Chair of Industrial Logistics

Master's Thesis

Development of a logistics concept for strategic plant development

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Kurzfassung

Die Steigerung der Produktionskapazität wirkt sich maßgeblich auf die bestehenden Strukturen und Logistikprozesse eines Unternehmens aus und erfordert oft notwendige Anpassungen. Die Identifizierung der spezifischen Bereiche, die Veränderungen benötigen, sowie die Entwicklung kosteneffizienter Wege zur Umsetzung dieser Modifikationen sind entscheidende Schritte.

Diese Masterarbeit basiert auf einem realen Projekt in der Brauerei Göss und konzentriert sich auf die Erhöhung der aktuellen Produktionskapazität für die Abfülllinie. Die Rekonstruktion der Abfülllinie soll bis 2025 abgeschlossen sein, mit einer prognostizierten Produktionssteigerung von 38% bis 2027 im Vergleich zu 2023. Die Studie beinhaltet die Entwicklung eines strategischen Konzepts zur Erweiterung des Logistikbereichs, die Anpassung des Lagerlayouts, die Optimierung von Prozessen und Verkehrsflüssen sowie die Anpassung der Lagerkapazität.

Die Anfangsphase umfasste die Zusammenstellung von Daten über das akutelle Lagerlayout, den Logistikprozessen und Verkehrsflüssen. Diese Daten wurden unter Anwendung von Lagerverwaltungstechniken analysiert, um Engpässe zu identifizieren und etwaige Probleme zu lösen. In Anbetracht der prognostizierten Produktionssteigerung wurden anschließend Änderungen am Layout des Lagers vorgeschlagen, um die erforderliche Kapazität zu schaffen, sowie Verbesserungen der Logistikprozesse einschließlich der Verkehrsflüsse. Darüber hinaus wurde die Einführung alternativer primärer Transportoptionen über Züge empfohlen. Vergleichende Bewertungen wurden zwischen diesen vorgeschlagenen Änderungen und den aktuellen Konfigurationen durchgeführt. In Fällen mit mehreren vorgeschlagenen Alternativen wurde eine detaillierte Bewertung dieser Optionen vorgenommen, um das effektivste Szenario auszuwählen.

Die durchgeführte Arbeit wurde durch einschlägige Literatur auf dem jeweiligen Fachgebiet unterstützt.

Abstract

Ramping up production capacity significantly influences a company's existing structures and logistics processes, often calling for necessary adaptations. Identifying the specific areas in need of change and devising cost-efficient ways to implement these modifications are crucial steps.

This master thesis is founded on a real project at the Göss brewery, focusing on increasing the current production capacity for the bottle line. The reconstruction of the bottle line is scheduled to be completed by 2025, with a projected 38% production increase by 2027 compared to 2023. The study entails the development of a strategic concept for expanding the logistics area, adjusting the warehouse layout, optimizing processes and traffic flows, and adapting warehouse storage capacity.

The initial phase involved compiling data on the current warehouse layout, logistics processes, and traffic flows. This data underwent analysis employing warehouse management techniques, aimed at identifying bottlenecks and addressing any issues in need of resolution. Subsequently, considering the projected production increase, modifications to the warehouse layout were proposed to accommodate the necessary capacity, alongside enhancements to logistics processes including traffic flows. Additionally, the introduction of alternative primary transport options via trains was recommended. Comparative assessments were made between these proposed changes and the current configurations. In instances with multiple proposed alternatives, a detailed evaluation of these options was conducted, to select the most effective scenario.

The conducted work has been supported by relevant literature in the respective field.

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List of Abbreviations

BUA	BRAU UNION ÖSTERREICH AG
bph	bottle per hour
cph	can per hour
DOH	Days On Hand
FLT	Forklift
hl	hectoliters
JIT	Just In Time
kph	keg per hour
LIFO	Last In First Out
Mhl	Million hectoliters
OTM	Oracle Transportation Management
pal.space	Pallet space
RGB	Returnable Glass Bottle
TMS	Transportation Management System

1 Introduction

The need for transportation, movement, and logistical operation rises because of increased globalization, the growth of world economies, and the increasing consumerism in society [1].

Logistics is the function that is responsible for transport and storage of materials on their journey between suppliers and customers [2]. Therefore, logistics is a dynamic and diverse function that must be adaptable and flexible to the different constraints and demands placed on it with respect to the environment in which it operates [3]. Only the fastest, cheapest and most efficient in terms of productivity wins in the current development of logistics [4].

There is a potential increase in customer demand expected at Göss Brewery in the coming years. Therefore, construction of a new bottle line production is planned to keep up with demand. This mater thesis is based on “capacity extension of the bottle line production” project. A new production line is scheduled to be built by the end of 2025, replacing the existing one. This development is projected to increase production by 38% by 2027 compared to 2023. This transition affects the warehouse layout and logistics processes. The aim is to identify bottlenecks and address any issues in need of resolution to help the company to have a smooth transition.

1.1 Company History

Göss brewery, is one of the oldest and most famous breweries in Austria, has a long tradition of brewing beer. Göss was founded around 1020 and was the oldest monastery in Styria. Beer was brewed there for their own consumption and to serve any visitors. In 1860, Max Kober acquired properties and part of the monastery buildings, where he founded the Göss brewery. In the first year, he brewed 2,240 hl (Hectoliters) beer. In the following years, he was able to increase production, reaching 63,000 hl in 1893 [5].

Göss brewery is a pioneer when it comes to using new technical innovations. In 1920, it became the first brewery in Austria to use pasteurization and crown cork (at that time the crown cork and bottle opener was an invention that had to be explained in newspaper). This new technology allowed Göss to begin shipping its products outside of Austria. In the 1960s, the brewery reached the production of 828,000 hl. It was in 1966 that Göss formulated the slogan ”Gut Besser Gösser”. In 1972, Steirerbrau was formed between Reininghaus - Puntigam brewery and Göss Brewery [5]. Brau

AG and Steirerbrau were merged in 1998 and founded BRAU UNION ÖSTERREICH AG (BUA). Since 2003, Brau Union Österreich has been a part of the parent company Heineken [6].

In 2021, the brewery reached the production of 1,386 Mhl (Million hectoliters). Nowadays, Göss brewery has in total 41 production and storage tanks with a capacity of 5,000 hl each. Over time, production has continuously increased in line with demand. Consequently, it's projected that production should reach 1,617 Mhl by 2027 to fulfill market demand [7].

Figure 1 shows an aerial photo of the Göss brewery.

Figure 1: Aerial photo of Göss brewery

Göss brewery is the first world's largest "Green Brewery" and uses only renewable energy to brew beer. This means that the whole production process is completely CO_2-neutral (Figure 2). It is important to have high quality products, so they only use raw material from Austria to ensure the quality [5].

Figure 2: Overview of the energy supply for the Göss brewery [8]

1.2 Motivation and problem statement

This master thesis is based on a real project at the site Göss brewery in Leoben. The main project is about the increase of the production capacity for the RGB (Returnable Glass Bottle) filling line from 36,000 bph (bottle per hour) to 55,000 bph. The existing RGB line will be disassembled, and the new line will be installed and commissioned until 2025 [9]. These changes have a major impact on the logistics process and the capacity of the warehouse. Therefore, it is necessary to develop logistics concept to have a smooth flow of materials and goods and to accommodate the required capacity.

The points that we focused on are optimizing the warehouse layout to have a smooth traffic flow with lowest cross point and adequate storage capacity. The palletizing and depalletizing of the production line needs to be relocated to have a shorter distance to empties (bottles, cans, kegs) and storage area [10].

1.3 Structure of the work

This master thesis is divided into three main sections: literature review, practical section and conclusion. The practical section consists of three parts:

1. Data collection and current state analysis: collecting data to have a better understanding of the current state and analyzing the current state
2. Analysis of the current state: warehouse management techniques are employed to identify bottlenecks and address any issues in need of resolution

3. Proposed changes to the current state: multiple alternatives are evaluated and best options are proposed to modify the warehouse layout, logistics processes and traffic flows

Implementing the logistics concept is not part of this master thesis.

2 Literature review

The need for transportation, movement, and logistical operation rises because of increased globalization, the growth of world economies, and the increasing consumerism in society. This results in the creation of new logistics systems and supply chains, as well as development and increasing complexity of existing supply chains and logistics system [1].

Logistics refers to the integrated planning, design, execution, and control of the entire material flow from suppliers to the company, within the company, from the company to the customer, the return of goods in a cycle, and the information flow required to plan and control the material flow [11]. The goal of logistics is to deliver the right product, in the right quality, in the right quantity, at the right place, at the right time for the right customer and at the right cost. These 7Rs are a general roadmap for achieving efficiency, effectiveness and increased customer satisfaction in logistics services [12]. The role of logistics facilities is important to all supply chains, as they play a significant role in handling materials that move from production sites to consumers. The correct operation of warehouse facilities enables them to perform their logistics tasks at a level of quality that is appropriate and acceptable to the customer [1].

Each industry has unique characteristics, and each company in that industry may have significant differences in strategy, size, product range, market coverage, etc. Therefore, logistics is a dynamic and diverse function that must be adaptable and flexible to the different constraints and demands placed on it with respect to the environment in which it operates [3].

2.1 Warehouse

The term "warehouse" is employed when the main function involves buffering and storage [13]. Warehouses play an important role in supply chain. Because of the unpredictability of markets, companies need to hold stock at different stages within the supply chain [14].

The operation of warehouses is expensive and requires careful planning [2]. Therefore, optimizing warehouse design becomes crucial to minimize costs. To maximize warehouse efficiency, it is important to identify and optimize the critical factors that affect the warehouse processes, speed of warehouse procedures and execution quality. A certain level of optimization can be achieved by using simple methods and tools without relying on complex and difficult algorithms [15].

2.1.1 Layout

The layout of a warehouse is one of the most important decisions, which includes the physical arrangement of storage racks, equipment, loading and unloading areas, office space, and other relevant facilities. This has a major impact on the operations efficiency [2].

A good warehouse layout makes effective use of available space to reduce material handling and storage costs. The shape and size of the aisles, the location and orientation of the docking area, the height of the warehouse, the type of racking used for storage, and the level of automation involved in the storage and retrieval of products are some of the factors that should be considered when designing a warehouse [16]. An efficient warehouse layout should reduce the number of travel and labor touch points, avoid bottlenecks and cross traffics, and ensure that movements follow a logical sequence [14].

Considering internal transportation costs is crucial when designing a warehouse layout. The number of cross-aisles as well as their configuration, such as directions and locations, influence the cost of material handling. Depths of the bay also have an impact on the travel distance. To replenish the layout with deeper bays, a longer distance must be traveled [17].

2.1.2 Storage system

Stacking pallets of Stock Keeping Units (SKUs) on top of each other on a warehouse floor is known as block stacking. This storage system does not usually require any storage racks, and it is inexpensive to implement, but it is a challenge to space planning, because the lower pallets cannot be accessed until the pallets stacked above and in front of them have been removed. This storage system is commonly used in warehousing and cross-docking, especially for large and heavy pallets [17].

2.1.3 Material handling

In general material handling deals with the movement of materials for short distances through a warehouse or between storage areas and transport. It costs money, takes time, and creates an opportunity for damage or error every time an item is moved.

Efficient warehouses minimize the amount of movement and make the movements that are necessary as efficient as possible. These objectives depend on the choice of handling equipment. This can have an impact on the speed of the movement, material types that can be moved, layout, costs, the number of employers, and so on [2].

2.1.4 Storage space

Many factors must be taken into consideration when calculating the storage medium and the amount of storage space required. Once the quantity of the product items stored per product line has been calculated and converted into pallet quantities, the total number of pallets we need to store for each product line can be determined. The next step is selecting the storage medium, which might involve block stacking, pallet racking, automated storage, shelf and bin locations or a mix of these options [14].

In situations where warehouse space is insufficient, there are several solutions that can be used, such as expanding the warehouse, renting additional space, or optimizing the available area within the current premises. Reducing the inventory level can also be a good solution for increasing warehouse space [14].

2.2 Logistics process

Logistics processes encompass a series of activities involved in the management and movement of goods and resources from their point of origin to their final destination. In a warehouse, the basic flow of material within it can be divided into four processes: receiving, storage, order picking, and shipping. Any additional processes, such as sorting, have a direct impact on the selection of technical means and equipment. In receiving process, trucks or internal transport bring the product into the warehouse. The storage process refers to the activities of placing the items into storage area. Order picking refers to the retrieval of goods from storage to fulfill customer order. Orders are checked, packed, and then loaded onto trucks to ship it to the customer [18].

To ensure optimal functionality and efficiency of a warehouse, the warehouse must be carefully designed. The design process generally begins with a functional description, through a technical specification, followed by the selection of equipment, and determination of a layout. Warehouse design often requires a mixture of creativity and analytical skills [18].

In warehousing, analyzing product flows helps to identify potential improvements in the physical facility's design. To understand how the network of logistic activities is structured, it is better to visualize the physical flows through the warehouse. This can help to identify unnecessary moves or to illustrate the storage time of each item [19].

Transport is an important component which must be considered in the warehouse design. Transport is changing the physical location of goods and moving them from a source to a destination. Transport is divided into external (to and from a company) and internal (between functional areas of the company). Depending on economic and time factors as well as the type of goods to be transported different means of transport (truck, train, airplane) is used [11]. One of the most crucial components in a manufacturing organization is internal transport. Logistics costs often account for up to 20% of total costs. This is why the design and optimization of the logistics processes is a high priority. In fact, it is not just about logistics costs, it is also about production processes that rely on internal transportation and logistics [20].

To change the internal logistics process or multiple logistics processes, it is essential to thoroughly map or analyze the existing state of internal logistics processes. After obtaining an overview of the existing state of individual processes and identifying deficiencies or shortcomings, the next step is to design solutions to optimize the logistics processes. And finally, assessing the impact of changes in the logistics process [21].

Process mapping involves creating a model that illustrates the relationships between the activities, individuals, data and objects within the production process of a defined output [22].

In the physical flows, movement of people such as order pickers, forklift drivers, etc. is also important in terms of distances travelled and time spent, which affects total costs. Many of these movements occur without carrying any goods, representing a significant potential for optimizing the flow of people as well [19].

2.3 Analysis methods

Inventory management is important for making organization efficient and effective. Increasing the various cost related inventory due to lack of inventory control system have negative impact on the profitability of the organization. ABC and XYZ analysis as well as Days On Hand (DOH) are various methods used for inventory control. ABC analysis is the type of technique that provides the means to identify the items that have the greatest impact on the organization's overall inventory cost. ABC analysis is a very simple inventory model and is recommended a lot because it considers the consumption of materials [23].

An ABC analysis is not sufficient for optimized stocking because the accuracy of its predictions and therefore the optimization of the ordering process is affected by fluctuations in product demand. To handle these fluctuations, the probability of predicted product demand patterns can be grouped by a method generally referred to as an XYZ analysis [24].

DOH is one of the metrics in inventory management, that determines the average number of days that a product stays in warehouse before being sold [25]. Higher DOH means the product lasts at warehouse longer than others.

2.3.1 ABC analysis

There may be thousands of SKUs in an organization, even moderate size. To efficiently control this huge amount of inventory, the traditional approach is to divide the inventory into different groups. This allows different inventory control policies to be applied to different groups [26].

The most well-known method of partial classification method is ABC analysis. It is based on practical experience that a small part of a basic quantity often causes a high percentage of the total effort (Pareto principle). In companies, an analysis of the business will usually show that a small number of items (e.g. 20%) account for most of the overall result, such as sales or contribution margin (e.g. 80%). For instance, to make decisions on how to improve the storage arrangement, an ABC classification based on how often items are retrieved can be performed [11].

The supply manager can identify inventory hot spots through this categorization and set them apart from the rest of the items, especially those that are plentiful but not particularly profitable [23].

These are the three groups employed in ABC analysis [27], as depicted in Figure 3:

- The 15-20% of the items that account for 75-80% of the total annual inventory value are classified as A-items (high value items)
- The 30-40% of the items that account for ~15% of the total annual inventory value are classified as B-items (medium value items)

- The 40-50% of items that account for 10-15% of the total annual inventory value are classified as C-items (low value items)

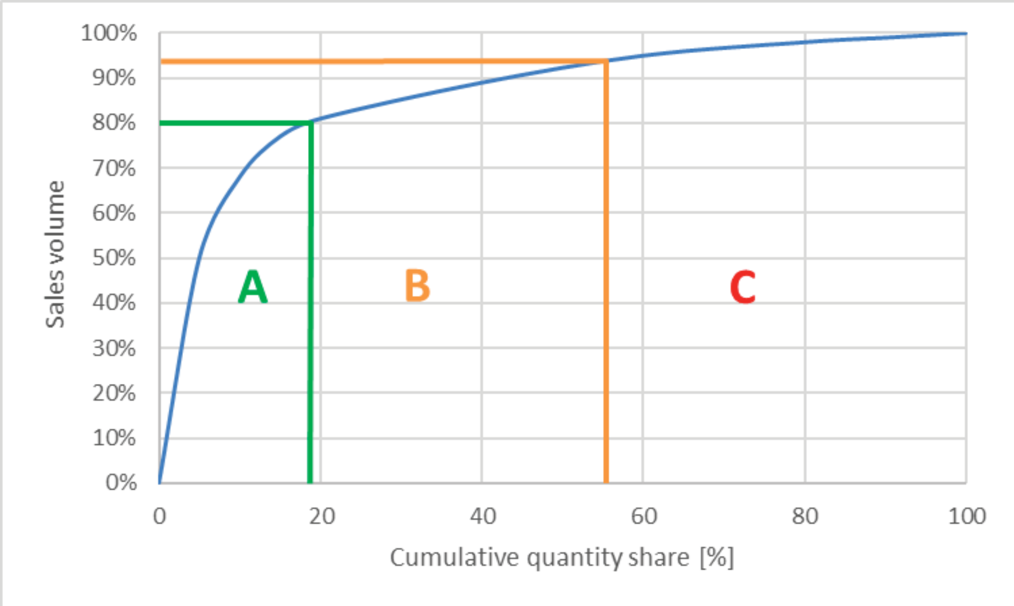

Figure 3: Pareto chart of ABC classification

Depending on the company, the exact shape of the Pareto curves and the boundary between classes may be different [28].

2.3.2 XYZ analysis

XYZ analysis is used together with ABC analysis for partial classification. It is used to analyze the regularity of material consumption. According to the characteristics of consumption, the XYZ analysis divides the items into three groups [11], as depicted in Figure 4:

- X-items: regular consumption, high prediction accuracy, easy to plan
- Y- items: fluctuating or trending upward or downward consumption, average prediction accuracy, hard to plan
- Z-items: irregular consumption, low prediction accuracy, hard to plan

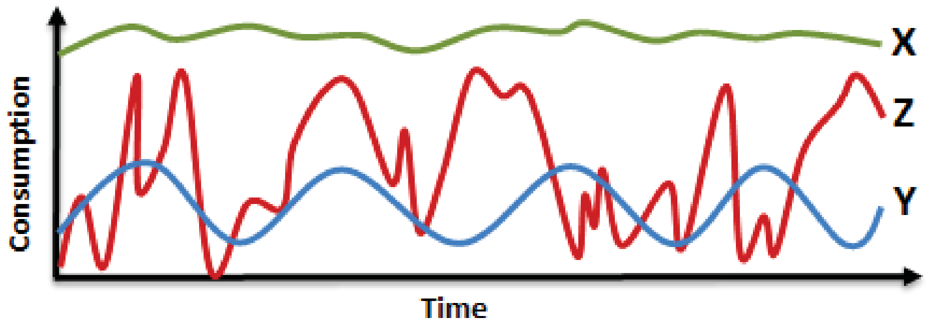

Figure 4: Consumption pattern of XYZ products

XYZ analysis evaluates the fluctuation in demand or consumption of the product. The coefficient of variation is calculated for each item, and the items are categorized according to the following ratio: 20%, 30% and 50% for items X, Y and Z, respectively. The decision on the classification is made by analyzing the demand quantities per statistical period. The dispersion of demand quantities is therefore a metric for this classification [28].

The combination of ABC and XYZ analysis is called field matrix. Effective inventory management and control can be achieved through a field matrix [23]. To determine the activities for each of the defined groups of items in a paired comparison matrix, the combined ABC-XYZ analysis is used [29].

The items in group A/X have a significant percentage of the total value, continuous consumption and the demand forecast is extremely accurate. There is no need to maintain large safety stock levels, because these items can be precisely planned and ordered.

The items in group A/Y have a large share of the total value, but their demand is discontinuous and the accuracy of their forecasts is lower. In order to reach purchase prices at the lowest cost, this group of products should get adequate planning attention.

The items in group A/Z have a large share of total value, but are sold on an occasional basis. This makes the prediction of their demand difficult and the inventory management within this group is the most complex.

The items in group B/X have a middle share of the total value. They exhibit a continuous consumption, and the demand forecast is highly accurate for them. For this group of products, it is necessary to determine the purchasing dynamics and at the same time determine the lowest inventory levels.

Group B/Y consists of the products with a middle share of the total value, with discontinuous consumption, and for which demand prediction accuracy falls within a moderate range.

The items in group C/X have a low share of total value, continuous consumption and the demand forecast is highly accurate. These products should be ordered according to demand.

Since the items in the groups B/Z, C/Y, and C/Z have a minimal impact on a company's operations, they are rarely purchased and their planning is often disregarded or left to suppliers in combination with another product.

In general, it can be said that categories AX, BX, and AY are suitable for JIT (Just In Time) techniques, while for low value items with low demand predictability, which located in category CZ, the effort must be minimized. All the other groups in between need to be considered individually [29]. The field matrix is shown in Table 1.

Table 1 : Field matrix; combined ABC-XYZ analysis

	A	B	C
X	High value Continuous demand High predictability Low inventory	Average value Continuous demand High predictability Low inventory	Low value Continuous demand High predictability Low inventory
Y	High value Fluctuating demand Average predictability Low inventory	Average value Fluctuating demand Average predictability medium inventory	Low value Fluctuating demand Average predictability High inventory
Z	High value Irregular demand Low predictability medium inventory	Average value Irregular demand Low predictability medium inventory	Low value Irregular demand Low predictability high inventory

2.3.3 Days on hand

Every company wants to provide a high service level at minimum cost, which is the main element of inventory management [30].That means to have right amount of products in stock.

Days On Hand (DOH) is one of the key performance metrics in inventory management. It determines the number of days that an average inventory in a company lasts on daily usage. Days on hand can be calculated by dividing average inventory by average usage in a specific period of time [31]. A higher DOH means to have lower inventory turnover, consequently the capital in inventory is high.

3 Practical part

This chapter initiates the practical segment, beginning with observation and data collection in the warehouse area, logistics processes, and process and traffic flow. An analysis of the current situation is conducted to identify bottlenecks and address any issues that require resolution. Finaly, the chapter concludes with the optimization and development of a logistics concept aimed at increasing warehouse capacity and improving overall process.

3.1 Data collection and current state analysis

In the first phase, data was collected to gain a full understanding of the current state at Göss Brewery. Data was collected through self-observation, internal document, employees, and SAP records. A site visit was necessary to collect data directly and gain a thorough understanding of factors such as the number of pallets stored, the current storage system, the layout of the warehouse and the operational processes. A comprehensive review of all warehouse facilities was done, and adjustments were made to the layout and data to ensure the reliability and accuracy of the data for the next phase.

The brewery is equipped with 3 packaging lines:

1. One keg line with a capacity of 600 kegs per hour (kph), operating in 3 shifts
2. One Canning line with a capacity of 40,000 cans per hour (cph) operating in 2-shift system, with the possibility of operating in a 3-shift system if necessary
3. One Bottling line with a capacity of 36,000 bottles per hour (bph), operating in 3 shifts

Brau Union deals with ~2,300 products through the hub located in Wundschuh. However, the Göss warehouse only stocks 102 SKUs. These 102 SKUs are divided into three categories:

1. Products that are produced in Göss
2. EIGEN/Bestellen from SOBSL-Werk (products that are produced in other breweries)
3. HAWA/Bestand-Material (products from other suppliers)

At Göss, production planning is done on a weekly basis, with detailed plans for each production line. This includes verifying the quantity of empties and available pallets required for the upcoming week's production. To ensure a smooth production process, the quantities of empties and pallets required for production are strictly monitored and managed.

Sections 3.1.1 to 3.1.2 provide more details about warehouse layout, logistics process and warehouse capacity.

3.1.1 Warehouse layout

The brewery is equipped with keg-, can- and bottle-filling lines. The location of the palletizing and depalletizing for each of filling lines can be seen in Figure 5. To feed the filling machines, forklift trucks deliver two pallets of empties at the same time (bottles, cans or kegs) to a depalletizing station, and at the other end, forklift trucks pick up the finished goods from the palletizing station to the storage area.

