Investing in repacking

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Summary

Van Kommer BV is a family business that specializes in the storage and transportation of animal feed raw materials for business customers. The stored products are bags of 25 kg and big bags of 1 ton (1000 kg). As an extra service, Kommer offers the possibility to their customers to repack the products into big bags or trucks (25 ton). However, the current repacking process is not efficient. Furthermore, because the demand has grown rapidly over the last couple of years, there is a problem with handling the demand. Kommer can choose between two solutions to solve these problems. Kommer can decide to improve the current repacking process or to invest in a new one by investing in new machinery. In this thesis, we answer the following research question:

"Which repacking process has the lowest costs of the raw materials per ton while having sufficient capacity to handle orders?"

We determine the repacking costs per ton per repacking option with help of the Activity Based Costing method. The results are shown in Table 1. For all three repacking options, the solution with the lowest costs per ton is to invest in a new repacking process.

ABC-analysis repacking costs per ton	from bags to bulk	from bags to big bags	from big bags to bulk
current process	€ 9.46	€ 12.19	€ 6.67
improving current process	€ 6.32	€ 8.58	€ 5.30
investing in a new repacking process	€ 4.00	€ 5.20	€ 3.82

Table 1. Costs per ton (1000 kg) per repacking option at the current repacking process and for the two solutions.

In the current process the biggest part of the repacking costs per ton, around 80%, is for all three repacking options the staff costs. We proposed two ways to decrease these. The first way is to repack more tons in an hour and the second way is to repack the same number of tons with fewer employees in the process. Therefore, we have focused on the decrease of idle time (non-productive time) and the increase of automatization. We decreased waiting time and invested in machinery.

If Kommer decides to invest in a new repacking process, they finance this with a mortgage. The total investment (including interest) is 1,085,593 euro. The Return On Investment (ROI) is 40% per year, which means that in 2.5 year the investment is earned back one time. The return we take into account is the cost savings compared to the current process. When the revenue stays the same and the costs decrease, the profit increases. Due to the fact that the lifespan of the new repacking process is at least 20 years, this investment will be earned back 8 times. After subtracting the initial investment, the total savings on repacking costs would be 7 times the investment over a time horizon of 20 year. This results in an increase in profit of more than 7.5 million euro. Because there is a lot of expensive overtime saved, we can generate this profit in 20 years. Money earned in the future is worth less than money earned today, due to its potential earning capacity. Therefore, we calculate the Net Present Value (NPV) to determine the current worth of this investment by discounting future cashflows back to the present. We compute the NPV with a hurdle rate (discount rate) of 10%. We have an NPV of 2.7 million euro. Because the NPV is positive, the hurdle rate is met, and the investment is worth taking.

In the year that the current repacking process started operating, the required capacity was 40 tons per day (11,000 tons per year). In the future we expect a required capacity of 285 tons per day (74,000 tons per year). This means the required capacity increases with a factor 7. This has the result that the current repacking process does not have the ability anymore to handle the demand. The current repacking process has a capacity of 125 tons on a working day of 10 hours. This is four times less than the new repacking process, which has a capacity of 500 tons. This repacking process consists of two sub-processes which can each repack 250 tons per day. The first sub-process repacks bags and the other repacks big bags. With this extra capacity each sub-process has enough capacity to repack orders with a buffer capacity for peak demand.

Contents

1. Introduction

We start in Section 1.1 with the background information of the company in which this assignment has taken place. In Section 1.2 we motivate why the company provides this assignment. In Section 1.3 we describe the process in order to understand the process. In Section 1.4 we describe the context of the problem in order to understand the causes. In Section 1.5 we select the core problem we need to deal with in order to solve our action problems. In Section 1.6 we design a problem-solving approach for our core problem. In Section 1.7 we describe the limitations regarding our research. In Section 1.8 we describe the deliverables of our research.

1.1 Kommer

The company in which this bachelor graduation assignment has been executed, Kommer, is located in Barneveld. Kommer is a family business, specialised in storage and transportation of raw materials for the animal feed industry. The customers of Kommer are dealers who buy their raw materials in China and sell their products in Western Europe. Kommer stores the products until they are sold by the dealers. The business was established in 1956 in Nijkerkerveen. In 2014 the company decided, partly because of huge growth, to change its location to Barneveld. In the years that Kommer was operating in Barneveld, the company again experienced a huge growth. Kommer has various holdings within the company: Warehousing & Repacking, Feed Logistics, Customs & Forwarding and Expedition. The warehouse has possibilities for storage and Value Added Logistics (VAL) are offered, such as palletizing, unloading and loading containers, labelling products and repacking services. The other departments are focused on transportation in Western Europe and on the regulations that come with transportation to other countries.

The company has three repacking processes to repack bags and big bags filled with raw materials. At the first one, milk powder is repacked. The second one can be used for every type of product the customer wants to repack. The third one is used for three types of animal feed.

In the warehouse, customers can store their products before they sell it to their customers. The common factor is that the products are stored in bags (25 kg) or big bags (1000 kg). For the transport to the indirect customers, the direct customers can use the services of Feed Logistics or hire another transportation firm. The Customs & Forwarding department handles the customs formalities. In most cases, Kommer handles the transport in Western Europe. For transport further away, it is cheaper for the customers to hire another transportation firm.

1.2 Motivation

We focus on a repacking process in the Warehouse. At the third process the capacity is too low to handle the orders and this process has several functional problems with as a result high repacking costs per ton (1000 kg) and a capacity shortage. Kommer has the possibility of investing in a new repacking machine to replace the old one. However, Kommer also has the possibility to improve the current process. In this assignment we investigate which of the two options has the best results. What we want as a result is a repacking process with lower repacking costs per ton and a capacity that is high enough to fulfil expected future orders with a buffer capacity for peak demand.

1.3 Process description

To understand the process, it is important to know the reason why people are asking for repacking. Most customers are dealers of animal feed who are paying Kommer to store their products in the warehouse until they have sold it to the end customers. However, most of the customers of the dealers ask the product in bulk (25 ton). This size is perfect for transportation because 25 ton is equal to one truckload. Therefore, Kommer offers repacking services.

The repacking process has two inputs at the start of the process. The first input is used to cut bags and the second input is used to cut big bags. Further we investigate that there are two outputs at the end of the process. The first output is used to fill big bags and the second output is used to fill trucks. This means that there are 2x2=4 repacking services available. The first option is to repack bags to big bags. The second option is to repack bags to trucks. The third option is to repack big bags to big bags and the fourth option is to repack big bags to trucks. Kommer also offers the possibility to use a breaker to crumble the product at the beginning of the repacking process. However, in practice the breaker is not used very often. There is also no demand for the third option, because it does not make sense to repack big bags to big bags. Therefore, we focus us on the option to repack bags to big bags, the option to repack bags to trucks and on the option to repack big bags to trucks.

We want to calculate the repacking costs per ton at the current process for the repacking options we are going to investigate. Further we want to determine the capacity the current process can repack. We also want to investigate where the problems occur in the process. To make research doable we split the process into parts. This means we can focus on one part of the process at a time instead of the whole process at once. We need a method which helps us do that. Therefore, we create a Value Stream Map of the repacking process with use of the Value Stream Mapping (VSM) method of the lean methodology. The VSM method identifies which components there are in a process and how components are connected with each other (Kooijman, 2021). In that way, we can identify the physical stream of the raw materials in the process. The Value Stream Map is shown in Figure 1. We explain the VSM method in more detail in Chapter 2.

Firstly, we discuss the bag cutting part of the VSM. The forklift driver places the bags of an order (placed on pallets) at the front of the repacking process. When the order is complete, the forklift driver places a pallet on the lift table. A worker puts the bags on the assembly line. Then the bags move through the bag cutter. Another worker takes the bags out of the bag cutter. The product inside the bags falls into a funnel with storage option inside. A rotating component which has the same shape of a screw called a transport screw is placed to transport the product from the storage to the bucket elevator. The bucket elevator transports the product through a sieve to a transport screw in the air.

Secondly, we discuss the big bag cutting part of the VSM. The big bags are emptied above the dumping cabinet. A forklift driver places a big bag above the dumping cabinet and the big bag is cut at the bottom by an employee, so that the raw materials fall into the dumping cabinet. The transport screw transports the product to the bucket elevator. From the bucket elevator the repacking process is the same as for bags. The bucket elevator transports the product through a sieve to a transport screw in the air.

The two outputs are the two filling stations that are connected with this transport screw. The first filling station is to fill trucks. A truck drives in, the workers connect the truck to the filling station and the filling process starts. When the truck is full the workers disconnect the truck, the truck drives away and the process starts again. The second filling station is to fill big bags. A worker places manually a big bag under the filling station. Then the big bag is filled and removed by the forklift driver. With buttons the workers can decide whether they want to fill a truck or big bags.

Emptied bags and emptied big bags are put in a bag press. The bag press is emptied by the forklift truck. The waste collected by the sieve falls into a bucket that is emptied by an employee. The extractors in the process decrease the amount of dust with the effect that the working environment is much healthier.

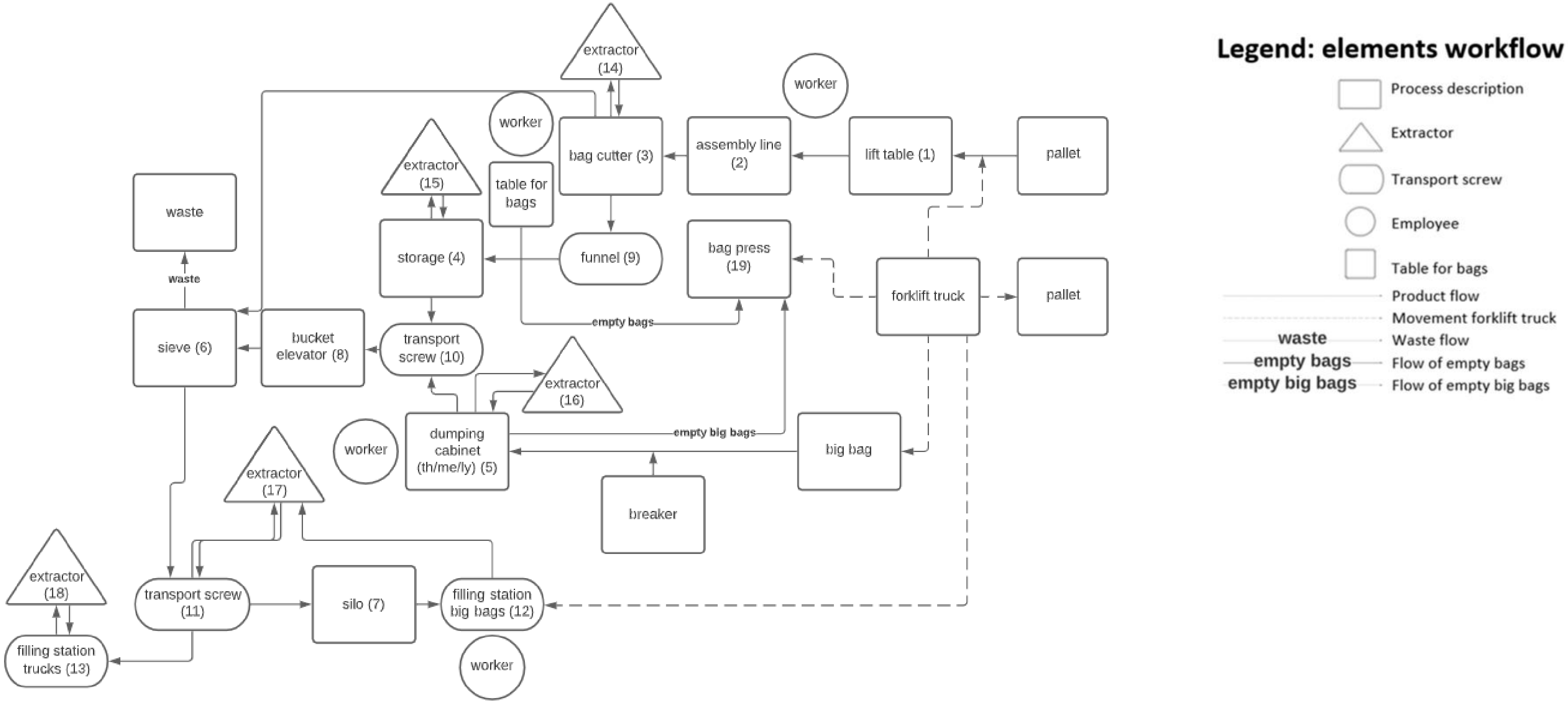


Figure 1. Value Stream Mapping of the raw materials of the current repacking process.

1.4 Context of the problem

Through interviews (see Appendix B) with the employees and observation when the repacking process is operating we are able to find the problems that occur at the repacking process. First of all, the repacking process involves a lot of manual labour causing high repacking costs per ton. Further we observed a lot of idle time, such as downtime of components in the process and waiting time on (dis)connecting trucks in order to start or finish an order of a customer. Idle time is time that an employee or machine is unproductive (Kenton, 2020b). When the employee cannot work under worktime because of idle time, the employee still gets paid. Because there are fewer tons of raw materials repacked per hour, this problem causes high repacking costs per ton. The available capacity is also reduced because of this problem. Due to huge growth in the past years, the company now has a shortage of available capacity in the current repacking process. Finally, there are problems at the current repacking process with the safety of the employees. For instance, the employee at the end of the bag cutter has to reach into the machine to grab the empty bag with the risk of injuries.

We explain the most common problems in terms of the "triple constraint" (Cheap-Good-Fast). In Figure 2 the Triple Constraint is shown (Haughey, 2011). The meaning of the triple constraint is that the repacking orders are repacked under certain constraints. In our case the constraints are the following:

- The repacking costs per ton are not too high. (Cheap)
- The repacking orders are finished under safe working conditions. (Good)
- There is enough capacity in the current repacking process to repack orders of the customers. (Fast)

Figure 2. The Triple Constraint (Haughey, 2011).

Based on the Triple Constraint, we identify two action problems. An action problem is a discrepancy between the norm and the reality, as perceived by the problem owner (Heerkens, 2017). This means that it is a problem that we can see in practice, without directly knowing why it exists. The two action problems are the high repacking costs per ton and the too low capacity of the current repacking process. Kommer already solved the most important safety issues in the past, therefore we will not focus on this problem.

It is unlikely that both action problems are solved at a maximum. When we focus more on one goal, another goal suffers from this. We need to make a trade-off between capacity and costs. For instance, when we want unlimited capacity, the process needs to be able to repack unlimited tons. This means that a lot of money needs to be spent into a new process, which means the repacking costs per ton increase. On the other hand, when the process is designed without a lot of buffer capacity, the repacking costs per ton will be lower. However, then the customers have to wait longer on busy days when peak demand occurs. Therefore, we have to make a trade-off between solving these action problems to what is needed and can be reached.

