing
Operational	Micro process planning	Resource-based project planning	Order picking, routing and batching

Table 2-1: Framework for Manufacturing Planning and Control (Zijm (2000), and Hans (2012))

2.2. Application of the framework

Since more and more companies are looking for more profit, cutting costs and improving efficiency within their organizations, logistic operations have gained extra attention. In order to measure the performances of the logistic operations, a performance evaluation model can be used. Gu et al. (2010) argue that a good performance evaluation model can help the designer to quickly evaluate many (design) alternatives and narrow down the design space during the early design stage. A performance evaluation model includes analytical models, simulation models and benchmarking. But before a performance model can be used, we need to identify the factors that we want to evaluate.

The original manufacturing planning and control framework is not appropriate to use in this warehouse research, because the examples given are too general and do not provide instructions for practical research directions. Because we want to investigate both operational and strategic warehouse operations, we have to translate the manufacturing planning and control framework into a warehouse planning and control framework. In the next sections, we review the managerial levels, provide suggestions for further research (literature-based) at hierarchical level and conclude with the research directions for this research.

2.3. Technological planning

The first managerial level Zijm (2000) defines is technological planning. This is described as the planning and execution of processes. Firms hold inventories because production and procurement processes cannot instantaneously match product demand. When a company faces a stock-out, two adverse consequences can be considered: immediate forgone profit and long-run loss of revenue arising from the shift of customers to more reliable sources of supply (Blazenko & Vandezande, 2003). Within a warehouse, there are four warehouse processes that can be reviewed: receiving, storing, order picking and shipping activities (Rouwenhorst, 2000). Each process has its own characteristics and developments.

Strategic

When looking at the strategic decisions to be made for the warehouse processes, we see a lot of new developments, automation and research topics. It is hard for a warehouse manager to cover all new warehouse trends, because of the amount of information. That is why design of warehouse's processes is very important (Cakmak, et al., 2012). By knowing the desired position of the warehouse managers, directions can be formulated. This can result in trade-offs like internal or external warehouse operations, building a new warehouse or implementing new features.

Tactical

At the tactical phase, we assume that there is a warehouse available, but the organization of the processes is not designed. At each process, decisions need to be made about the execution of the warehouse operations. An decision is for example, the start and finish time of the operations, which includes the time window for order picking, and the opening hours of the receiving area. Also the flow through the warehouses must be elaborated, i.e., where is the receiving area positioned, and which stacking methods are most suitable for the operations (Park & Kim, 2010).

Operational

An example of checking the performances of the processes within a warehouse is safety (de Koster et al. 2011). Safety has gained a lot of attention in the recent years and is seen as additional factor in existing methods. Look for example at Toyota which uses the 5-S model for continues improvement and lean manufacturing. That same model has evolved into the 5S +1S model, in which the addition of 1S, represents *Safety.* An operational factor like safety can easily be translated into KPIs that measure the performances of the organization on a specific part. There are a lot of possible KPIs that can be formulated to measure *Safety.* De Koster et al. (2011) give directions for measuring Safety by providing two Key Performance Indicators (KPIs): the number of accidents during a certain period and the second the severity of accidents related to financial consequences.

2.4. Resource capacity planning

A resource is defined as the materials that can be re-used many times for executing the processes (Zijm, 2000). Hans (2003) provides examples of Rough Cut Capacity Planning, in which he explains how the machine capacity is used to come to feasible production plans. We see that the machines are the resources in a production facility and can be used for a long period to produce products. Within a warehouse, we also use machines that enable us to execute the operations. Clear examples are: employees, reach trucks, docks, barcode scanner, and so on (Rouwenhorst et al., 2000). The capacity and use of these resources are interdependent and correlated. This means that it is not possible to optimize each resource individually, but we need to optimize the whole set of resources (Hans, 2003).

Strategic

To run operations and processes in a warehouse, we need to know the characteristics of the warehouse. Therefore, we need to define the warehouse design. Lots of articles have been written about warehouses designs. Gu et al. (2010) structure the warehouse design into five major decisions:

1) Determining the overall warehouse structure
2) Sizing and dimensioning the warehouse and its departments
3) Determining the detailed lay-out within each department
4) Selecting warehouse equipment
5) Selecting operational strategies.

The costs of warehouse operations are largely determined during the design phase (Rouwenhorst et al., 2000). Therefore, full information is needed about the expected inventory levels, operation methods and level of automation (like automated storage and retrieval systems). Every decision taken, influences and restricts the next decision, so decisions need to be taken well-founded and with care.

Tactical

After making the definitive design of the warehouse and its departments, it is necessary to dimension the warehouse equipment. This involves for example the number of employees (e.g., order pickers), the number of the storage locations and their capacity. Also, we need to make decisions about the storing methods, order pick strategies and ways of batching. At Vezet, we see two different types of storing methods. Each strategy has its own advantages and disadvantages, as can be seen in table 2-2 (Chan and Chan, 2011).

A dedicated order picking method results in high throughput rates, because the SKUs are always positioned at the same place, it can easily be found by the employee. The disadvantage is that when a product is not present in the warehouse, it still has a location (that cannot be used by another product). Therefore, the required storage area is large.

A more efficient way of making use of storage areas is random storage. This means that a location can be used by every type of product and as soon as the product is not in stock anymore, the location can be used by another product. The consequence of this process is that an order picker is not sure where the product is located, and has to search for it. This will take time and leads to lower throughput rates.

The combination of the two pick strategies is class-based storage. A product is divided into a strategically chosen class along with other products. This class (or these products actually) has its own fixed location in the warehouse. Within the class, random storage is used. So for example, we know that a product is always positioned at zone 3, but we do not know the exact location of the product. This ensures that the throughput is higher than at random storage, but lower than dedicated storage. The same applies to the storage area required.

Storing method	Advantage	Disadvantage
Dedicated	High throughput rates	Large storage area required
Random	Less storage area required	Low throughput rate
Class-based	Median throughput Median storage area required	Median storage area required Median throughput

Table 2-2: advantages and disadvantages of storing methods (Chan and Chan, 2011)

Operational

The choices made in the tactical decision stage have consequence for the operational performances. One of the most important factors in the performance of a warehouse is the service level or product availability, because it is for many companies important to avoid losing their customers, profits and market share (Blazenko & Vandezande, 2003). Warehouses need to be a reliable partner, against reasonable costs. That is why the service level is important to know. One way to measure the service level is measuring the number of missing or erroneous deliveries to a customer. It is also important to know what the impact of these deliveries is, because the (financial) consequences for missing an order can differ per customer.

To measure the performances of the resources deployed, we measure the utilization rate (Cormier, 1992). There are lots of different ways to measure the utilization rates. The choice of the right way to measure the utilization rate is dependent on the resource, company preferences and historical measurements. Gu (2010) makes a suggestion that can be used to measure the utilization of a storage location. The first measure is to divide the number of products placed at a storage location by the total amount of products that the storage location can hold. The second measure is storage utilization which measures the number of locations (partly or fully) occupied.