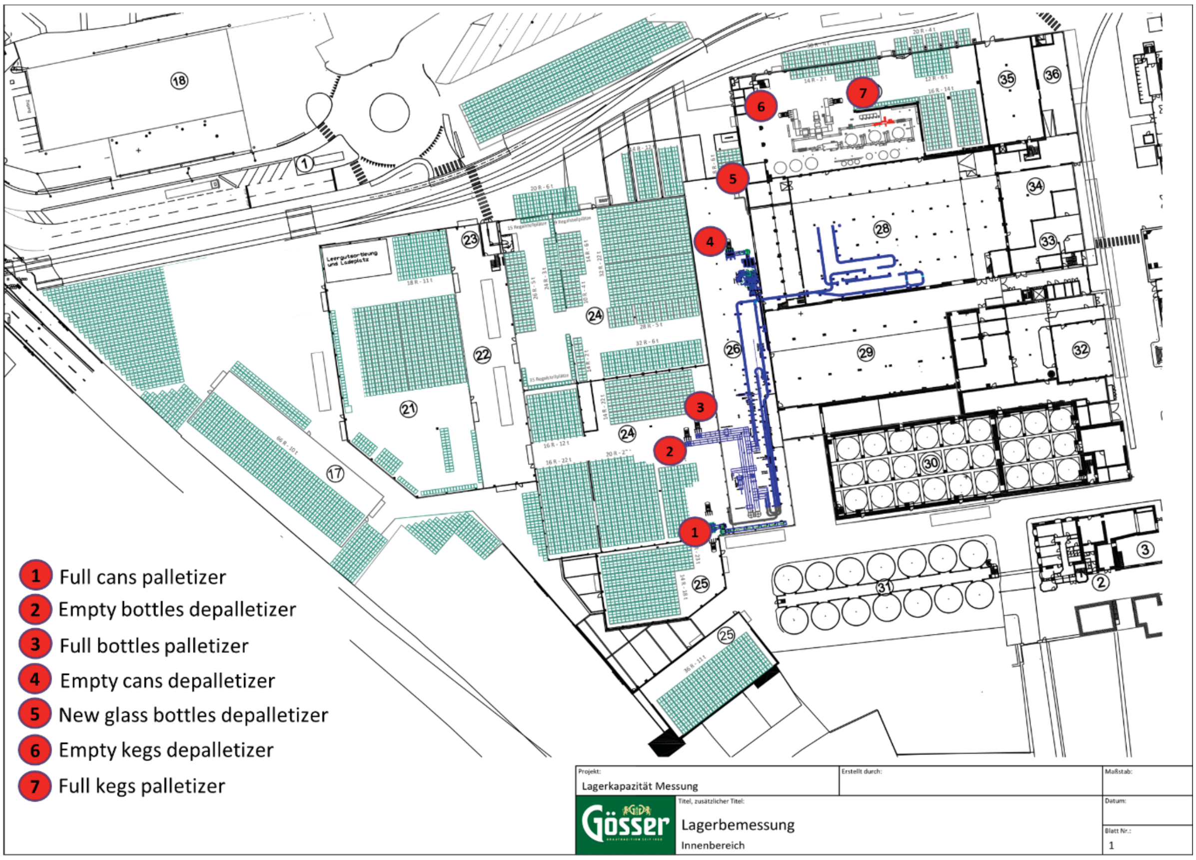

Figure 5: Current locations of palletizing and depalletizing stations

The storage area is divided into covered and uncovered areas, as portrayed in Figure 6. In the open-air storage area empty bottles and empty kegs are stored. Empty cans are stored under roof for safe storage, conveniently located close to the depalletizing station.

Storing empty bottles in uncovered areas presents certain difficulties. The glass bottles can become filled with rainwater or snow, especially in the winter. When the temperature drops and the water freezes, it expands, which can cause the bottles to shatter. Furthermore, there is a risk of bottle breakage during the production process, especially during washing and sterilization, due to temperature difference. Such occurrences contribute to increased costs and the loss of bottles.

All finished goods are stored in a covered storage area to protect the product and packaging from the sun and bad weather.

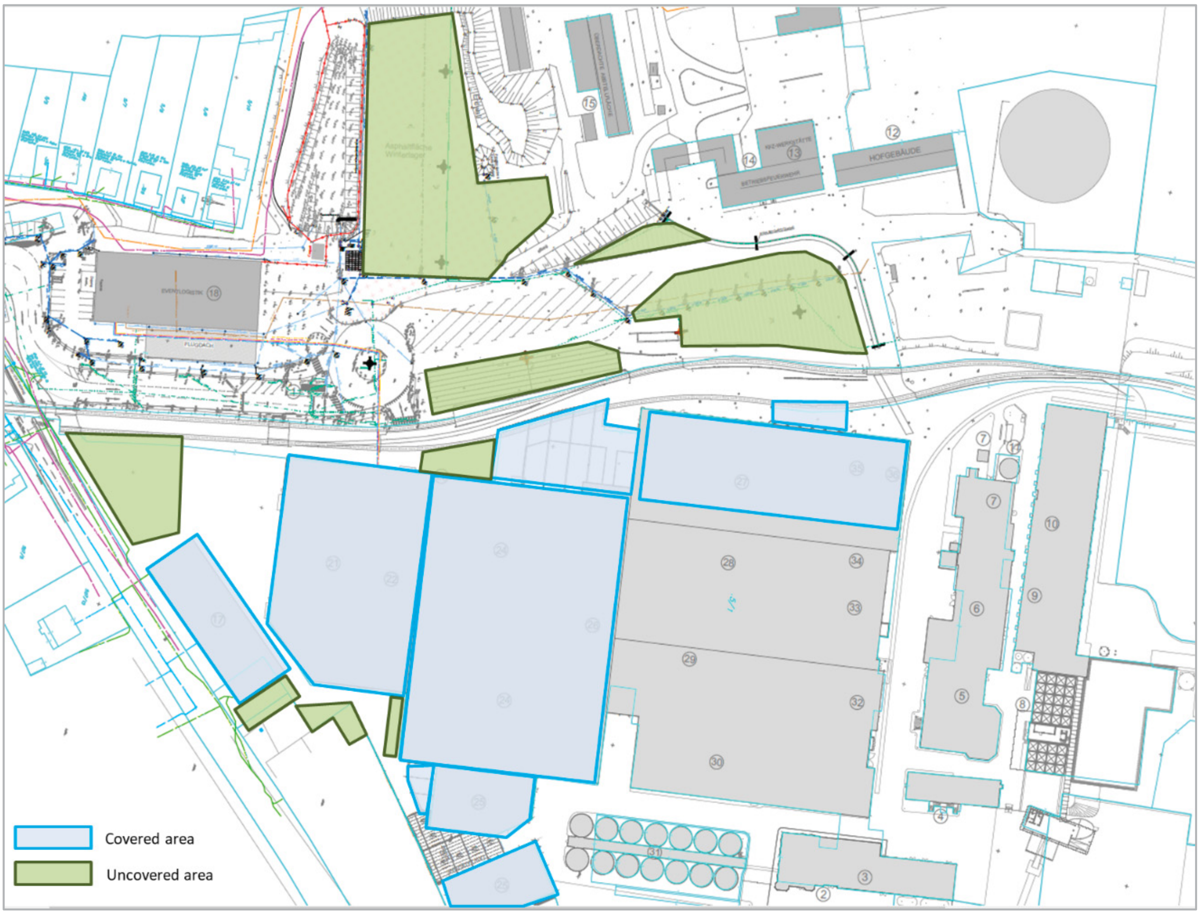

Figure 6: Covered and uncovered storage areas

Within Göss there are two different types of transportation, delivering goods to customers: primary and secondary transport. Each of these forms of transport is associated with specific truck loading and unloading areas and designated picking areas. Primary transport involves loading an entire truck with a single SKU for delivery to a particular customer. In some exceptional cases, if the truck is not fully filled, it may be loaded with orders from more than one customer. There are four designated areas for loading and unloading, labeled by B, C, D and E in Figure 7. Depending on the type of load (cans, bottles and kegs), trucks are loaded at the designated loading and unloading area for these products. In primary transport, the warehouse serves as the picking area, without any forward areas involved.

A different approach is taken for the secondary transport, which is for local customers such as restaurants, organizations, universities, etc. Here, trucks are loaded with orders for more than one customer. There is one location for loading and unloading the trucks with a capacity of handling 5 trucks parallel at the same time (labeled by A in Figure 7). There is a forward area in storage area 21, the red boundary shown in Figure 7, to speed up order picking and to reduce labor time. This area houses C-items (products that are produced in other breweries and products from other suppliers) and some of the produced products that are ordered in small quantities. The red boundary labeled 'Y' indicates the staging area allocated for small quantity orders intended for primary transportation.

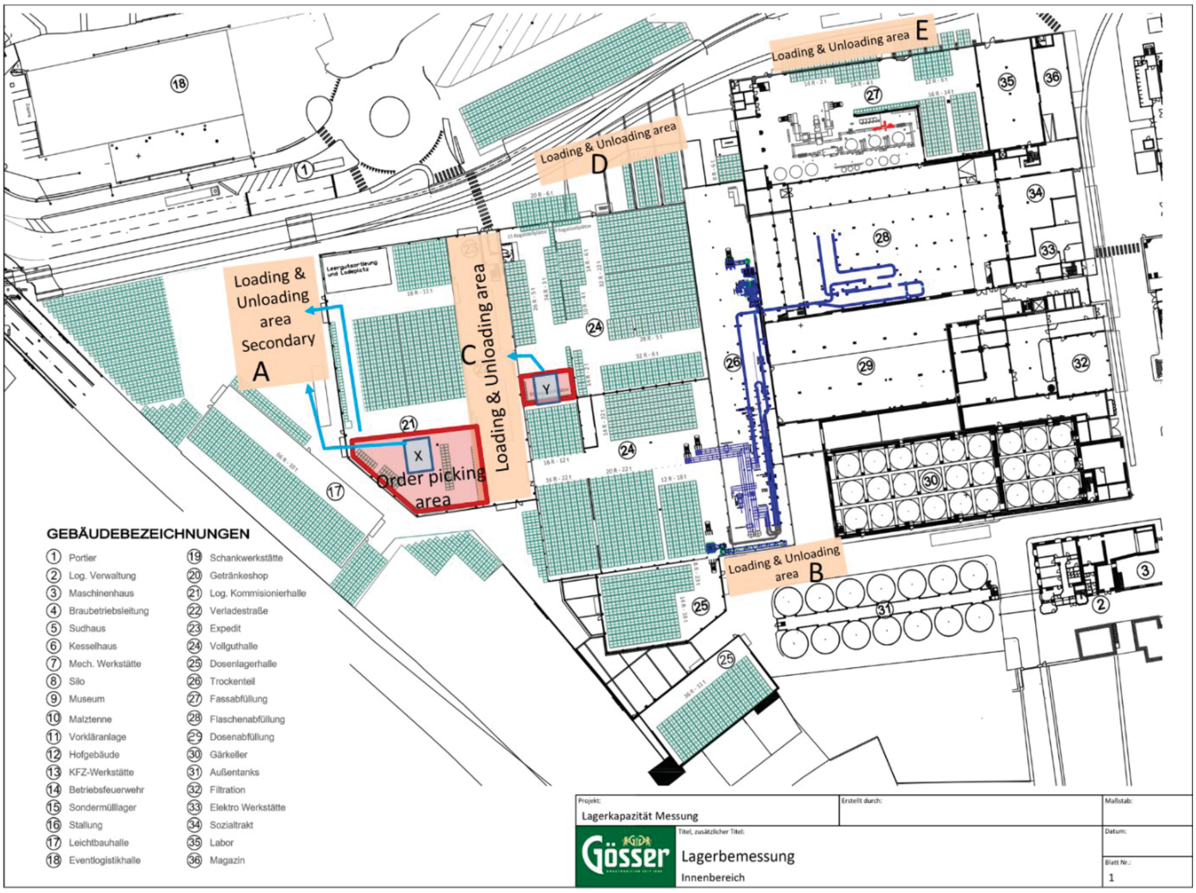

Figure 7: Loading and unloading areas

There are some zoning challenges in the current warehouse layout. Some storage halls are allocated to specific product groups close to the production line and loading and unloading areas in order to reduce travel time. However, there are instances where different product groups have to be stored in these halls due to increased production volumes of certain product groups to meet customer demand for a certain period. Figure 8 details the storage locations of different product groups. The challenge here is that the picker must know the location of the SKUs or search them in specific hall and find products with closer expiration dates. This has an impact on order picking time.

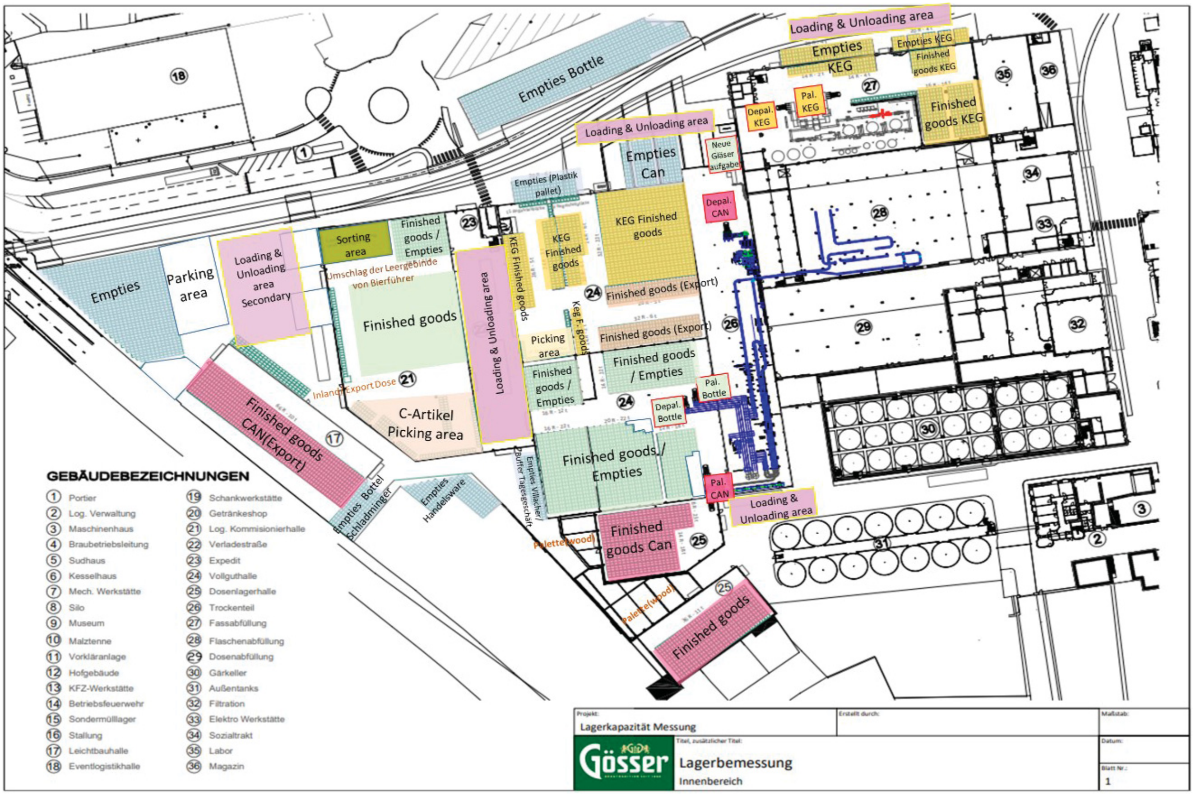

Figure 8: Warehouse layout-storage locations at current state

The focus of this master thesis is on expanding and rearranging the warehouse as well as optimizing the available area within the current premises. Sections 3.1.1.1 and 3.1.1.2 provide additional information and details on two primary factors, storage system and material handling, which influence the warehouse layout.

3.1.1.1 Storage systems

The cost-effective and flexible storage option employed here is block stacking, utilizing three pallets in height across most areas, and in some select areas four pallets in height. This storage system is very efficient for stackable items, like bottles, cans and kegs. Unlike most racking systems that allow the transportation of only one pallet at a time, block storage enables the transportation of two pallets per trip. The ability to handle multiple pallets with forklift trucks allows for increased operational speed.

In Göss Brewery, block stacking is the predominant storage system utilized across the warehouse and open areas. Single pallet racking is only used in the order picking and sorting areas. There are also racks in two other areas, but they are not currently in use. Figure 9 and Figure 10 portray the type of storage systems in covered and uncovered storage areas, respectively.

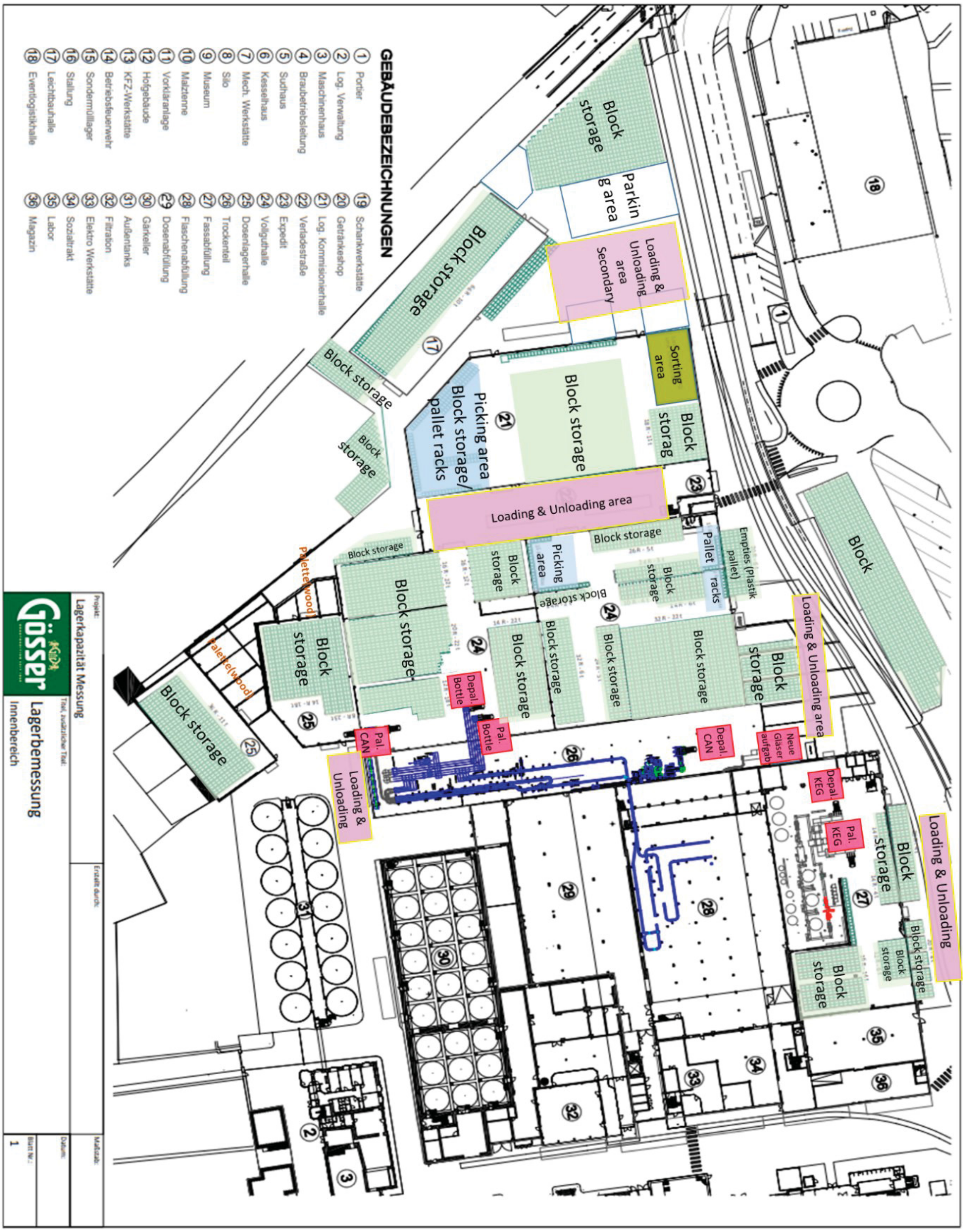

Figure 9: Storage system in covered areas

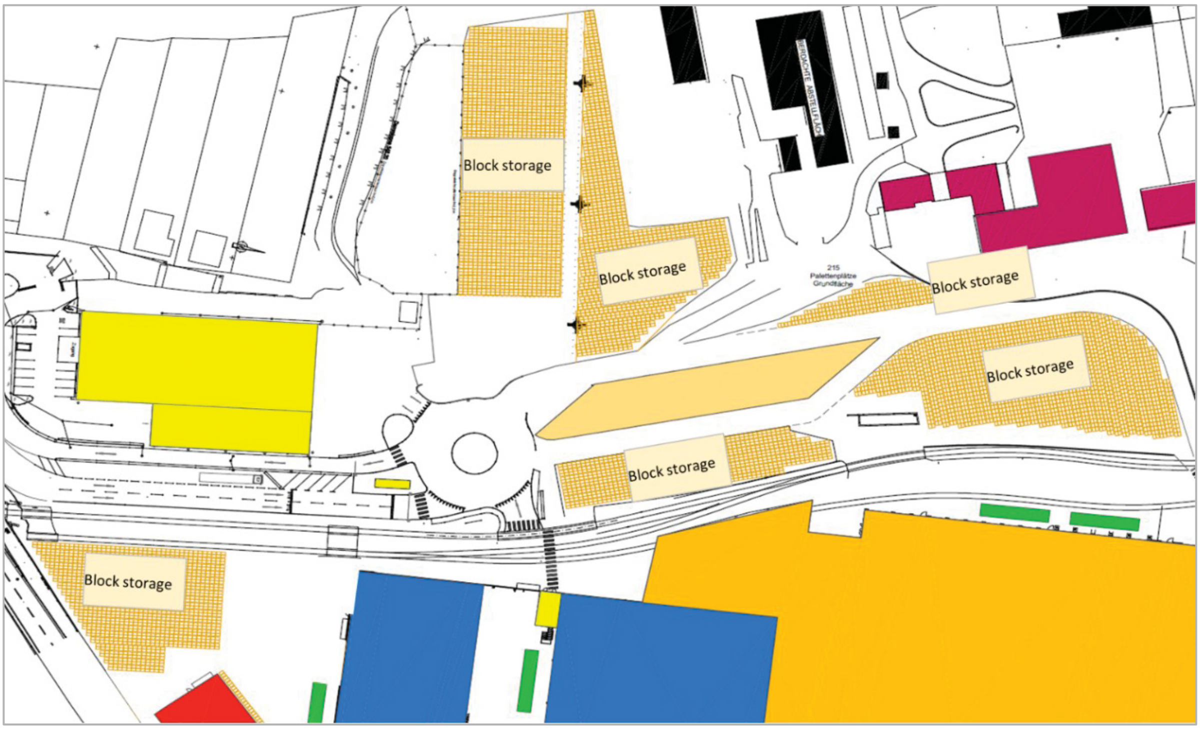

Figure 10: Storage system in uncovered areas

The Last In First Out (LIFO) approach is employed for depleting the lanes, since they are accessible from one side. Just one bay in area 21 is accessible from both sides.

The pallet is considered as a unit of floor space for calculation and measurement. Due to variations in size, shape, and volume across products, maintaining consistent unit dimensions is essential. This necessitates placing a specific quantity of each product onto individual pallets. Details for individual products are given in Table 2. Some products, such as the Keg 50L, pose challenges in stacking multiple layers on a single pallet. To ensure stability and stackability, an extra pallet is used for each additional level.

The safest stacking height is typically limited to three pallets, yet certain SKUs, such as full or empty bottles, can be stacked up to four pallets high when required. The advantage of stacking four pallets in height is high space utilization. However, it decreases transport efficiency as forklift drivers need to exercise greater caution when picking and placing pallets at elevated levels.

Table 2: Quantity of each product on a pallet

Product	Number of products on one unit	Number of pallets/unit	Picture of one unit
cans 0,5 l	24 cans in 1 box and 63 box on 1 pallet = **1512 cans**	1	
bottle 0,5 l	24 bottle in 1 box and 40 boxes on 1 pallet = **960 bottles**	1	
keg 20 l	1pallet has 18 kegs and one unit is 2 pallets on top of each other = **36 kegs**	2	
keg 30 l	1pallet has 6 kegs and one unit is 3 pallets on top of each other=**18 kegs**	3	
keg 50 l	1pallet has 6 kegs and one unit is 2 pallets on top of each other=**12 kegs**	2	

The safest stacking height for empty cans is limited to two pallets. This is due to the higher quantity of cans on each pallet, as empty cans become less stable when stacked higher, necessitating a lower stacking level for safety reasons. Figure 11 shows an overview of the stacked pallets for each product group.