In order to measure our action problems, we select a Key Performance Indicator (KPI) for each action problem. A KPI is a measurable value that demonstrates how effectively a company is achieving key business objectives (Wille, 2021). KPIs are used by individuals and organizations to evaluate their success at reaching critical targets. The two KPIs that come from the two action problems are costs and capacity. With the first KPI we measure the decrease in costs per ton measured in euros. Regarding the two solutions this means we take the investment and the repacking costs into account. What we want to achieve is the minimal expected repacking costs per ton. Whether Kommer decides to invest in a new repacking machine or wants to improve the current repacking machine, money will be invested. Because Kommer wants a certain return on its investment, we have to take a hurdle rate into account. A hurdle rate is the minimum rate of return required on a project or investment (Kenton, 2021). With the second KPI we measure whether there is enough capacity to fulfil the expected orders. Because demand has some fluctuation, there are days there is more demand than on average and vice versa. The capacity is measured in tons. What we want to achieve is enough available capacity to serve the expected orders and to have a buffer for peak demand.

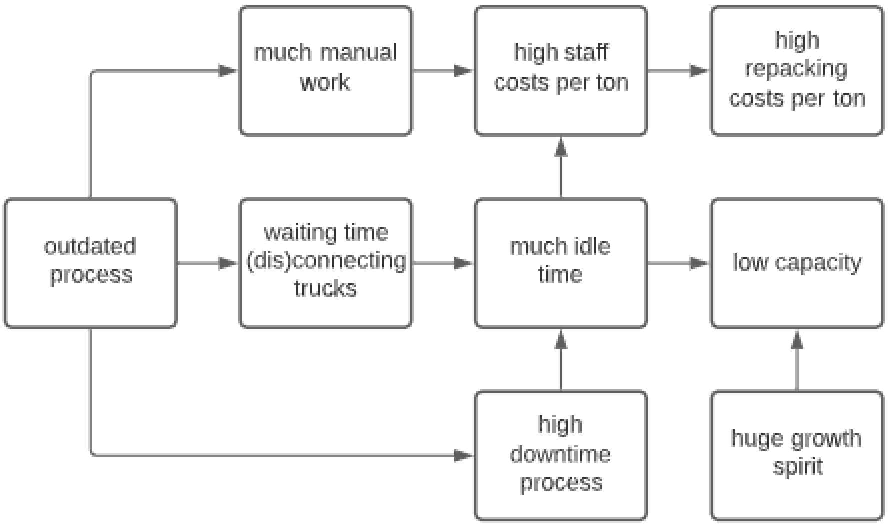


Figure 3. Problem cluster current repacking process.

With help of the problem cluster in Figure 3 we identify the causes of the action problems. The problem cluster shows the action problems and their relations we have identified as such. We only record a problem in the cluster if it has a connection with the two action problems we are going to investigate. In our case, investigation means the data gathering and the formulation of solutions.

The first action problem is the high repacking costs per ton. This problem occurs because of high staff costs per ton. This consists of a lot of idle time that occurs at the process and of the amount of manual work that is involved in the process. If the process is not operating for a certain period, fewer tons are repacked per hour. Because staff is paid per hour, the costs per ton increase. The idle time is caused by downtime of the process and by the waiting time of (dis)connecting the trucks. The downtime occurs because the process is outdated, and parts of the machinery get stuck. If the process has a defect, some workers try to make the machinery working again while the rest are waiting. The waiting time occurs because the machinery can only operate if there is a big bag or truck connected to one of the filling stations. It takes more than half an hour to connect and disconnect a truck to the filling station of the machine. In that time, it is not possible to repack products and workers are waiting. When we put multiple silo’s (storage units) at the end of the process, we do not have to wait. When one silo is full, the workers start filling another silo. In the meantime, the truckdriver empties the first silo. Before the second silo is full, the first one is already empty, and the workers start filling the first silo again.

The second action problem is the lack of capacity. This is partly due to the idle time as explained above and partly because of a huge growth in the past years. When a lot of idle time occurs, there is less time left for the repacking itself. The repacking process is further not designed for the current capacity. The reason for this is that Kommer did not expect such a huge growth when the current process was designed.

1.5 The core problem

As shown in Figure 3, the two action problems are caused by the core problem, namely an outdated process. Because we know the core problem, we know which problem is the actual cause of the action problems. A core problem does not have a cause itself. The first action problem, high repacking costs per ton, is caused by high staff costs per ton. High staff costs per ton occurs when there is a lot of manual work needed to repack the same quantity or when there are fewer products repacked per hour because of much idle time. The idle time is caused by downtime and waiting time to (dis)connect trucks. The downtime is caused by components of the process that get stuck. The waiting time to (dis)connect trucks is caused because the process is designed in a way that it is only possible to start repacking bags or big bags to a truck load (bulk) after connecting the truck. Because the current process is not as automated as possible, the amount of manual work in the repacking process is huge. This problem occurs because the repacking process is outdated.

"Core problem: The repacking process is outdated"

The fact that the process is outdated means that the process has components that need to be replaced because more automatizations can be achieved by restructuring the process. The problem that the process is outdated has no direct cause itself. A criterion for selecting the core problem is that it can be influenced and measured (Heerkens, 2017). In other words, we need to be able to solve the core problem. It is possible to influence this core problem. We measure the outcome of the process in repacking costs per ton. This measurement is chosen because the customer also pays per ton repacked.

1.6 Problem-solving approach

In order to solve our core problem, we design our research question. With the research question we formulate the action problems we want to identify. The two action problems that are defined from the problem cluster are the lack of capacity and the high repacking costs per ton. Based on our action problems, we define the following research question:

"Which repacking process has the lowest costs of the raw materials per ton while having sufficient capacity to handle orders?"

In order to answer our research question, we need to solve our core problem. Therefore, we create the following sub questions. The sub questions are designed to split the core problem in small problems. This makes it easier to answer the research question. The sub questions are based on the problems in the problem cluster in Figure 3 that are directly related to the core problem:

1. How to decrease the amount of manual work needed for repacking?
2. How to decrease the waiting time to (dis)connect trucks?
3. How to decrease the amount of downtime?
4. How to increase the capacity (in tons) to a sufficient level with buffer capacity for unexpected orders?

We need to follow a problem-solving approach in order to solve the core problem accurately. We use the Managerial Problem Solving Method (MPSM), (Heerkens, 2017) to design a problem solving approach. The MPSM has seven phases.

1. **Defining the problem. (Chapter 1)**
    - Map the process with a Value Stream Map.
    - Make a problem cluster.
    - Find the action problems.
    - Find the core problem.
    - Design a research question.
    - Describe the limitations.
    - Describe the intended deliverables.
2. **Formulating the approach. (Chapter 1)**
    - Draft a problem-solving approach.
    - Indicate which steps have to be taken to find the solution.
3. **Analysing the problem. (Chapter 2 and 3)**
    - Investigate which methods help to solve our sub questions of the core problem by reviewing literature. (Chapter 2)
    - Calculate the available capacity at the current repacking process and the required capacity needed in the future. (Chapter 2 and 3)
    - Investigate which costs occur at the current repacking process. (Chapter 3)
4. **Formulating (alternative) solutions. (Chapter 4)**
    - Formulate the two solutions. Provide for every solution:
        - An overview of the Value Stream Map of the solution with a description.
        - The repacking costs per ton per repacking option.
5. **Choosing a solution. (Chapter 4)**
    - Choose which solution is the most attractive, based on the criteria.
6. **Implementing the solution. (Chapter 5)**
    - Indicate which steps have to be taken to implement the solution.
    - Identify key persons who are responsible for a task.
7. **Evaluating the solution. (Chapter 5)**
    - Describe how the evaluation actually need to go.

1.7 Limitations

There are two limitations connected to the research. The first one is the time, which causes a limitation to the sixth and seventh step of the MPSM methodology. We conduct this research in 20 weeks. The first 10 weeks are used for the preparation of the research. This means we can do the actual research in 10 weeks. This means we are not able to implement and evaluate the solution. Therefore, we give the company recommendations about how to implement and evaluate the solution.

The second limitation is the access to information. In order to formulate solutions, we need to analyse the costs that occur in the current process. Therefore, we need information about the components, for instance the lifetime and the new price of the components. However, information about the components of the repacking process we are investigating has been lost because the company that installed the components of the repacking process does not exist anymore. Kommer has not stored this information either. This means we need to estimate this information. Therefore, we use offers of new machinery and bills from the past to identify costs of components. Furthermore, we ask the service engineer who is maintaining the repacking process to give a proper estimation about some types of costs. We also carry out interviews by phone with engineering companies for specific information about components. Because information of the repacking capacity of components is lost, we have measured in practice the repacking capacity in tons per hour to identify the repacking capacity of the components. We also want to know the required capacity in the future. Therefore, we use data of the past to estimate how much demand there will be in the future.

1.8 Deliverables

At the end of this research, we have three deliverables:

- Cost analysis of the two possible solutions.
- Advice of which solution will decrease the repacking costs per ton the most.
- Recommendations about how to implement and evaluate the solution.

In order to solve the current problems at the repacking process Kommer can improve the current repacking process or they can invest in a new repacking process. In order to compare the two possible solutions, we need to compare the costs per ton of repacking the raw materials. Therefore, we need to design a cost analysis of the repacking costs per ton.

We make a cost analysis in which we distinguish between the three different repacking options. Because the current repacking process consists of multiple components, Kommer can decide to use in the future only a part of the current repacking process for one or two repacking options and invest in a new but smaller repacking process. If the best solution differs significantly between repacking options, Kommer can choose this combined solution. We will only design this combined solution if there is not a unanimous winning solution. So, if all three repacking options prefer the same solution, we will not design and discuss the option to choose a combined solution. However, for simplicity, Kommer prefers to have only one repacking process. Therefore, this combined solution will only be chosen if there are extreme differences between the repacking costs per ton per repacking option for the two solutions. We distinguish the costs between the three most used repacking options:

- From bags to bulk.
- From bags to big bags.
- From big bags to bulk.

After designing the two cost analyses we investigate which solution results in the lowest repacking costs per ton. After selecting the best solution, we provide recommendations about how to implement and evaluate the solution. The reason for providing these recommendations is because we are not able to implement and evaluate the solution due to the time limitation of the research.

2. Literature review
In this chapter we discuss the literature we use in order to answer our research question and explaining how this literature is related to each other. Firstly, we explain how the literature is build up in Section 2.1. Then we explain the different literature we use in the other sections. The literature parts are used to answer one of the sub questions directly related to the core problem in order to answer our research question.

2.1 Literature framework
In this section we select some techniques in order to determine which of the two solutions we want to choose. We use the Value Stream Mapping (VSM) method to solve the problems in the current process in a structured way. The VSM method identifies the components of a process and how these are connected (Kooijman, 2021). In order to support the VSM method, we use a bottleneck analysis to determine which part of the current process is slowest. The bottleneck analysis gives us information about how many tons per hour a process is able to repack if there is no idle time. We can compare the outcome of the bottleneck analysis with the number of tons there are repacked in practice. Then we can decide if we want to increase the repacking capacity in tons per hour of the bottleneck or decrease the amount of idle time that occurs in the process.

We have identified two action problems. The first is the capacity shortage at the current repacking process. We want to be sure that the solution has enough capacity to fulfil orders in time. Therefore, we calculate the expected required capacity on the long term. We also need to calculate whether this solution has enough buffer capacity to serve also by peak demand. To describe the expected demand, we can use the empirical distribution. The empirical distribution can be used to describe a sample of observations of a given variable (Taboga, 2017). The second action problem is the high repacking costs per ton (1000 kg). In order to choose a solution, we need to compute the repacking costs per ton of the current repacking process and of the two solutions. Therefore, we will select a method to calculate the repacking costs per ton. We want to assign the different costs to the different repacking options. To do this we use also the VSM method to break the process into pieces and calculate costs first per piece. First, we identify the different costs per component. Then we determine which components are used to repack one ton for a certain repacking option. Lastly, we sum the costs per component up and we have the repacking costs per ton per repacking option.

We want to evaluate the best solution to determine the return. The return we take into account is the decrease in costs compared to the current process. An increase in profit can either be made by selling the repacking service for more money or decreasing the cost price of this service. The money we save on repacking costs will turn into profit if the selling price of the repacking service stays the same. Furthermore we want to evaluate the time value of this return. Money that we expect to get over a couple of years is less worth than money that we get today due to the potential earning capacity of money.

We want to decrease the waiting time of (dis)connecting trucks in order to decrease the idle time. When we use silos (storage units) we do not have to wait until a truck is (dis)connected from the filling station. With the steady state distribution, we determine whether we can use the silos in a particular solution. The steady state distribution is the distribution that states that the throughput of the output needs to be more than the throughput of the input. In that case, the system can handle the flow (Winston, 2004). Throughput is the number of units that can be produced by a production process within a certain period of time (Bragg, 2021). Every transport screw further in the process needs to go a little faster to prevent accumulation. The farther the silos are placed, the more transport screws there are needed. If the silos are placed too far from the process, it can be the case that the silos cannot be used. We need to determine if we can use the silos for a particular solution.

2.2 Lean management

The current process has to deal with some problems. There is a lot of manual work involved in the process, the process has a high downtime because of component failure and the employees have to wait when trucks are (dis)connected to the filling station. The process consists of a lot of components and therefore the process can be hard to analyse. We want to solve these problems in a structured way, in which we can analyse costs and capacity. Therefore, we need a method that helps us to analyse the current process and the processes of the two solutions. A good way to identify wasteful activities is with lean management (Kanbanize, 2020). Lean management focuses on decreasing waste in the process (Rodriguez, 2020). We can use lean management to reduce the inefficiency of the process. This increases the capacity and reduces the repacking costs per ton. There are many lean methods, which means that for almost every problem there is a method available to help solve the problem. Therefore, we use lean management in order to reduce the inefficiency of the current repacking process. Within lean management there are at least 35 lean methods (Kooijman, 2021). We only use the Value Stream Mapping (VSM) method and the bottleneck analysis.

VSM

According to the lean methodology, the Value Stream Mapping (VSM) method can help us to solve the problems in the current process in a structured way. The VSM method identifies which components there are in a process and how components are connected (Kooijman, 2021). In that way, we are able to identify the physical stream of the raw materials in the process. The VSM is used to map the flow of materials and information through a process (Hoffmann, 2018). The VSM distinguishes between value added and non-value added streams in the process. The VSM has two main goals (Kooijman, 2021). The first goal is to identify the waste that occurs. According to the lean methodology, there are 7 types of waste: transportation, inventory, motion, waiting, overproduction, over-processing and defects (Kanbanize, 2020). We have identified two of the 7 wastes in our process: motion and waiting. The waste in motion includes any wasted time and effort related to unnecessary movements by people. This waste occurs because there is manual work involved in the process that can be avoided. The waste in waiting includes all the time spent by employees waiting for the next process step to occur. This waste occurs because of the idle time that occurs in the process. The employees have to wait when trucks are (dis)connected to the filling station and when the process cannot operate because of component failure. Because a Value Stream Map gives a detailed overview of the process, it is easier to determine which element in a process is responsible for a certain problem. After finding out where the waste occurs in the process, we want to solve the problems. The second goal is to make the production process more efficient. We want a more efficient process with as a result lower repacking costs per ton and sufficient capacity. It is easier to determine the repacking costs of a process if we can determine costs first per component instead of the whole process at once. Therefore, we use the VSM method.