2.5. Materials planning

Material planning involves resources that can only be used once. At Vezet, we see the products received and picked as this type of resource. We are allowed to make this assumption because once the products have left the warehouse they do no return to the warehouse. In this section, we describe the consequences of handling these materials at the three hierarchal levels.

Strategic

At strategic level, we need to analyze the market requirements for the materials (Dotoli et al., 2015). This means that a warehouse manager has to ask himself what can the warehouse offer to the market and what the market offers the warehouse. Therefore, we need to keep track of developing markets, expected growth or decline, new possibilities. The market trends need to be translated in product volumes, so the warehouse manager can calculate the required storage area, investment costs and possibilities for expansion.

Tactical

To prepare the warehouse for the operational processes, we need to define the tactical material planning, which means that we have to formulate our expectations for the near future. Are we seeing new developments like new product introductions, or products leaving the inventory or an increase in demand/production (Guerriero, 2013). By identifying the future needs of the warehouse, the manager becomes able to make early adaptations.

Operational

A commonly used performance factor is productivity, which is the amount of products processed within a given time (Hopp and Spearman, 2011). For production operations, the productivity rate is used, for example to identify the bottleneck process, the operation that limits the capacity or performance of an entire system. The most common way to calculate the throughput of a system is explained by Little. He states that the number of units contained within the system equals the time it takes for all units to go through the process, multiplied by the rate at which the system delivers output.

2.6. Conclusions

In this chapter, we saw the Manufacturing Planning and Control framework of Zijm (2000) translated into a Warehouse Planning and Control framework (see Table 2.3). The framework explains how and why decisions influence each other. This is important in order to understand the current situation of a warehouse, but also to shape its future requirements.

We will use this framework as a roadmap for this research. In order to measure the performances of the warehouse processes, we need to look into the operational level and check whether or not possibilities for improvements are seen. The importance of each operational factor depends on the company, which can be seen by the huge amount of Key Performance Indicators formulated. There is no single way to check the performance of a warehouse (Gu et al., 2010).

In chapter 3, we will measure the four operational performances factors of the warehouses, safety, service level, utilization and productivity, at Vezet. When knowing the operational performances, we can identify possible problems.

3. Data analysis

Since Vezet has no detailed information about the inventory flows, we measure and visualize the inventory patterns in the warehouses, in section 3.1. This enables us to recognize recurring patterns and deviations with the inventory flows. In section 3.2, the capacity of the warehouses is added to our analysis. This is used, in section 3.3, to identify performances and challenges within the warehouses on the four indicators found in chapter 2, safety, utilization, service level and productivity. In section 3.4, the findings are summarized in a problem cluster which provides an overview of the most important problems within the warehouse processes at Vezet.

3.1. Inventory pattern

In this section, the physical inventory pattern at Dailycool and Expedition are analyzed. Anno October 2014, Vezet had no information and insight in the process flows at the warehouses. Therefore, we create a method that can be used to visualize the inventory position. This method is explained in section 3.1.1., and can be, if needed, used in future research or to replicate this research. In section 3.1.2., we present and discuss the physical inventory flow at Dailycool. The same analysis is made for Expedition, which is presented in section 3.1.3.

3.1.1. Method

For our analysis of the inventory flows at Vezet, we used a number of data sources. In this section we explain the data source we used. All data is provided by the system '**X**', a program which enables the user to collect a wide range of data from the ERP-system. There are different data structures available and a selection of the most suitable data had to be made. The data used in this research is reported in: SMOVRAP2, PICKSTAT and TELLST. These names seem rather odd, but they are just derived from software languages. In the next paragraph, these systems are described shortly, as well as the steps taken to come to the graphs of the inventory flows.

The data collected from SMOVRAP2 provides understanding of the moment at which a product has reached the end of the production line and is moved to the warehouse. At this point, the number and type of crates produced is counted, and the barcode of the product is scanned. This data is imported into the computer system and standard information about the products is added (e.g., storage zone). Not every data point in SMOVRAP2 is relevant for this research, so the tags, '*Imvnulcorr*' and '*Voorrep*', had to be removed. The PICKSTAT command can be used to collect information about the picking process. Each order picker has a barcode scanner, which is used to pick the product. When a product is picked, the number of items, the time and information about the shipping process is stored in the system. These two information systems can be used to calculate the number of products in inventory. In order to calculate the marginal difference in inventory at a certain point in time, the number of products from PICKSTAT, should be subtracted from the number of products from SMOVRAP2. Combining these marginal differences with the physical inventory at the beginning of the measurement, results in the number of products held in inventory at a certain moment in time. We use this method to check the inventory position every half hour, in order to create smooth graphs. We took the starting inventory position at the beginning of each week from TELLST. This also gives the opportunity to check the real inventory position with the calculated inventory position from the information systems.

One of the three challenges involved within the data collection for this research is the huge amount of data points. Every action is recorded within the system, which leads to x production and x picking data points, every single day. This is only a small part of the whole system of Vezet, which needs to be very detailed, because in case of a recall (e.g., small pieces of metal in products) all process details must be identified. To prevent the system from an information overflow, most detailed data is deleted after three month. Consequently, it is not possible to review the inventory levels for prior periods. Other data are stored for a couple of years (e.g., general data about production volumes and accident reports).

Another challenge is that a product can be switched to another picking zone when situations change (e.g., introduction of new products). This leads to changes in the system which corrupts the data for this research. Therefore manual changes in storage zone were required.

The third challenge involves externally produced items, like sauerkraut, which are transported to Vezet and placed in the EA-warehouse. These items can be seen in the PICKSTAT data, but are not produced at Vezet, so these are not visible in the SMOVRAP2 system and impossible to analyze.

We use graphs to visualize patterns within the data points. This requires a choice of unit, because graphs can be expressed in individual items (CE), storage units (crates) or storage units (pallets or rollies). In this research we express all data in crates, because data from the system is also expressed in crates, and commonly used within the plant, which is convenient for data validation. Besides, the number of crates stacked on a pallet or rolly may vary, because these are not required to be fully stacked. However, we need to account for the pallets and rollies which are used within the warehouses of Vezet. These storage units determine the space issue, because for storing one crate, we require one storage unit (e.g., pallet). For now, we neglect this complication.

We have chosen to set certain intervals for these graphs, in order to reduce the number of data points. For all graphs we chose an interval of 30 minutes is. This is, because choosing a smaller interval will lead to too many data points and unstable patterns. Choosing a larger interval blurs the details of the graph, because it will be unclear when events, like machine cleaning or break-downs, happen.

3.1.2. Physical inventory level at Dailycool

The physical inventory level at the EA-warehouse, the warehouse of Dailycool, depends on the crates that are received from production. These are the crates that need to be stored in the warehouse. When looking at the production data from the period November 2014 – April 2015, we see the following data in table 3-1.