It should be noted that layouts with high space utilization have lower transportation efficiency and layouts with high transportation efficiency have low space utilization [17].

Figure 11: Stacked pallets for each product group

Each unit of product groups has a different density in [hl]. As tabulated in Table 3, cans exhibit the highest density with 22.68 [hl], while bottles have the lowest density with 12 [hl].

Table 3: Density of each product group

Product	[hl/pal]	Stack height [pal]	Per Unit [hl]
Cans 0,5 l	7.56	3	22.68
Bottle 0,5 l	4	3	12
Keg 20 l	3.6	6	21.6
Keg 30 l	1.8	9	16.2
Keg 50 l	3	6	18

One of the important factors to be considered in designing a warehouse layout is the depth of the lanes. The depth of lane in the warehouse should not be excessively long, primarily due to safety concerns, particularly during night shifts. Extended lane depths require forklift drivers to cover longer distances, both loaded and unloaded. Although in uncovered storage areas, the lane depth tends to be longer compared to covered storage areas.

Pallets which are used in Göss brewery are EUR/EPAL-pallets and have dimensions of 800 mm width, 1200 mm length and 144 mm height. Based on logistic design and material handling guidelines from Heineken [32] storage segments have been designed as depicted in Figure 12. In this design there is 100 mm distance between each segment. One segment has a width of two pallets next to each other, short side leading. There should be a minimum gap of 250 mm between the top pallet and the roof beam. The corridor width is 5500 mm.

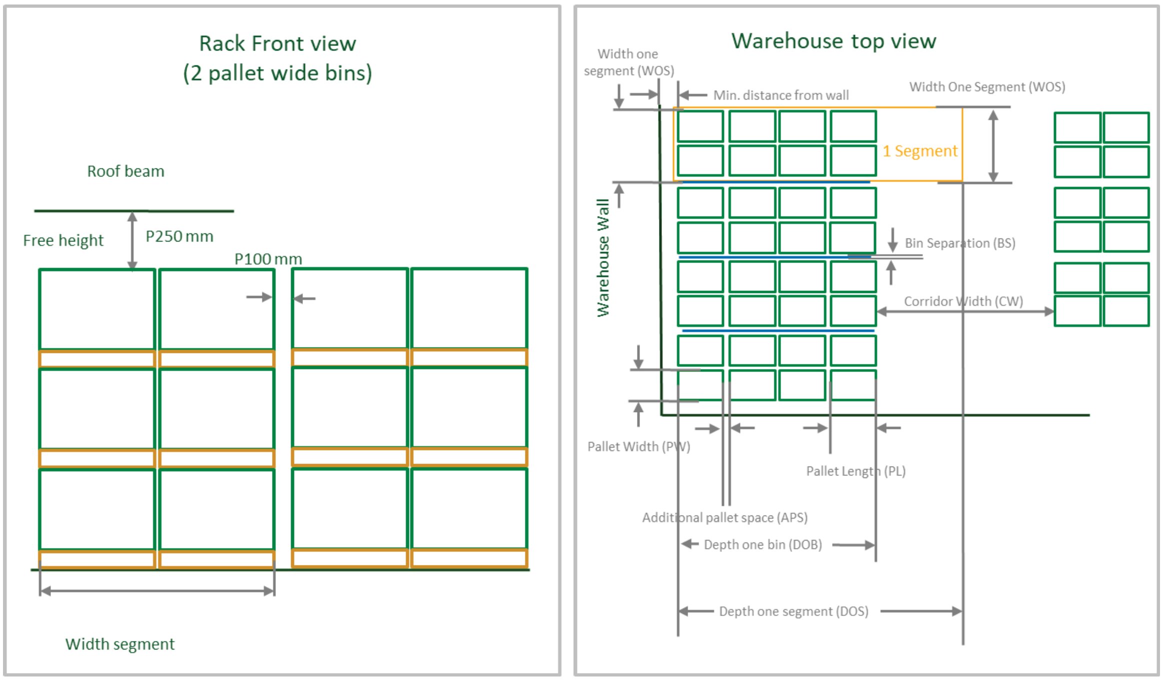

Figure 12: Warehouse rack front view and top view [33]

3.1.1.2 Material handling

In mechanized warehouses the material handling is done by forklift and cranes. Forklift trucks, available in a variety of models and are the primary equipment for moving pallets and similar loads for short distances. They offer excellent maneuverability and flexibility for a variety of tasks [2].

The main material handling equipment in Göss warehouse is forklift trucks. All aisles have the proper width to accommodate forklift trucks with a load (2 pallets). Forklift trucks with 2 to 4 pallet capacity are used for loading and unloading. Electric high lift pallet trucks and hand pallet jacks are used in the sorting and order picking areas.

The necessary corridor width for forklift trucks significantly impacts the utilization of warehouse and loading space. The width of the corridor depends on forklift truck dimensions and capacity, safety requirements related to pedestrians and pallet dimensions [33]. The corridor width can be estimated as described below. The typical clearance is 30 cm and the bidirectional corridor width, shown in Figure 13, for handling two pallets in each direction is approximately 5.5 m.

For loading and unloading areas, depicted in Figure 14, the corridor width suitable for a bidirectional corridor to handle two pallets per forklift is about 6.9 m.

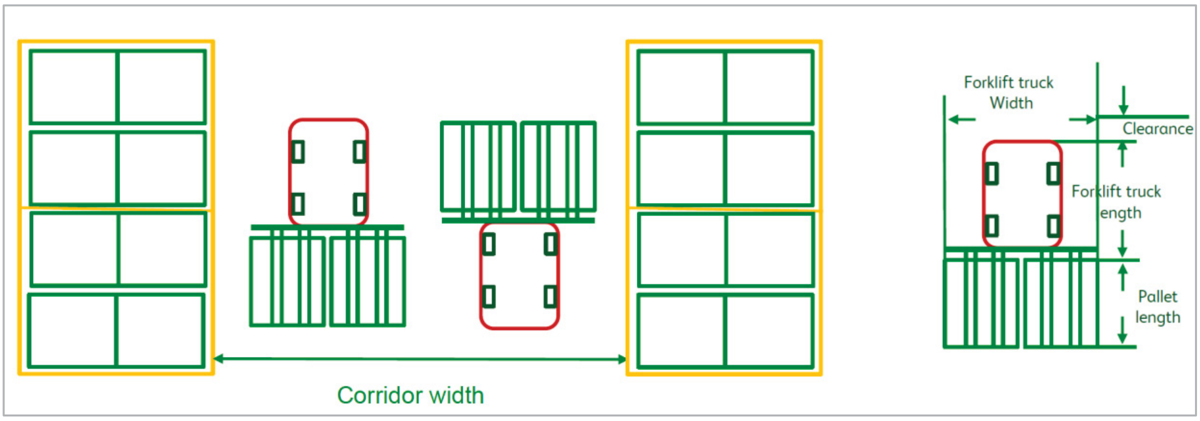

Figure 13: Two lane double forklift truck path [33]

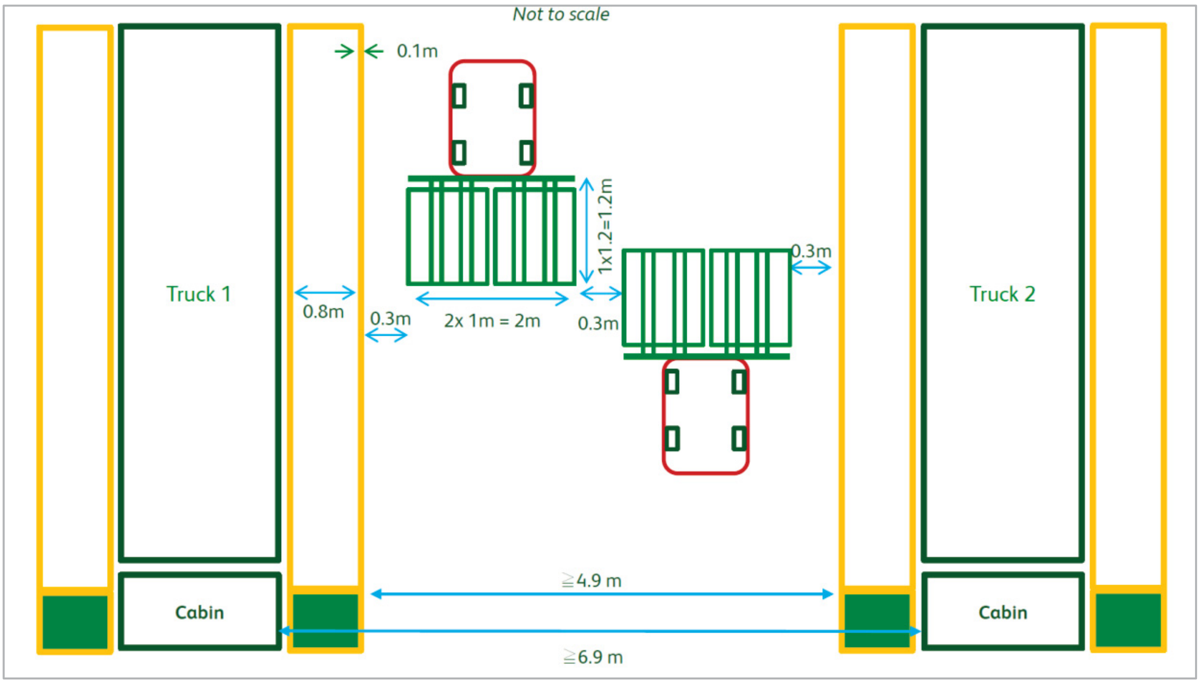

Figure 14: Corridor width in bidirectional loading and unloading areas [33]

3.1.2 Warehouse capacity

Figure 15 and Figure 16 display the covered and uncovered storage areas at the current state (as of the data on 01.02.2023). The storage areas are identified by numbers and differentiated by colors. Appendix 2 contains a detailed table summarizing the storage capacity of each individual hall for further reference.

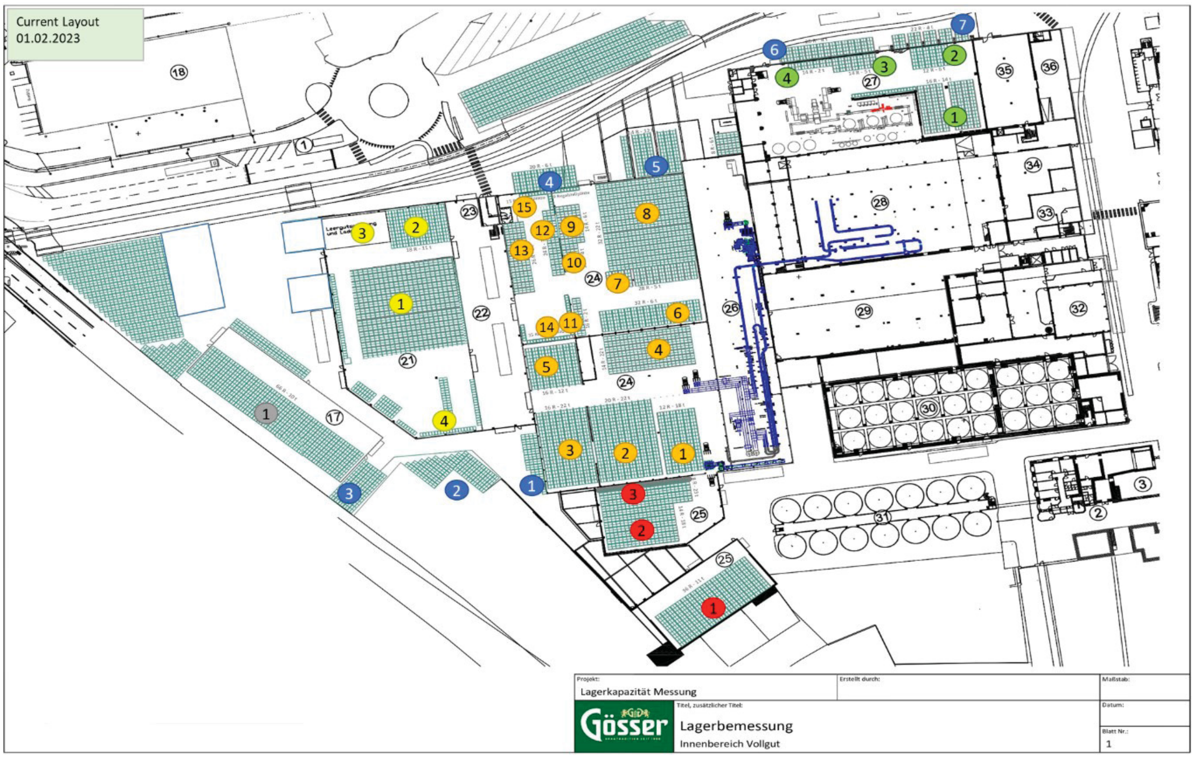

Figure 15: Covered storage areas - current state

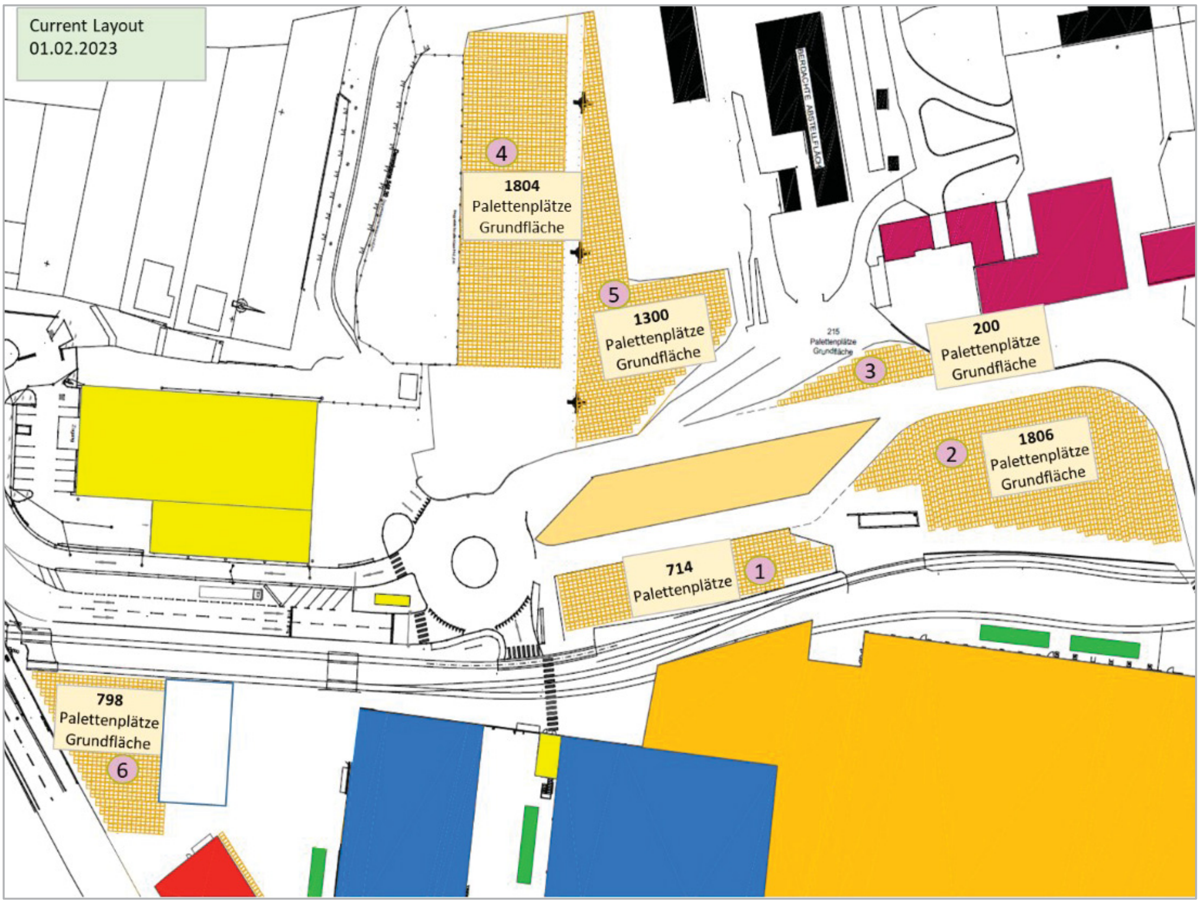

Figure 16: Uncovered storage areas - current state

Table 4 lists the total warehouse capacity in pallet units. This capacity encompasses the total ground-level storage, signifying storage at a single pallet height, and the complete storage capacity within the warehouse, which includes storage up to three pallets high. Notably, the calculations do not consider the racks because some of them are either unused or are designated for use in the picking/forward area. At the current state Göss brewery has a total storage capacity of 39,525 pallets. 17,181 pallets are designated for finished goods and 22,344 pallets are allocated for empties.

Table 4: Warehouse capacity - current state

Storage place	Pallets place on the floor	Sum of the pallets
Sum of finished goods	5,754	17,181
Sum of empties	7,448	22,344
Sum of empties & finished goods	13,202	39,525
Sum without racks	13,091	39,273

3.1.2.1 Storage volumes

The data for stocked quantity was extracted from SAP. As of 06.06.2023, a total number of 32,880 pallets were stored in the warehouse, accounting for 83% of the warehouse's capacity utilization on that date, as detailed in Table 5. This data served as a proxy for the annual warehouse stocked volume. Notably, there is a 1% surplus of empties storage capacity on this date, which they were stored in the finished goods storage area. Conversely, storing finished goods in the empties storage area is not allowed since they require a proper designated storage space.

Table 5: Stocked quantities on 06.06.2023 - current state

Items	Warehouse capacity	Product in stock	Usage percentage	Difference
Finished goods [pal]	17,181	10,324	60%	6,857
Empties [pal]	22,344	22,556	101%	-212
Sum [pal]	39,525	32,880	83%	6,646

3.1.2.2 Sales volume

The sales volume data spanning from April 2022 to April 2023 was extracted from SAP. The total sales volume during this period amounts to 1,471,990 hl. The monthly average sales volume is 122,666 hl. Figure 17 illustrates the monthly sales volume for all products throughout this specific time period. The total sales volume between May and September surpasses the average, indicating a high season during this period. Moreover, November and December exhibit another peak attributed to the Christmas and New Year festivities.

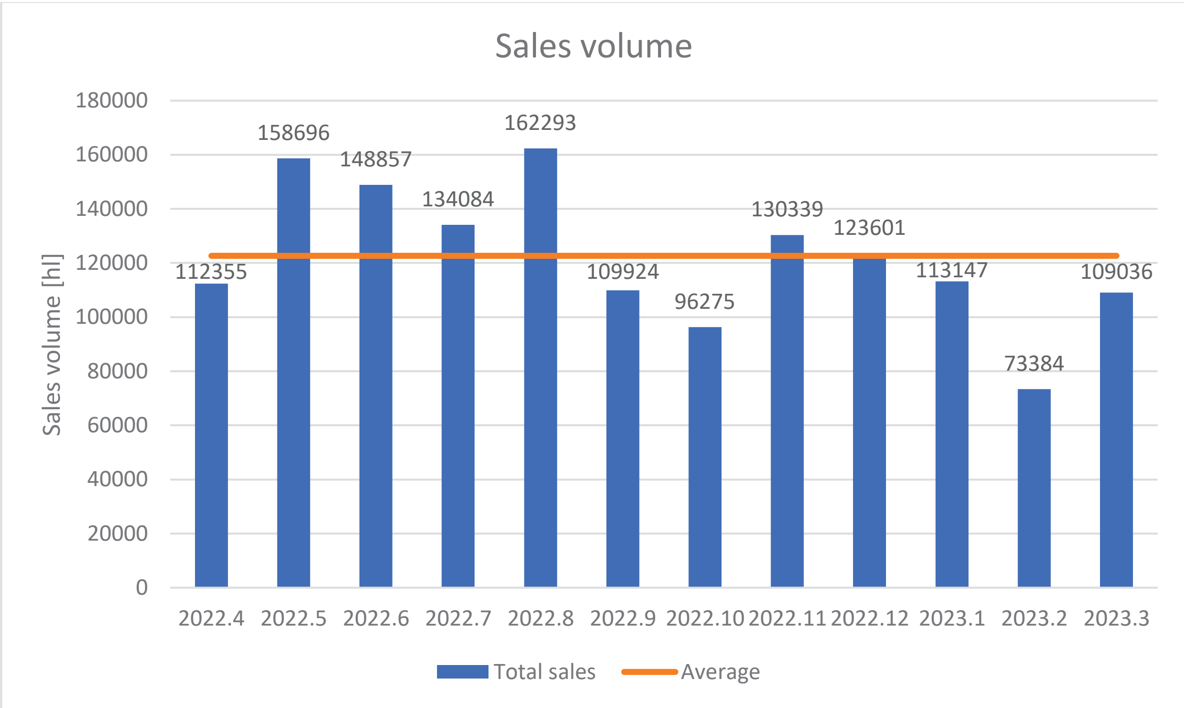

Figure 17: Monthly sales volume – all products

3.1.2.3 Seasonality

As depicted in Figure 17, demand varies according to the season, and holidays such as Easter and Christmas. The peak season spans from May to the end of September, while the remaining months represent the low season. The consumption of beer is significantly influenced by weather, festivals and holidays. Export levels are influenced by seasonality, with exports rising in the spring and summer months and declining during winter.

On average, sales volume is 122,666 hl/month. About 48% of the total sales occur during the peak season, which spans five months. The sales volume in October and February is the lowest, coinciding with the reopening of schools and universities and onset of cold weather.

3.1.3 Logistics processes

This section focuses on primary and secondary transportation processes, alongside loading and unloading, handling, picking and shipping processes.

There are two types of items that enter and leave the warehouse at site Göss:

- Finished goods from production line and products from other breweries and from the hub
- Empties (returnable bottle and kegs) from customer, other breweries and suppliers

Items such as empty pallets, beer tanks, etc. also enter the warehouse but are out of the scope of this project.

Internal transportation is performed using forklift trucks with a capability of handling 2 to 4 pallets simultaneously. External transport, which includes the transport of goods and empties to customers and suppliers, as well as from customers to the brewery, is carried out by trucks. Each truck has a capacity of 30 pallets, resulting in 15 lifts (2 pallets in one lift). The loading and unloading process for a truck typically takes on average 40-45 minutes.

3.1.3.1 *Primary and secondary transport processes*

In Figure 18, the red boundary marked as 'X' denotes the order picking area for secondary transport. This area consists of block stacking and single pallet racking. Most of the products in this area are C-items, items that are not produced in Göss brewery but are in stock, such as Coca Cola, mineral water, carbon dioxide (liquefied gas), etc. The items that are produced in Göss brewery are retrieved from the warehouse directly. Based on the pick list, the items for each customer are packed on pallets and then loaded onto the trucks in loading area. There are five loading and unloading area as illustrated by Figure 18. Area A is just for secondary transport and area B, C, D and E are for primary transport. The red boundary labeled 'Y' indicates the staging area allocated for small quantity orders intended for primary transportation.

As previously stated, there are ~2,300 products in Brau Union, which are handled through the hub. Customer orders are loaded onto trucks at the hub and transported to the site Göss, where the products, stored specifically at the Göss warehouse, are also loaded onto the trucks for delivery to customers. The items packed in the hub do not undergo any further inspection at Göss; instead, they are directly integrated into the remaining customer order.