Bottleneck analysis

One of the two results we want is to have enough repacking capacity to handle orders. Therefore, in order to support the VSM method, we use a bottleneck analysis to determine which part of the current production process is the slowest. A bottleneck is a point of congestion in a production system that occurs when workloads arrive too quickly for the production process to handle (Barone, 2020). A process is as fast as its slowest component (Kooijman, 2021). If a component before the bottleneck processes more tons than the bottleneck can process, then there is a buffer created before the bottleneck. Components farther in the process than the bottleneck are depending on the throughput of the bottleneck, so they cannot process more than the bottleneck. This means every component in the process is processing as many tons as the bottleneck can handle, which means the input is as much as the bottleneck can process. This means a process is as fast as his slowest component.

At the start of repacking an order a process has to start up; which means, before a filling station (which is the last component) can start filling a truck or a big bag, the raw materials have to travel to this component. Because there are yet no raw materials in the process, the raw materials have to travel to the end of the process from the starting point. It can take some time before raw materials have travelled from the start of a process to the end. Once every component starts working, each component is delivering and receiving local end product. In our case we consider a continuous process. A continuous process is a process in which the product comes out without interruption and not in batches (CED, 2021). Continuous processes usually require a series of discrete unit operations, with the output of one step being the input for the next step. This means components are getting and giving on a constant level material to process further. In our current process, the time between the last component (the filling station) starts filling a truck or big bag and the first component gets raw materials, is around 1 minute. This means the big bag or truck start getting filled 1 minute after the process starts processing the raw materials of an order. Measurement is done by measuring with a stopwatch the time until the first raw materials are seen at the end of the last component. In comparison to the duration of a whole repacking order, this time is almost nothing. Therefore, we neglect the start up period of a repacking order.

Because a process is as fast as its slowest component, we can determine the throughput of the process by finding out which component is the slowest (Kooijman, 2021). Throughput is the number of units that can be produced by a production process within a certain period of time (Bragg, 2021). For every component in the process, we determine the throughput. Within a bottleneck analysis we compare the throughput of every component in the process. The component with the lowest throughput is the bottleneck of the process. In this bottleneck analysis we exclude components that do not play a role in determining the throughput of the process. For example, the extractors in the current process are not influencing the throughput. When the throughput of the bottleneck is significantly lower than the other components, we can decide to improve the throughput of the bottleneck to increase the repacking capacity per hour. When the throughput of the bottleneck is almost the same as the other components, there is a chance it does not make sense to increase the throughput of the bottleneck. After all, we must then also increase the throughput of the components that are almost as slow as the bottleneck to make a real difference. It can also be the case that the throughput of the bottleneck differs significantly from the throughput of the process measured in practice because of the idle time that occurs in the process. This means we can also decide to solve the problems that are responsible for the idle time instead of increasing the throughput of the bottleneck.

Conclusion

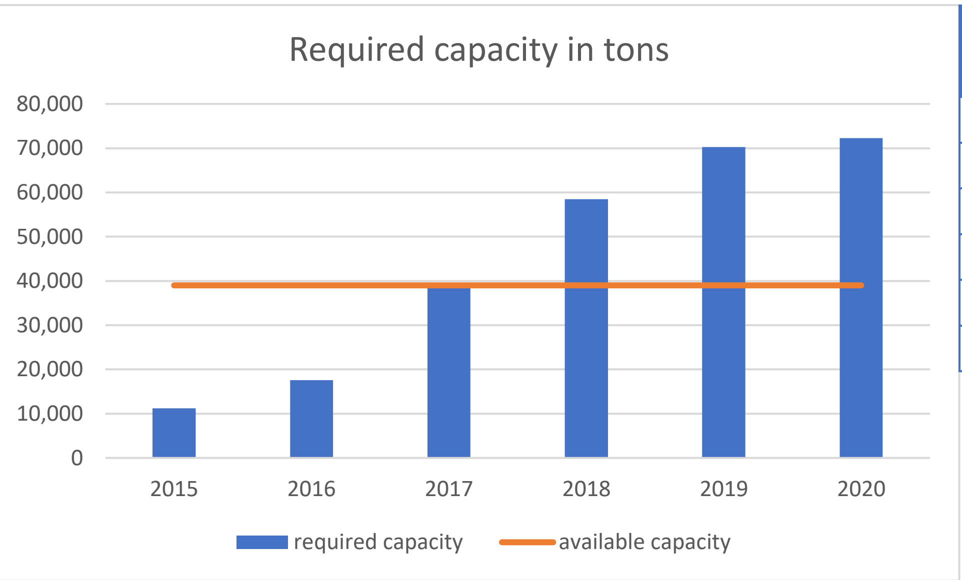
In order to solve the problems that occur in the current process in a structured way, we use the Value Stream Mapping (VSM) method. The VSM method identifies which components there are in a process and how components are connected with each other. Because we can now distinguish one component from another, we can find out where problems occur in the process. We also want to be able to calculate the repacking costs per ton of a process. It is easier to calculate costs first per component and then add them up than calculate costs directly without intermediate steps. With a bottleneck analysis, we are able to determine the throughput of the slowest component. Because a process is as fast as his slowest component, we can determine the throughput of the process by finding out which component is the slowest. When we know the bottleneck, we can consider whether we want to increase the capacity of this bottleneck or solve other problems in the current process in order to decrease idle time.

2.3 Distribution of required capacity

One of the action problems is the capacity shortage at the current repacking process. If Kommer chooses a solution, we need to be sure that the solution has enough capacity to fulfil orders in time. Therefore, we calculate the expected required capacity on the long term. We also need to calculate if the buffer capacity of a solution is high enough to serve also during peak demand. We can calculate this manually or use a formula of a distribution. If the data is distributed according to a known distribution, we are allowed to use the formula connected to this distribution type. Otherwise, we need to calculate this manually. Therefore, we also determine with the use of a statistical test if we can use a formula of a distribution.

Required capacity on the long term

In order to identify the required capacity on the long term, we calculate the required capacity in tons over a 10-year period. Figure 4 shows the capacity needed in the past 6 years. The required capacity of the past is gathered with the use of an Excel-document with information of the customer orders of Kommer. From 2017 on, we can see that the growth is flattening. According to the director of Kommer the company has gained their market share in the Netherlands, and he is not expecting a huge growth in the future. Therefore, we can expect that the growth is flattening. The orange line shows the available capacity. The available capacity of the current repacking process is 150 ton in a working day of 12 hours. The company operates 5 days in a week and 52 weeks a year. Therefore, the available capacity in the current process is 39,000 ton a year.



year	required capacity
2015	**11,210**
2016	**17,609**
2017	**39,430**
2018	**58,468**
2019	**70,257**
2020	**72,317**

Figure 4. Required capacity in tons of the past.

In Figure 4 the required capacities in tons for the past six years is shown in a bar chart. The bars show the cumulative required capacity, which means the total required capacity in tons per year is shown. We expect the capacity on the long term around 74.000 ton a year. For calculating the future growth, we calculate how the growth rate dropped since 2017, because this was the first year that the growth was flattening. As can be read in Figure 4, the growth from 2016 to 2017 was around 22,000 tons. The growth from 2019 to 2020 is around 2,000 tons. This means that in 2020 the growth is 9% of the growth in 2017 (2,000/22,000=0.09). The length of the measured period is 3 years (2017-2020). 3 years is not a lot, but we can use it to estimate what the required capacity will be on the long term. Every year the growth rate decreases on average to 45% of the growth the year before as shown in Equation 1.

$$decrease\ in\ growth\ rate = 0.09^{\frac{1}{3}} = 0.45$$

Equation 1. Decrease in growth rate required capacity.

In 10 years, a capacity of 74.000 ton is required for a year as shown in Equation 2. The sum of the decrease in growth rate is 0.81 as shown in Equation 3. This means the required capacity grows to 285 tons per day in the next 10 years as shown in Equation 4. Equation 2 can be calculated with help of Equations 3 and 4. The timeline of the increase in required capacity can be found in Figure 5.

$$required\ capacity\ 2020 + increase\ capacity\ 2020\ regarding\ 2019 * \\ sum\ of\ growth\ rate\ over\ 10\ year = 72{,}317 + (72{,}317 - 70{,}257) * 0.81 = 73{,}989 \approx 74{,}000$$

Equation 2. Expected capacity 10 year with as base year 2020.

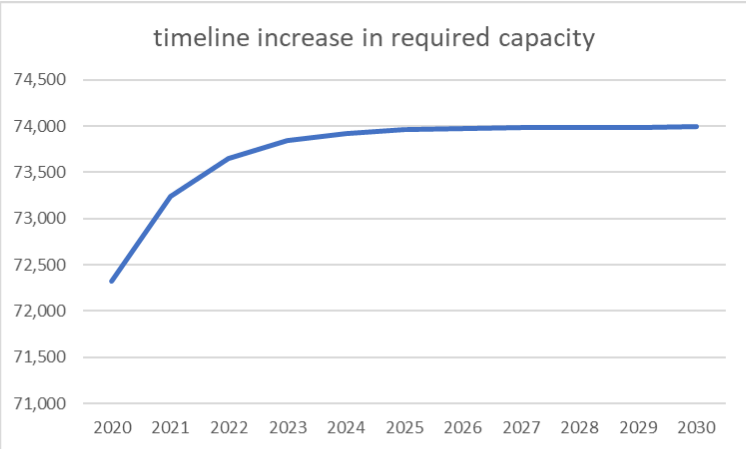


Figure 5. Timeline of the increase in required capacity from 2020 to 2030.

The growth rate is calculated by calculating the growth per year and then summing the growth of every year up. According to Equation 3, the sum of the total growth in the next 10 years is equal to 81% of the growth of this year.

$$\sum_{t=1}^{10} (1 + 0.45^t) - 1 = 0.81$$

Equation 3. Sum of decrease in growth rates over a period of 10 year.

The required capacity in tons per day can be calculated by dividing the required capacity in tons per year by the number of working days in a year.

$$\frac{required\ capacity\ in\ tons\ per\ year}{number\ of\ working\ days\ in\ a\ year} = \frac{74{,}000}{260} = 285$$

Equation 4. Required capacity in tons per day within 10 years.

Statistical test on normal distribution

After having identified the expected capacity, we need to determine how we are going to calculate if the buffer capacity of a solution is high enough to repack orders when peak demand occurs. We use the expected capacity per day over 1 year to have enough data points. We can calculate this manually or use a formula of a distribution. If we calculate this manually, we can use the empirical distribution. The empirical distribution can be used to describe a sample of observations of a given variable (Taboga, 2017). The data for an empirical distribution are gathered in practice. In our case, it is the number of repacking orders that are ordered in a day. We will not use the orders directly in our calculation, but the sum of the orders over a certain time period. In our calculations we use data measured on a daily basis, which means that we have a time period of one day. For example, when 10 orders arrive randomly on day 1 with their own demand and 8 orders arrive on day 2, we have 18 data points on 18 different points in time with 18 different demands which we must work with. We sum the demand of the orders up over a period of one day. This means we have 2 data points left and every data point has also the length of exactly one period (in our case 1 day). Solid time points are easier to work with than random time points. Because every period has the same length, we do not have to analyse orders that came in randomly over time.

If the daily demand is distributed according to a known distribution, we are allowed to use the formula connected to this distribution type that calculated if there is enough buffer capacity. When the data are not spread evenly over the year but are grouped together at certain points in time it can be the case that the repacking process needs more capacity to deliver their service also by peak demand. We perform a statistical test in order to determine the distribution of the required capacity. However, it is time consuming to perform a statistical test. Because there are many different distributions, we choose to only test the normal distribution. In Equation 5 the formula is shown to calculate the buffer capacity if the distribution is normal. Reason for this choice is that the formula of the normal distribution to calculate whether there is enough capacity available is easy to define parameters for and logical to explain.

$$buffer\ capacity\ normal\ distribution = z_{1-\frac{a}{2}}\left(\frac{\sigma}{\sqrt{n}}\right)$$

Where:

$z_{1-\frac{a}{2}} = confidence\ coefficient$

$\sigma = standard\ deviation$

$n = sample\ size$

Equation 5. Formula buffer capacity of the normal distribution (Buscaglia, 2020).

If the required capacity is Normally distributed, we can use the Z-table (Poortema, 2019) to determine the confidence coefficient. The Z-table provides the confidence coefficient which determines the confidence level, based on a normal distribution. A confidence coefficient is a measurement of how many standard deviations below or above the population mean a raw score is. The higher the confidence level, the higher the confidence coefficient. We need to determine a confidence level in order to determine which percentage of the customers will be served within the given time interval. The most commonly used confidence level is 95% (Devault, 2020). Because there are no reasons to choose a higher confidence level, we assume a confidence level of 95%. This means that a=(1-0.95)=0.05. A confidence level of 95% means that the lowest 2.5% and the highest 2.5% cannot be served in time. However, orders cannot be too low to be served. So, we can forget the lower bound. Because we are only interested in the upper bound, we need to work with a confidence level of 97.5%. According to the Z-table, the confidence coefficient (z) is 1.96.

For the statistical test we use the required daily capacity. We use the required capacity of 2020 as input for our test, because 2020 has the most actual data. As can be seen in Figure 4, the required capacity of 2020 is 72,317 tons. However, the expected capacity needed in the future is 74,000 tons per year. Therefore, as calculated in Equation 6, we multiply the data with a factor 1.02 in order to perform a statistical test. Because the data are adapted by ratio, this does not affect the chance that a dataset fits a certain distribution.

$$factor\ year\ 2020 = \frac{74{,}000}{72{,}317} = 1.02$$

Equation 6. Factor to multiply with the required capacity on a daily basis of the year 2020.

In Figure 7 a histogram shows the estimated required capacity in the future. This histogram does not show a normal distribution. The shape of the normal distribution is shown in Figure 6. This means it is unlikely that the normal distribution fits our data set. However, we carry out a statistical test to show how this test works and when it is allowed or not to assume a certain distribution. Therefore, we test if the required capacity is normal distributed. The normal distribution means that almost all observed data falls within three standard deviations of the mean for a normal distribution (Hayes, 2021). Furthermore, half of the data points are higher than the mean and the other half are below the mean. Also corresponds the surface under the curve to 100% of the data.