Production day	Average volume (crates)	Minimum volume (crates)	Maximum volume (crates)
Monday	x	x	x
Tuesday	x	x	x
Wednesday	x	x	x
Thursday	x	x	x
Friday	x	x	x
Saturday	x	x	x
Sunday	x	x	x

Table 3-1: Crates received from production for the EA-warehouse during November 2014 – April 2015

We see that the average production volume varies on normal production days, special events (like Christmas) are filtered out in this analysis. The beginning of the week (Sunday – Tuesday) is comparable, while at Wednesday the production volumes are raising, which continues until Friday. On Saturday, production is rather low, because of lower demand of the Sunday stores of Albert Heijn.

Figure 3-1 shows the inventory position of the EA-warehouse during the day. We see the same pattern on each day, expect for Saturday. From 7:00 till 9:00 hours, crates are produced, but no crates are picked, so the number of crates in inventory rises. At 9:00 hours, many crates are picked and transported to the docks of Dailycool, which leads to a massive drop in the inventory. The same can be noticed (in smaller proportions) at lunch break. Then, the physical inventory stabilizes and increases until 20:00 hours, after which the employees start picking again.

Figure 3-1: Physical inventory level at Expedition in week 47, 2014 (from Monday 17-11 till Sunday 23-11)

We, again, see a different pattern on Saturday. This highest point in graph is on the line of 19 November and is caused by a number of reasons. Firstly, the inventory position at the beginning of the day was already high (around **X** crates). Secondly, the number of crates picked was not big enough to compensate the high inventory level and thirdly, the production volumes remain constant, causing the inventory to grow.

One may notice that the inventory position in this week is fluctuating between **X** and **X** crates during a short period. This makes it even harder to identify problems, we see that on average **X** crates are in inventory, but we have a maximum at **X** crates. At this moment, we are not able to identify whether the warehouse has problems or not, because it is possible that the capacity problem already exists at this point. Therefore we cannot simply look at the average values, but have to keep the outliers in mind and need to know the utilization of the storage locations.

A second thing that can be noticed is that the daily production volume is not fully stored at the EA-warehouse. On average **X** crates are on stock, while more than **X** crates are made. So we can assume that the average time a product spends in inventory is half a day.

3.1.3. Physical inventory level at Expedition

In table 3.2, the production data from November 2014 – April 2015 for the EAA-warehouse (the Expedition warehouse) is visualized. From this table, we see that the production data from Sunday to Thursday are quiet similar. However the product volume is already rising on Wednesday and Thursday. On Friday, we see the largest production volume, while on Saturday the production volumes are low. The pattern is similar with the EA-warehouse of Dailycool.

Production day	Volume (crates)	Minimum volume (crates)	Maximum volume (crates)
Monday	x	x	x
Tuesday	x	x	x
Wednesday	x	x	x
Thursday	x	x	x
Friday	x	x	x
Saturday	x	x	x
Sunday	x	x	x

Table 3-2: Crates received from production for the EAA-warehouse

In figure 3-2, we calculated the physical inventory position for week 47 in 2014 at the Expedition department (zone 6, 7 and 9). Two lines (Friday 21 and Saturday 22 November) are very high compared to the other lines. This is caused by not performing order picking operations on Friday for the COOP supermarkets in Denmark. COOP does not want to be supplied on Saturday evening, because the stores are closed on Sunday. However, due production capacity restrictions, a part of the COOP order is already produced on Friday. So, there is an inflow of products in the warehouse, while there is no outflow (pick actions), causing inventory levels in the warehouse to increase.

A regular pick day at Expedition starts at 7:00 hours and ends at 1:00 hours, which can also be seen in the graphs. When neglecting the lines on Friday and Saturday, we see the same pattern every day. On a regular day, the number of crates held in inventory drops, and rises again. Most often, the highest inventory level can be found between 17:00 and 19:00 hours, because of breaks of the employees and distribution orders that require more time to pick (e.g., multiple product types on one pallet). Furthermore, the lowest inventory level can be seen between 8:00 and 10:00 hours, because within this interval, order pickers are picking as many products as possible in order to lower the inventory level. This results in a low physical inventory level at the storage zones and high inventory levels at the temporary shipping locations (see figure 1-6). These temporary shipping locations are only cleared when a truck is available, which causes these products to stay at this location for a couple of hours, which leads to numerous dangerous situations.

Figure 3-2: Physical inventory at Expedition in week 47, 2014 (from Monday 17-11 till Sunday 23-11)

Unlike the findings at Dailycool for Wednesday 19 November, we do not see any deviations for that day. Apparently the inventory positions at Dailycool and Expedition do not have the same problems at the same time. The physical inventory is high on Tuesday and Thursday, and at both days we see a significant drop in inventory somewhat later. Also for the Expedition department, it is hard to identify the size of the problems. We can see high levels of physical inventory, but are unable to check whether there is still space at the storage location to store crates. So, the next step is to determine the capacity.

3.2. Warehouse capacity

To calculate the performances and to identify problems at the warehouses, we need to know the utilization rates. This requires identifying the number of crates present in the warehouse and the capacity of the warehouse. However, the maximum theoretical capacity in the warehouse differs because of the different types of crates used. An alternative is to express the capacity in number of pallets, but also this number fluctuates. Both fluctuations are caused by the stack heights of the crates on a pallet. At Vezet, four different types of crates are used: CBL 7 cm, CBL 8 cm, CBL, 11 cm and CBL 17 cm. For example, we can put five pallets with CBL 7 cm on a location, while only three pallets with CBL 17 cm can be put on that location. So, it makes more sense to use the number of crates as gauge. There are four different types of crates within the warehouses, and two types of load carriers, resulting in eight stack heights (see table 4-1). The warehouse operators do not have influence on the choice for a crates size or load carrier. These decisions are set default as end item characteristics by Albert Heijn, in agreement with the commercial department of Vezet.

	# crates stacked on a pallet	# crates stacked on a rolly
CBL 7 cm	60	44
CBL 8 cm	120	88
CBL 11 cm	75	30
CBL 17 cm	50	20

Table 3-3: Number of crates per full load carrier

3.2.1. Dailycool

To calculate the theoretical capacity of the Dailycool warehouse, we distinguish six types of locations. Each type has its own dimensions which determines the number of crates that can be stacked on that location type. Every location has a fixed width of 1.2 meters that matches the width of one pallet. When taking the average number of crates per type multiplied with the number of locations, the maximum theoretical capacity of the warehouse can be calculated. To this end, we need to know the distribution of crate types. Currently, we do not know this distribution, because it changes every moment. Therefore, we estimate the maximum theoretical capacity by the number of CBL 11 cm crates (common used crate type). This equals approximately **X** crates.

Location type	Depth (meters)	Height (meters)	Number of locations	# crates CBL 7	# crates CBL 8	# crates CBL 11	# crates CBL 17
Type 1	x	x	x	x	x	x	x
Type 2	x	x	x	x	x	x	x
Type 3	x	x	x	x	x	x	x
Type 4	x	x	x	x	x	x	x
Type 5	x	x	x	x	x	x	x
Type 6	x	x	x	x	x	x	x

Table 3-4: characteristics of the storage locations at Dailycool

The picked products are, unlike the Expedition processes, directly loaded into a truck. So, we do not have temporary storage locations, but we do need a lot of space around the docks to perform final checks on the picked products to safely drive the reach trucks and to sort the products per destination.