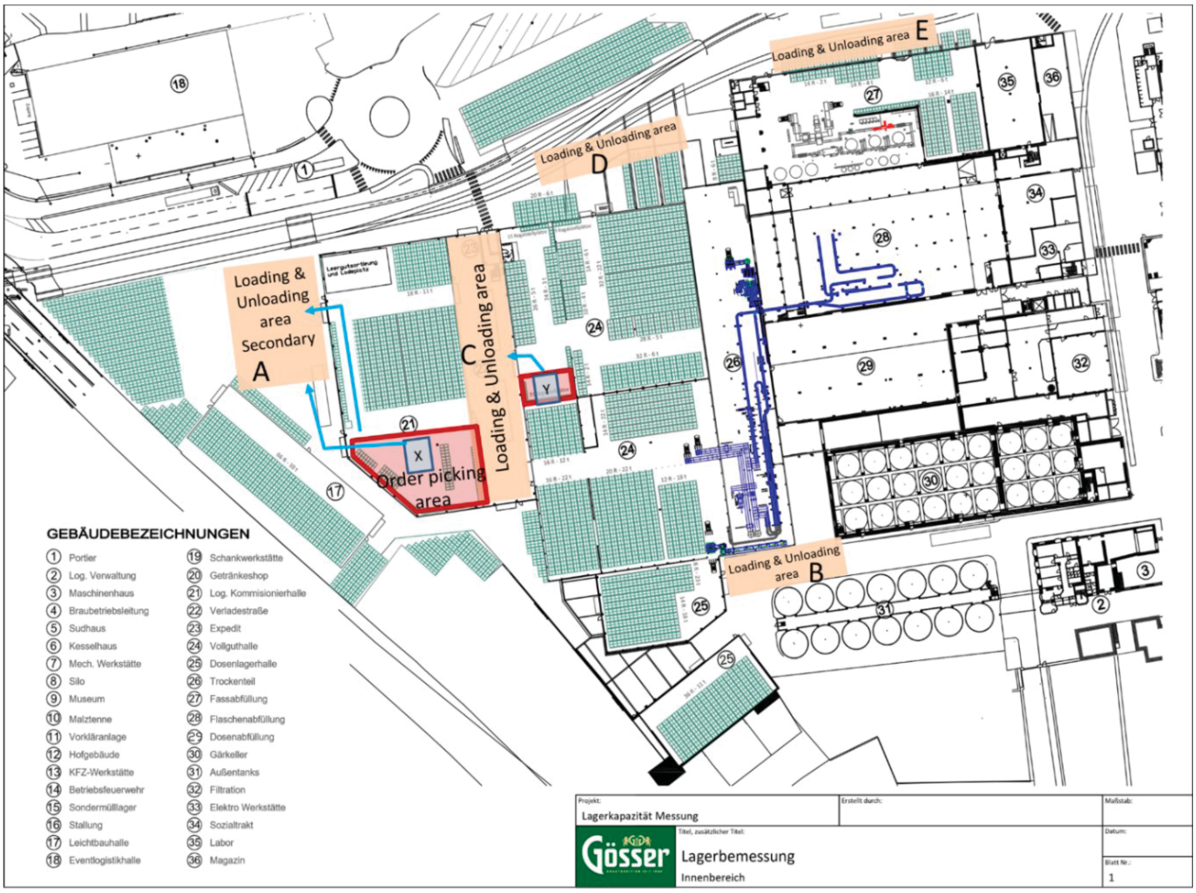

Figure 18: Overview of order picking and loading-unloading areas

Secondary transport is for local customers such as restaurants, organizations, universities, etc. Customer orders are divided into two categories: goods that are in stock and goods that must be ordered from the hub. The trucks for secondary transport have a capacity of 14 pallets. The trucks are usually loaded in advance for deliveries scheduled the following day to customers. Customers' orders are taken (online with eazle app or via phone) until 12:30. Then the tour planning starts at 12:30 until 14:00. Simultaneously, the hub receives customer orders that need to be shipped to Göss. After completing the tour planning, the Göss expedition receives the pick list. Each truck is identified by a unique number and an assigned driver. Customer orders are then allocated to trucks based on their size, volume, and weight criteria. Items are stored in area X (refer to Figure 18) and are loaded onto the trucks in the evening along with the remaining customer orders received from the hub. The orders are delivered on the next day from 06:30 to 15:00, according to the tour plan. The process description is shown in Figure 19.

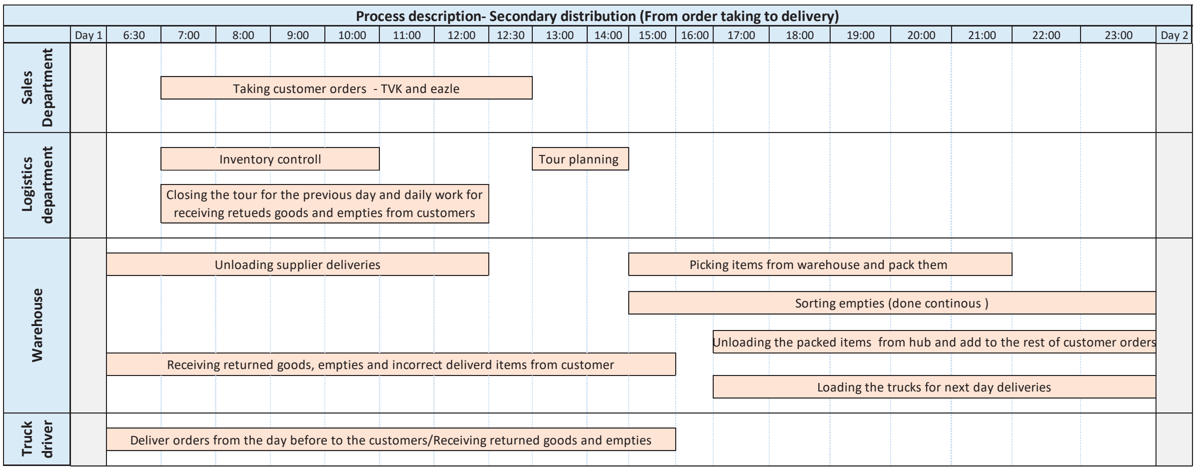

Figure 19: Secondary transport process - from order taking to delivery

The primary transport trucks have a capacity ranging from 30 to 32 pallets, depending on the type of load material. Göss has four trucks dedicated to primary transport, operating across two shifts. The first shift spans from 06:00 to 14:00, followed by the second shift running from 15:00 to 23:00. Normally, primary transport entails delivering a single SKU to a customer. However, if the trucks aren't fully loaded to their maximum capacity, they might carry different SKUs for various customers.

Sale orders are received by the sale department in Graz from 06:00 to 10:00. The list of orders and their destinations is accessible in SAP at location Göss. The staffs in the expedition and primary manager select specific shipments that can be delivered with their own trucks and plan the transport at site Göss. The remaining transport planning is done automatically by OTM (Oracle Transportation Management), which uses an external freight company. OTM is worldwide Heineken standard Transportation Management System (TMS). The process description is shown in Figure 20.

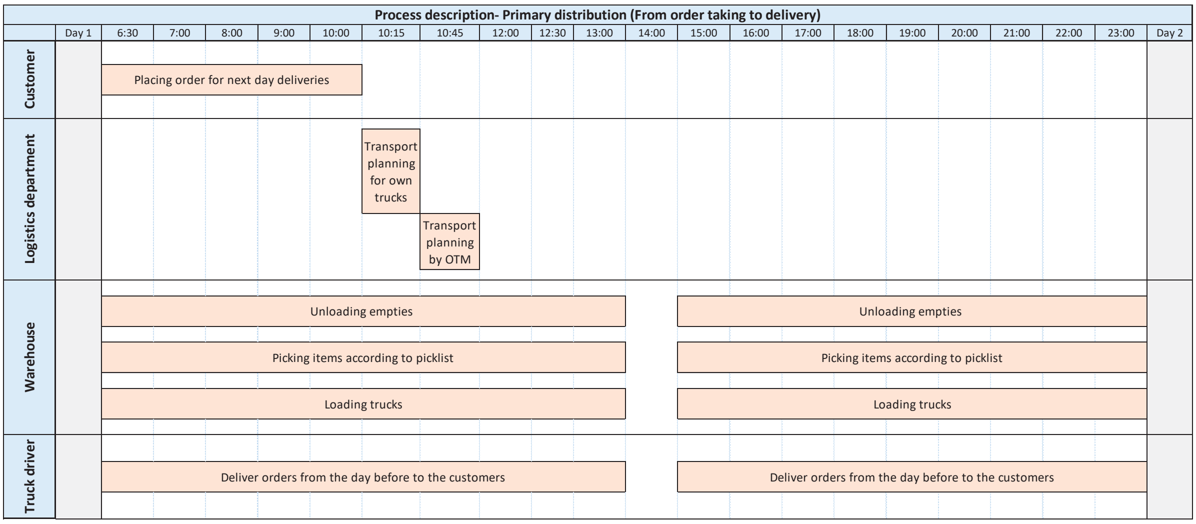

Figure 20: Primary transport process - from order taking to delivery

Primary transport process commences when the truck's driver checks in at the gate. The employee at the gate updates the status in Transporeon, a transportation management platform, to other department and warehouse staff (order picker, expedition staff and checkers) and notifies them of the truck's arrival (Station 1). Trucks can enter the brewery 15 minutes before the scheduled appointment. After registration, the driver parks the truck in the designated parking area (Station 2) and goes to the expedition office to complete the necessary documents (Station 3). The checker informs the driver of the designated loading and unloading area (Station 3 or 4). At the expedition office, transportation documents are processed in SAP. Order pickers are informed by Transporeon about the next shipments. Forklift drivers receive pick lists and retrieve the required products to the buffer zone near the loading and unloading area and load the truck (Station 5). Once loading is complete, the checker updates Transporeon to notify expedition office that the loading process has been completed. Expedition staffs complete the delivery documents and print them. The driver returns to the expedition office to sign and collect the delivery documents (Station 6). Figure 21 illustrates all the stages involved in primary transport process, from check in to check out of a truck.

By receiving empties, the truck is just unloaded, and the empties are stored in the warehouse.

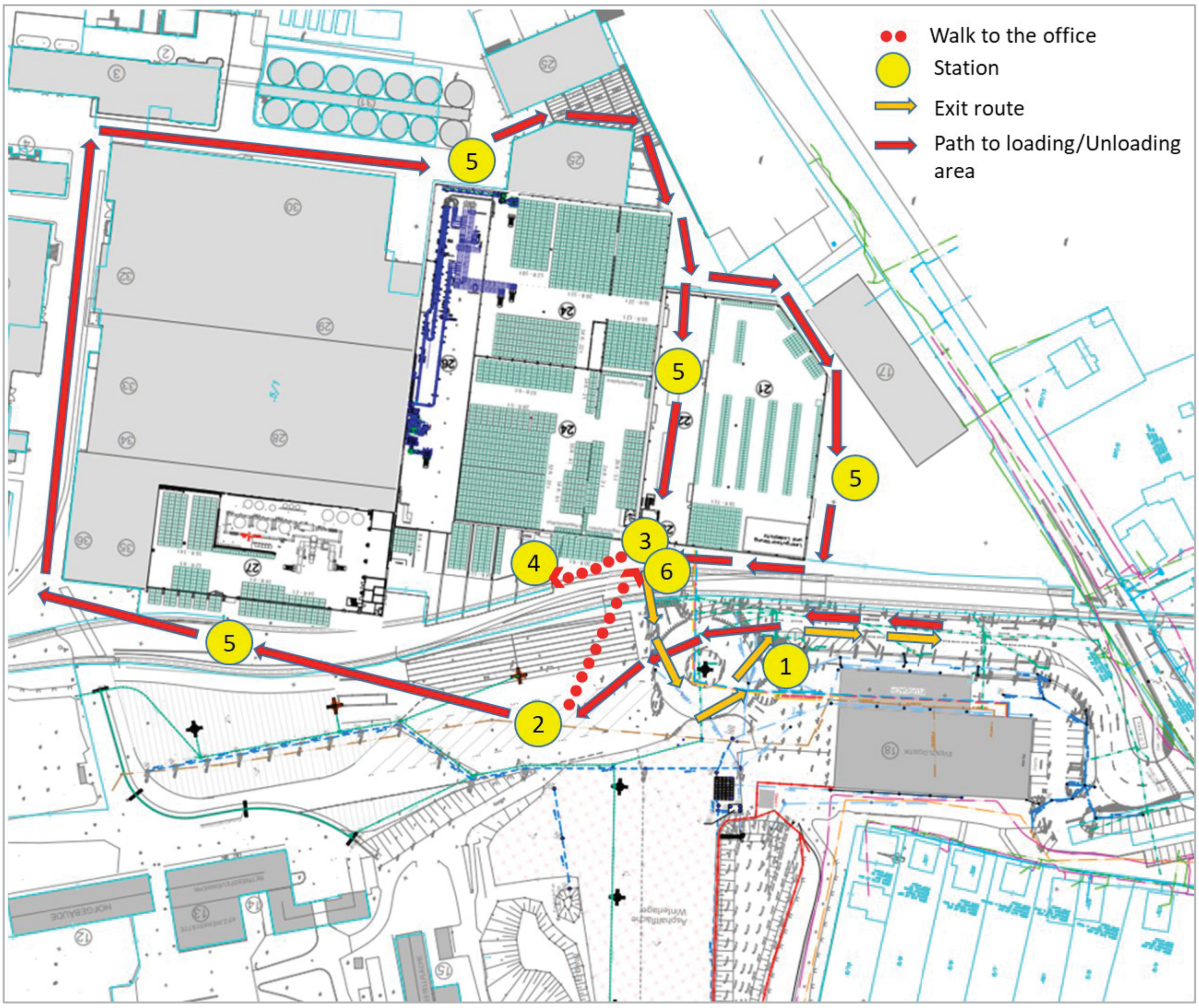

Figure 21: Primary transport process stages – from check in to check out

3.1.3.2 Loading/unloading and handling processes and traffic flows

This section illustrates the internal logistics within the warehouse and calculates the time taken to handle the incoming goods and ship them to the customer. Information flow is not considered as a part of this project. All finished goods and empties are transferred by forklift trucks and the pathways, shown in Figure 22, are the routes that the forklift trucks travel.

There are five main processes within the warehouse: receiving, sorting, storing, picking and shipping. The incoming goods can be finished goods or empties such as bottles, cans and kegs. Empty bottles are sorted before being stored. Following sorting, the empties are stored in the warehouse until they are needed in the filling line. After filling, finished goods are stored in the warehouse. If the incoming products are finished goods, they are directly stored in the warehouse.

In the shipping process, items are picked from the warehouse according to the picklist, palletized as needed, checked for quality and quantity, then loaded onto trucks for delivery to the customer. Figure 22 shows an example of goods handling path for shipping products. The rest of the process paths is appended in Appendix 1.

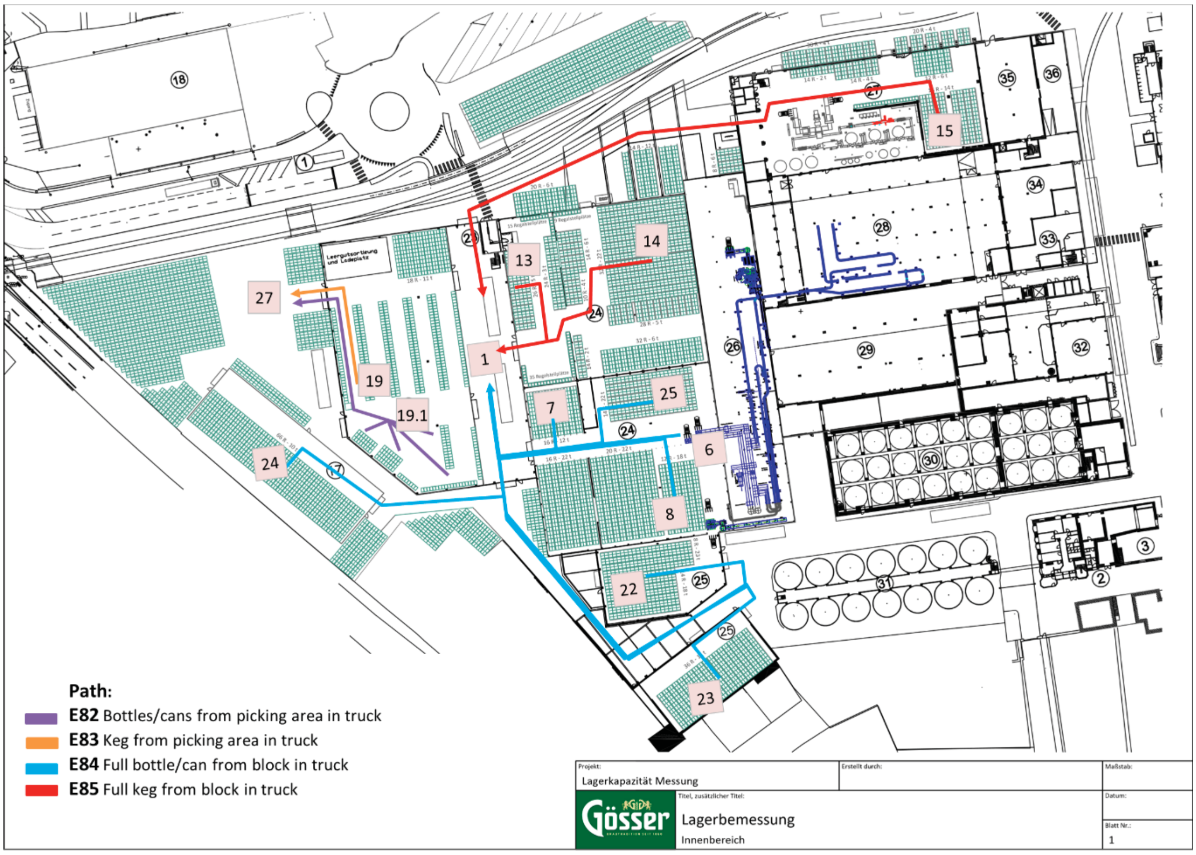

Figure 22: Shipping process path

Table 6 lists the details of related process steps for incoming and shipping items. Table 7 summarizes the calculation of the total pallet handling time for each of the receiving and shipping processes. Total time for handling the items is 67,017 hours per year. The goal is to reduce the total time in the new concept.

Table 6: Description of receiving and shipping process paths

Process	Path	Description
Receiving	E80	Empty bottle from truck in block + empty bottle from block on production line + full bottle from production line in block
	E81	Empty keg from truck in block + empty keg from block on production line + full keg from production line in block
	E90	Empty can from truck in block + empty can from block on production line + full can from production line in block
	E84	Unloading full bottle/can from truck and storing it in block
	E85	Unloading full keg from truck and storing it in block
Shipping	E82	Bottles/cans: picking time + inspection time + travel time + loading time
	E83	Keg: order picking time + inspection time + travel time + loading time
	E84	Retrieve full bottle/can from block and loading it in truck
	E85	Retrieve full keg from block and loading it in truck

Table 7: Total handling time for receiving and shipping processes - current state

Process	Path	Description	Loading/ unloading [min/pal]	Buffer time [min/pal]	Checking [min/pal]	Total time [min/pal]	Pal/year	Total time [min/year]
Receiving	E80	Receiving bottles from production line to warehouse	4.22	0.63	0.50	5.35	139,838	748,414
	E81	Receiving kegs from production line to warehouse	3.82	0.57	0.50	4.90	123,641	605,660
	E90	Receiving cans from production line to warehouse	5.94	0.89	0.50	7.33	67,521	494,958
	E84	Receiving full bottles/cans	1.30	0.19	0.50	1.99	3,660	7,286
	E85	Receiving full kegs	1.27	0.19	0.50	1.96	825	1,618
Shipping	E82	Outgoing goods bottles/cans	6.18	0.93	3	10.11	16,558	167,436
	E83	Outgoing goods kegs	6.18	0.93	3	10.11	9,127	92,293
	E84	Full bottle/can from block in truck	2.93	0.44	0.5	3.87	338,813	1,312,672
	E85	Full keg from block in truck	1.48	0.22	0.5	2.21	267,685	590,659
Total							967,668	4,020,997

3.2 Analysis of the current state

There are over 2300 products in database system, however, the primary focus in this master thesis is only on those which are stored in the Göss warehouse. Data for 102 SKUs was extracted from SAP on a monthly basis for one year. Although some products are no longer in production, they are still included in the analysis. This phase of the project primarily centers on three analyses: ABC analysis, XYZ analysis and Days on hand. To simplify calculations, all product units have been converted to either hectoliters (hl) or pallet space (pal.space), and the time units used are either the calendar week or month.

3.2.1 ABC analysis

Sales volumes for each SKU over a 12-month period, from April 2022 to April 2023, were utilized for the ABC analysis. The unit of the product for this analysis is pal.space. The annual sales volume for each SKU was computed and arranged in descending order based on sales volume. Subsequently, the sales percentage for each SKU was calculated. This helps to rank the items from the most important to the least important. The accumulated sale percentage was used to assign the items to three categories (A, B and C). The products with 0-80 percent of the accumulated sales volume are classified as group A, the products with 80-95 percent are classified as group B and the products with 95-100 percent are classified as group C. The result of the ABC classification is displayed in Table 8, listing only the A class products. Appendix 3 includes a comprehensive table that summarizes the complete ABC classification results for all SKUs.

Table 8: ABC analysis – Class A SKUs

Product	Sales vol. [pal.space]	Share %	Cum. %	ABC
GÖSSER Märzen MW Kiste 20x50cl	78074.3	29.76%	29.76%	A
GÖSSER Märzen Dose Tray 24x50cl	25346.3	9.66%	39.43%	A
PUNTIGAMER D.Bierige Dose Tray 24x50cl	21181.8	8.07%	47.50%	A
PUNTIGAMER Panther Fass 50L	15376.2	5.86%	53.36%	A
GÖSSER Märzen Fass 50L	14768.3	5.63%	58.99%	A
PUNTIGAMER D.Bierige MW Kiste 20x50cl	13694.9	5.22%	64.21%	A
GÖSSER NaturRad.Zit.DoseTray24x50 DE neu	11063.0	4.22%	68.43%	A
GÖSSER NaturRadl.0,0% MW Kiste24x33cl DE	7753.7	2.96%	71.39%	A
GÖSSER NaturGold AF MW Kiste 20x50cl	7563.4	2.88%	74.27%	A
GÖSSER NaturRadl.Zitr. Dose Tray 24x50cl	5678.6	2.16%	76.43%	A
GÖSSER NaturRadl.Zitr. MW Kiste 20x50 EX	5174.8	1.97%	78.41%	A

The products groups for ABC classification were formed according to cumulative boundaries in Table 9

- Group A contains 11 products, representing 10.8% of the total number of products, account for 80% of sales volume
- Group B contains 23 products, representing 22.5% of the total number of products, account for 15% of sales volume
- Group C contains 68 products, representing 66.7% of the total number of products, account for 5% of sales volume

Table 9: ABC classification

Class	Cumulate %	Quantity	Share%
A	<80%	11	10.8%
B	80%<B<95%	23	22.5%
C	95%<	68	66.7%

Figure 23 presents the distribution of products across the three categories. Most of the products in group C are the seasonal products or export products, that are produced for a short period of time.

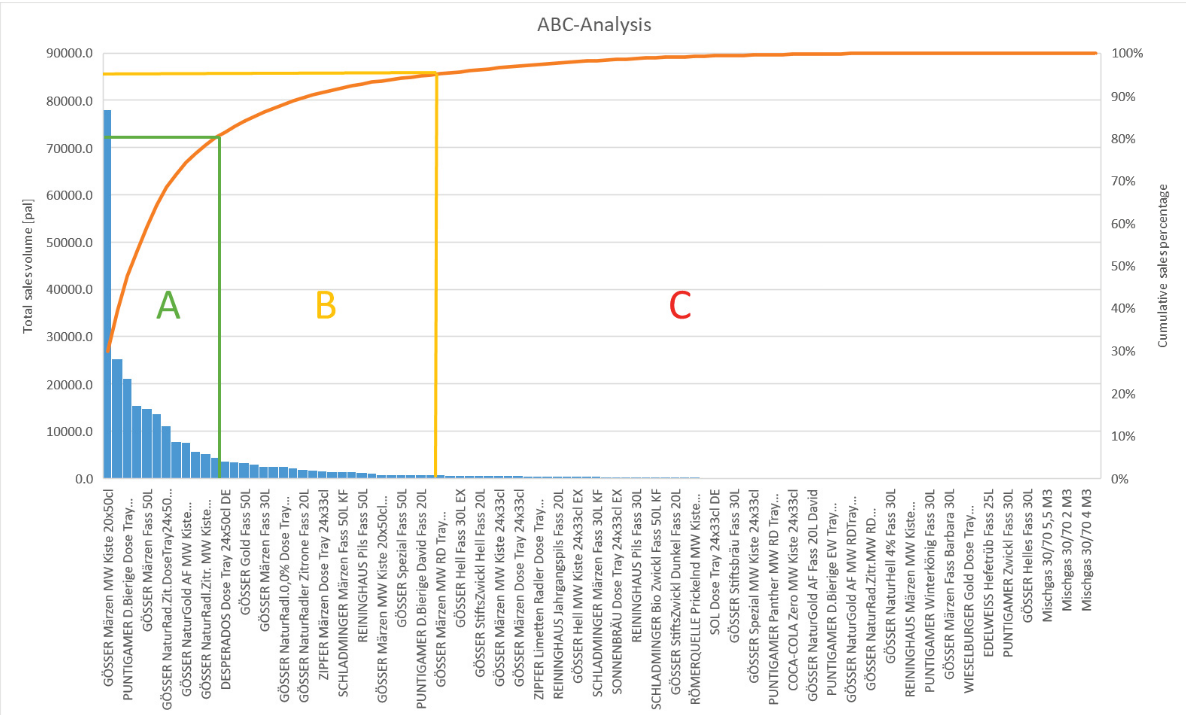

Figure 23: ABC classification diagram

3.2.2 XYZ analysis

The data utilized for the ABC analysis is also employed for the XYZ analysis. For each SKU, the standard deviation was calculated and the coefficient of variation was determined by dividing the standard deviation by the average quantity of the products that delivered to the customer over the course of a year.