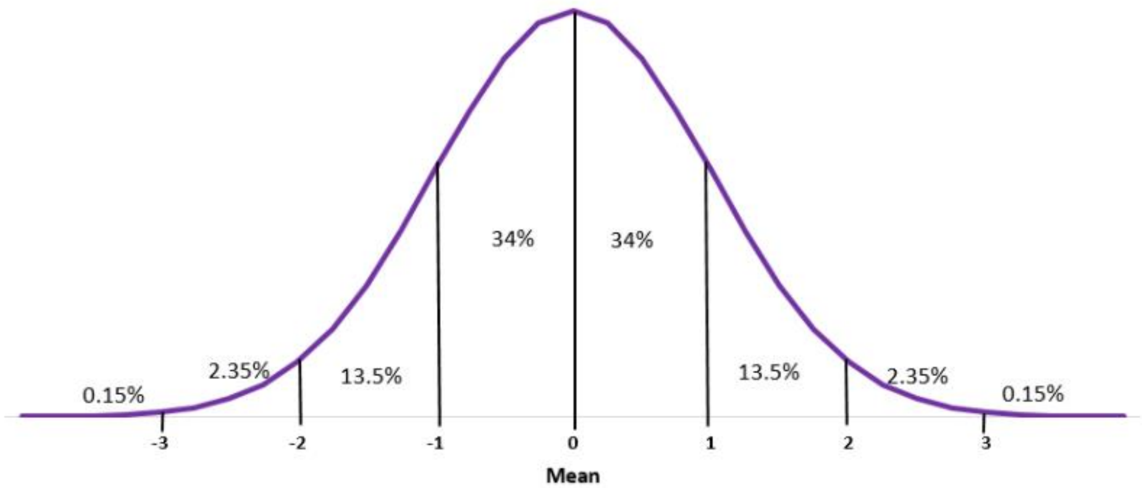
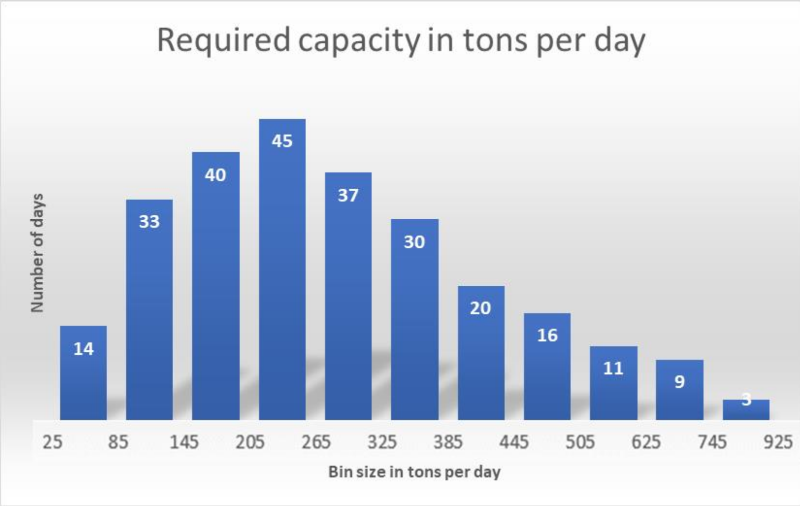


Figure 6. Normal distribution divided in intervals of 1 standard deviation each (Hayes, 2021).

In order to determine whether the distribution of the required capacity in tons per day fits a normal distribution, we carry out a Chi-squared test (Meijer, 2019). This test is used to determine if there is a significant difference between the observed values and the expected values. We use the daily data of the year 2020, shown in Appendix C. In order to carry out a Chi-squared test we multiply the data with 1.02 to determine the expected daily data. The Chi-squared test consists of 8 steps.

1. Give a probability model of the observed values (the statistical assumptions).
2. State the null hypothesis and the alternative hypothesis, using parameters in the model.
3. Give the proper test statistic.
4. State the distribution of the test statistic if H_0 is not rejected.
5. Compute (give) the observed value of the test statistic.
6. State the test and
    a. Determine the rejection region or
    b. Compute the p-value
7. State your statistical conclusion: reject or fail to reject H_0 at the given significance level.

8. Draw the conclusion in words.



i	observed numbers (N_i)	expected numbers (E_0N_i)	observed value
1	14	13	0.06
2	33	21	6.32
3	40	30	3.22
4	45	37	1.82
5	37	39	0.09
6	30	36	0.88
7	20	28	2.38
8	16	19	0.57
9	11	17	2.33
10	9	4	7.96
11	3	0	14.16

Figure 7. Histogram of the expected required capacity in tons per day.

The number of bins is calculated by taking the square root of the number of observations. The square root of 258 is around 16. Bins with a few observations (a good guideline is 5 observations) are grouped together. We determine 11 bins (intervals) with the bin sizes as shown in Figure 7. We use the standard normal table.

With Equation 7, we estimate the standard deviation.

$$standard\ deviation\ (\sigma) = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{\bar{x}})^2}{n-1}}$$

Where:

$x_i = Value\ of\ the\ i^{th}\ point\ in\ the\ data\ set$

$\bar{\bar{x}} = The\ estimated\ mean\ value\ of\ the\ data\ set$

$n = The\ number\ of\ data\ points\ in\ the\ data\ set$

Equation 7. Formula to calculate standard deviation (Meijer, 2019).

The estimated mean value of the data set is 285 and the number of data points in the data set is 258. The estimated standard deviation (σ) is 157. We carry out the 8 steps of the Chi-squared test as explained above.

1. The numbers N_i for i=1,2,3,...,11 are multinomially distributed with total n=11 and unknown success probabilities p_i.
2. We test H_0: “The distribution is Normally distributed” with expected numbers (E_0N_i) for i=1,2,3,…,11 as shown in Figure 7 against H_1: “The distribution is not Normally distributed” with a = 5%.
3. Test statistic: $X^2 = \sum_{i=1}^{8}(N_i - E_0N_i)^2/E_0N_i$ (observed values) with observed numbers (N_i) and expected numbers (E_0N_i) as shown in Figure 7.
4. Under H_0 X^2 has a Chi-squared distribution with df=k-1=10.
5. Observed value: X^2 is the sum of the observed values (are shown in Figure 7) =39.78
6. We will reject H_0 if X^2 >= c. a=0.05, so from the X^2_{12}-table it follows that c=21.03
7. The observed value 39.78 does lie in the Rejection Region, so we will reject H_0.
8. At a 5% significance level we have proven that the distribution from which the data is drawn is not the normal distribution.

The data we use are not normally distributed. This means we cannot use the formula of the Normal distribution. We can also decide to test other distributions to determine if we can use a formula of another distribution to calculate the buffer capacity. However, testing other distributions is time consuming. Furthermore, not all formulas are as easy to use as the formula corresponding to the normal distribution. Therefore, after we have determined which solution we want to choose, we calculate manually if this solution has enough capacity available.

Conclusion
In 2020 there was around 72,000 tons needed to repack the orders. We expect on the long term a required capacity of 74,000 tons per year. This is an increase of 2% compared with the year 2020. When we divide this number with the number of working days in a year, we expect a required capacity of 285 tons per day. However, demand differs per day. On some days demand is below average, on other days demand is above average. When a solution has exactly enough space to repack the expected required capacity, it can be the case that there are long waiting times to repack orders when peak demand occurs. When the expected demand is not spread out evenly over the year, but is grouped together at certain points in time, it can be the case that at some moments the process has nothing to repack and at other moments the process has too much to repack. In order to serve also by peak demand, we need to calculate if the buffer capacity of a solution is high enough to fulfil orders in time. There are two ways to do this. The first possibility is to calculate manually whether the buffer capacity is high enough. Then we use the required capacity on a daily basis of the year 2020. Because we expect the demand to grow with 2%, we multiply this data by a factor 1.02. The second possibility is to use a formula of a distribution. Using a formula is less work than calculating manually. Therefore, we have tested the data with a Chi-squared test whether the distribution is normal. Reason to test on the normal distribution is because the corresponding formula for the buffer capacity is easy to use. However, the distribution is not normal. Because it takes a lot of time to test other distributions without any guarantee that we find a distribution that fits, we calculate manually if there is enough buffer capacity available for the solution we want to choose.

2.4 Cost accounting method

One of the two action problems is the high repacking costs per ton (1000 kg). In order to choose a solution, we need to compute the repacking costs per ton of the current repacking process and of the two solutions. We identify the way we compute the costs by selecting a cost accounting method. A cost accounting method is a method which assesses a company's production costs (Mansa, 2021a). We need to distinguish the costs between the different repacking options. If repacking costs per ton differs significantly between repacking options Kommer can choose to focus on a certain repacking option to improve. It can also be the case that the best solution for the repacking options differs between improving the current repacking process and investing in a new repacking process. In order to decide which solution is the best we want to know for all three repacking options which solution is preferable. Every repacking option uses other components of the repacking process. Therefore, we have to take into account the costs that occur with the different ways to repack a product.

There are three repacking options used in the process: from bags to big bags, from bags to bulk and from big bags to bulk. We want to determine the repacking costs per ton of these three repacking options. This means we need to divide the total costs made between these three repacking options. If we had only one repacking option, we could simply sum up all the costs that are made and divide these by the number of tons repacked. However, the repacking options can have different costs. For instance, repacking bags to big bags can have a higher repacking cost per ton than repacking bags to bulk. Therefore, we need to allocate the costs to the different repacking options. There are two types of costs we can allocate, namely direct costs and indirect costs. Direct costs are costs that are directly associated with the production (Davis, 2021). In our case this means that we can identify without much effort which costs belong to which repacking option. Indirect costs are costs that are made in the whole process, so by different repacking options, and are difficult to be traced back to one repacking option. In our case, these costs are also related to the machinery. Only it is not directly clear which costs belongs to which repacking option. Some bills are hard to allocate per repacking option. For instance, the process uses a lot of electricity. Every month an electricity bill is coming in and needs to be paid. However, the bill does not say anything of which repacking option uses which amount of electricity. Therefore, we need to divide this type of cost between the three repacking options. To do this, we can use the Activity-Based Costing (ABC) method. The ABC-method is a method of assigning overhead and indirect costs (such as utilities) to products and services (Kenton, 2020b). Overhead costs are the costs not directly attributed to creating a product or service (Tuovila, 2021a). Think for example of the salary of the director. The ABC system of cost accounting is based on activities, which are considered any event, unit of work or task with a specific goal. In our case we want to assign indirect costs to three different repacking options. We want to determine the repacking costs per ton of the current process and of the process of the two possible solutions. No matter which process we choose as solution, the overhead costs will stay the same. The salary of the director, the salary of the cleaning lady who is cleaning the toilets, or the depreciation of the computers in the office; all these costs and all the other overhead costs are not going to change if we change the repacking process. Because we are only going to change the repacking process, we only assign costs which have an influence on the repacking process itself. This means we do not use the overhead costs.

We want to assign the different costs to the different repacking options in a structured way. Therefore, we compute the costs by using the Value Stream Map of a process. First, we identify the different costs per component. Then we determine which components are used to repack one ton for a certain repacking option. Lastly, we sum the costs per component up and we have the repacking costs per ton per repacking option. For example, we can calculate the electricity costs per component per ton by determining the energy consumption of a component in Kilowatt per hour, multiply the result with the energy cost per Kilowatt and then divide with the number of tons repacked per hour. The result is the cost in euros of the energy consumption per component per ton. Then we sum the costs of the components up that are used by a repacking option, and we have the energy costs per ton per repacking option. As an extra check, we can verify if the total estimated electricity costs are approximately the same as the electrical bill. For this, we multiply for all three repacking options the number of tons repacked by the energy costs per ton. Then we sum up the three results and we have the total energy costs of all tons repacked. If this result is approximately the same as the electrical bill, we have a confirmation that we have done our calculations correctly. Only the repacked tons have to be taken into account over the same time period as the electrical bill mentions.

The disadvantage of the ABC-method is that it is a time-consuming method. It costs more time to assign certain costs to a certain repacking option than just split the costs equally over the repacked tons without focusing on which repacking option is used. For some costs this can be really time consuming. For instance, when we want to analyse the repairs costs of the current repacking process, we use the repairs bills from the past. However, these bills do not mention which part of the process has been repaired and which new parts are bought for which component of the process. This means we have to call the company who is repairing the components and find out which part of a bill is for which part of the process. Because this is very time consuming, we can then decide to just split the bills equally over the tons repacked, no matter which repacking option is used. For every type of cost, we are going to allocate to the repacking options we determine if it is the effort worth to use the ABC-method or just split the costs equally. This means we do not use the ABC-method completely. Therefore, we let the ABC-method inspire us to allocate the costs as precisely as possible but sometimes we split the costs equally over the tons repacked.

Conclusion
We identify the way we compute the costs by selecting a cost accounting method. We want to distinguish the costs between the different repacking options. The costs we want to allocate are indirect costs. Indirect costs are costs that are made in the whole process, so by different repacking options, and are difficult to be traced back to one repacking option. To do this, we can use the Activity-Based Costing (ABC) method. No matter which process we choose as solution the overhead costs will stay the same. Because we are only going to change the repacking process, we only assign costs which have an influence on the repacking process itself. This means we do not use the overhead costs. With the Value Stream Map of a process, we are able to allocate costs first per component and then per repacking option. The disadvantage of the ABC-method is that it is a time-consuming method. It cost more time to assign certain costs to a certain repacking option than just split the costs equally over the repacked tons. Because this can be really time consuming for some costs, we determine for every type of cost if it is the effort worth to use the ABC-method or just split the costs equally. Because we do not use the ABC-method completely, we let the ABC-method inspires us to allocate the costs as precisely as possible.

2.5 Valuation method

We need to consider whether we take the time value of money into account. The time value of money is the concept that money you have now is worth more than the identical sum in the future due to its potential earning capacity (Fernando, 2021a). Money that we expect to get as a return on investment over a couple of years is worth less than money that we get today as a return on investment. Therefore, we want to select a valuation model. A valuation model is a model which determines the current worth of an investment (Chen, 2020). If Kommer is going to invest in a new repacking process, we want to met a hurdle rate. The hurdle rate is the minimum rate of return required on a project or investment (Kenton, 2021).

NPV
We have the possibility to use the Net Present Value (NPV). The NPV is the difference between the present value of cash inflows and the present value of cash outflows over a period of time (Fernando, 2021c). The NPV relies on a discount rate. The NPV is used to calculate the current total value of a future stream of payments by discounting future cashflows back to the present. In order to know whether the hurdle rate is met, we need to calculate the NPV. If the NPV is greater than 0, which means the NPV is positive, the hurdle rate is met, and the investment is worth taking. If Kommer decides to invest in a new process, they borrow the money from the bank and pay it back in periods. For calculating the NPV, we consider the whole investment as an initial investment at the beginning instead of small investments of paying the bank back over a time period. Reason for this is that the interest that comes with borrowing money is part of the discount rate.