3.2.2. Expedition

Each location at Expedition has a fixed width of 0.7 meters, which corresponds with the width of a rolly, and a variable depth. The depth is dependent on the position of the location. Rollies cannot be stacked on top of each other, so the number of rollies on a location is calculated by the depth divided by the length of a rolly (0.8 meter). Expedition uses dedicated storage, which means that each product has its own location. We know for every product: the position of the storage location, the maximum number of rollies for that location and the number of crates stacked on a rolly. So, it is easier to calculate the capacity of this department. As stated in section 3.1, we estimate the capacity of Expedition on **X** crates. This holds for the situation of December 2014.

Location type	Depth (meters)	Height (meters)	Number of rollies	Number of locations
Type 1	x	x	x	x
Type 2	x	x	x	x
Type 3	x	x	x	x
Type 4	x	x	x	x
Type 5	x	x	x	x

Table 3-5: characteristics of the storage locations at Expedition

Besides zone 7 & 9, Expedition has three Temporary Shipping Locations (TSLs) that contain picked products that are ready to be transported to the truck. The operations performed at the TSLs cannot be analyzed, because there is no information available. We can deduce the moment that a product is transported to the TSL, but we have no information about when these products from the TSL are loaded into the truck. These locations are also storage locations and need to be taken into account in our research. So, we measured the number of rollies present at several moments in time and calculated an average. It turned out that on average **X** TSL was occupied, which equals **X** rollies. On an average rolly, 23 crates are stacked, so the number of crates stacked on average on the TSLs is **X**.

3.3. Measuring warehouse overall performances

To measure the performances of the warehouses, we need to retrieve information about their processes. Because of the in-house location of both warehouses, it is not easy to assign a clear cause and effect. Lots of activities take place close to the production line, so communication is easy and errors are rapidly detected. Both, Dailycool and Expedition have a kind of control function. They perform the final check on quality and quantity of the products. In this section, we will look into the factors that were found in chapter 2 and check how the two warehouse operators perform.

3.3.1. Safety

3.3.2. Service Level

3.3.3. Utilization

3.3.4. Productivity

3.4. Summary

The findings from this chapter are summarized in figure 3-4. From the problem cluster, we see that the main problems found are related to utilization. The volume utilization seems rather low, while the location utilization is high. The latter is the cause for the space problems in the warehouses, but we also need to keep in mind the volume utilization. Also, 'productivity' need to be kept in mind, but we do not see urgent problems at this point. For 'safety' and 'service level' we have no indication for problems, so we will not focus on these topics. In chapter 4, we will analyze performance at the utilization in more detail.

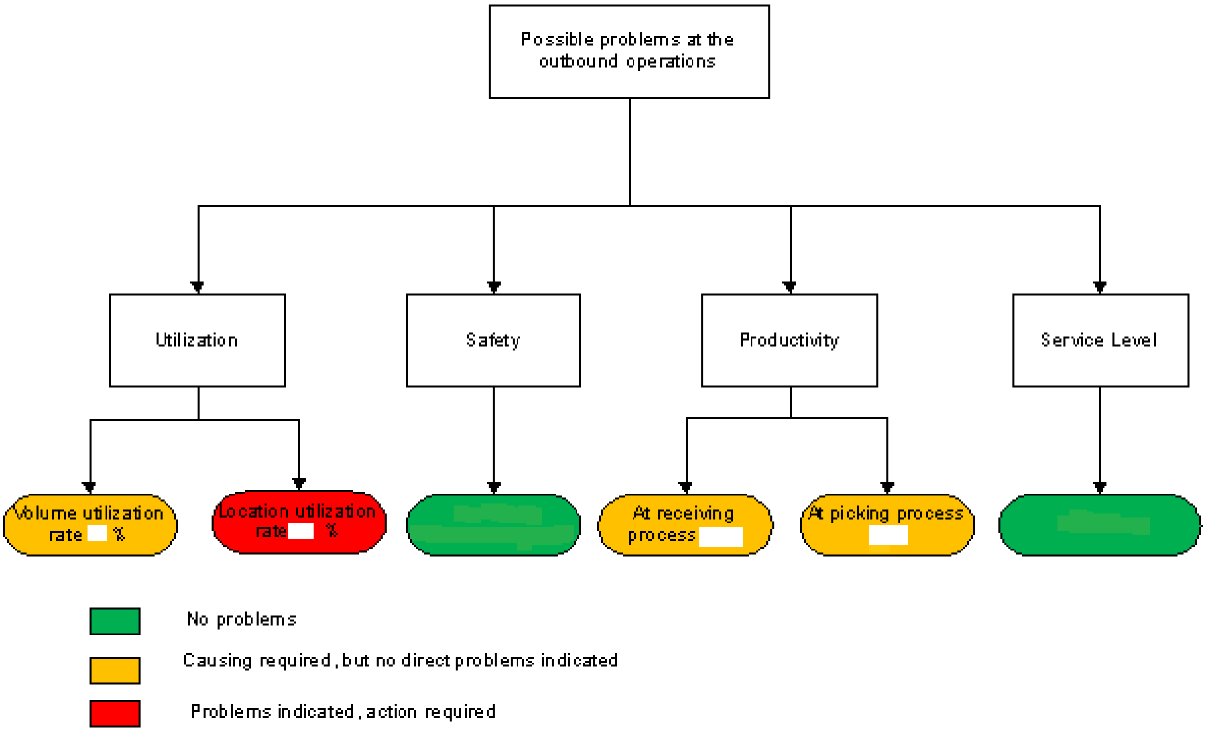

Figure 3-3: problem cluster for identifying possible problems at the outbound processes

4. Performance analysis

From chapter 3, we learnt that the most urgent problem occurs at the location utilization of the warehouses, but also the volume utilization and productivity must be kept in mind. We have stated that there are problems in the warehouses of Vezet, but were not able to indicate the size and severity of the locations utilization problems. In this chapter we use a model to simulate the warehouse operations in both warehouses. As described in chapter 1, we used 'Plant Simulation' (version 10.1), a discrete-event simulation program that can handle large amounts of data. This program is able to measure the utilizations rates in the warehouses and answers the second sub-question about the magnitude of the operational warehouse problems. In section 4.1, we describe the global structure of the system, followed by an overview of the assumptions and decisions made in the model, in order to represent the dynamic processes at Vezet. In section 4.2, the Dailycool real life data model is validated and used to analyze the performances at the EA-warehouse. Finally, in section 4.3, the Expedition real life model is discussed and analyzed.

4.1. Real life data analysis

Due to the highly fluctuating physical inventory levels and complex processes at the warehouses, activities and capacity problems cannot easily be analyzed. Therefore, we need a software program that is able to simulate the actual processes in the warehouses and measure the size and frequency of the problems. A suitable simulation program is 'Plant Simulation', which is licensed by the University of Twente. Discrete event simulation, like the 'Plant Simulation program', is one of the most commonly used techniques for analyzing and understanding the dynamics of manufacturing systems. It is a highly flexible tool which enables the user to evaluate different alternatives of system configurations and operating strategies to support decision making in the manufacturing context (Negahban & Smith, 2014).