For classifying, the coefficient of variation, which is an indicator for stability of consumption was used. The products with coefficient of variation less than 0.5 are classified as group X, the products with coefficient of variation between 0.5 and 1 are classified as group Y and the products with coefficient of variation greater than 1 are classified as group Z [34].

The result of the XYZ classification is displayed in Table 10, listing only the A class products. Appendix 4 includes a comprehensive table that summarizes the complete XYZ classification results for all SKUs.

Table 10: XYZ analysis –Class A SKUs

Product	ABC	Std. Dev.	Coeff. of Var.	XYZ
GÖSSER Märzen MW Kiste 20x50cl	A	1493.82	0.23	X
GÖSSER Märzen Dose Tray 24x50cl	A	568.26	0.27	X
PUNTIGAMER D.Bierige Dose Tray 24x50cl	A	587.45	0.33	X
PUNTIGAMER Panther Fass 50L	A	336.27	0.26	X
GÖSSER Märzen Fass 50L	A	380.06	0.31	X
PUNTIGAMER D.Bierige MW Kiste 20x50cl	A	1033.29	0.91	Y
GÖSSER NaturRad.Zit.DoseTray24x50 DE neu	A	430.23	0.47	X
GÖSSER NaturRadl.0,0% MW Kiste24x33cl DE	A	350.45	0.54	Y
GÖSSER NaturGold AF MW Kiste 20x50cl	A	121.32	0.19	X
GÖSSER NaturRadl.Zitr. Dose Tray 24x50cl	A	287.56	0.61	Y
GÖSSER NaturRadl.Zitr. MW Kiste 20x50 EX	A	533.93	1.24	Z

The groups were formed according to coefficient of variation boundaries in Table 11:

- Group X contains 50 products, representing 49% of the total number of products, which have high and relatively stable demand
- Group Y contains 28 products, representing 27.5% of the total number of products, which are trendy and have average predictable demand
- Group Z contains 24 products, representing 23.5% of the total number of products, which have irregular and unpredictable demand

Table 11: XYZ classification

Class	Coeff. of Var.	Quantity	Share%
X	X<0.5	50	49%
Y	0.5<Y<1	28	27.5%
Z	1<Z	24	23.5%

3.2.3 ABC-XYZ matrix

The ABC-XYZ matrix is a combined analysis framework that merges two different inventory management methodologies: ABC and XYZ analyses. It provides important information about materials and inventories. In fact, it makes it possible to define appropriate measures for optimizing stocks [35].

Table 12 displays the outcomes of the merged ABC-XYZ matrix, indicating the count of products within each respective group. Appendix 5 includes the complete ABC-XYZ matrix, listing all products in each subgroup.

Table 12: Combined ABC-XYZ matrix

	X	Y	Z
A	7	3	1
B	16	5	2
C	27	2	21

Reference [29] is used to interpret the results of ABC-XYZ matrix.

Group AX consists of 7 products representing 6.7% of the total number of products. Products in this category exhibit consistent demand patterns, allowing for precise demand forecasting, and hold substantial value. This allows for accurate production planning and eliminating the need for large safety stock levels. All these products are the main products of Göss brewery.

Group AY consists of 3 products, which have discontinuous demand, lower forecast accuracy and high value. It is important to give this product group sufficient planning attention. One of the products in this group is GÖSSER NaturRadl which is an export product, therefore the forecast is not so accurate.

Items within the A/Z group are sold infrequently, leading to challenges in demand forecasting, and have high value. Therefore, it requires more sophisticated inventory control. The sole product within this group is GÖSSER NaturRadl.Zitr. Despite its significance within the Gösser brewery range, this particular item experiences notable fluctuations in sales volume. This variance is attributed to its status as an export product with unique packaging and barcode, thus treated as a distinct SKU.

Group B/X have steady demand, with highly accurate demand forecasting, and moderate value. Maintaining a high inventory level is unnecessary. The use of reorder points helps to manage these items effectively.

Items in group B/Y have a discontinuous demand and their demand forecast is middle in accuracy. These items also have moderate value. Using dynamic safety stock levels helps mitigate out of stocks and without excessive overstocking, ensuring consistent product availability.

C/X items have sporadic demand and have low value. A “just-in-case” inventory strategy ensures that a minimal stock level is available to meet unexpected demand.

Items in C/Y, B/Z and C/Z have a low financial impact on the inventory. A significant portion of C/Y and C/Z items are seasonal or export products. Forecasting demand for export products is often unreliable, therefore production (filling) typically begins after a customer order is received. Seasonal products are manufactured in the month required to meet customer demand.

3.2.4 Days on hand

The production forecast data, listed in Table 13, is used for calculating the necessary storage capacity of the warehouse. The production forecast is computed based on the projected increase in production for each group in each year[36]. The production forecast data has been converted into pallet unit beforehand for direct utilization in the storage capacity calculations, as it serves as the basis for these calculations.

Table 13: Production forecast

Product		2023	2024	2025	2026	2027
Bottle [pal/day]	0.5 l	474	488	554	718	694
	0.33 l	12	13	78	160	219
Keg [pal/day]	50 l	171	157	144	133	122
	30 l	27	25	23	21	19
	20 l	22	20	19	17	16
Can [pal/day]	0.5 l	328	358	369	369	369
	0.33 l	13	14	15	15	15
Sum [pal/day]		**1,047**	**1,077**	**1,201**	**1,433**	**1,453**

There is an anticipated production increase from an average of 1,047 pal/day in 2023 to an estimated 1,453 pal/day in 2027, an increase of 38%. As a result, the storage capacity should be increased. This section focuses on determining the required storage capacity based on the calculation of DOH. Days on hand can be calculated from two perspectives: in the context of inbound flow and or in terms of outbound flow. For this calculation, the second necessary variable is time.

The inventory turnover in the Göss warehouse occurs twice a month, leading to complete stock replenishment. With a total of 20 working days in a month, this implies that the stock will change every 10 days. To ensure there is no shortage or bottleneck, it is important to consider the outbound and inbound flow as being equal in the long run. The question at hand is: if we produce for a span of 10 days and then store the output, how many storage spaces will be required?

At the end of the production forecast period, year 2027, 14,533 pallets will be accumulated in 10 days, as presented in Table 14. The storage utilization policy in Heineken is set within a range of 70% to 85%. In this context, a storage utilization rate of 80% is applied for the calculations. Consequently, to accommodate the production of 14,533 pallets with an 80% storage utilization rate, the required storage capacity should be 18,166 pallets.

It is important to note that the current storage capacity at Göss is 17,181 pallets for finished goods. This results in a deficit of 985 pallets to meet the required capacity by

2027. It is worth noting that the existing storage capacity is expected to remain sufficient until the year 2025.

Table 14: Storage capacity calculations

Product		2023	2024	2025	2026	2027
Bottle [pal]	0.5 l	4,742	4,884	5,536	7,184	6,935
	0.33 l	122	126	777	1,601	2,189
Keg [pal]	50 l	1,708	1,573	1,444	1,330	1,221
	30 l	271	250	229	211	194
	20 l	222	204	188	173	159
Can [pal]	0.5 l	3,277	3,584	3,687	3,687	3,687
	0.33 l	132	144	148	148	148
Total pallets in 10 days		10,473	10,765	12,007	14,334	14,533
Needed capacity for 80% storage utilization		13,092	13,457	15,009	17,917	18,166

3.3 Proposed changes to the current state

Increasing production has a major impact on the warehouse layout and logistics processes. During the initial phase, several challenges were identified, which have been taken into consideration in the new developed concept.

The location of products in a warehouse has a significant impact on customer service and logistics costs. Typically, the warehouse layout is optimized to reduce material handling costs, minimize space requirement and reduce energy costs [37].

There are some zoning challenges in the current warehouse layout. Some storage halls are allocated to specific product groups close to the production line and loading and unloading areas in order to reduce travel time. However, during peak seasons, different product groups have to share available storage space. To overcome this, it is proposed to create zones for each category to optimize space utilization for high-demand season. The majority of place would be assigned to a specific product group, with one or two locations designated for a mix of product groups.

Increasing production capacity also has an impact on the number of primary transports. Given that a major portion of transportation is facilitated by external freighters, there's room for an increase in the number of trucks to complement this aspect. This also has an impact on material handling operation.

3.3.1 Relocating palletizers and depalletizers

Installing a new production facility for RGB line has presented several complex challenges, particularly in terms of the positioning of the palletizing and depalletizing machines. Since all three existing production lines will continue to operate throughout the two-year construction of the new facility, certain adjustments will be required. One notable adjustment involves the relocation of palletizing and depalletizing units for the canning lines to accommodate the simultaneous operation of the current RGB line alongside the construction of the new RGB line. The map in Figure 24 illustrates the proposed locations, aiming to streamline the process by minimizing potential cross points for forklifts, integrating the new RGB line into the existing space, and optimizing storage utilization.

Relocating the palletizers and depalletizers helps to build a zone for each product category. Location 1 and 2 are the pal/depalletizing areas for cans, location 3, 4 and 5 are the pal/depalletizing areas for bottles and location 6 is the pal/depalletizing area for kegs.

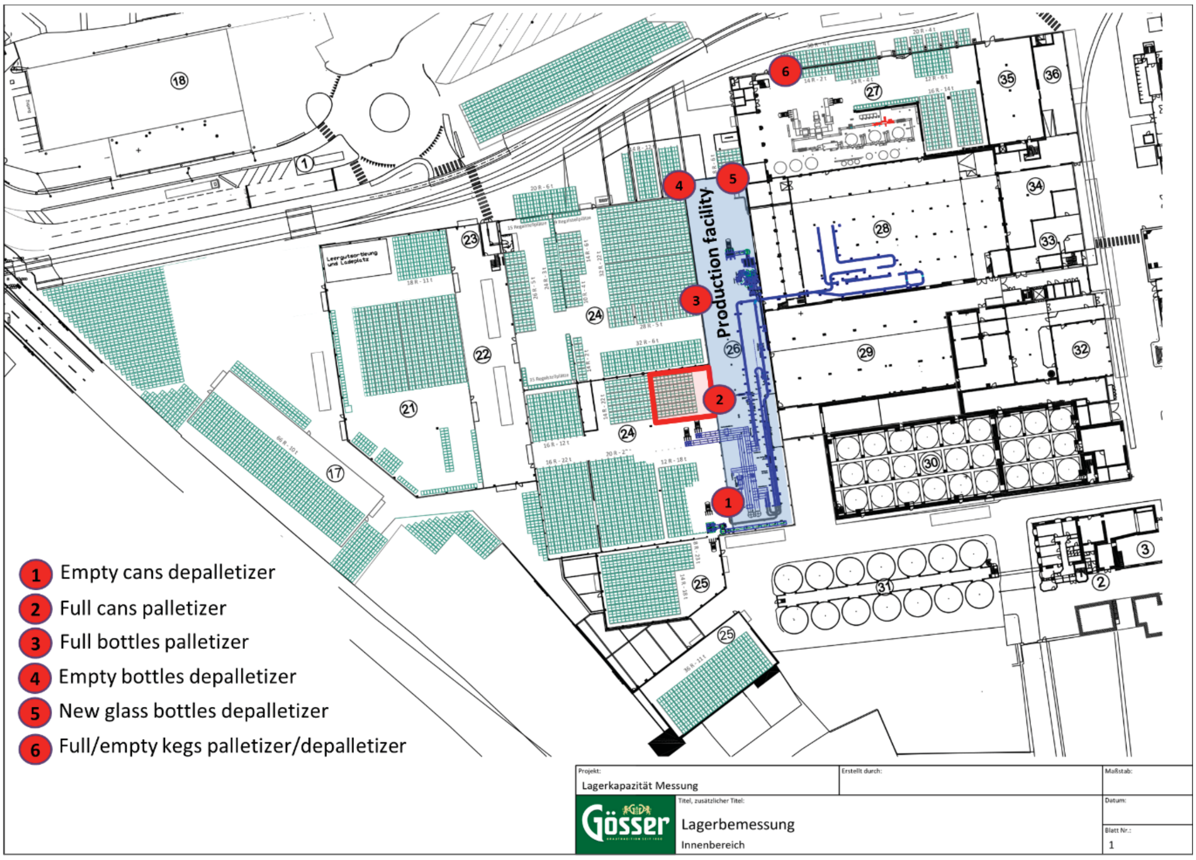

Figure 24: Palletizers and depalletizers locations

Yet, issues arose regarding the positioning of the can depalletizer at the intended site (Location 1 in Figure 24). During the design phase, the machine didn't align with the dimensions of the production area. Two alternative locations for the can depalletizer machine were proposed, as depicted in Figure 25.

In alternative 1, the machine's placement in the warehouse presents a challenge: it results in the loss of approximately 140 pallet spaces, equivalent to a reduction of 560 pallets in storage capacity when factoring in the four-pallet height. Additionally, compared to alternative 2 forklift drivers must cover 50% more distance. Forklifts encounter a minimum of 239 crossing points with other forklifts responsible for supplying the RGB production line and retrieving the finished goods. The data utilized in these calculations is extracted from the filling plan for calendar weeks 26 and 27 in 2023.

In Alternative 2, the machine is moved to a position between the production building and the fermentation cellar. This relocation necessitates moving the can shredder and the container for shredded cans located in that area. There is no roof for this area and the floor is asphalted, therefore a proper area for the machine must be built, which increases the capital cost. There is no crossing point between the forklifts.

The travel distance is approximately 33% shorter compared to alternative 1. No storage capacity is lost. The pathways for the two alternative options are color-coded for enhanced visual clarity, as depicted in Figure 25. The travel distances for the two alternatives are summarized in Table 15.

Despite the higher initial capital cost associated with alternative 2, it stands as the preferred and proposed option due to its reduced travel distance and absence of crossing points between the forklifts.

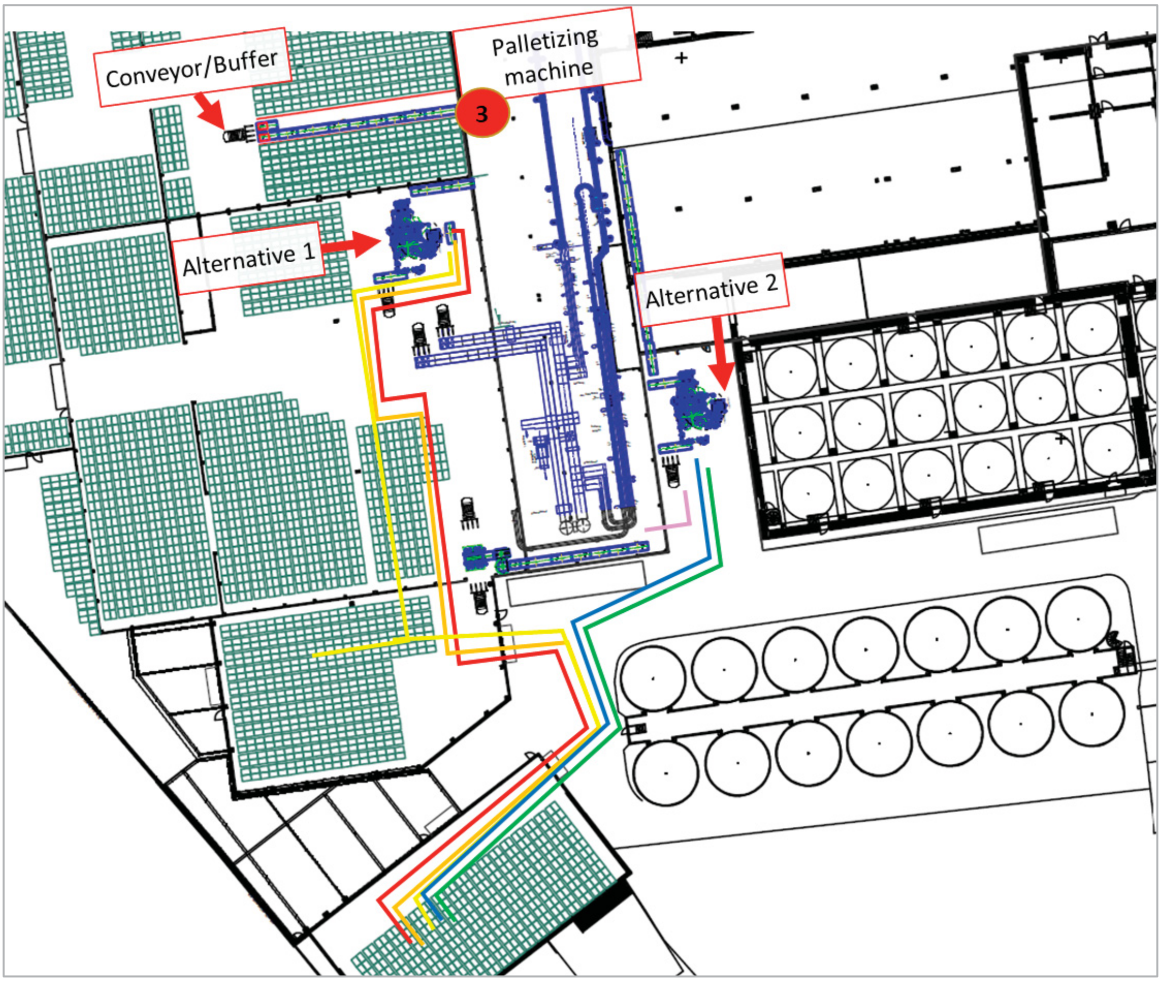

Figure 25: Depalletizer location - alternatives 1 and 2

Table 15: Travel distances for alternatives 1 and 2

Option	Path	Length [m]	Total length [m]
Alternative 1	Red	125.5	342,5
	Orange	125.5	
	Yellow	91.5	
Alternative 2	Green	72.5	228
	Light blue	70	
	Dark blue	72.5	
	Pink	13	

In Figure 25, at location 3, the bottle palletizing machine is planned near the wall. Here, the challenge arises as forklift drivers need to cover long distances within the stored pallets to pick up the finished goods and maneuver back through the entire section. This poses greater risks during night shifts; hence it is proposed to construct a conveyor for the entire distance. One advantage of this option is that the conveyor also generates a small buffer space, which facilitates smoother timing for the forklift pickups.

3.3.2 Warehouse capacity

Section 3.2.4 outlined an identified deficit of 985 pallets necessary to meet the increased capacity required by 2027. The intention is to enhance capacity by utilizing the existing warehouse facility; constructing a new warehouse is not within the scope of this project. Two alternative plans are proposed to increase the storage capacity.

Alternative 1, shown in the Figure 26, proposes to optimize the layout of the existing facility to maximize space utilization. This approach involves repurposing the forward area as a storage zone utilizing block stacking to maximize space efficiency. In addition, area 4 will be reconfigured to improve space utilization. The forward area and the loading/unloading zone for secondary transport will be relocated to area 5. Presently, area 5 functions as the event logistics area, managing the storage and transportation of equipment necessary for events to customers. At location 6, the capacity for serving trucks can potentially be increased to accommodate up to 6 trucks for primary transport.

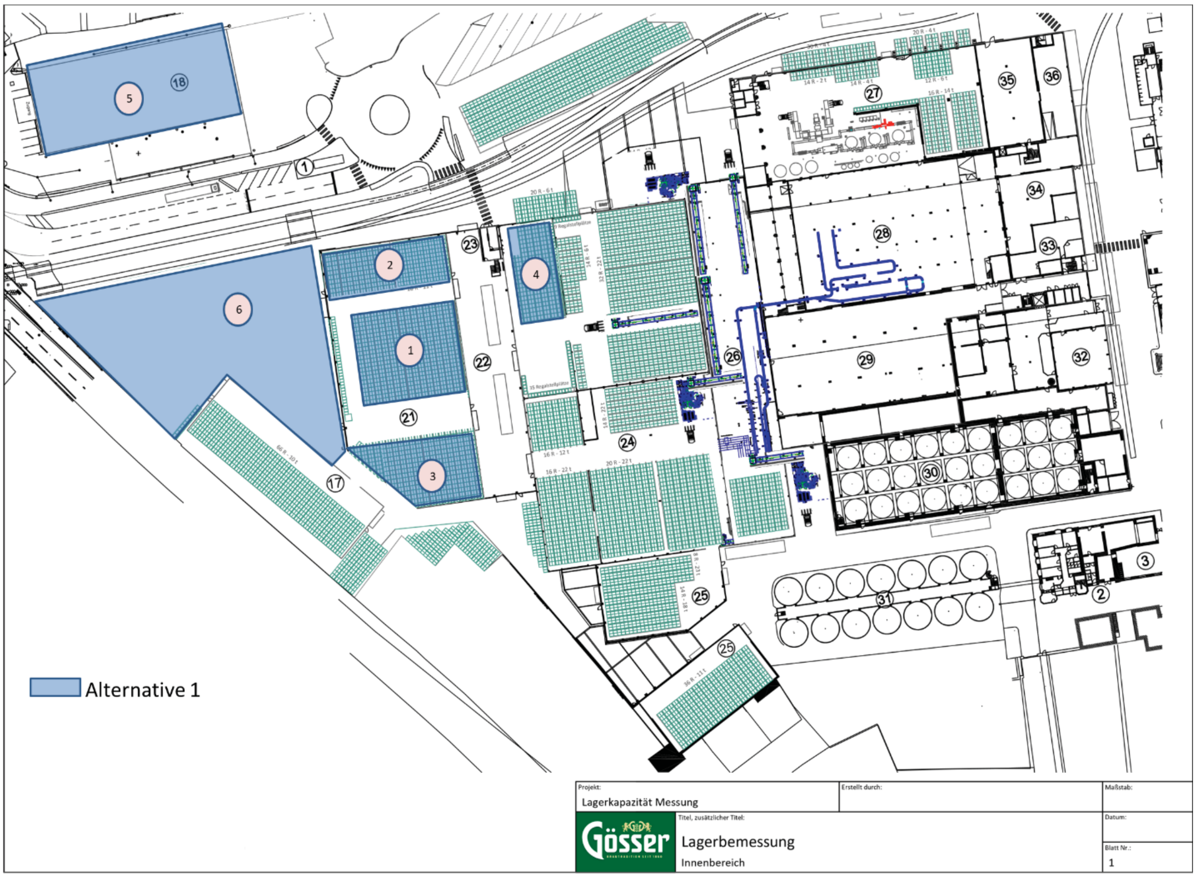

Figure 26: Proposed plan to increase storage capacity - alternative 1

Table 16 illustrates the capacity of each section in alternative 1 of the proposed plans. The table compares data from the current state (as of 01.02.2023) with the proposed plan. The new layout enhances warehouse capacity by up to 2082 pallets with a stacking height of three pallets.

Table 16: Comparison between current state and proposed plan alternative 1

Section Nr.	Proposed plan alternative 1	Current state (01.02.2023)	Difference
1	780	780	0
2	440	198	242
3	420	147	273
4	390	211	179
Total pal capacity	2030	1336	694

Advantages of alternative 1 plan:

- Cost-effective when compared to other option (alternative 2)

- Separates secondary logistics from the warehouse (reduce process complexity)

Alternative 2, illustrated in Figure 27, involves removing the wall that separates the primary loading/unloading area from storage hall 21, converting it into storage space. Additionally, the forward area and secondary loading/unloading area will be moved to location 5, which currently serves as the event logistics area. The expedition office will be relocated to location 7, which is close to the primary loading/unloading area. At location 6, a lightweight roof structure will be constructed to function as a covered loading and unloading area for primary transport. Additionally, the capacity for serving trucks in this area can be increased to accommodate up to 6 trucks for primary transport. During the cold and rainy season, this space can also be used to store empty bottles.