Hurdle rate
If Kommer decides to invest in a new repacking process, we want to take a hurdle rate of minimal 10% per year into account. For an investment Kommer takes a mortgage of the bank. This means Kommer need to pay off this mortgage and the interest that comes with it. In order to implement a

solution, Kommer wants to have a minimum return on their investment. If the return on the investment is too low, it is not interesting for Kommer to invest money in a solution.

$$hurdle\ rate\ formula = Weighted\ Average\ Cost\ of\ Capital\ (WACC) + risk\ premium$$

Equation 8. Formula hurdle rate (Kenton, 2021).

Equation 8 shows the way the hurdle rate is calculated. The hurdle rate is the sum of the Weighted Average Cost of Capital (WACC) and the Risk Premium. The WACC is the weighted average of the cost of the capital of a company (Mukhopadhyay, 2021). This means if Kommer decides to borrow the money from the bank they have to pay interest to the bank. According to the accountant of Kommer, the expected interest rate is 3% per year.

The risk premium is the premium that should be assigned for the expected risk involved with the project (Thakur, 2021). If Kommer is not able to get enough repacking orders or something happens with the new repacking process, Kommer needs still to pay off their mortgage. The risk premium can be calculated by comparing this investment with a risk-free investment, as shown in Equation 9.

$$risk\ premium\ formula = R_a - R_f$$

$$R_a = asset\ or\ investment\ return.$$

$$R_f = risk\ free\ return.$$

Equation 9. Formula risk premium (Thakur, 2021).

There are two possibilities to get a return that is almost risk free. The first possibility is to put the money in the bank. Putting money in the bank is not so risky, but there is still a chance that a bank will collapse. However, this risk is very low. The second possibility is to invest in government bonds. A government bond is an obligation of the government with a solid interest percentage and a fixed duration (NU, 2014). Investing in Dutch government bonds can be seen as a really safe investment. The chance that the Dutch government does not pay back the government bond is really small. However, the average government bond has a negative return at the moment and the interest of the bank is approximately 0% (NSR, 2021). This means when we invest in a safe investment, with little or no risk, we get also a small to no return on our investment. Therefore, we take as a risk-free return 0%.

In our case we want to determine the minimum expected return of investing in a repacking process at Kommer. This means we want to determine the minimum investment return when we invest in a process of a company. Investing in a company can also be done by buying shares of a company, which has approximately the same risks. Most expected returns for investments are between 5% and 10% for buying shares of a company (Beleggen, 2021). Based on this numbers, we assume that the investment return is 7%. Because the risk-free return is 0%, the risk premium is also 7%. When we sum the WACC of 3% with the risk premium of 7%, we get a hurdle rate of 10% per year.

IRR

The Internal Rate of Return (IRR) is a method to estimate the profitability of potential investments. IRR is the rate of growth that an investment is expected to generate annually (Fernando, 2021b). IRR is a discount rate that makes the NPV equal to zero in a discounted cash flow analysis. IRR calculations rely on the same formula as the NPV does. In this case, IRR is the annual return that makes the NPV equal to zero. The higher the IRR, the more desirable an investment is. The goal of IRR is to identify the rate of discount, which makes the present value of the sum of annual nominal cash inflows equal to the initial net cash outlay for the investment. IRR is often ideal for analysing the potential return of an investment. This means we can analyse what the maximum hurdle rate can be.

For instance, if the hurdle rate is 10% and the IRR is 20% the return is 20% per year. An IRR of 20% means that the hurdle rate is met as long as the hurdle rate is not higher than 20%. This means if Kommer would change the hurdle rate to 12% instead of 10% we know already, without calculating the new NPV, that the hurdle rate is met.

Payback period

The payback period refers to the amount of time it takes to recover the cost of an investment. In other words, the payback period is the length of time an investment needs before earning the investment back (Kagan, 2021). The shorter the payback period, the more attractive the investment. The payback period is calculated by dividing the investment costs with the extra generated positive cashflow. In our case we want to consider whether the repacking costs decrease enough to make the investment attractive enough. This means if the cash outflow decreases and the cash inflow stays the same, we can estimate the number of years before the investment is earned back.

ROI

The Return On Investment (ROI) is a performance measure used to evaluate the profitability of an investment (Mansa, 2021a). The ROI measures the amount of return on a particular investment, relative to costs. This means the ROI will calculate the return on an investment in percentages per year (Beattie, 2021). The ROI is calculated by dividing the return of an investment by the investment. The result is a percentage per year of which part of the investment is earned back.

An increase in profit can either be made by selling the repacking service for more money or decreasing the cost price of this service. The return we take into account is the decrease in costs. Every euro we save on repacking costs will turn into profit if the selling price of the repacking service stays the same. This means we focus us not on increasing the selling price of the repacking service, but on decreasing the cost price of this service. This will also lead to an increase in profit.

Conclusion

We use the NPV in order to discount the cashflows back to the present. The maximal discount rate for which the investment is profitable can be determined with use of the IRR. In order to valuate whether the return on an investment is high enough, we have calculated a hurdle rate. In this case the minimum return should be 10%. We use the ROI to calculate the return on an investment. When we know the ROI, we know which percentage of the investment is earned back each year.

2.6 Steady state distribution

We want to decrease the waiting time of (dis)connecting trucks in order to decrease the idle time. With the use of silos (storage units) we do not have to wait until a truck is (dis)connected from the filling station. Every output needs at least two silos. If one silo is full, the process operator can start filling the second silo. Filling a silo takes longer than to empty a silo. Before the second silo is full, the first one has already been emptied by the truckdriver. In that way, there is always one silo available, and the repacking process can operate continuously instead of waiting before a truck is switched. However, according to the steady state distribution, it is not possible to use silos if the distance from the process to the silos is too far. The steady state distribution is the distribution that states that the throughput of the output needs to be more than the throughput of the input. In that case, the system can handle the flow (Winston, 2004).

We can repack more tons in an hour if we replace the filling station of the trucks with silos in order to waste no time with placing and connecting the truck to the filling station. The silos are too high to place inside the warehouse and therefore they need to be placed outside the warehouse. However, the current process is placed in the middle of the warehouse instead of against a wall at a side of the warehouse. This means that many transport screws are necessary to connect the current process with the silos.

$$steady\ state\ distribution: \rho = \frac{\lambda}{\mu} < 1$$

Where:

$$\lambda = throughput\ transport\ screw\ "n"\ in\ tons\ per\ hour$$

$$\mu = throughput\ transport\ screw\ "n+1"\ in\ tons\ per\ hour$$

Equation 10. Steady state distribution: throughput decreases when number of transport screws in a row increases (Winston, 2004).

According to the steady state distribution as shown in Equation 10, every transport screw farther in the process needs to go a little faster to prevent accumulation. This has the result that ρ is less than 1. The throughput of transport screw "n+1" needs to be more than the throughput of transport screw "n". This means, according to Equation 10, that the repacking capacity per hour decreases with every extra transport screw the raw materials need to go through in order to repack the products. The longer the distance to travel raw materials over, the more transport screws are needed. The maximum throughput of a transport screw is a little bit higher than the process. Therefore, according to the service engineer of the current repacking process, this is not a problem for short distances. However, transporting raw materials to the other side of the warehouse slows down the repacking process significantly. Because the current repacking process is placed in the middle of the warehouse and the silos need to be placed outside the warehouse, the distance is too far to travel the raw materials over according to the service engineer. Therefore, we cannot use the silos if Kommer decides to improve the current process. If Kommer decides to invest in a new repacking process, this process will be placed against a wall with a short connection with the silos outside the warehouse. Therefore, we can use the silos if Kommer invests in a new repacking process.

Conclusion
In order to decrease the waiting time of (dis)connecting trucks, we can use silos (storage units). If one silo is full, the process operator can start filling the second silo. Before the second silo is full, the first one has already been emptied by the truckdriver. In that way, there is always one empty silo available to fill. However, according to the steady state distribution, if the silos are placed to far from the process it is not possible to use the silos. According to the steady state distribution, every transport screw further in the process needs to go a little faster to prevent accumulation. This means that the repacking capacity per hour decreases with every extra transport screw needed. The longer the distance to travel raw materials over, the more transport screws are needed. The silos need to be placed outside. If Kommer decides to invest in a new repacking process, this process will be placed against a wall with a short connection with the silos. However, because the current repacking process is placed in the middle of the warehouse, the distance is too far to travel the raw materials over and the throughput will decrease significantly. Therefore, we can use the silos only if Kommer invests in a new repacking process.

2.7 Conclusion
The current process has problems we want to solve. The process consists of a lot of components and therefore the process can be hard to analyse. In order to solve the problems in a systematic way we use the Value Stream Mapping (VSM) method in order to identify which components there are in a process and how components are connected with each other. This enables us to identify the physical

stream of the raw materials in the process. We can also carry out a bottleneck analysis to determine which part of the current process is the slowest. After we know the throughput of the bottleneck, we can decide if we want to improve this bottleneck. We can also decide to solve the problems that are responsible for the idle time instead of increasing the throughput of the bottleneck.

One of the two action problems is the capacity shortage at the current repacking process. We need to be sure that the solution has enough capacity to fulfil orders in time. This means we need to have enough available capacity to repack the expected required capacity with a buffer capacity for peak demand. The expected required capacity is 74,000 tons per year, which is 285 tons per working day. This is 2% more than in the year 2020. Reason to have a buffer capacity is because it can be the case that the orders are not coming in evenly over the year but are grouped together at certain points in time. This can have the result that at some moments the process has nothing to repack and at other moments the process has too much to repack. In order to serve also by peak demand, we need to calculate if the buffer capacity of a solution is high enough to fulfil orders in time. We have the possibility to calculate this manually or use a formula of a distribution. We have tested with a Chi-squared test if the data is distributed according to the normal distribution. However, the distribution is not normal. We can test the data on other distributions, but this will take a lot of time. Therefore, we calculate manually if there is enough buffer capacity available for the solution we want to choose.

One of the two action problems is the high repacking costs per ton. In order to choose a solution, we need to compute the repacking costs per ton of the current repacking process and of the two solutions. We identify the way we compute the costs by selecting a cost accounting method, which is a method to assess a company's production costs. We want to distinguish the costs between the three different repacking options. We can use the Activity-Based Costing method to allocate costs. We want to determine the repacking costs per ton of the current process and of the process of the two possible solutions. Because we are only going to change the repacking process, we only assign costs which have an influence on the repacking process itself. We want to assign the different costs to the different repacking options in a structured way. Therefore, we compute the costs by using the Value Stream Map of a process. The disadvantage of the ABC-method is that it is a time-consuming method. It cost more time to assign certain costs to a certain repacking option than just split the costs equally over the repacked tons without focusing on which repacking option is used. For some costs this can be really time consuming. Therefore, we determine for every type of cost if it is the effort worth to use the ABC-method or just split the costs equally. This means we do not use the ABC-method completely.

We want to take the time value of money into account. We can use a valuation model to determine the current worth of an investment. Therefore, we use the Net Present Value (NPV) to calculate the current total value of a future stream of payments by discounting future cashflows back to the present with a hurdle rate. The hurdle rate is the minimum rate of return required on a project or investment. If the NPV is positive, the hurdle rate is met, and the investment is worth taken. With the Internal Rate of Return (IRR) we can calculate what the maximum hurdle rate can be while still having a positive NPV. With the return on investment (ROI) we measure the amount of return on a particular investment relative to costs. The return we take into account is the decrease in costs. Every euro we save on repacking costs will turn into profit if the selling price of the repacking service stays the same. Reason for this is that an increase in profit can either be made by selling the repacking service for more money or decreasing the cost price of this service. Decreasing the cost price will therefore also lead to an increase in profit.

We want to decrease the waiting time of (dis)connecting trucks in order to decrease the idle time. With the use of silos (storage units) we do not have to wait until a truck is (dis)connected from the filling station. Every output needs at least two silos. If one silo is full, the process operator can start filling the second silo. Before the second silo is full, the first one has already been emptied by the truckdriver. In that way, there is always one silo available, and the repacking process can operate continuously instead of waiting before a truck is switched. However, according to the steady state distribution, it is not possible to use silos if the distance from the process to the silos is too far. Because the silos are too high to place inside, the silos can only be placed outside the warehouse. The current process is placed in the middle of the warehouse, which means that if Kommer decides to improve the current repacking process, the silos are very far placed from the current process. This slows down the process significantly. If Kommer decides to invest in a new repacking process, this process will be placed against a wall with a short connection with the silos outside the warehouse. Therefore, we can only use the silos if Kommer decides to invest in a new repacking process.

3. Context analysis

The goal of the context analysis is to explain the context of the action problems and to gather the data we need to analyse the current process. In Chapter 1 we discussed our action problems and our intended deliverables. The action problems we want to solve are the high repacking costs per ton and the capacity shortage of the current repacking process. We can improve the current process or invest in a new process. Therefore, we are going to design two solutions and we investigate which solution is the best to solve the two action problems. Both solutions need to meet the minimum required capacity to repack the product. In order to design the two solutions, we need to know our capacity shortage and our current costs. Therefore, we need to know the available capacity and the required capacity on the long term. When we know our current costs, we can focus us on the most important costs. We use the Value Stream Map in Figure 1 to identify the available capacity and the current costs per component.

3.1 Available capacity

To calculate the shortage of the required capacity, we need to calculate the available capacity. To calculate the available capacity, we calculate the throughput in tons per hour of every component in the current repacking process who is influencing the throughput of the process. Throughput is the number of units that can be produced by a production process within a certain period of time (Bragg, 2021). With use of the Value Stream Mapping of raw materials in Figure 1, we can determine which components are used for which repacking option. With the current repacking process Kommer can repack 12.5 ton per hour, which is 150 tons in 12 hours. We want to know how much capacity is lost due to idle time caused by the waiting time to (dis)connect trucks and the downtime of components. Idle time is paid time that an employee or machine is unproductive (Kenton, 2020b). When we have the available capacity per component, we can determine for every repacking option which component of the process has the lowest throughput in tons per hour. A process is as fast as the component with the lowest throughput, as explained in Section 2.2. Therefore, we carry out a bottleneck analysis to determine which component has the lowest throughput. Then we compare the result with the throughput time measured in practice and we know how much capacity per hour is lost due to idle time. The idle time is the difference between the throughput of the process and the throughput measured in practice. In this section, we calculate the throughput in tons per hour of the components that are influencing the throughput of the process. The components of the current process are shown in the Value Stream Mapping of raw materials in Figure 1.

In order to determine the throughput of the process we are going to determine the throughput of the components. Some components are not considered for determining the throughput because they do not influence the throughput of the current repacking process. The throughput of the components is measured in practice as much as possible. To know the throughput in tons of a component per hour, the throughput of a component is measured for 1 minute and then multiplied by 60. The measuring time is long enough because the throughput of every component is constant. We measured the throughput of the components without idle time, so under perfect circumstances. In some cases, we need the density of the products to calculate from cubic meters to tons (1000 kg). To calculate the density, we measure the size of a big bag and divide the amount of cubic meters with the number of tons in the big bag. 1.4 cubic meter is equal to one ton. An overview of the throughput per component can be found in Appendix A.