By using detailed warehouse data from the Vezet system as an input channel for the model, we can simulate the events in both warehouses per minute. As stated in chapter 3, it is rather hard to assume accuracy from the distribution functions due to the limited amount of data points of total production volumes. That is why we start with another strategy, to make a model which represents the warehouse operations at the EA and EAA warehouse. We provided the model with real data points from previous months, after which we are able to draw conclusions about the operational level of the warehouses of Dailycool and Expedition. Because of the difference in storing rules, Dailycool used class-based storage while Expedition uses dedicated storage, we created two separate models.

4.1.1. Input of the data model

Besides the differences in allocation rules between Dailycool and Expedition, both models have the same basis, which is explained in this section. The basis of the model exists of input parameters, methods and attributions to simulate processes and output parameters.

<u>Production input</u>

When an item is produced at the production site, it is registered in the system and immediately sent to the warehouse. The transport always takes place on a load carrier, a pallet or a rolly. In the table below, we show two examples of events that are used as input for the data model. An event must be read as follows: event number '*35*' consists of 75 crates with freshly cut onions, stacked in crates of 11 centimeters, and happens on the first day of the simulation period at 8:03 hours. At that exact time the crates enter the warehouse and are sent to a location in storage zone 2. The second example occurs at the second day at 13:35 hours. The average number of events per day is **X**.

Production event	Time	Description	Number of crates	Zone	CBL
35	1:08:03:00.000	AH_uien_250gr	75	2	11
2569	2:13:35:00.000	AH_zuurkool_400gr	50	4	17

Table 4-1: Examples of input data for production

For the data model, we used production input of the Vezet system from November 2014 – February 2015.

<u>Order picking input</u>

The system of Vezet also registers when an employee has performed a pick action. After a pick action, the product is immediately loaded into the truck and does not require a storage location in the warehouse anymore. The pick information is almost identical to the production data, but has one major difference, which is the lack of the storage zone column. The zone of a product is not interesting anymore, because the order picker must pick the oldest product, no matter its storage location. Although, a product has a fixed storage zone, it may happen that this zone is fully occupied and the product is located at another zone. So, the data model looks for the oldest production date and picks that product. This can also been seen in the table. The oldest 'fruit salade' is produced on day 23, and will be picked firstly. The 'fruit salade' produced today (day 24) is pick 30 minutes later, when product with an older production date is distributed to Albert Heijn.

Pick event	Time	Description	Production day	Number of crates	CBL
109	24:10:24:00.000	AH_fruit_salade_250gr	23	120	11
143	24:10:58:00.000	AH_fruit_salade_250gr	24	60	11

Table 4-2: Examples of input data for order picking

<u>Capacity</u>

To model the processes in the warehouses, we added the capacity per location to the model. The capacity per location is dependent of the size of the crates, as explained in section 3.2. The model has to check in which crates the product is stacked and then use the corresponding capacity. For example, a product stacked in CBL 17 cm crates, can be put in a location that has a capacity of 300 crates of this type, while its capacity with CBL 11 cm is 450 crates.

<u>Start inventory</u>

Before we could run the model with detailed production and pick data, we had to know the number of crates in inventory at the start of the period. From the graphs presented in chapter 3, we concluded that the level of inventory at the start of the day is an important factor in the warehouse processes. Therefore, we used the 'TELLST' from the Vezet system to calculate the real inventory level per product. This leads to a detailed inventory list that can be used to create the start position of the model.

4.1.2. Description of the model

<u>Event Controller</u>

The event controller manages and synchronizes the points in time that are required for the model (e.g., minutes, hours, days).

<u>Method</u>

A method is used to program the desired steps to be taken by the model. For example, in our model a method is used to assign a product to a specific location.

Generator

This device is used to activate a method, given pre-specified intervals. We use a generator to check the inventory levels every 30 minutes.

Table

A table can be used to store data in rows and columns. A table can contain input as well as output data, and can easily be saved as an Excel-file.

Variables

This can be used to measure general settings, for instance the day number. In our model the days of the week are indicated with a number to be able to measure the differences between the days.

Zones

'Plant Simulation' uses frames to create an additional layer within the model. In our simulation model, a frame is called a zone and is similar to the real lay-out of the warehouses. Within a zone we can find storage locations and crates.

Moveable unit

A moveable unit represents a load carrier (either a pallet or a rolly), which contains a number of crates. Other characteristics of the crates are also saved at the moveable unit, like product description, production date and the preferred storage zone.

Location

A location is used to stack crates and has a pre-specified capacity (depending on the size of the crates). The number and capacity of the locations, used in the model, match the warehouse situation of December 2014.

4.1.3. Output of the data model

This data model is designed to measure the performances of the two warehouses. The three most important performances for our analysis are: physical inventory level, volume utilization and location utilization of the warehouses.

Physical inventory level

The physical inventory level represents the total number of crates in inventory on a certain moment of time. When using real data as input for the model, we can compare the physical inventory level of the data model with the inventory levels we calculated in section 3.1. When using the same input range, the same inventory levels must be measured. So, this provides us with a method to verify the model.

Volume utilization

The volume utilization measures the number of crates present in the warehouse divided by the total capacity of the warehouse. As stated in section 3.2, the capacity of the warehouse is fluctuating due to the different dimensions of the crates. When measuring the capacity, we exactly know the capacity of the occupied locations, because we know the crate type at the location. However, for the free locations we do not know the capacity yet, because we do not know which product is to be expected at that location. Therefore, we have to estimate the capacity of the empty locations. To estimate the capacity of a free location, we take the average and most frequent encountered crate size: CLB 7. The volume utilization is measured every 30 minutes and stored in a table.

Location utilization

The location utilization is used to analyze the locations of the warehouse. We divide the number of occupied locations by the total number of locations. The total number of locations is a fixed unit, so the most important part is to investigate how many locations are occupied. To this end, we implemented the allocation rules of the warehouse and measured, in the data model, how many locations are occupied.

4.1.4. General structure of the data model

Both models consist of a production facility, a receiving area and storage zones (see figure 5-1 for the simulation model of Dailycool). At the *input* section, products are created according to the table '*production data'* that contains production data from the past months. We use a *movable unit* to represent a pallet or rolly containing a number of crates. A *movable unit* (yellow products in the model, figure 4-2), moves from production to the receiving area where the products receive its characteristics, like number of crates on a rolly, product name and production time. Next, the products are transported to a predefined storage zone. Every action is determined and trigged by *generators*. By subtracting the number of crates picked from the number of crates produced, we know the marginal difference in physical inventory position. Combining this with the inventory position at the beginning of the simulation, we can calculate the inventory position at every point of time.