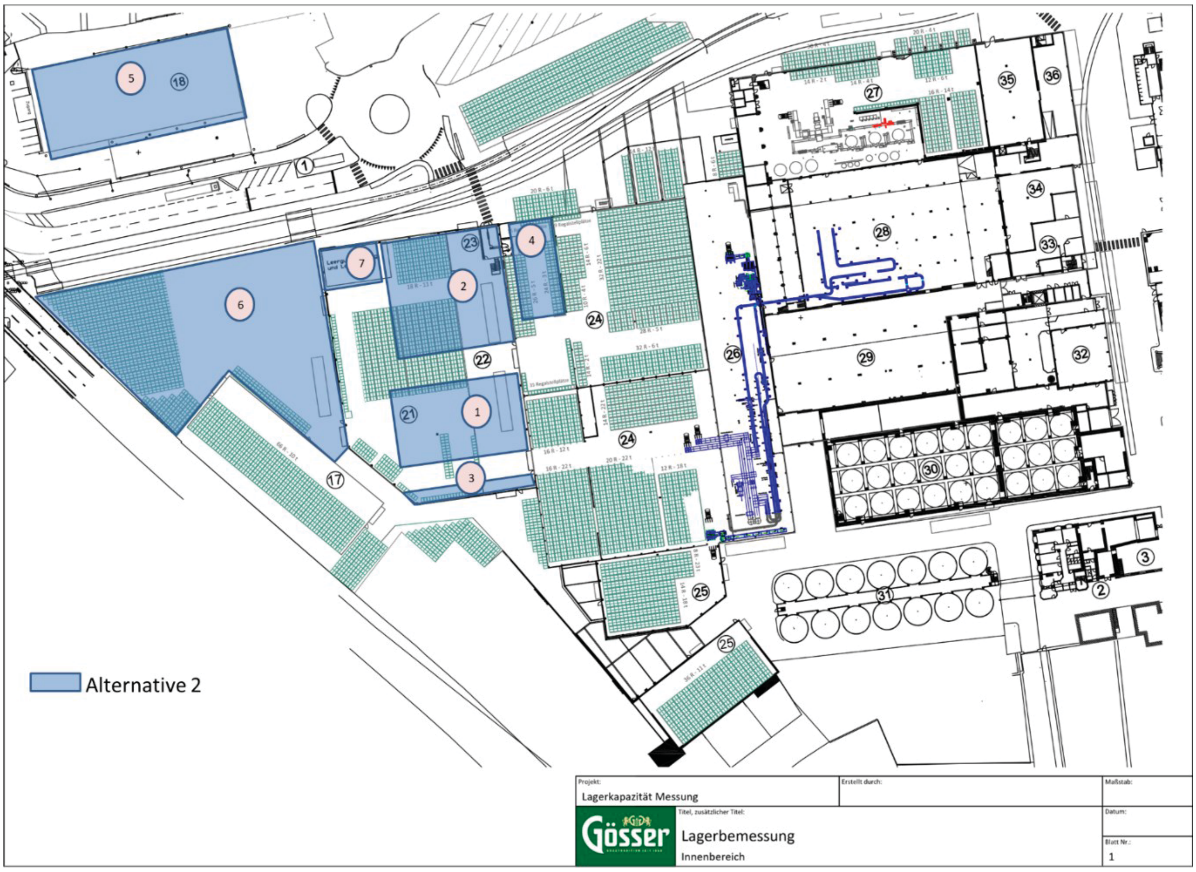

Figure 27: Proposed plan to increase storage capacity - alternative 2

Table 17 shows the capacity of each section in alternative 2 of the proposed plans. The table compares data from the current state (as of 01.02.2023) with the proposed plan. The new layout enhances warehouse capacity by up to 2042 pallets with a stacking height of three pallets.

Table 17: Comparison between current state and proposed plan alternative 2

Section Nr.	Proposed plan alternative 2	Current state (01.02.2023)	Difference
1	960	780	180
2	667	198	469
3	0	147	-147
4	390	211	179
Total pal capacity	2017	1336	681

Advantages of alternative 2 plan:

- Having a roof enhances the loading/unloading processes and concurrently shields finished goods from potential damage during unfavorable weather conditions
- Some sections of the area can serve as winter storage for empty bottles, protecting them from breakage

Disadvantages of alternative 2 plan:

- This option entails a higher cost compared to alternative 1
- The installation of pillars within the area can be a safety concern due to the large roof, especially in areas with high daily traffic volume
- Requires relocation of the expedition office
- Time consuming to implement

Alternative 1 presents several advantages over alternative 2 and stands as the preferred choice for increasing storage capacity within the existing warehouse facilities. It offers greater cost-effectiveness, ease of implementation, and comparable increased storage capacity to alternative 2.

Figure 28 presents additional potential opportunities involving the repurposing of existing structures within the brewery. Location 1, an unused old building, can be rebuilt to function as a covered storage area, effectively boosting storage capacity. Location 2, an underutilized workshop with ample space, offers the potential for renovation and repurposing to serve as both a workshop and additional storage space.

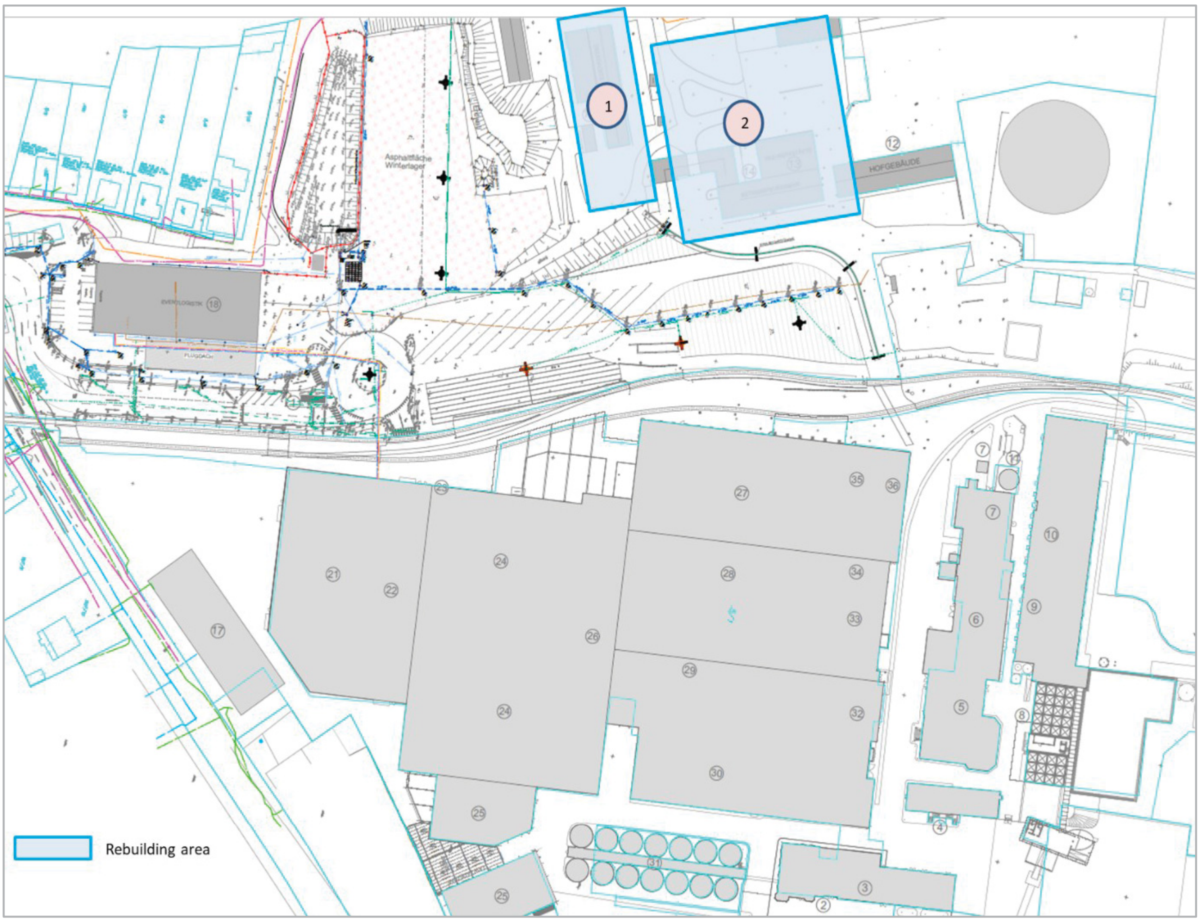

Figure 28: Additional potential opportunities to increase storage capacity

3.3.3 Improvement of process and traffic flows

The objective of this section is to optimize the movement of forklifts and materials within the warehouse, aiming to reduce both travel time and distance. This improvement contributes to fostering a safer working environment. Additionally, enhancements in the primary transport process are underway to expedite tour planning and extend the order window for customers.

3.3.3.1 Primary and secondary transport processes

Based on choosing alternative 1 in warehouse layout, to manage the growing transportation requirements, the primary transportation yard has been expanded from 5 to 11 locations.

In order to improve the primary transportation process, it is recommended to handle all transportation planning using OTM. This change results in an extended order window for customers. As a result, the primary transportation manager won't need to dedicate time to tour planning, enabling a shift in focus towards more critical tasks. As a part of this transition, tour planning will be fully automated. The improved process description is shown in Figure 29.

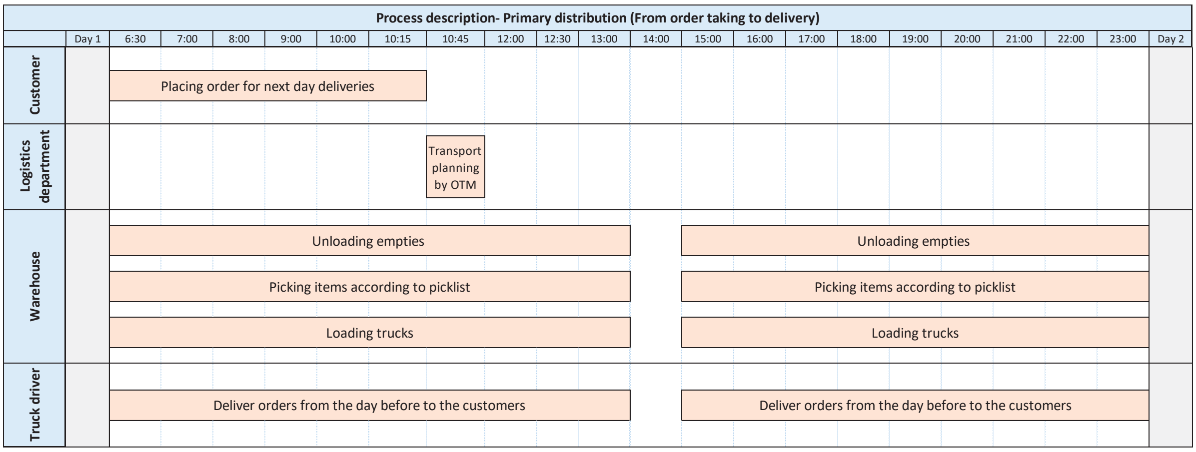

Figure 29: Improved primary transport process - from order taking to delivery

The secondary transportation process remains the same. The only change is the relocation of the forward area and loading and unloading area.

3.3.3.2 Loading/unloading and handling processes and traffic flows

Changing the warehouse layout significantly influences both processes and traffic flows. In the proposed layout, the goal is to optimize efficiency by minimizing travel time and reducing traffic congestion and cross points in the warehouse.

Figure 30 shows the improved goods handling path for shipping products, for the case which was presented in Figure 22 (Section 3.1.3.2). As can be seen, there is a decrease in cross points, resulting in a more organized traffic flow. The internal transportation process of each product group has been separated as much as possible, which has reduced the complexity of the system. The rest of the process paths are presented in Appendix 6.

Table 18 lists the details of related process steps for incoming and shipping items for the improved plan. The total time spent on handling items per year is 58,605 hours, indicating a decrease of 8,412 hours per year compared to the current state. This represents a 12.6% reduction, signifying increased efficiency.

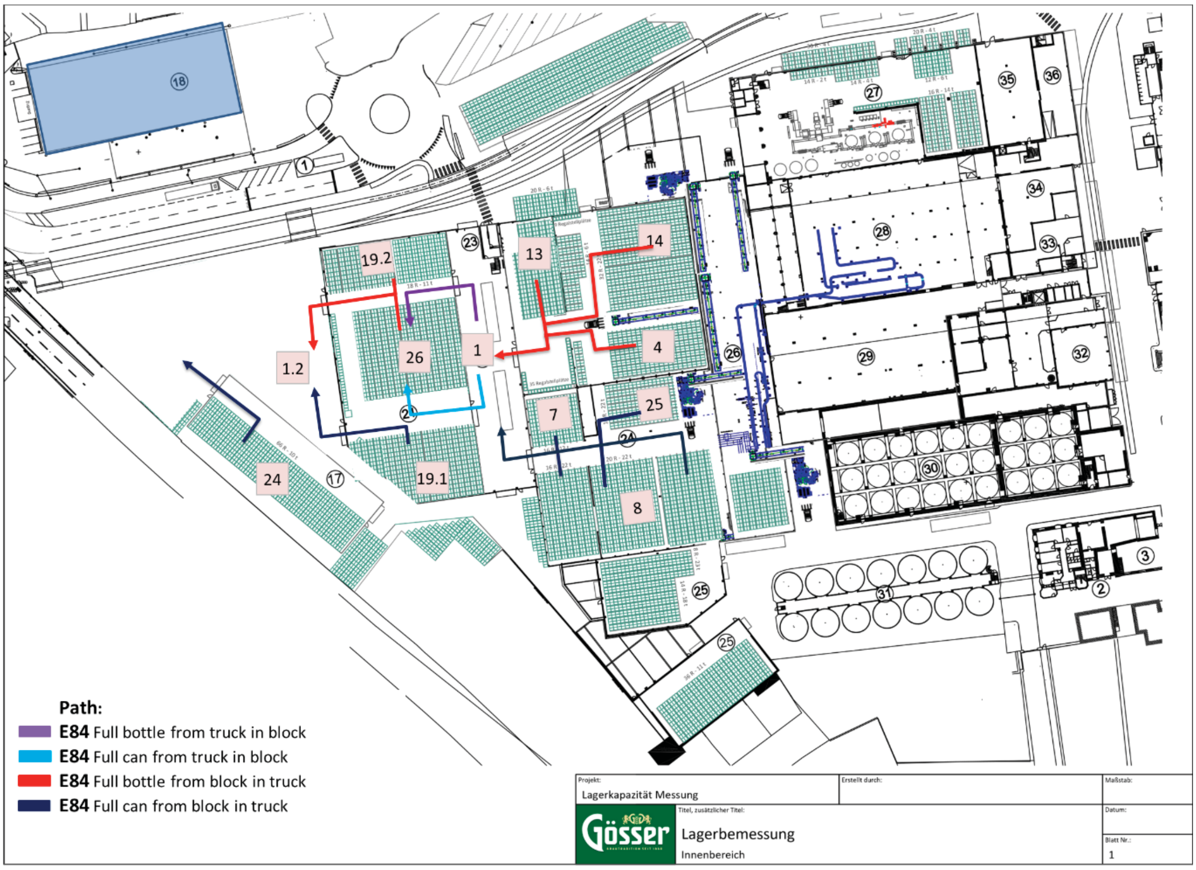

Figure 30: Improved shipping process path

Table 18: Total handling time for receiving and shipping processes - improved plan

Process	Path	Description	Loading/ unloading [min/pal]	Buffer time [min/pal]	Checking [min/pal]	Total time [min/pal]	Pal/year	Total time [min/year]
Receiving	E80	Receiving bottles from production line to warehouse	4.00	0.60	0.50	5.10	139,838	712,995
	E81	Receiving kegs from production line to warehouse	3.70	0.56	0.50	4.76	123,641	588,220
	E90	Receiving cans from production line to warehouse	5.32	0.80	0.50	6.62	67,521	447,065
	E84	Receiving full bottles/cans	0.51	0.08	0.50	1.09	3,660	3,981
	E85	Receiving full kegs	1.36	0.20	0.50	2.07	825	1,707
Shipping	E82	Outgoing goods bottles/cans	4.69	0.70	3	8.40	16,558	139,018
	E83	Outgoing goods kegs	4.69	0.70	3	8.40	9,127	76,628
	E84	Full bottle/can from block in truck	2.12	0.32	0.5	2.94	338,813	995,577
	E85	Full keg from block in truck	1.36	0.20	0.5	2.06	267,685	551,134
Total							967,668	3,516,325

3.3.3.3 Primary transport by train

There is a railroad that crosses the site, depicted in Figure 31. Most of the buildings and covered storage areas are situated on one side of the railroad, with the uncovered storage area located on the opposite side. The brewery owns the railroad, yet it is not used by them for any transportation. Conversely, Mayr-Melnhof frequently utilizes this rail connection daily. The train passes the site up to 5 times a day, operating at schedules convenient for Mayr-Melnhof or ÖBB, but not for the brewery. The challenge arises when the train passes through brewery site, requiring employees to temporarily stop work for safety reasons. To make matters worse, there is no predetermined schedule or plan for these train crossings, causing disruptions during peak hours.

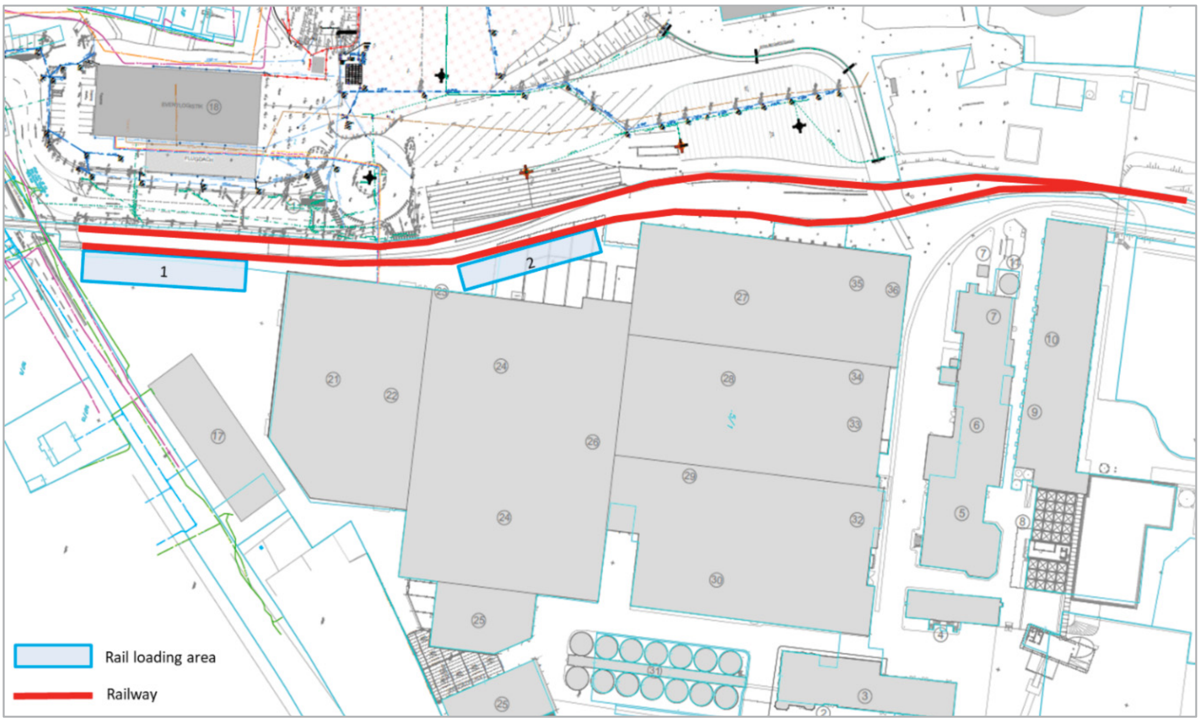

Figure 31: Railway connection and rail loading locations

This presented a notable opportunity for Göss to leverage its existing railway infrastructure and improve the efficiency of their transportation operations, particularly for long distances. And potentially shift some of its road transportation to railway. There are several advantages to this transition:

- As production increases, so does the demand for transportation. In addition, this shift could potentially alleviate some of the operational strain on the limited number of truck loading and unloading yards at the company. Shifting to rail has significant environmental benefits as well, including a reduction in CO_2 emissions and a positive impact on overall traffic congestion.

- Each wagon of the train has a capacity of 63 pallets, effectively twice of the transport capacity of a truck.
- The loading operation of the wagons is significantly faster than loading two trucks.

Figure 31 depicts two suggested locations for train loading. Loading area 1 is designated as the main loading area due to its location, ensuring minimal disruption to daily operations. However, it is important to note that this area is situated in an open area and the product packages are susceptible to moisture damage during rainy or snowy weather. In winter the exports decrease, so the problem is minimal in winter.

Loading area 2 is designated as an additional loading location to accommodate potential increase of transportation needs. Its main advantage is the presence of a roof, which protects operations from bad weather conditions. However, a drawback is its proximity to the RGB line, which can cause inconvenience to forklift drivers feeding the machines. To mitigate this, it is recommended to schedule train loading in the early morning or late evening.

A successful trial was conducted in May 2023 to evaluate the feasibility of using trains to ship products to Germany. The following month, Göss started regular shipping operations, with two shipments daily, with each shipment utilizing two wagons (126 pal per shipment).

4 Conclusion

In alignment with the company's strategic plan to address rising customer demand, enhance efficiency and productivity, and foster business growth, the choice has been made to construct a new production line for bottle beer by 2025. Production is expected to rise over the next four years, reaching a 38% increase by 2027.

In accordance with the implementation of the new production line, the placement of the palletizer and depalletizer are optimized, creating dedicated zones for each product group. This adjustment aims to minimize traffic flow and intersections for forklifts, thereby enhancing safety.

To manage the increased production within the current warehouse, the warehouse layout is optimized by repurposing and rearranging the existing storage halls. This yields an additional storage capacity of 985 pallet spaces for finished goods, all achieved without the need for constructing any extra storage space. In conjunction with the modifications to the warehouse layout, the travel distance for forklifts is reduced by 34%, leading to a 12.6% decrease in travel time.

To handle the surge in transportation needs, the primary transportation yard is expanded from 5 to 11 locations. Additionally, certain long-distance primary transport operations are transitioned to rail, offering advantages in CO_2 emissions reduction and shorter loading times. In order to speed up tour planning for primary transport and extend the order window for customers, the entire process should be handled exclusively by OTM. Meanwhile, the secondary transport process remains unchanged, with the only adjustments being the relocation of the forward area and transportation yard, both will be transferred to event logistics.