Lift table

The first component is the lift table. The lift table is the component that is used to bring the bags on the perfect height for the employee, so that the employee can put the bags easily on the assembly line. The forklift driver puts a pallet on the lift table before the worker puts the bags on the assembly line. The lift table goes higher when the pallet goes emptier. This makes sure that the workers do not have to bend down. The throughput the lift table can handle is partly determined by the throughput made by the worker. Therefore, we have taken the theoretical throughput. We have searched on the internet for the same model and taken the throughput from the model (Manutan, 2021). It is possible to empty 25 pallets in one hour. One pallet contains 40 bags of 25 kg, so one pallet is one ton. So, the throughput of the lift table is 25 tons per hour.

Assembly line

The second component is the assembly line. The worker puts the bags on the assembly line. The assembly line transports the bags to the bag cutter. On the assembly line are small blocks monitored. The bags are placed between two blocks. To determine the throughput of the assembly line, we set the speed of the assembly line on a maximum and count the number of blocks that disappear at the end of the assembly line in one minute. When we know the number of blocks, we know the number of bags. In one minute, it is possible to put 39 bags of 25 kg on the assembly line. This means the assembly line can handle a capacity of 59 ton per hour.

Bag cutter

The third component is the bag cutter. The main part of the bag cutter consists of two chains with notches to hold the bags. The bags are transported through the bag cutter while lying on the two chains. In the middle of the bag cutter is a knife. The knife is placed between the two chains. The bag goes from the assembly line on the chains and got cut in the middle of the bag cutter with the knife. The product falls in the funnel and the worker pulls the empty bag at the end of the machine. The throughput of the chains can be measured by the number of rotations of the axis. One rotation is 1.5 bag. We measure the throughput of the bag cutter by the number of times the axis goes round in one minute. The bag cutter has a throughput of 47 ton per hour.

Bucket elevator

The fourth component is the bucket elevator, as shown in Figure 8. The buckets of the bucket elevator take the material from the storage 2 meters underground and the buckets are emptied 9 meters above the ground through a sieve in a transport screw. We want to know the available capacity of the bucket elevator in tons per hour. To determine the capacity, we need to determine the speed of the bucket elevator and the capacity of the buckets inside the bucket elevator. To determine the speed, we need to know the cycle time and the number of buckets on the belt. The cycle time is the time it takes to move the buckets one cycle (Koo, 2021). To determine the number of buckets on the belt, we need to know the length of the belt and the distance between the upper side of two buckets. To determine the capacity of the buckets we will measure the size of a bucket and calculate the volume.

We measure the cycle time of the bucket elevator by opening a part of the housing, marking one bucket, turning the speed on maximum, and measuring with a stopwatch on our phone the time before we see the mark again. We calculate the length of the belt by calculating the circumference of the two semicircles and the length of the two straight parts. The total cubic meters transported is 87 cubic meter per hour. 1.4 cubic meter is equal to one ton. This means that the capacity is 62 tons per hour.

capacity bucket elevator	
distance between upper side of two buckets in meters	0.15
radius circle in meters	0.40
straight part in meters	9.60
circumference semicircle (pi*radius) in meters	1.25
length of the belt in meters	21.70
number of buckets on the belt	**145**
cycle time bucket in seconds	12
number of cycles per hour	**300**
volume of a bucket in cubic meters	0.002
capacity in cubic meters per hour	87
density factor	1.4
capacity in tons per hour	**62**

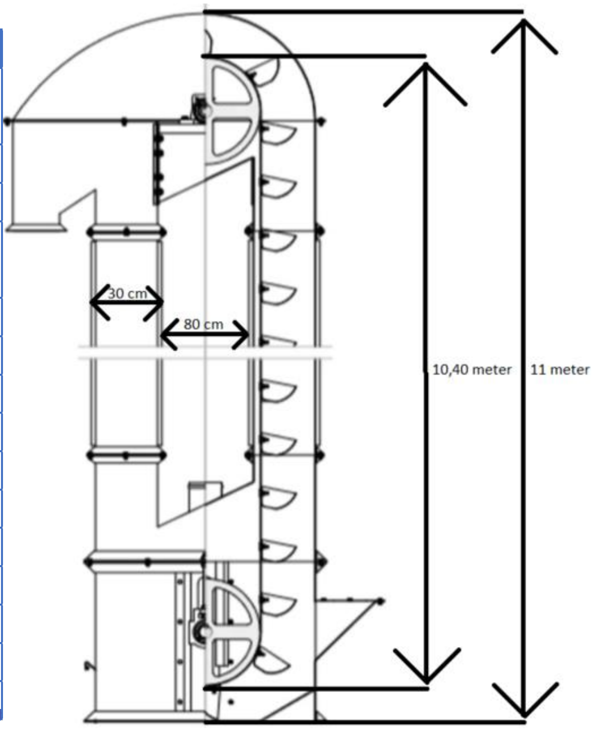


Figure 8. Capacity in tons per hour of the bucket elevator.

Transport screws

In the process there are five transport screws. The function of the transport screws is to transport the product from one component to another. We can calculate the transported capacity in tons per hour with Equation 11. To measure the capacity per hour of the transport screws, we measure the revolutions per hour, and we calculate the transported capacity per revolution. The transported capacity per revolution can be calculated with Equation 12. As shown in Figure 9, a transport screw has a distance of 15 cm between two blades. The outside diameter is 30 cm and the inside diameter is 7 cm. To calculate the area of the outside and inside circle of the transport screws in Equation 12 we use Equation 13. As shown in Equation 13, the area of a circle is calculated by squaring the radius (r) and multiplying the outcome with π (approximately 3.14) (IPG-Math, 2020). According to Figure 9, the diameter of the outside circle is 30 cm and the diameter of the inside circle is 7 cm. This means that the radius of the outside circle is 15 cm and the radius of the inside circle is 3.5 cm. Every rotation a screw transports 0.1 cubic meter. 1.4 cubic meter is equal to 1 ton. Therefore, the density factor is 1.4.

$$\begin{aligned} &transported\ capacity\ in\ tons\ per\ hour \\ &\qquad = transported\ capacity\ per\ rotation * number\ of\ rotations\ per\ hour \end{aligned}$$

Equation 11. Transported capacity transport screws in tons per hour.

$$\begin{aligned} &transported\ capacity\ per\ rotation \\ &\qquad = (area\ outside\ circle - area\ inside\ circle) * distances\ between\ two\ blades \\ &\qquad * density\ factor \end{aligned}$$

Equation 12. Transported capacity per revolution of the transport screws.

$$A = \pi * r^2$$

Equation 13. Formula area circle (A) (IPG-Math, 2020).

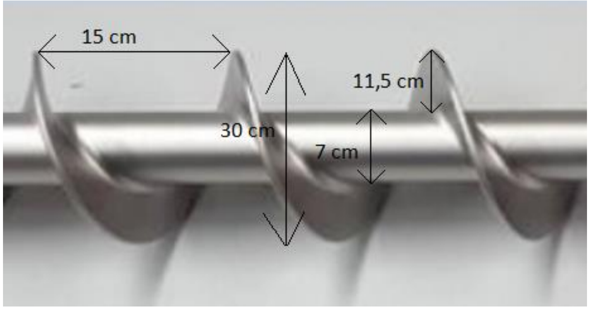


Figure 9. Dimensions of a transport screw.

For Equation 11 we need to measure the number of rotations per hour for every transport screw. Measuring is done by sticking a piece of tape on the end of the axis and counting the number of times the tape goes round in one minute. Then we calculate the revolutions per hour by multiplying the outcome with 60. Because the throughput is constant, it is enough to measure for a short period. The capacity in tons per hour of the transport screws can be found in Table 2.

transport screw	rotations per hour	capacity in tons per hour
funnel	5460	39
transport to bucket elevator	3600	26
transport to filling stations	6180	44
filling station big bags	4620	33
filling station trucks	7620	54

Table 2. Capacity in tons per hour of transport screws.

Bottleneck
The bottleneck for repacking big bags to bulk of the current process is the transport screw to the bucket elevator. This screw has a capacity of 26 tons per hour. This transport screw is used for every repacking option. The bottleneck for the other two repacking options is the lift table at the beginning of the bag cutter with a capacity of 25 tons per hour. However, this capacity is not reached. At the moment, the company repacks 12.5 tons per hour due to idle time. This means the idle time decreased the capacity with 25-12.5=12.5 tons per hour. The idle time consists of the waiting time to (dis)connect the trucks and because of the high downtime in the current process. Therefore, the capacity is reduced to 12.5 tons per hour for every repacking option.

Conclusion
We want to decrease the amount of idle time, which consists of the waiting time of (dis)connecting trucks and the downtime of the repacking process. Therefore, we want to measure how much idle time there occurs. In order to measure the amount of idle time, we have calculated the throughput of the components. We have used the Value Stream Map in Figure 1 to identify the components that we need the throughput of. Some components are not considered because not every component can influence the throughput of the repacking process. The bottleneck of the process has a throughput of 25 tons per hour. However, the throughput in practice is 12.5 tons per hour. This means the capacity in tons per hour lost due to idle time is 25-12.5=12.5 tons.

3.2 Cost analysis current costs

To be able to create a solution, we need to know the current costs first. We want to know which types of costs are affecting the repacking costs per ton significantly. When we know the most important costs, we know where we need to focus on when creating the solution of improving the current repacking process. Costs depend on which components of the repacking process are used.

Because every repacking option uses different components of the repacking process, every repacking option has different costs. Therefore, we create an Activity-Based Costing (ABC) analysis of the current situation. The ABC-method gives us a proper view in the costs per repacking option instead of the total costs. In this section we explain how we calculate these costs. The ABC-analysis is showed in Table 3.

The ABC-method is a method of assigning overhead and indirect costs to products and services (Kenton, 2020b). No matter which process we choose as solution, the overhead costs will stay the same. Because we are only going to change the repacking process, we only assign costs which have an influence on the repacking process itself. This means we do not use the overhead costs. The disadvantage of the ABC-method is that it is a time-consuming method. Splitting the costs equally over the repacked tons without focusing on which repacking option is used is easier than assigning certain costs to a certain repacking options. We determine for every type of cost we are going to allocate if we want to use the ABC-method or just split the costs equally. Therefore, the ABC-method inspires us to allocate costs as precise as possible but sometimes we split the costs equally over the tons repacked.

In order to gather the data, we need to analyse the costs that occur at the current repacking process, we need information about the components. However, information about the components of the repacking process we are investigating is lost because the company who installed the repacking process does not exist anymore. Because Kommer has not stored this information either, we need to estimate the costs. Therefore, we use offers of new machinery and bills from the past to identify costs of components. Further we ask the service engineer of the repacking process to give a proper estimation about some types of costs we cannot identify ourselves. We also carry out interviews by phone with engineering companies for specific information about components.

We identify six types of costs. These costs are the forklift, the space, the staff, the depreciation, the energy costs and the repairs and maintenance. We came to these costs by brainstorming which costs there will occur. To be sure we do not have the wrong costs on our ABC-analysis or to forget a type of cost, we ask also for the different costs that occur by the operational manager. Further we ask which types of bills there are to be paid every month by the financial manager.

Activity-Based Costing (ABC) analysis current situation		from bags to bulk	from bags to big bags	from big bags to bulk
forklift				
rent per year	€ 6,000.00			
electricity and external costs per year	€ 900.00			
current capacity	39,000			
total costs forklift per ton		€ 0.18	€ 0.18	€ 0.18
space costs warehouse				
rent of 1 square meter per year	€ 45.00			
number of square meters	229			
space costs per year	€ 10,305.00			
current capacity	39,000			
space costs per ton		€ 0.26	€ 0.26	€ 0.26
staff costs				
staff costs per hour per employee	€ 33.00			
number of employees (incl. forklift driver)		3	4	2
capacity per hour	12.5			
staff costs per ton		€ 7.92	€ 10.56	€ 5.28
depreciation				
depreciation cost per ton		€ 0.41	€ 0.50	€ 0.34
energy costs				
energy costs per hour		€ 4.41	€ 4.41	€ 3.35
capacity per hour	12.5			
energy costs per ton		€ 0.35	€ 0.35	€ 0.27
reparations and maintenance				
reparations and maintenance costs per year	€ 13,254.95			
reparations and maintenance costs per ton		€ 0.34	€ 0.34	€ 0.34
repacking costs per ton		€ 9.46	€ 12.19	€ 6.67

Table 3. ABC-analysis current repacking process.

Forklift

The first cost is the forklift. Kommer hires a forklift to assist the repacking process. Additional costs of the forklift are electricity and standard maintenance. For every repacking option 1 employee needs a forklift. For all three repacking options the capacity per hour is 12.5 tons. This means for every 12.5 tons repacked 1 forklift is for 1 hour involved, no matter which repacking option is used. Because the forklift is equally involved in every repacking option, we divide the costs of the forklift per ton with a total available capacity of 39.000 ton.

Space costs warehouse

The second cost is the space cost of the warehouse. The warehouse is used for the repacking processes and for the storage of the products. Every square meter the process uses cannot be used for storage. Because of a lack of storage at Kommer's own facility, Kommer is renting external space to have extra storage of their customers products. We assume that every square meter the process is using means a square meter extra to rent elsewhere for storage. Therefore, we take the rent of the other facilities to determine the cost per square meter. It is hard to measure the used size of every single component. So, we have measured the size taken by the total process and divide the costs equally per ton, based on an available capacity of 39.000 ton.

Staff costs

The third cost is the cost of the staff. The staff costs can be found in Table 4. Because Kommer must pay extra for overtime, we calculate the average staff costs per hour per employee. The staff costs per hour is 30 euro. This is including tax and insurances. The company must pay 30% per hour extra if an employee is working more than 40 hours per week. In the current situation, employees are working 12 hours a day. This means they are working 4 hours over. This brings the average staff costs per hour per employee on 33 euro.

staff costs	
staff costs per hour	30
extra costs overtime	30%
fixed hours per day	8
overtime per day	4
average staff costs per hour per employee	€ 33.00

Table 4. Average staff costs per hour per employee.

When repacking bags to bulk 3 persons are involved. The bag cutting involves two employees. One who put the bags on the assembly line and one who takes the empty bags out of the bag cutter. The forklift driver places the pallets on the lift table and removes the empty pallets. Connecting or disconnecting the truck to the filling station also involves manpower. However, the current repacking process cannot operate before a truck is connected. This means 1 of the 3 employees can help (dis)connecting the truck to the filling station, because otherwise he is just waiting. Therefore, we do not need an extra employee for this.

It involves 4 persons to repack bags to big bags. Two persons for the bag cutter, one person for the filling station of the big bags and one forklift driver. The forklift driver is working on the bag cutter and on the filling station. The employee on the filling station need to place empty big bags under the filling station, load the big bags and remove the big bag with assistance of the forklift driver.

2 persons are involved if there are big bags repacked to bulk: One person for the dumping cabinet and one forklift driver. The big bags need to be emptied above a dumping cabinet. The forklift driver places a full big bag above the dumping cabinet and the employee on the dumping cabinet cut the big bag at the bottom.