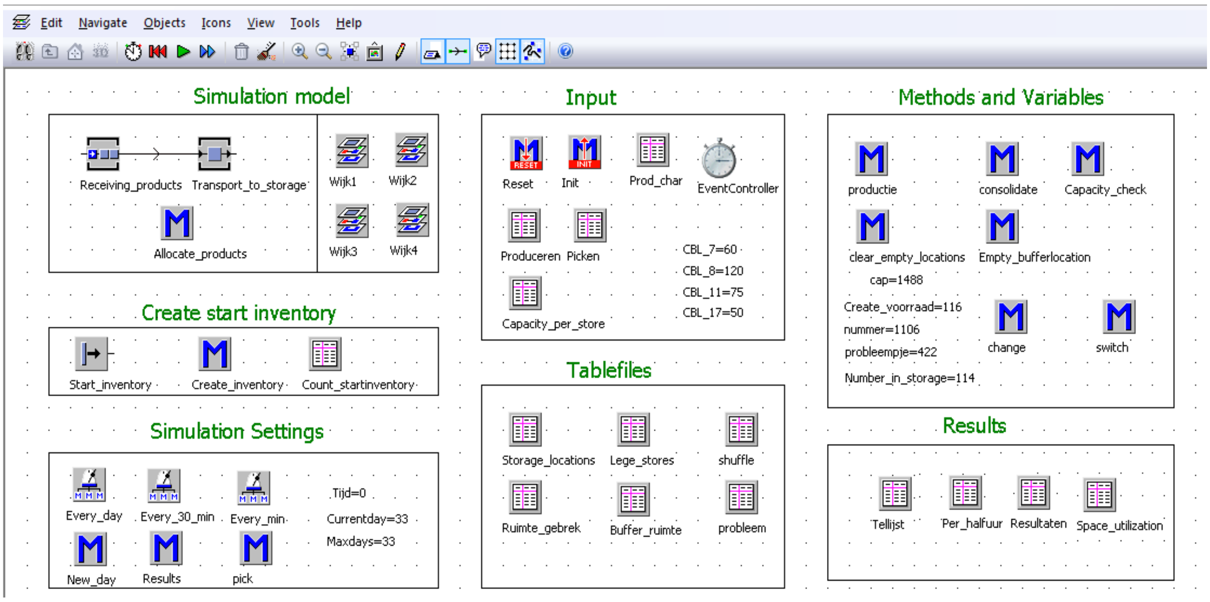

Figure 4-1: global structure of the model

To illustrate the actions within a storage zone, we present storage zone 7 in figure 4-2. This is the Expedition warehouse, in which every SKU has its dedicated storage location. After a pallet is made in figure 4.1, it is sent to a storage zone. Within the storage zone, the product is immediately sent to its location (represented in figure 4-2 by a square with little dots). Each location has its own capacity and registers the amount of crates present at the location. When a product is required for distribution, it needs to be picked. The command for picking actions is given in figure 4.1, after which we see that the required crates (the yellow units) will move from the storage location to 'the order picker location' in the middle of the picture. He will prepare the crates for distribution and loads them into a truck.

Figure 4-2: Lay-out of storage zone 7

4.2. The EA-warehouse real life data model

4.2.1. The allocation rules at the EA-warehouse

4.2.2. Results of the Dailycool model

4.2.3. Verification and validation of the Dailycool model

We want to know whether the model contains errors and if it matches reality. Therefore, we use the verification and validation methods made by Law (2007). He defines verification as determining whether input data and assumptions are correctly translated into the computer program. Validation is the process of determining whether the model is an accurate representation of the real system.

For the verification of the model, we used the debug tools of 'Plant Simulation'. This tool enables the user to review the programmed code by a step-for-step method. In this case the user can see how the model deals with the calculations and checks whether the results are without any errors. This would result in a model that can run without encountering errors. Also, animations are important to review, because this shows whether the moveable unit follows the expected path. To check for errors in the model, we can also compare the physical inventory levels found in the data model with the inventory levels, calculated in section 3.1. Because the input for both models is the same, the results should be identical. By comparing the inventory levels from section 3.1 and the inventory in the model, we noticed that the results are identical, which means that the model is valid.

We learned that it is impossible to simulate the real processes into a model, but we have made a model that shows no bugs. Also, the physical inventory level found in the data model matches the graphs found in section 3.1, which indicates that the crates are handled as in daily circumstances.

To check the validity of the model, we would like to make a quantitative analysis of the results. However, we have nothing to compare this data to. There is currently nothing known about data of the inventory levels in the warehouse or the utilization rates of the warehouse. So, we have only two ways of validation. The first one is to check with the warehouse manager whether the volume and location utilization do represent the actual situation at the warehouse. The patterns, we found in the analysis, are recognized by the warehouse operator and match reality. Secondly, we have counted the number of occupied locations at certain moments and checked the percentage with the values found in the data model. During these measurements, the location utilization was **X** percent, which is a close match to the results of the model. So, we assume that the model describes the actual situation at the EA-warehouse and does not contain errors, and can use this model for our research.

4.3. The Expedition real life data model

Also for the EAA-warehouse of Expedition, we created a real life data model. This model does not behave in the same way as the EA-warehouse model, because of the differences in the allocation rules. However, the results, validation and verification of the model are executed in the same way as the EA-warehouse model.

4.3.1. The allocation rules at Expedition

4.3.2. Results of the EAA-model

4.3.3. Verification and validation of the model

To validate and verify the model, we applied the same methods as described in section 4.2.3 of the EA-warehouse. Because of the Temporary Shipping Location at this warehouse, it is hard to measure the exact inventory levels. The EAA-warehouse operator supports the graphs and the employees recognize the patterns and fluctuations.

4.4. Summary

In this chapter, we looked at both the volume and location utilization, because these two indicators have some correlation. We have created a model that allows us to measure the performances of the warehouses during a specific period of time. From a series of interviews with warehouse employees and comparisons with the findings about the inventory level in chapter 3, we concluded that the model was suitable to be used for the analysis. An advantage of the interviews with the warehouse employees was that support was created for the research. They understand the purpose and significance of the research.

For the EA-warehouse, managed by Dailycool, we found that the most important problem can be found at the location utilization and not at the volume utilization. Therefore, we concluded that the EA-warehouse requires more locations, but they do not require having a high capacity. The problems at the location utilization have a high frequency and occur on average in **X** percent of the days we measured.

The problems at the EAA-warehouse have a different nature. At this warehouse, no obvious problems are encountered when looking at the overall utilization rates. However, because of the dedicated storage policies, we see lots of volume utilization problems at individual location. This means that more rollies need to be stored than the capacity permits. So, the EAA-warehouse requires more capacity at its storage locations.

In the next chapter, we provide an overview of the events that both warehouses face within 2015 and 2016. The model will be used to measure the consequences of these events and their alternatives.

5. Tactical analysis

Vezet faces several events, in the period 2015-2025, that require attention. These developments affect the processes and capacity of the warehouses and consequently, we need to assess the impact on the warehouse performances and to come up with solutions in case of problems. In section 5.1, we start this analysis with week 23, 2015, in which **X** new products are introduced at the EAA warehouse. The second part, the switch of **X** RDC products to the LVC, is discussed in section 5.2. After that section, we continue with section 5.3, the event of a new distribution center at the end of 2015. In section 5.4, we figure out the consequences of the introduction of a new production line at the location of the current COOP activities. And we conclude this chapter with a solution approach for these tactical events.