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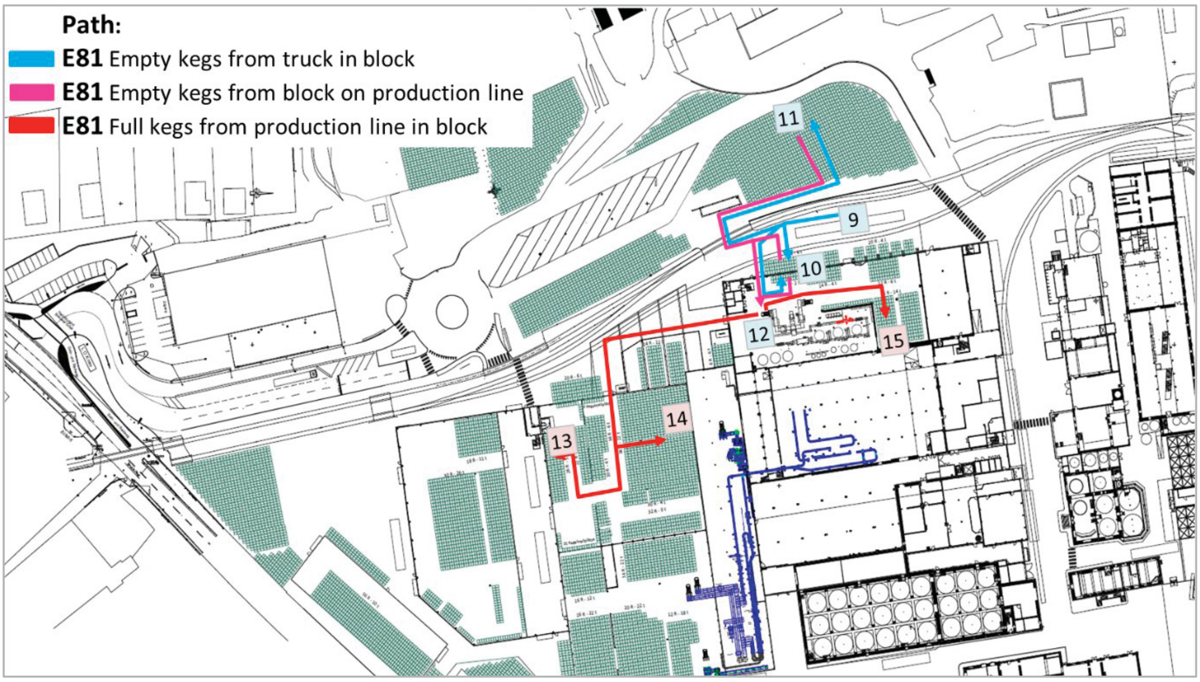
Appendix 1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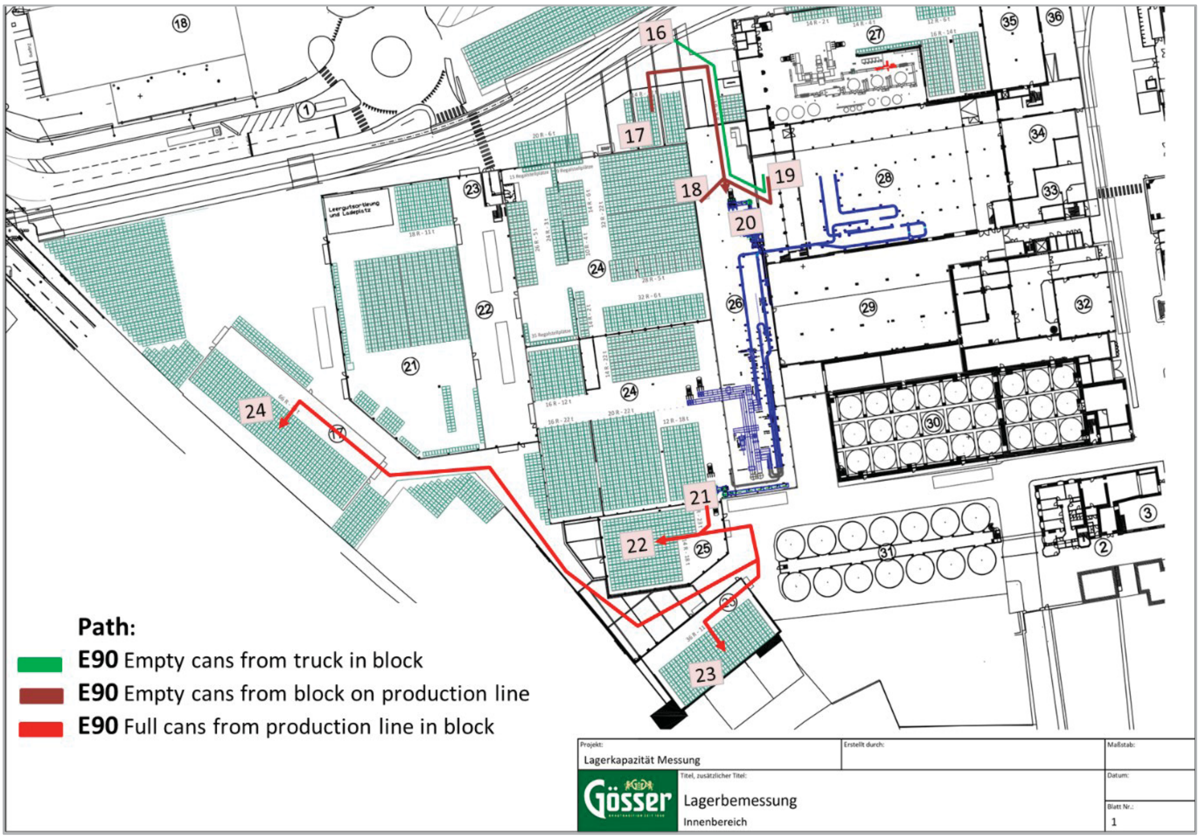
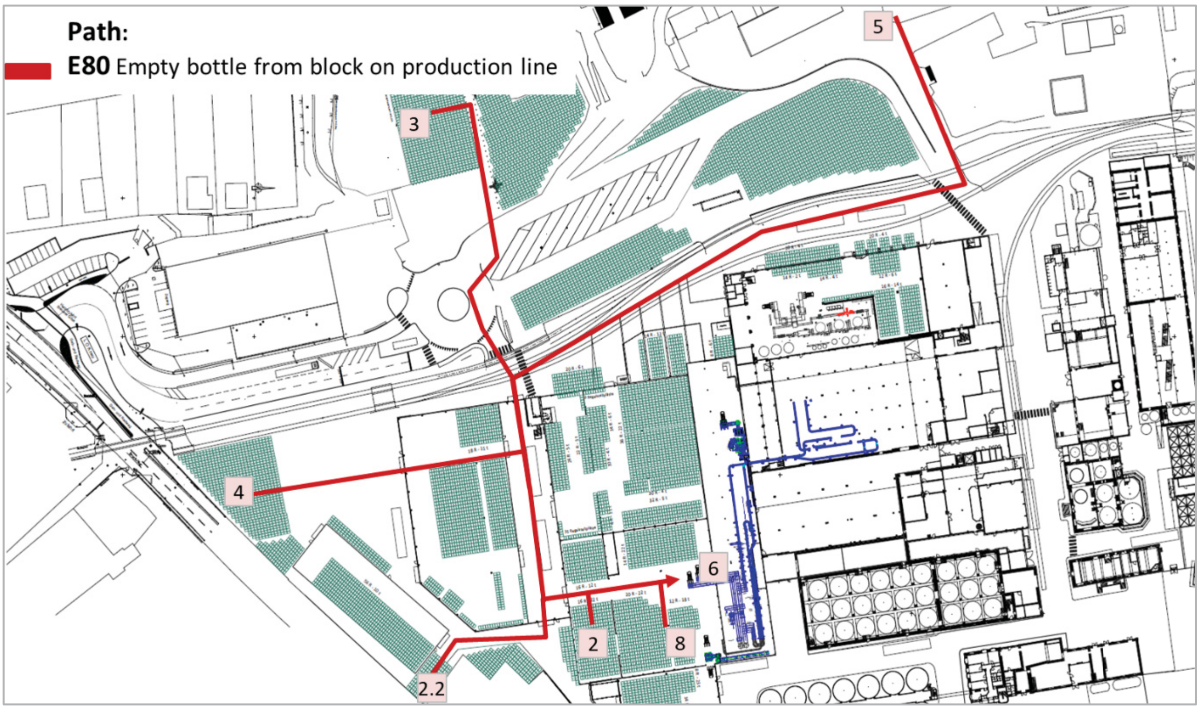
E81 Empty kegs from truck in block
E81 Empty kegs from block on production line
E81 Full kegs from production line in block
9
10
11
12
13
14
15


Path:
E90 Empty cans from truck in block
E90 Empty cans from block on production line
E90 Full cans from production line in block
16
17
18
19
20
21
22
23
24
Projekt:
Lagerkapazität Messung
Erstellt durch:
Maßstab:
Titel, zusätzlicher Titel:
Lagerbemessung
Innenbereich
Datum:
Blatt Nr.:
1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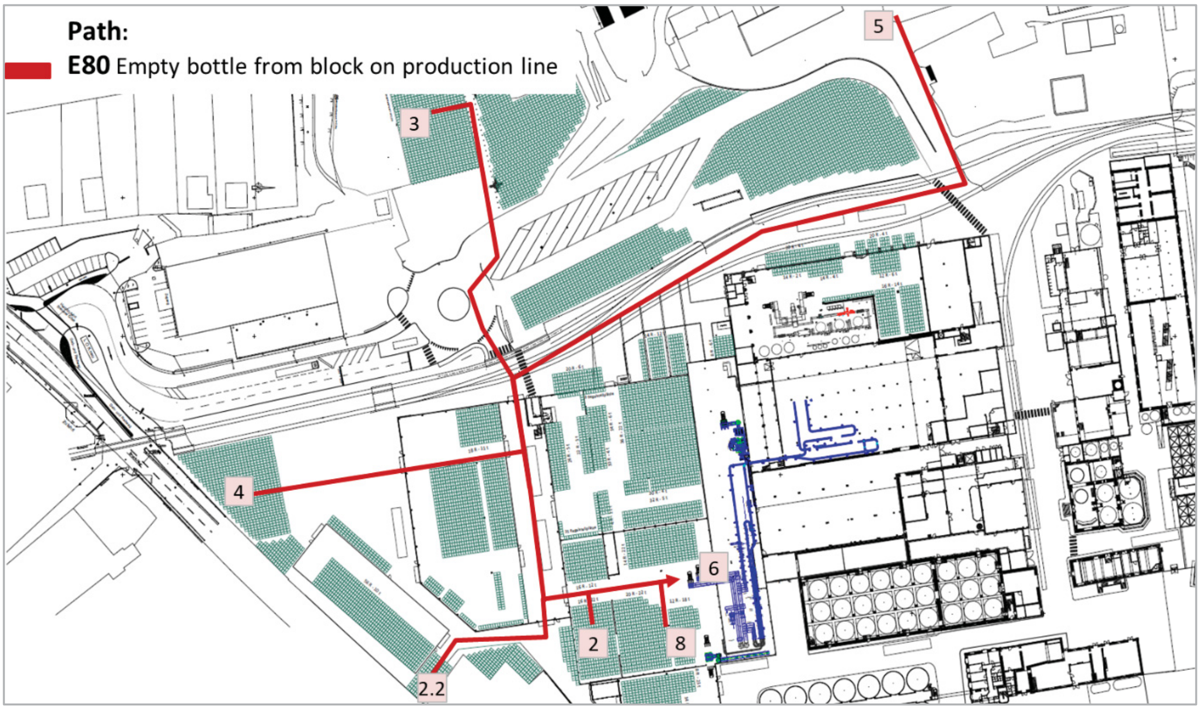
E80 Empty bottle from block on production line
5
3
4
6
2
8
2.2


Path:
E80 Empty bottle from block on production line
5
3
4
6
2
8
2.2

Appendix 2

Storage place	Pallets place on the floor	Sum of the pallets
17 - Leichtbauhalle-1	560	1680
21 - Kommissionierhalle - 1	780	2340
21 - Kommissionierhalle - 2	198	594
21 - Kommissionierhalle - 3	72	216
21 - Kommissionierhalle - 4- Regal	75	150
24 - Vollguthalle - 1	128	384
24 - Vollguthalle - 2	454	1362
24 - Vollguthalle - 3	352	1056
24 - Vollguthalle - 4	308	924
24 - Vollguthalle - 5	192	576
24 - Vollguthalle - 6 KEG50	180	540
24 - Vollguthalle - 7 KEG30	120	360
24 - Vollguthalle - 8	792	2376
24 - Vollguthalle - 9	84	252
24 - Vollguthalle - 10	40	120
24 - Vollguthalle – 11&12 -KEG20	110	330
24 - Vollguthalle - 13-KEG30	130	390
24 - Vollguthalle - 14-Regal & Pallet	36	102
24 - Vollguthalle - 15 - KEG 30	15	45
25 - Dosenlagerhalle - 1	396	1188
25 - Dosenlagerhalle - 2	252	756
25 - Dosenlagerhalle - 3	184	552
27 - Fassabfüllung - 1	224	672
27 - Fassabfüllung - 2 -20 lt KEG	72	216
27 - Fassabfüllung - 3-Leergeb	56	168
27 - Fassabfüllung - 4-Leergeb	28	84
Außenlager klein - 1	78	234
Außenlager klein - 2	184	552
Außenlager klein - 3	40	120
Außenlager klein - 4- Plastik pallet	72	216
Außenlager klein - 5- Leer Dose	168	504
Außenlager klein - 6	120	360
Außenlager klein - 7	80	240
Lagerfläche 1 - Kiste	714	2142
Lagerfläche 2 - Fass	1806	5418
Lagerfläche 3 - aktuell mit Leerpaletten	200	600
Lagerfläche 4 - Kiste	1804	5412
Lagerfläche 5 - Kiste	1300	3900
Lagerfläche 6 - Kiste Ist	798	2394
Sum finished goods	**5754**	**17181**
Sum empties	**7448**	**22344**
Total Sum (Empties/Finished goods)	**13202**	**39525**
Sum without racks	**13091**	**39273**

Appendix 3

Product	Sum of sales volume [pal.space]	Share %	Cum. %	ABC
GÖSSER Märzen MW Kiste 20x50cl	78074.3	29.76%	29.76%	A
GÖSSER Märzen Dose Tray 24x50cl	25346.3	9.66%	39.43%	A
PUNTIGAMER D.Bierige Dose Tray 24x50cl	21181.8	8.07%	47.50%	A
PUNTIGAMER Panther Fass 50L	15376.2	5.86%	53.36%	A
GÖSSER Märzen Fass 50L	14768.3	5.63%	58.99%	A
PUNTIGAMER D.Bierige MW Kiste 20x50cl	13694.9	5.22%	64.21%	A
GÖSSER NaturRad.Zit.DoseTray24x50 DE neu	11063.0	4.22%	68.43%	A
GÖSSER NaturRadl.0,0% MW Kiste24x33cl DE	7753.7	2.96%	71.39%	A
GÖSSER NaturGold AF MW Kiste 20x50cl	7563.4	2.88%	74.27%	A
GÖSSER NaturRadl.Zitr. Dose Tray 24x50cl	5678.6	2.16%	76.43%	A
GÖSSER NaturRadl.Zitr. MW Kiste 20x50 EX	5174.8	1.97%	78.41%	A
PUNTIGAMER D.Bierige Fass 50L	4392.0	1.67%	80.08%	B
DESPERADOS Dose Tray 24x50cl DE	3561.7	1.36%	81.44%	B
SCHWECHATER Bier Dose Tray 24x50cl	3511.6	1.34%	82.78%	B
GÖSSER Gold Fass 50L	3280.3	1.25%	84.03%	B
SCHLADMINGER Märzen MW Kiste 20x50cl	2938.3	1.12%	85.15%	B
GÖSSER Märzen Fass 30L	2546.4	0.97%	86.12%	B
ZIPFER Urtyp Dose Tray 24x50cl	2473.5	0.94%	87.06%	B
GÖSSER NaturRadl.0,0% Dose Tray 24x50 DE	2414.0	0.92%	87.98%	B
GÖSSER NaturRadl. Zitr. MW Kiste 20x50cl	2232.6	0.85%	88.83%	B
GÖSSER NaturRadler Zitrone Fass 20L	1847.6	0.70%	89.54%	B
PUNTIGAMER Panther Fass 30L	1654.7	0.63%	90.17%	B
ZIPFER Märzen Dose Tray 24x33cl	1529.0	0.58%	90.75%	B
GÖSSER NaturGold AF Dose Tray 24x50cl	1403.7	0.54%	91.29%	B
SCHLADMINGER Märzen Fass 50L KF	1355.9	0.52%	91.80%	B
GÖSSER NaturRadler Zitrone Fass 50L	1333.3	0.51%	92.31%	B
REININGHAUS Pils Fass 50L	1194.9	0.46%	92.77%	B
GÖSSER NaturRadl.Zitr. DoseTray 24x50 EX	1111.9	0.42%	93.19%	B
GÖSSER Märzen MW Kiste 20x50cl ÖBB DoN	772.5	0.29%	93.49%	B
GÖSSER Märzen Fass David 20L	744.7	0.28%	93.77%	B
GÖSSER Spezial Fass 50L	735.6	0.28%	94.05%	B
SCHLADMINGER Bio Zwickl Fass 20L KF	715.5	0.27%	94.32%	B
PUNTIGAMER D.Bierige David Fass 20L	707.9	0.27%	94.59%	B
GÖSSER NaturHell 4% MW Kiste 20x50cl	702.9	0.27%	94.86%	B
GÖSSER Märzen MW RD Tray 30(6x50cl)	664.5	0.25%	95.11%	C
PUNTIGAMER Panther MW Kiste 24x33cl	650.3	0.25%	95.36%	C
GÖSSER Hell Fass 30L EX	629.0	0.24%	95.60%	C
GÖSSER Märzen Dose Tray 24x50cl EX	626.0	0.24%	95.84%	C
GÖSSER StiftsZwickl Hell Fass 20L	619.8	0.24%	96.08%	C
PUNTIGAMER Panther Fass 30L EX	593.9	0.23%	96.30%	C
GÖSSER Märzen MW Kiste 24x33cl	593.2	0.23%	96.53%	C
REININGHAUS Märzen Fass 50L	593.1	0.23%	96.76%	C
GÖSSER Märzen Dose Tray 24x33cl	566.5	0.22%	96.97%	C
GOLDENBRÄU Dose Tray 24x50cl IT	484.9	0.18%	97.16%	C
ZIPFER Limetten Radler Dose Tray 24x50cl	461.5	0.18%	97.33%	C
GÖSSER Gold Fass 30L	432.8	0.16%	97.50%	C
REININGHAUS Jahrgangspils Fass 20L	422.1	0.16%	97.66%	C

ZIPFER Märzen Dose Tray 24x33cl HU	418.2	0.16%	97.82%	C
GÖSSER Hell MW Kiste 24x33cl EX	391.7	0.15%	97.97%	C
GÖSSER NaturRadl.Zitr. MW Kiste 24x33cl	387.0	0.15%	98.11%	C
SCHLADMINGER Märzen Fass 30L KF	345.6	0.13%	98.25%	C
VILLACHER Märzen Dose Tray 24x50cl	308.9	0.12%	98.36%	C
SONNENBRÄU Dose Tray 24x33cl EX	306.2	0.12%	98.48%	C
COCA-COLA Coke MW Kiste 24x33cl	297.0	0.11%	98.59%	C
REININGHAUS Pils Fass 30L	286.7	0.11%	98.70%	C
SONNENBRÄU Dose Tray 24x50cl IT	267.4	0.10%	98.81%	C
SCHLADMINGER Bio Zwickl Fass 50L KF	235.7	0.09%	98.90%	C
GÖSSER Märzen Dose Tray 24x33cl EX	233.5	0.09%	98.98%	C
GÖSSER StiftsZwickl Dunkel Fass 20L	217.6	0.08%	99.07%	C
REININGHAUS JG-Pils MW Kiste 24x33cl	211.5	0.08%	99.15%	C
RÖMERQUELLE Prickelnd MW Kiste 20x33cl	203.9	0.08%	99.23%	C
SODAWASSER Fass 50L	169.3	0.06%	99.29%	C
SOL Dose Tray 24x33cl DE	157.8	0.06%	99.35%	C
SODAWASSER Fass 20L	150.5	0.06%	99.41%	C
GÖSSER Stiftsbräu Fass 30L	129.6	0.05%	99.46%	C
SCHLADMINGER Schneew.BIO MW Kiste20x50cl	126.0	0.05%	99.50%	C
GÖSSER Spezial MW Kiste 24x33cl	122.3	0.05%	99.55%	C
GÖSSER NaturHell 4% Fass 50L	112.1	0.04%	99.59%	C
PUNTIGAMER Panther MW RD Tray 30(6x50cl)	108.0	0.04%	99.64%	C
RÖMERQUELLE Prickelnd MW Kiste 12x1L	100.5	0.04%	99.67%	C
COCA-COLA Zero MW Kiste 24x33cl	99.6	0.04%	99.71%	C
SCHLADMINGER Schneew.BIO Fass 20L KF	86.7	0.03%	99.74%	C
GÖSSER NaturGold AF Fass 20L David	86.5	0.03%	99.78%	C
Kohlensäure Kurz 10KG	67.8	0.03%	99.80%	C
PUNTIGAMER D.Bierige EW Tray 24x33cl	65.8	0.03%	99.83%	C
GÖSSER NaturRadl.Zitr. MW Kiste 20x50 HB	60.6	0.02%	99.85%	C
GÖSSER NaturGold AF MW RDTray 30(6x50cl)	50.5	0.02%	99.87%	C
COCA-COLA Light MW Kiste 24x33cl	50.5	0.02%	99.89%	C
GÖSSER NaturRad.Zitr.MW RD Try30(6x50cl)	41.3	0.02%	99.91%	C
GÖSSER NaturGold AF MW Kiste 20x50cl HB	35.1	0.01%	99.92%	C
GÖSSER NaturHell 4% Fass 30L	29.4	0.01%	99.93%	C
GÖSSER Märzen MW Kiste 20x50cl HB	28.2	0.01%	99.94%	C
REININGHAUS Märzen MW Kiste 20x50cl	26.7	0.01%	99.95%	C
Kohlensäure 5KG	17.0	0.01%	99.96%	C
PUNTIGAMER Winterkönig Fass 30L	14.0	0.01%	99.96%	C
GÖSSER Hell Fass 30L IT	13.7	0.01%	99.97%	C
GÖSSER Märzen Fass Barbara 30L	11.9	0.00%	99.97%	C
ZIPFER Märzen Dose Tray 24x50cl DE	11.1	0.00%	99.98%	C
WIESELBURGER Gold Dose Tray 24x50cl	11.0	0.00%	99.98%	C
WINTERBOCK Fass 20L	10.4	0.00%	99.99%	C
EDELWEISS Hefetrüb Fass 25L	9.7	0.00%	99.99%	C
BRÜNDLWEG Bier MW Kiste 20x50cl	6.6	0.00%	99.99%	C
PUNTIGAMER Zwickl Fass 30L	5.4	0.00%	99.99%	C
Kohlensäure 20KG	3.5	0.00%	99.99%	C
GÖSSER Helles Fass 30L	3.0	0.00%	100.00%	C
Kohlensäure David 2KG Pfand	2.5	0.00%	100.00%	C
Mischgas 30/70 5,5 M3	2.2	0.00%	100.00%	C
GÖSSER Hell EW Karton 24x33cl EX2	2.0	0.00%	100.00%	C

Mischgas 30/70 2 M3	1.4	0.00%	100.00%	C
GÖSSER NaturRadl.Zitr. EW Tray 12x33 IT	1.0	0.00%	100.00%	C
Mischgas 30/70 4 M3	1.0	0.00%	100.00%	C
BARBARA Bier Anstichfass 20L	0.1	0.00%	100.00%	C

Appendix 4

Products	ABC	standard deviation	Coefficient of variation	XYZ
GÖSSER Märzen MW Kiste 20x50cl	A	1493.82	0.23	X
GÖSSER Märzen Dose Tray 24x50cl	A	568.26	0.27	X
PUNTIGAMER D.Bierige Dose Tray 24x50cl	A	587.45	0.33	X
PUNTIGAMER Panther Fass 50L	A	336.27	0.26	X
GÖSSER Märzen Fass 50L	A	380.06	0.31	X
PUNTIGAMER D.Bierige MW Kiste 20x50cl	A	1033.29	0.91	Y
GÖSSER NaturRad.Zit.DoseTray24x50 DE neu	A	430.23	0.47	X
GÖSSER NaturRadl.0,0% MW Kiste24x33cl DE	A	350.45	0.54	Y
GÖSSER NaturGold AF MW Kiste 20x50cl	A	121.32	0.19	X
GÖSSER NaturRadl.Zitr. Dose Tray 24x50cl	A	287.56	0.61	Y
GÖSSER NaturRadl.Zitr. MW Kiste 20x50 EX	A	533.93	1.24	Z
PUNTIGAMER D.Bierige Fass 50L	B	106.70	0.29	X
DESPERADOS Dose Tray 24x50cl DE	B	174.02	0.59	Y
SCHWECHATER Bier Dose Tray 24x50cl	B	518.89	1.77	Z
GÖSSER Gold Fass 50L	B	84.83	0.31	X
SCHLADMINGER Märzen MW Kiste 20x50cl	B	36.24	0.15	X
GÖSSER Märzen Fass 30L	B	55.82	0.26	X
ZIPFER Urtyp Dose Tray 24x50cl	B	75.12	0.36	X
GÖSSER NaturRadl.0,0% Dose Tray 24x50 DE	B	136.86	0.68	Y
GÖSSER NaturRadl. Zitr. MW Kiste 20x50cl	B	99.78	0.54	Y
GÖSSER NaturRadler Zitrone Fass 20L	B	74.18	0.48	X
PUNTIGAMER Panther Fass 30L	B	29.42	0.21	X
ZIPFER Märzen Dose Tray 24x33cl	B	40.07	0.31	X
GÖSSER NaturGold AF Dose Tray 24x50cl	B	30.06	0.26	X
SCHLADMINGER Märzen Fass 50L KF	B	26.64	0.24	X
GÖSSER NaturRadler Zitrone Fass 50L	B	77.52	0.70	Y
REININGHAUS Pils Fass 50L	B	29.22	0.29	X
GÖSSER NaturRadl.Zitr. DoseTray 24x50 EX	B	55.40	0.60	Y
GÖSSER Märzen MW Kiste 20x50cl ÖBB DoN	B	10.68	0.17	X
GÖSSER Märzen Fass David 20L	B	18.52	0.30	X
GÖSSER Spezial Fass 50L	B	18.90	0.31	X
SCHLADMINGER Bio Zwickl Fass 20L KF	B	9.34	0.16	X
PUNTIGAMER D.Bierige David Fass 20L	B	13.36	0.23	X
GÖSSER NaturHell 4% MW Kiste 20x50cl	B	67.23	1.15	Z
GÖSSER Märzen MW RD Tray 30(6x50cl)	C	20.18	0.36	X
PUNTIGAMER Panther MW Kiste 24x33cl	C	13.28	0.25	X
GÖSSER Hell Fass 30L EX	C	23.67	0.45	X
GÖSSER Märzen Dose Tray 24x50cl EX	C	27.81	0.53	Y
GÖSSER StiftsZwickl Hell Fass 20L	C	10.00	0.19	X
PUNTIGAMER Panther Fass 30L EX	C	29.94	0.60	Y
GÖSSER Märzen MW Kiste 24x33cl	C	14.69	0.30	X
REININGHAUS Märzen Fass 50L	C	17.34	0.35	X
GÖSSER Märzen Dose Tray 24x33cl	C	18.43	0.39	X
GOLDENBRÄU Dose Tray 24x50cl IT	C	27.97	0.69	Y
ZIPFER Limetten Radler Dose Tray 24x50cl	C	26.17	0.68	Y
GÖSSER Gold Fass 30L	C	11.95	0.33	X
REININGHAUS Jahrgangspils Fass 20L	C	6.85	0.19	X