The capacity of the current process is for every repacking option 12.5 tons per hour. We want to identify the staff costs per ton per repacking option. For every repacking option, we multiply the average staff costs per hour per employee with the number of employees needed. Then we divide the result with the available capacity per hour to identify the staff costs per ton. The result is the staff costs per ton per repacking option.

Depreciation
The fourth cost is the depreciation cost per ton per repacking option. The term depreciation refers to an accounting method used to allocate the cost of a tangible asset over its useful life or life expectancy (Tuovila, 2021b). Because components have a certain lifespan in which a certain number of tons can be repacked, we can divide the costs of a component over the expected number of tons repacked in one lifespan. Therefore, we want to know the depreciation costs per ton per repacking option and we use the investment costs and the different lifespans of components to calculate this. To calculate the depreciation cost per ton per repacking option we will first calculate the depreciation cost per ton per component. Then we sum the depreciation costs of the components up who are used by a certain repacking option. We use the Value Stream Map in Figure 1 to determine which repacking option needs which components. First, we calculate the depreciation costs of the components per ton. When a component needs to be replaced, it has a certain lifespan before it is going to be replaced again. In that lifespan that component helps repacking a certain number of tons.

When we divide the new price of a component with the number of tons a component helps repacking in his lifespan, we know the depreciation costs per ton per component.

	depreciation	costs per year	bags-bulk	bags-big bags	big bags-bulk
1	lift table	€ 400.00	€ 0.01	€ 0.01	€ 0.00
2	assembly line	€ 200.00	€ 0.01	€ 0.01	€ 0.00
3	bag cutter	€ 4,000.00	€ 0.14	€ 0.14	€ 0.00
4	storage	_	€ 0.00	€ 0.00	€ 0.00
5	dumping cabinet	€ 1,250.00	€ 0.00	€ 0.00	€ 0.12
6	sieve	€ 1,000.00	€ 0.03	€ 0.03	€ 0.03
7	silo	€ 400.00	€ 0.00	€ 0.04	€ 0.00
8	bucket elevator	€ 2,550.00	€ 0.07	€ 0.07	€ 0.07
9	transport screw 1 (funnel)	€ 750.00	€ 0.03	€ 0.03	€ 0.00
10	transport screw 2 (transport to bucket elevator)	€ 750.00	€ 0.02	€ 0.02	€ 0.02
11	transport screw 3 (transport to filling stations)	€ 873.75	€ 0.02	€ 0.02	€ 0.02
12	transport screw 4 (filling station big bags)	€ 791.25	€ 0.00	€ 0.09	€ 0.00
13	transport screw 5 (filling station trucks)	€ 942.50	€ 0.03	€ 0.00	€ 0.03
14	extractor 1	€ 250.00	€ 0.01	€ 0.01	€ 0.00
15	extractor 2	€ 250.00	€ 0.01	€ 0.01	€ 0.00
16	extractor 3	€ 250.00	€ 0.00	€ 0.00	€ 0.02
17	extractor 4	€ 250.00	€ 0.01	€ 0.01	€ 0.01
18	extractor 5	€ 250.00	€ 0.01	€ 0.00	€ 0.01
19	bag press	€ 901.25	€ 0.02	€ 0.02	€ 0.02
	total	€ 16,058.75	€ 0.41	€ 0.50	€ 0.34

Table 5. Depreciation costs per ton per component per repacking option.

We determine the depreciation costs per ton per component in two steps. Firstly, we determine the depreciation costs per year per component by dividing the new price of a component with his lifespan. Secondly, we determine the depreciation costs per ton per component by dividing the depreciation costs per year per component with the required number of tons that use that component to be repacked. The required capacity of the first repacking option (from bags to bulk) is 37,000 ton per year. Repacking option 2 (from bags to big bags) and 3 (from big bags to bulk) have a required capacity of respectively 17,000 and 20,000 ton per year. However, the required capacity is in total 74,000 and the available capacity is 39,000. What cannot be done in the current process is done with another (and more inefficient) repacking process. This means we are only able to repack 39,000/74,000=53% of the capacity in the current situation. For instance, the bag cutter is used by the first and the second repacking options. This means we divide the depreciation costs per year per component with 54,000 (=37,000+17,000) and we multiply the depreciation costs per year per component with 0.53 to get the depreciation costs per ton repacked per component. This means that we divide the depreciation costs per year of the bag cutter with 28,460 (=54,000*0.53) to get the depreciation costs per ton of the bag cutter (in this case 0.14 euro per ton). In Table 5 we have provided an overview with the depreciation costs per year and the depreciation costs per component. The numbers in the left column are referring to the components of the Value Stream Map in Figure 1. The new price and the lifespan of the components used to calculate the depreciation costs per year can be found in Appendix A. Not every component is used for every repacking option. We used the Value Stream Map in Figure 1 to determine which repacking option needs which components. As shown in the overview, we sum the repacking costs per ton per component up of the components used by a certain repacking option to calculate the repacking cost per ton per repacking option.

We want to know the depreciation per component per year to calculate the depreciation per component per ton repacked. Therefore, we need to know the costs of replacing a component and the lifespan of a component. However, the prices Kommer has paid for the components are lost because the company that installed the current repacking process does not exist anymore. Therefore, we estimate the depreciation of the current components by carrying out interviews by phone for specific information about components and by investigating old offers which Kommer has applied for in the past. As mentioned in the beginning, the term depreciation refers to an accounting method used to allocate the cost of a tangible asset over its useful life or life expectancy. Depreciation represents how much of an asset's value has been used (Tuovila, 2021b). We can measure the asset's value in the expected number of tons possible to repack in one lifespan. In the future we expect the required capacity to be constant. This means that every year approximately the same number of tons are going to be repacked as the year before. This means that every year we use a component as much as the year before, which result in using the same portion of a component's value as the year before. This means that every year the value of an asset decreases with the same portion as the year before. Therefore, we assume the depreciation to be linear.

The first component we investigate is the lift table. The specifications listed in the lift table gives us information to search for the model on internet. The second component we investigate is the assembly line. To be able to estimate the costs, we need to know the length of the assembly line. The assembly line is 1.70 meters long. An employee of a web shop was able to inform us on the lifespan and the new price of these two components. The third component we investigate is the bag press. Because the brand on the bag press is still visible, we can identify the life span and the new prices with help of the customer service desk. The fourth and fifth component we investigate are the bag cutter and the bucket elevator. After carrying out two interviews by phone with mechanical engineers we identified the lifespan and the depreciation. The sixth component we investigate is the dumping cabinet. With help of the service engineer, we can identify the lifespan and the new price. The seventh component we investigate is the sieve. After investigating an old quotation, we identified the lifespan and the new price.

There are five transport screws in the process. With help of an old offer, we can identify the price of a new transport screw (including the motor and installation) of 4 meter. After carrying out an interview by phone with a mechanical engineer specialised in transport screws, we identified the lifespan of a transport screw. The transport screws in the process have different lengths. The mechanical engineer has access to a price list which gives us the possibility to calculate the price of every extra meter (without motor or installation). This gives us the possibility to calculate the new price for every transport screw. Further, there are multiple extractors in the process. After carrying out an interview by phone with a mechanical engineer, we identified the lifespan and the new price of an extractor. According to the mechanical engineer, the differences in size of the extractors does not influence the price significantly.

Energy costs

The fifth cost we identify is the energy cost. To calculate the energy cost per repacking option, we identified which components are used for which repacking option. Then we sum the energy costs per hour up for every repacking option. To identify the costs per ton per repacking option, we divide the energy costs per hour with the available capacity per hour.

The energy costs depend on the energy consumption and on the price of energy. We measure the energy cost with help of the consumption of Kilowatt Hours (kWh), which is written on the engines in the process. The number of KWH is the number of Kilowatt that is consumed in one hour when the motor is at full speed. According to the service engineer, an engine normally uses 80% of its power.

Therefore, we can compute the energy consumption in KWH by multiplying the maximum number of KWH with 0.8. The price of one KWH is not constant but varies. The price of energy can be computed by counting the energy consumption and energy bills of the last three months and taking the average of these numbers. The average cost of electricity of the last three months is 0.12 euro. According to the service engineer, the extra energy consumption of starting and stopping the components is negligible. With use of these numbers, we can compute the energy costs per hour per component. The energy costs of the old process per component can be found in Appendix A. The numbers in the left column are referring to the components of the Value Stream Map in Figure 1.

Repairs and maintenance
The sixth cost is the cost for repairing and maintaining components. In order to identify this cost, we calculate the total repairing and maintenance cost of last year. It is difficult to identify which costs are for which components. Therefore, we divide the total repairing and maintenance cost by the total available capacity of 39,000 ton to find the repairs and maintenance cost per ton per repacking option.

Focus point
After investigating the ABC-analysis, it is clear that the staff cost is the most important cost. According to Table 6, for every repacking option around 80% of the repacking costs per ton can be assigned to staff costs. This means the Pareto-principle can occur. The Pareto principle states that if roughly 80% of the costs come from 20% of the types of costs, we have to focus us on this 20% to get most of the result instead of spending our time with the 80% that is only responsible for a small part of the result (Munday, 2016). We want to reduce costs as much as possible. According to the Pareto principle it is likely that we reduce the most costs when we focus us on the staff costs. Therefore, we focus us on decreasing the staff costs while creating the solution of improving the current repacking process. Because the other 5 types of costs are together responsible for roughly 20% of the repacking costs, it is unlikely that we reduce the most costs when we focus us on these costs.

ABC-analysis current situation	from bags to bulk	% of total	from bags to big bags	% of total	from big bags to bulk	% of total
forklift	€ 0.18	2%	€ 0.18	1%	€ 0.18	3%
space costs warehouse	€ 0.26	3%	€ 0.26	2%	€ 0.26	4%
staff costs	€ 7.92	84%	€ 10.56	87%	€ 5.28	79%
depreciation	€ 0.41	4%	€ 0.50	4%	€ 0.34	5%
energy costs	€ 0.35	4%	€ 0.35	3%	€ 0.27	4%
reparations and maintenance	€ 0.34	4%	€ 0.34	3%	€ 0.34	5%
repacking costs per ton	**€ 9.46**	**100%**	**€ 12.19**	**100%**	**€ 6.67**	**100%**

Table 6. ABC-analysis current situation cumulative costs.

Conclusion
To improve the current repacking process, we want to identify the most important costs that occur. We identified six types of costs. The most important costs are the staff costs, which are responsible for 80% of the cost price. Therefore, we focus us on the staff costs when we create the solution of improving the current repacking process.

3.3 Conclusion

To calculate the available capacity, we calculate the bottleneck of the current repacking process. We use the Value Stream Map of raw materials in Figure 1 as basis for the components we want to determine the throughput of. It became clear that the component with the lowest throughput has a throughput of 25 tons per hour. However, because of idle time caused by downtime of machinery and waiting time of (dis)connecting trucks, there are 12.5 tons per hour repacked. This means that the idle time is (25-12.5)/25 = 50%.

With use of the Value Stream Map of raw materials in Figure 1, we were able to create an ABC-analysis of the current repacking process specified per repacking option. The ABC-analysis shows the costs per ton repacked per repacking option. We have identified six types of costs. The goal was to find the most important costs to focus on. After investigating the ABC-analysis, it is clear that the staff cost is the most important cost to focus on. Approximately 80% of the repacking costs can be assigned to staff costs. According to the Pareto principle, if 80% of the costs come from 20% of the types of costs we have to focus us on this 20% to get the most result. Therefore, when we create the solution of improving the current repacking process, we focus us on decreasing the staff costs.

4. Solution

In this section we design two solutions. In order to solve our two action problems, we choose one solution of these two solutions. The two action problems are the high repacking costs per ton and a too low capacity of the current process. The first solution is investing in a new process, as explained in Section 4.1. The second solution is improving the old process, as explained in Section 4.2. The solution needs also to meet the required capacity. What we want as a result is to find the solution with the lowest repacking costs per ton per repacking option. In Section 4.3 we discuss which of the two solutions will solve our action problems the best. In Section 4.4 we provide a conclusion.

4.1 Investing in a new repacking process

In this section, we discuss the possibility to invest in a new process to solve our two action problems. Kommer has asked two engineering companies for an offer for a part of a new repacking process. Therefore, the offer consists of two parts. Kommer has asked for an offer of a bag cutter and an offer of a dumping and bagging line. The only components Kommer have to arrange themselves are the silos. Kommer has already bought most of the silos in the past. We explain the working of the components of the investment, and we make an ABC-analysis of the repacking costs per ton per repacking option. Firstly, we explain the working of the components of the bag cutter in Section 4.1.1. Secondly, we explain the working of the components of the dumping and bagging line in Section 4.1.2. Thirdly, we create an ABC-analysis to calculate the repacking costs per ton per repacking option in Section 4.1.3. The prices are put in Appendix A. Prices are including installation and transport.

4.1.1 Working of the bag cutter

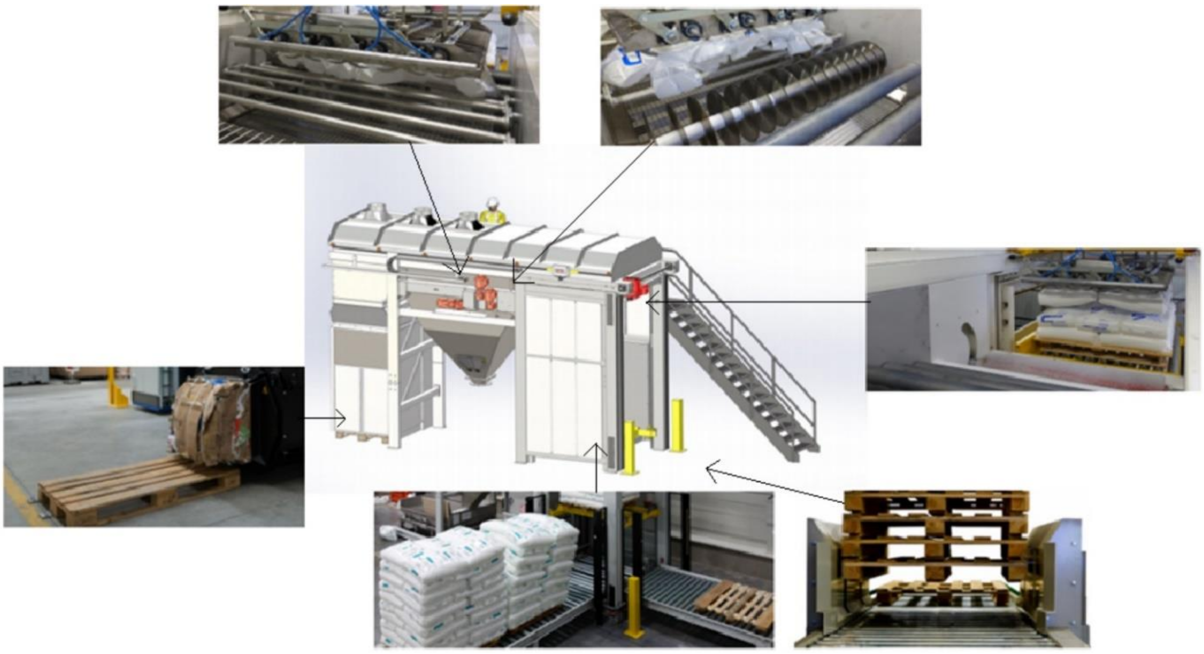


Figure 10. Functions of the bag cutter.