5.1. Introduction of new LVC-products

5.2. Switch 16 products from RDC to LVC

5.3. Switch to a new distribution center

5.4. Expansion of production capacity

5.5. Solution approach tactical analysis

We analyzed the current performances, problems and expected developments for the next year. Besides the specific actions mentioned in the previous sections, we identified some additional improvements that need to be taken to avoid problems in the future and to optimize the current processes at the warehouses. As we have seen in section 5.4, the EAA-warehouse will lose its function within 6 months, leading to the inability of implementing sustainable options in the warehouse. For the EA-warehouse of Dailycool, we see several realistic and sustainable improvements.

5.5.1. Align the picking and production activities

5.5.2. Align volume and location utilization

5.6. Summary

There are four major events in 2015 that affect the finished goods warehouse operations seriously. We found ways to deal with these changes, which were presented in this chapter. By switching to the SFC, Vezet does not require the storage area at the EAA-warehouse, which then can be used for the COOP-activities. So, when looking at the future situations in chapter 6, we do not account for the developments of the EAA-warehouse, because it is not used anymore for Albert Heijn products. However, dealing with these events is not the only challenge Vezet faces. Especially in the EA-warehouse, we have to rapidly adjust some processes in order to make it more efficient and less sensitive to rush hours, especially since future growth is expected in production volumes.

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6. Strategic analysis

As stated in the research question, Vezet wants to know what the company requires for the next 10 years. In the previous chapters, we found that the problems and performances in the warehouse operations were difficult to measure. Therefore, we created a model that brought us understanding of the processes. In this chapter, the model is extended, in order to use it for the strategic analysis. The model from chapter 4 is rebuilt into a simulation model, which is explained in section 6.1. In section 6.2, we look at the factors that can be used to describe the future of warehousing processes, which relates to the third sub-question. To this end, we use the market developments of the Rabobank and the forecasts of Vezet. This information is implemented in the simulation model, after running the model, we found problems related to the expected growth. This is described in section 6.3, along with solutions for the expected growth. This corresponds with sub-questions 4 and 5.

6.1. Simulation model of the EA-warehouse

6.1.1. Production volumes per day

6.1.2. Production interval

To model the production, and thus the receiving at the EA-warehouse, we have to divide the day into intervals. This is necessary, because the number and type of products change frequently. The most suitable interval is one hour, which results in 16 intervals. During these intervals most of the **X** product types need to be made. According to the constant production rate, we need to receive seven product types per hour. These seven product types are chosen by the model, using a uniform distribution. This ensures that every product has the same opportunity to be produced. Using this uniform distribution, it may happen that some products types are produced twice. This matches the real situation at Vezet.

6.1.3. Pick volumes per day

6.1.4. Validation of the simulation model

Now that the input of the simulation model approximately matches the current situation of the EA-warehouse, we have to verify whether the model indeed provides approximately the same results. Again, we choose January 15, because this represents a normal day at Vezet. The other data set is chosen from the simulation results, which is called day ‘214’. This shows the 214th day of the simulation model. We chose this day, because the start and end point are almost identical, which enables us to validate the patterns during the day. Both days are visualized in figure 6-1.

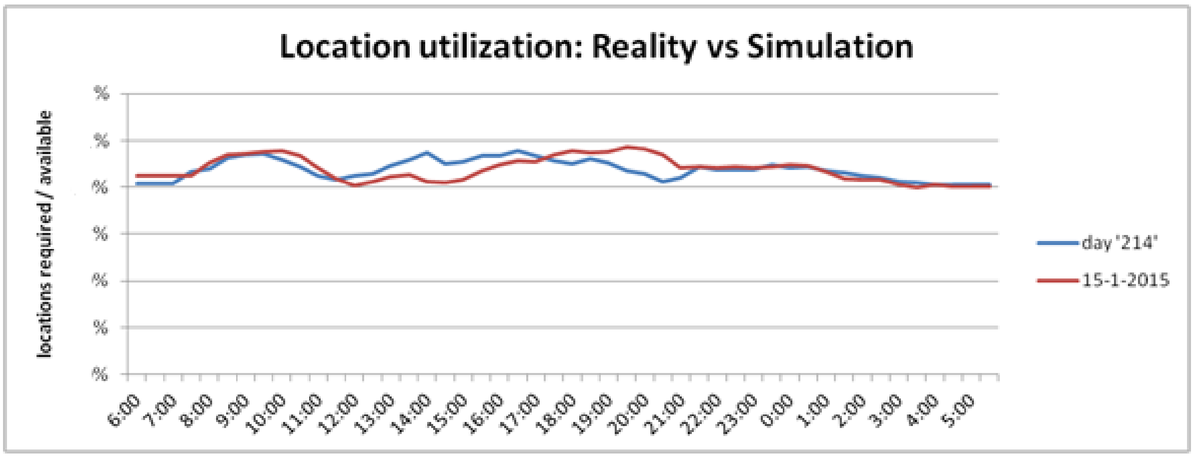

Figure 6-1: Comparison between real life data model and simulation model

6.2. Growth scenarios

6.3. Future requirements at the EA-warehouse

6.4. Summary

In this chapter, we researched the requirements for the outbound process at Vezet for the next 10 years. The model from chapter 4 is translated into a simulation model, which is used to simulate the warehouse processes at the EA-warehouse. In order to create an accurate model, we had to calculate distribution functions and test whether the model fits reality or not. We concluded that the model fits its requirements and can be used for analysis.

To investigate the consequences of the expected growth, we looked at the market developments and the forecasts of Vezet itself. We see that Vezet outperforms the market and is expected to continue this process. The yearly expected volume growth is on average **X** percent, while the growth in product types equals **X** percent per year.

These growth rates are implemented in the simulation model. After this, we were able to run the simulation model. Due to these expected growth and despite the before mentioned process improvements, in chapter 5, Vezet requires expansion of the finished goods warehouse. This is already needed in 20**XX**. The EA-warehouse requires, at that moment, an expansion of at least **X** %, but it is thoughtful to be prepared for the future. When the required **X** % is built in 20**XX**, the building is again too small at the end of 20**XX +1**. We do not desire such situations. Therefore, we recommend to be prepared for 2025 and build an expansion of at least **X** percent of the current warehouse. This equals approximately **X** square meters. This space can also be used for storing other products or performing other processes. For example, there are currently some processes that cannot be executed in the EA-warehouse, while these processes do involve finished goods (for example, storage of pizzas and COOP activities). These processes can be placed in EA-warehouse, when capacity is sufficient.

7. Conclusions and recommendations

During this research, we found possibilities to measure performances and problems in the warehouses at Vezet. We also conducted a tactical and strategic analysis. These findings enable us to answer the research question, posed in chapter 1. This is discussed in this chapter, along with the answers to the sub-questions.