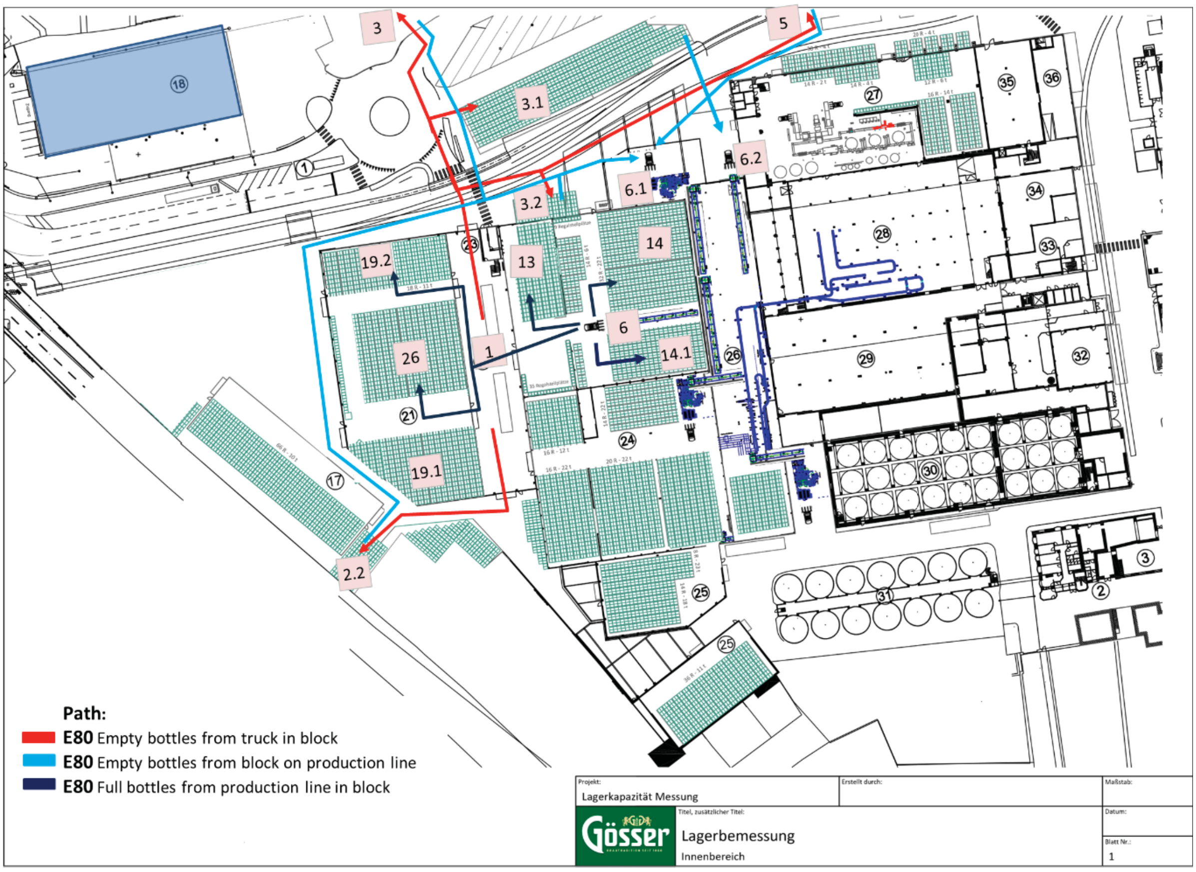
ZIPFER Märzen Dose Tray 24x33cl HU	C	52.67	1.51	Z
GÖSSER Hell MW Kiste 24x33cl EX	C	14.37	0.44	X
GÖSSER NaturRadl.Zitr. MW Kiste 24x33cl	C	10.72	0.33	X
SCHLADMINGER Märzen Fass 30L KF	C	8.42	0.29	X
VILLACHER Märzen Dose Tray 24x50cl	C	8.09	0.31	X
SONNENBRÄU Dose Tray 24x33cl EX	C	21.79	0.85	Y
COCA-COLA Coke MW Kiste 24x33cl	C	11.59	0.47	X
REININGHAUS Pils Fass 30L	C	3.91	0.16	X
SONNENBRÄU Dose Tray 24x50cl IT	C	20.57	0.92	Y
SCHLADMINGER Bio Zwickl Fass 50L KF	C	5.26	0.27	X
GÖSSER Märzen Dose Tray 24x33cl EX	C	15.30	0.79	Y
GÖSSER StiftsZwickl Dunkel Fass 20L	C	4.64	0.26	X
REININGHAUS JG-Pils MW Kiste 24x33cl	C	6.02	0.34	X
RÖMERQUELLE Prickelnd MW Kiste 20x33cl	C	7.92	0.47	X
SODAWASSER Fass 50L	C	8.35	0.59	Y
SOL Dose Tray 24x33cl DE	C	29.40	2.24	Z
SODAWASSER Fass 20L	C	8.06	0.64	Y
GÖSSER Stiftsbräu Fass 30L	C	4.94	0.46	X
SCHLADMINGER Schneew.BIO MW Kiste20x50cl	C	3.58	0.34	X
GÖSSER Spezial MW Kiste 24x33cl	C	2.75	0.27	X
GÖSSER NaturHell 4% Fass 50L	C	10.78	1.15	Z
PUNTIGAMER Panther MW RD Tray 30(6x50cl)	C	2.61	0.29	X
RÖMERQUELLE Prickelnd MW Kiste 12x1L	C	1.35	0.16	X
COCA-COLA Zero MW Kiste 24x33cl	C	3.68	0.44	X
SCHLADMINGER Schneew.BIO Fass 20L KF	C	3.17	0.44	X
GÖSSER NaturGold AF Fass 20L David	C	1.64	0.23	X
Kohlensäure Kurz 10KG	C	4.86	0.86	Y
PUNTIGAMER D.Bierige EW Tray 24x33cl	C	5.12	0.93	Y
GÖSSER NaturRadl.Zitr. MW Kiste 20x50 HB	C	8.94	1.77	Z
GÖSSER NaturGold AF MW RDTray 30(6x50cl)	C	3.07	0.73	Y
COCA-COLA Light MW Kiste 24x33cl	C	2.82	0.67	Y
GÖSSER NaturRad.Zitr.MW RD Try30(6x50cl)	C	3.31	0.96	Y
GÖSSER NaturGold AF MW Kiste 20x50cl HB	C	7.29	2.49	Z
GÖSSER NaturHell 4% Fass 30L	C	2.30	0.94	Y
GÖSSER Märzen MW Kiste 20x50cl HB	C	4.73	2.02	Z
REININGHAUS Märzen MW Kiste 20x50cl	C	1.63	0.73	Y
Kohlensäure 5KG	C	1.05	0.74	Y
PUNTIGAMER Winterkönig Fass 30L	C	1.72	1.48	Z
GÖSSER Hell Fass 30L IT	C	3.78	3.32	Z
GÖSSER Märzen Fass Barbara 30L	C	2.43	2.45	Z
ZIPFER Märzen Dose Tray 24x50cl DE	C	1.32	1.42	Z
WIESELBURGER Gold Dose Tray 24x50cl	C	3.04	3.31	Z
WINTERBOCK Fass 20L	C	1.95	2.25	Z
EDELWEISS Hefetrüb Fass 25L	C	0.82	1.02	Z
BRÜNDLWEG Bier MW Kiste 20x50cl	C	0.67	1.22	Z
PUNTIGAMER Zwickl Fass 30L	C	0.62	1.37	Z
Kohlensäure 20KG	C	0.34	1.16	Z
GÖSSER Helles Fass 30L	C	0.83	3.32	Z
Kohlensäure David 2KG Pfand	C	0.16	0.75	Y
Mischgas 30/70 5,5 M3	C	0.11	0.59	Y
GÖSSER Hell EW Karton 24x33cl EX2	C	0.37	2.24	Z

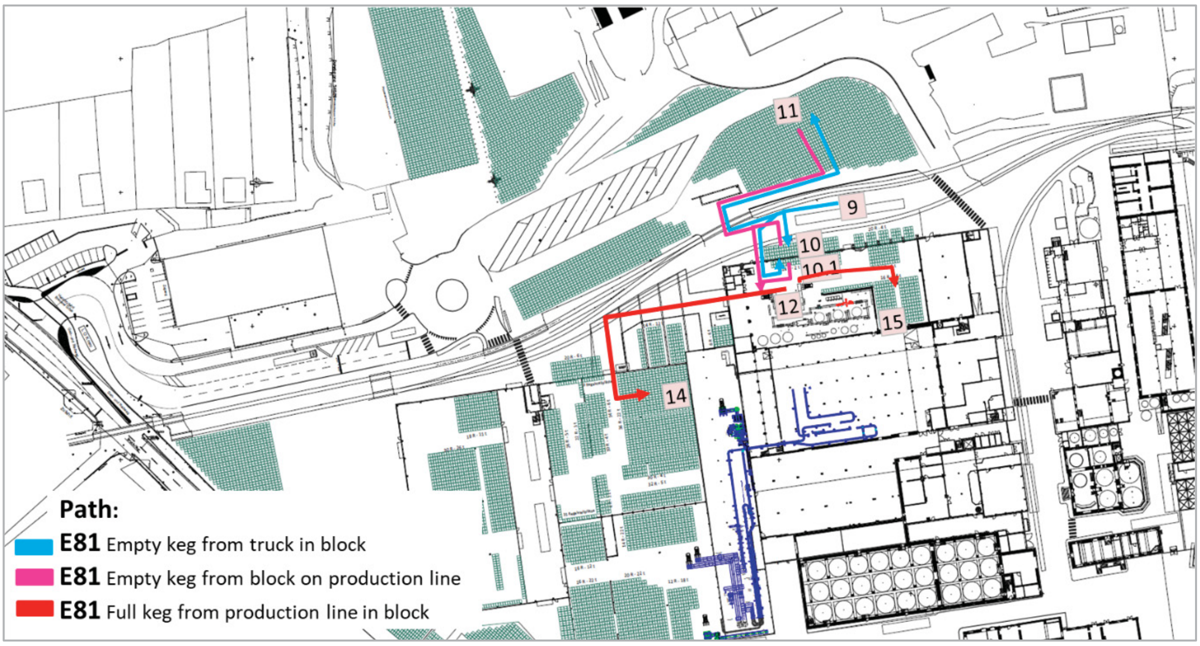
Mischgas 30/70 2 M3	C	0.10	0.83	Y
GÖSSER NaturRadl.Zitr. EW Tray 12x33 IT	C	0.11	1.29	Z
Mischgas 30/70 4 M3	C	0.28	3.32	Z
BARBARA Bier Anstichfass 20L	C	0.02	3.32	Z

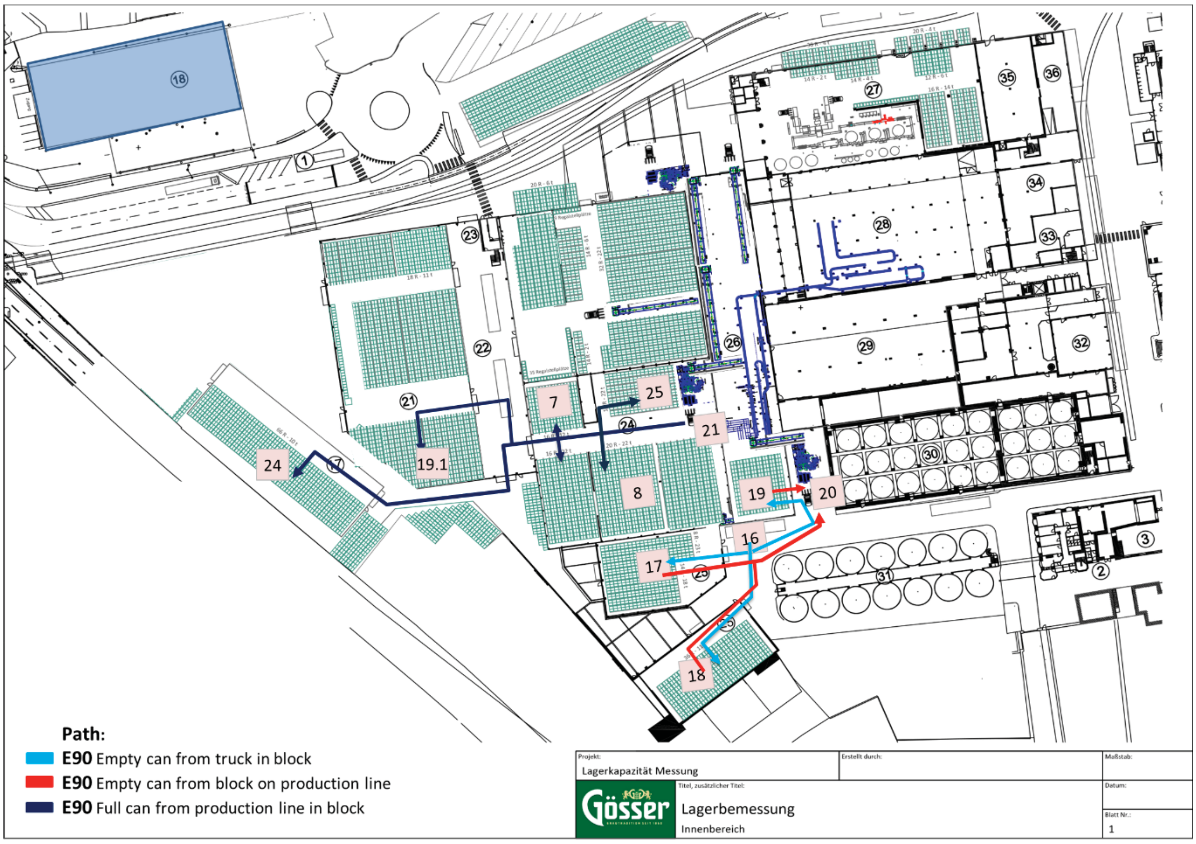
Appendix 5

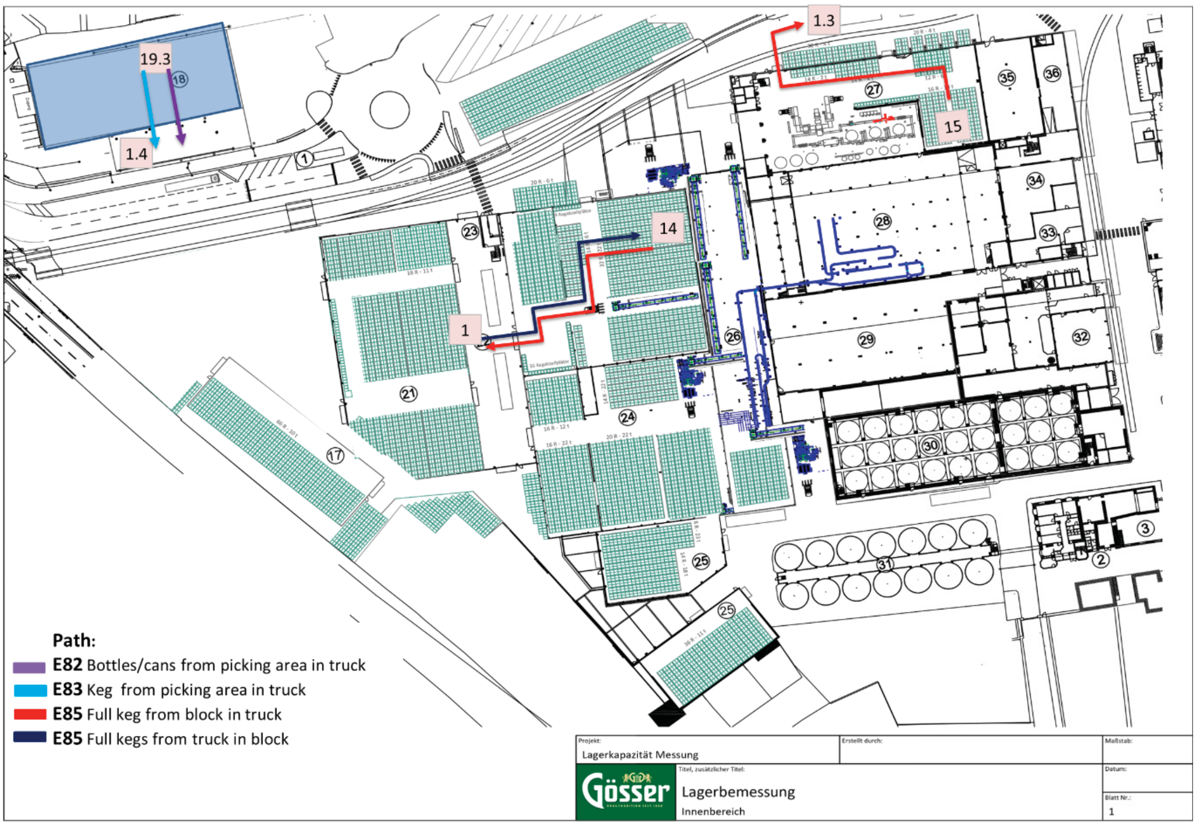
	X	Y	Z
A	GÖSSER Märzen MW Kiste 20x50cl GÖSSER Märzen Dose Tray 24x50cl PUNTIGAMER D.Bierige Dose Tray 24x50cl PUNTIGAMER Panther Fass 50L GÖSSER Märzen Fass 50L GÖSSER NaturRad.Zit.DoseTray24x50 DE neu GÖSSER NaturGold AF MW Kiste 20x50cl	PUNTIGAMER D.Bierige MW Kiste 20x50cl GÖSSER NaturRadl.0,0% MW Kiste24x33cl DE GÖSSER NaturRadl.Zitr. Dose Tray 24x50cl	GÖSSER NaturRadl.Zitr. MW Kiste 20x50 EX
B	PUNTIGAMER D.Bierige Fass 50L GÖSSER Gold Fass 50L SCHLADMINGER Märzen MW Kiste 20x50cl GÖSSER Märzen Fass 30L ZIPFER Urtyp Dose Tray 24x50cl GÖSSER NaturRadler Zitrone Fass 20L PUNTIGAMER Panther Fass 30L ZIPFER Märzen Dose Tray 24x33cl GÖSSER NaturGold AF Dose Tray 24x50cl SCHLADMINGER Märzen Fass 50L KF REININGHAUS Pils Fass 50L GÖSSER Märzen MW Kiste 20x50cl ÖBB DoN GÖSSER Märzen Fass David 20L GÖSSER Spezial Fass 50L SCHLADMINGER Bio Zwickl Fass 20L KF PUNTIGAMER D.Bierige David Fass 20L	DESPERADOS Dose Tray 24x50cl DE GÖSSER NaturRadl.0,0% Dose Tray 24x50 DE GÖSSER NaturRadl. Zitr. MW Kiste 20x50cl GÖSSER NaturRadler Zitrone Fass 50L GÖSSER NaturRadl.Zitr. DoseTray 24x50 EX	SCHWECHATER Bier Dose Tray 24x50cl GÖSSER NaturHell 4% MW Kiste 20x50cl
C	GÖSSER Märzen MW RD Tray 30(6x50cl) PUNTIGAMER Panther MW Kiste 24x33cl GÖSSER Hell Fass 30L EX GÖSSER StiftsZwickl Hell Fass 20L GÖSSER Märzen MW Kiste 24x33cl REININGHAUS Märzen Fass 50L GÖSSER Märzen Dose Tray 24x33cl GÖSSER Gold Fass 30L REININGHAUS Jahrgangspils Fass 20L GÖSSER Hell MW Kiste 24x33cl EX GÖSSER NaturRadl.Zitr. MW Kiste 24x33cl SCHLADMINGER Märzen Fass 30L KF VILLACHER Märzen Dose Tray 24x50cl COCA-COLA Coke MW Kiste 24x33cl REININGHAUS Pils Fass 30L SCHLADMINGER Bio Zwickl Fass 50L KF GÖSSER StiftsZwickl Dunkel Fass 20L REININGHAUS JG-Pils MW Kiste 24x33cl RÖMERQUELLE Prickelnd MW Kiste 20x33cl GÖSSER Stiftsbräu Fass 30L SCHLADMINGER Schneew.BIO MW Kiste 20x50cl GÖSSER Spezial MW Kiste 24x33cl PUNTIGAMER Panther MW RD Tray 30(6x50cl) RÖMERQUELLE Prickelnd MW Kiste 12x1L COCA-COLA Zero MW Kiste 24x33cl SCHLADMINGER Schneew.BIO Fass 20L KF GÖSSER NaturGold AF Fass 20L David	GÖSSER Märzen Dose Tray 24x50cl EX PUNTIGAMER Panther Fass 30L EX GOLDENBRÄU Dose Tray 24x50cl IT ZIPFER Limetten Radler Dose Tray 24x50cl SONNENBRÄU Dose Tray 24x33cl EX SONNENBRÄU Dose Tray 24x50cl IT GÖSSER Märzen Dose Tray 24x33cl EX SODAWASSER Fass 50L SODAWASSER Fass 20L Kohlensäure Kurz 10KG PUNTIGAMER D.Bierige EW Tray 24x33cl GÖSSER NaturGold AF MW RDTray 30(6x50cl) COCA-COLA Light MW Kiste 24x33cl GÖSSER NaturRad.Zitr.MW RD Try30(6x50cl) GÖSSER NaturHell 4% Fass 30L REININGHAUS Märzen MW Kiste 20x50cl Kohlensäure 5KG Kohlensäure David 2KG Pfand Mischgas 30/70 5,5 M3 Mischgas 30/70 2 M3	ZIPFER Märzen Dose Tray 24x33cl HU SOL Dose Tray 24x33cl DE GÖSSER NaturHell 4% Fass 50L GÖSSER NaturRadl.Zitr. MW Kiste 20x50 HB GÖSSER NaturGold AF MW Kiste 20x50cl HB GÖSSER Märzen MW Kiste 20x50cl HB PUNTIGAMER Winterkönig Fass 30L GÖSSER Hell Fass 30L IT GÖSSER Märzen Fass Barbara 30L ZIPFER Märzen Dose Tray 24x50cl DE WIESELBURGER Gold Dose Tray 24x50cl WINTERBOCK Fass 20L EDELWEISS Hefetrüb Fass 25L BRÜNDLWEG Bier MW Kiste 20x50cl PUNTIGAMER Zwickl Fass 30L Kohlensäure 20KG GÖSSER Helles Fass 30L GÖSSER Hell EW Karton 24x33cl EX2 GÖSSER NaturRadl.Zitr. EW Tray 12x33 IT Mischgas 30/70 4 M3 BARBARA Bier Anstichfass 20L

Appendix 6


3
5
3.1
6.2
6.1
3.2
19.2
13
14
6
26
1
14.1
19.1
2.2
Path:
E80 Empty bottles from truck in block
E80 Empty bottles from block on production line
E80 Full bottles from production line in block
Lagerkapazität Messung
Gösser
Lagerbemessung
Innenbereich
1


11
9
10
10.1
12
15
14
Path:
E81 Empty keg from truck in block
E81 Empty keg from block on production line
E81 Full keg from production line in block


24
19.1
7
25
21
8
19
20
16
17
18
Path:
E90 Empty can from truck in block
E90 Empty can from block on production line
E90 Full can from production line in block
Projekt:
Lagerkapazität Messung
Erstellt durch:
Maßstab:
Titel, zusätzlicher Titel:
Datum:
Gösser
Lagerbemessung
Innenbereich
Blatt Nr.:
1


19.3
1.4
1.3
15
14
1
Path:
E82 Bottles/cans from picking area in truck
E83 Keg from picking area in truck
E85 Full keg from block in truck
E85 Full kegs from truck in block
Projekt:
Lagerkapazität Messung
Erstellt durch:
Maßstab:
Titel, zusätzlicher Titel:
Datum:
Gösser
Lagerbemessung
Innenbereich
Blatt Nr.:
1