In chapter 1, we posed the following research question:

> *"What improvements does Vezet B.V. require at the outbound processes (in terms of storage capacity and investments) to meet the current and future requirements in a way that the service level remains ensured?"*

We started the research by a literature research about warehouse operations and processes. From this research, we learned that there were multiple topics relevant for warehousing, but *volume utilization* and *location utilization* were the most important measures for the Vezet warehouses. In the EA-warehouse (managed by Dailycool), the main problem is related to the location utilization, while in the EAA-warehouse, the main problems are related to the volume utilization of individual locations.

To measure both utilization rates, we created a model that is able to analyze the warehouse processes. This helps us in acquiring understanding about the actions taken and the operations performed during this research. This also helps to ensure the service level, because all products need to be delivered in time to the customer, and it may not happen that products remain in storage for too long.

In the EAA-warehouse, we foresee two events that require immediate attention. The introduction of new products and the switch of **X** products to the LVC, require changes in the current lay-out of the warehouse. Also, additional storage space for the LVC-products is required, which is urgently recommended to be near the production facility. This is the only suitable location that can be used for storing these rollies. By the end of 2015, the LVC destination will be replaced by a new distribution center, the SFC. We concluded that these changes lead to storage problems, and that the best solution is to send these products directly to the SFC.

The production capacity of Vezet will also be expanded at the end of 2015, at the expense of the storage area of COOP. This intended expansion cannot occur before the switch from LVC to the SFC, otherwise it leads to the outsourcing of the COOP activities, which is not desired by the management. After the switch to the SFC, the COOP activities can be transferred to the current EAA-warehouse, because inventory of SFC-products is held in the SFC and not at Vezet.

In the EA-warehouse, we found patterns in the location utilization that enlarges the current problems. The reason for these problems is that production and distribution in the EA-warehouse are currently not aligned. Therefore, we suggest that the order pickers in the EA-warehouse start at the same time as the production employees. This increases personnel costs, but ensures that the capacity of the warehouse does not have to be expanded until **X**.

Also, we conducted a strategic analysis, which we used to analyze the future until 2025. We translated the model, we used before, into a simulation model which is able to simulate the future processes in the EA-warehouse. We include the tactical events (like the switch of **X** products from the RDC to the LVC) in the simulation model. This ensures that the model provides a realistic image of the future. There are two factors important for this analysis: the volume growth and the growth in product range. Growth is expected for both factors, respectively **X** and **X** percent. From the simulation model, we see that serious warehouse space problems occur. In 20**XX**, an expansion of **X** percent of the current warehouse area is required. However, we recommend Vezet to be prepared for the future (2025) and expand the warehouse building by **X** percent, which equals **X** square meters.

In order to answer the research question, we use five sub-questions in chapter 1. During the research, we answered these questions. In the remainder of this section, the answers to the sub-questions are shortly discussed.

<u>Sub-question 1: What patterns in the outbound processes can be distinguished in the current situation at Expedition and Dailycool?</u>

There was little information about inventory position known at Vezet, so we started by visualizing the inventory position in graphs. From these graphs we saw the differences between the EA and EAA warehouse. At the EA-warehouse, we saw that there was a peak around 09:00 and 19:00 hours, while at the EAA-warehouse no clear peak could be identified. Moreover, we were able to show the increase in inventory during the week, at which Thursday and Friday have high inventory volumes.

<u>Sub-question 2: What is the magnitude of the operational warehouse problems and how can support be created for these problems at management and production level?</u>

By designing a real life data model, we could simulate the warehouse processes of a six months. By combining real production and pick data, capacities and allocation rules, we were able to calculate the volume and location utilization. These were indicators for warehouse space problems. At the EA-warehouse, we often see problems with the location utilization, after which the products cannot be placed in the warehouse anymore. While at the EAA-warehouse, we faced volume utilization problems per location, at which the number of rollies present of a product exceeds the capacity of its location.

<u>Sub-question 3: Which factors can be distinguished to describe the future of warehousing processes at Expedition and Dailycool?</u>

The future of Vezet is divided into two parts, the tactical part that looks one year ahead, and the strategic part that looks ten years ahead. At tactical level, we see four events that affect the warehouse process.

1) New product introduction for the LVC
2) Switch of **X** product types from RDC to LVC
3) The introduction of a new warehouse (SFC)
4) The placement of a new production line at the COOP area

To describe the strategic warehouses processes, we have to distinguish two indicators, the production volume and the number of product types. For both indicators, growth is expected. The production volume at Vezet is expected to grow **X** percent annually, until 2025, while the number of product types is expected to increase with **X** percent annually until 2020 and **X** percent thereafter. We compared these growth rates with the fresh cut market and the production volume growth is higher than the market average. However, we have seen that Vezet is currently outperforming the market.

Sub-question 4: Which problems arise from the growth scenarios and what are the consequences of these problems?

On tactical level, we analyzed the impact of the four challenges that affect the warehouses processes. The recurring problem is that Vezet has not enough warehousing capacity to facilitate the events.

1) **X**
2) **X**
3) **X**
4) **X**

On strategic level, we looked at the volume and location utilization. Especially, in the EA-warehouse we see problems at the location utilization. We see that Vezet requires structurally additional storage space, which is directly related to the growth rates. We showed with a simulation model that the need for additional space in the EA-warehouse is approximately **X** percent per year.

Sub-question 5: What solutions can be identified to avoid the problems, and how can these solutions be implemented?

We create three indicators to measure problems at the warehouses. The first indicator shows the physical inventory in the warehouse, which is used to identify rush hours and patterns. The second, volume utilization, is used to check efficiency in the warehouse, because we want to know if the warehouse space is used as efficiently as expected. And the third indicator, location utilization, is used to show the storage area that the warehouse requires. The combination of these three indicators allowed us to see that expansion of the warehouse is not directly needed on tactical level. By rearranging current processes, efficiency is gained and problems are structurally solved.

By the end of 2015, a new distribution center will replace the current LVC. A part of the products cannot be stored at Vezet anymore, and has to be sent to this new distribution center immediately. This results in additional costs of € **X** per year.

To investigate the future requirements for the RDC-products, we simulated the processes at that in-house warehouse. This warehouse is expected to have structural problems, beginning in the period **X.** At this point, the warehouse requires an expansion of **X** m^2 (**X** % of the current warehouse size). For the next years, the warehouse problems are more severe and in the year 2025, an expansion of the finished goods warehouse of **X** m^2 is required.

Further research

By answering the research question and the sub-questions, we finalized this thesis. Nonetheless, we have some recommendations about topics for further research. In order to translate the current processes into future processes, we restricted ourselves to the currently used block stacking methods in the warehouse. During the research, we found evidence that would support the usage of racks. We would like to suggest performing a study into the effects of the introduction of rack stacking.

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Appendix A New lay-out factory due to RDC-LVC changes

Figure A-1: Lay-out of the new design of the storage area for the LVC --> LVC products (in green)

Appendix B Production rate EA-warehouse

Table B-2: Picking rates at the warehouses

Table B-1: Production rates of the factory

Appendix C Distribution identification production

Appendix D: Overview of the supply chain of Vezet (in Dutch)