In Figure 10, the new bag cutter is shown with extra pictures to focus on central points. The function of the bag cutter is to cut the full bags automatically and separate the raw materials from the empty bags and from the empty pallets. The machine is designed to process 25 to 30 ton per hour. The bag cutter automatically empties a pallet, cut the bags, stack the pallets, and presses the empty bags to bales. This means a forklift driver needs to place full pallets at the start and remove a pile of pallets and bales of waste. The rest goes automatically.

The process starts with the conveyor belt. The forklift driver places the full pallets on the conveyor belt. There is room for 3 pallets on the conveyor belt. The conveyor belt transports a full pallet in the lift. The full pallet in the lift lifts to the shuttle with gripping hooks. The integrated grippers grab the top layer of bags, as shown in the picture on the right. Then the lift moves down. The top layer of bags is now hanging onto the shuttle. The shuttle then moves horizontally over the rotating blades, as shown in the picture in the upper right corner. The blades cut the bags open, and the product falls into the product buffer. From there the product can be transported in the rest of the process. An agitating system ensures that the bags are emptied. The agitating system is shown in the picture in the upper left corner. Once the bags have been emptied, the shuttle moves to the farthest position and drops the empty bags in the empty bag compactor. Then the empty bags are pressed into bales, as shown in the picture in the left corner at the bottom. The bale is pressed onto a pallet and can easily be removed by the forklift driver. There are approximately 4000 bags needed for one bale, so every 100 ton will result in a bale. This means that every 4 hours one bale is pressed, so 2 or 3 bales will be pressed on a working day. After releasing the empty bags, the shuttle returns to its starting point to grab the next layer. When the pallet is completely empty, the pallet moves on the conveyor belt to the right and is stacked in a pile. The height of a stack is maximum 15 pallets. The stacks can be removed by the forklift driver.

4.1.2 Working of the dumping and bagging line

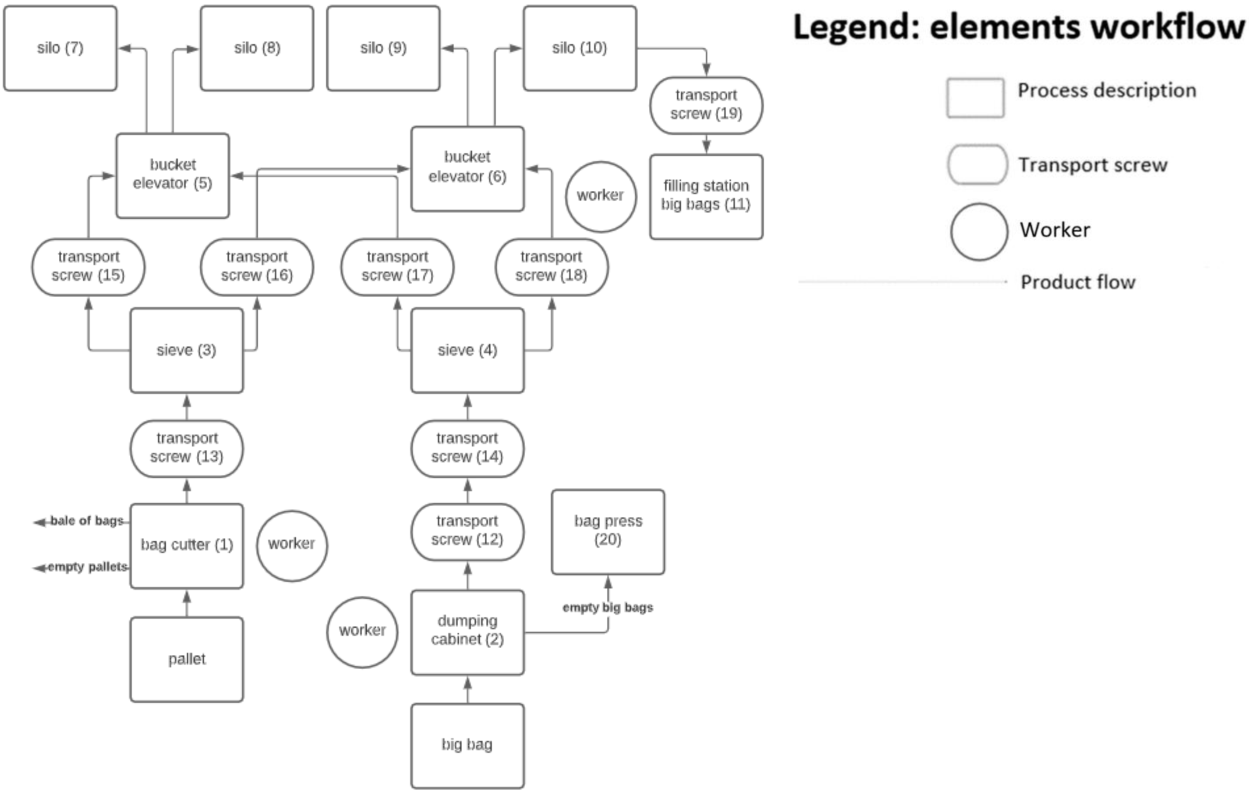


Figure 11. Value Stream Mapping of the raw materials; investing in a new repacking process.

The Value Stream Map in Figure 11 shows the product flow of the dumping and bagging line. The output of the product of the bag cutter is connected to a transport screw. There is a legend provided to explain the shapes and arrows in the product flow. If something else than the product is transported the arrow is labelled. The process is designed to repack 50 ton per hour. However, this is due to the double arrangement. The bag cutter is designed to repack 25 to 30 ton per hour. This is the same for the dumping cabinet and the filling station of the big bags, as well as the other components.

The process starts with the input of bags and big bags. The bag cutter is explained in the other section. The dumping cabinet construction is a combination of three dumping cabinets. The advantage of this system is that multiple big bags can be cut at the same time. There is a transport screw beneath to transport the product to the next transport screw, which transports the product to the sieve. The cutting of the big bags is not automated. Next to the dumping cabinets is a small platform where a worker can stand to cut the big bags.

There are two sieves in the process. The first sieve sieves the product that comes from the bag cutter, the second sieve sieves the product that comes from the dumping cabinet. The sieves are placed on a platform. The sieves have an under funnel with a controlled 2-way valve to choose which route the product will take. Four transport screws are leading from the two sieves to the bucket elevator. In this way, every sieve can send the product to every bucket elevator. The inside of the sieve can be taken out to be able to collect the waste.

There are two bucket elevators in the process. The bucket elevators both have an input section at the bottom and an output section at the top of the bucket elevators. The bucket elevators both have a controlled 2-way valve to choose which silo will be filled. Two filling tubes are connected to the output on both of the controlled 2-way valve. The filling tubes are leading to the silos.

There are four silos needed in the process. One silo can contain 25 ton, which is also the load of one truck. Each silo has a discharge bellow to make sure that the silos are emptied controlled in a truck. From the fourth silo there is a transport screw leading to the filling station of the big bags. The silos will stand outside the warehouse in order to save room inside and to make it easy to fill trucks. The silos need to be placed with the use of steel and a concrete floor.

The filling station of the big bags consists of a bunker with weighing cells and pneumatic slide. The bunker is filled by one of the silos. The filling process goes manually. A worker places an empty big bag under the bunker and fills the big bag with use of the weight system. When the big bag is full the big bag is removed from the filling station with help of the forklift driver.

4.1.3 Repacking costs new repacking process

In this section we provide a cost-benefit analysis to analyse the costs that occur if Kommer wants to invest in a new process. We use the Activity Based Costing (ABC) method to determine the repacking costs per ton per repacking option. In Table 7 the ABC-analysis of the repacking costs per ton is calculated of the solution of investing in a new repacking process. We identify six different costs of repacking a product with the new process. The costs are the forklift, the space costs of the warehouse, the staff costs, the investment, the energy costs and the repairs and maintenance. We discuss the way we calculate these costs. The average repacking costs per ton per repacking option are listed at the bottom of the ABC-analysis in Table 7.

ABC-analysis investing in a new repacking process		from bags to bulk	from bags to big bags	from big bags to bulk
forklift				
rent per year	€ 6,000.00			
electricity and external costs per year	€ 900.00			
current capacity	74,000			
total costs forklift per ton		€ 0.09	€ 0.09	€ 0.09
space costs warehouse				
rent of 1 square meter per year	€ 45.00			
number of square meters	326			
space costs per year	€ 14,670.00			
capacity per year	74,000			
space costs per ton		€ 0.20	€ 0.20	€ 0.20
staff costs				
staff costs per hour per employee	€ 31.80			
number of employees (incl. forklift driver)		2	3	2
capacity per hour		25	25	25
staff costs per ton		€ 2.54	€ 3.82	€ 2.54
depreciation				
depreciation per ton		€ 0.79	€ 0.74	€ 0.63
energy costs				
energy costs per hour		€ 2.93	€ 2.50	€ 2.50
capacity per hour		25	25	25
energy costs per ton		€ 0.12	€ 0.10	€ 0.10
reparations and maintenance				
reparations and maintenance costs per year	€ 13,254.95			
costs of 12 maintenance days per year	€ 5,760.00			
reparations and maintenance costs per ton		€ 0.26	€ 0.26	€ 0.26
repacking costs per ton		€ 4.00	€ 5.20	€ 3.82

Table 7. ABC-analysis investing in a new repacking process.

Forklift

The first cost is the forklift. Kommer hires a forklift to assist the repacking process. Additional costs of the forklift are electricity and standard maintenance. Since the forklift is equally involved in every repacking option, we divide the costs of the forklift per ton with a total expected required capacity of 74,000 ton.

Space costs warehouse

The second cost is the cost of the space of the warehouse. The total space that is reserved for the new process is 326 squared meter. This is including the bag cutter and the silos. Since Kommer is already hiring external space outside the company for storage, every square meter that cannot be used for storage also has to be hired externally. Therefore, the space costs of the new process is equal to the rental costs per square meter multiplied with the number of squared meters that is reserved for the new process. Since it is difficult to determine how many square meters a single repacking option needs, we divide the total space costs with the total capacity needed to determine the space costs per ton.

Staff costs

The third cost is the cost of hiring the staff. The total staff costs per ton are calculated by the staff costs per hour multiplied by the number of employees needed divided by the capacity per hour. In the new situation Kommer wants to operate no more than 10 hours a day. Therefore, we assume that the staff works 10 hours a day. This means that Kommer has to pay 2 overtime hours. According to Table 8, the staff costs are 30 euro per hour and the overtime hours are costing 30% more. This means that the average staff costs per hour is 31.80 euro.

As shown in the ABC-analysis, there are 2 or 3 employees needed per repacking option. The bag cutter needs one employee to operate the bag cutter and to make sure the product is transported to the right silo. The big bag filling station needs one employee to fill the big bags. The dumping cabinet to empty big bags also needs an employee to cut the bags. Every repacking option also needs a forklift driver. The forklift driver places pallets on the assembly line of the bag cutter, hold big bags above the dumping cabinet and removes big bags from the filling station of the big bags.

staff costs	
staff costs per hour	30
extra costs overtime	30%
fixed hours per day	8
overtime per day	2
average staff costs per hour per employee	€ 31.80

Table 8. Average staff costs per hour per employee.

Depreciation

If Kommer wants to buy new machinery, they need to invest a certain amount of money. Therefore, we calculate the investment per ton per repacking option. To do so we first calculate the total investment per repacking option, then we calculate the interest per repacking option and as last we calculate the capacity over the total lifespan of the investment. If we have these numbers, we can calculate the investment per ton per repacking option by dividing the sum of the investment and interest by the total capacity per repacking option over the lifespan of the investment, as shown in Table 9. The expected lifespan of the process is 20 years, according to the two offers.

Firstly, we calculate the total investment per repacking option. Therefore, we have divided the investment over the repacking options. We use the Value Stream Map in Figure 11 to determine which percentage of the component is used by which repacking option based on the expected required capacity. For every component we investigate which repacking options are using this component. Then we sum the investment up per component per repacking option. In Table 9, the total investment per repacking option is shown. The investment will be paid back in 10 years. The total investment is the sum of the new prices of the components, excluding the bag press of the big bags because we can take the bag press that is in the current process. The new price of every component can be found in Appendix A. We need to divide the investment between the repacking option based on the required capacity without the buffer capacity. The required capacity can be found in Table 9. We calculate which percentage of a component is used by which repacking option. Then we divide the investment between these repacking options. Every repacking option get that percentage of the costs that it is using on capacity.

Secondly, we calculate the interest over the investment per repacking option. If Kommer decides to invest in a new process then Kommer borrows the money from the bank. According to the financial manager of Kommer, the interest rate of a mortgage lies around 0.25% per month for a mortgage of 10 year. The mortgage will be paid off monthly. If Kommer decides to borrow money then the mortgage will be linear. This means that the mortgage will be paid off with the same amount every month and the interest of the mortgage will be added to this number. This means that the monthly payment decreases over time because over time the amount of interest will decrease.

The mortgage will be paid off in 10 years. As explained in Equation 14 we can calculate the total interest over a 10 year period by multiplying the monthly interest rate with the average mortgage multiplied by the investment per repacking option. “k” is the number of months still to pay the mortgage off. The more months to pay, the more interest to pay. The average mortgage to pay interest over per month is a 61/120 piece of the initial investment.

$$total\ interest\ over\ a\ 10\ year\ period = \sum_{k=1}^{120} \frac{k * monthly\ interest\ rate * investment}{duration\ of\ the\ mortgage\ in\ months}$$

Equation 14. Formula for total interest over the mortgage.

Thirdly, we calculate the capacity per repacking option over the total lifespan of the components. According to the two offers, the process can be operating for at least 20 years. Therefore, we calculate the total required capacity per repacking option by multiplying the required capacity per year with 20.

If we have the investment and interest per repacking option and the capacity over a 20-year period per repacking option we can calculate the investment per ton per repacking option. We then divide the sum of the investment and interest by the total capacity per repacking option over the lifespan of the investment. An overview of the calculation with the investment per ton per repacking option can be found in Table 9.

depreciation	from bags to bulk	from bags to big bags	from big bags to bulk	total
investment over a 10 year period	€ 505,020.49	€ 218,183.70	€ 219,764.81	€ 942,969.00
interest over a 10 year period	€ 76,384.35	€ 33,000.28	€ 33,239.43	€ 142,624.06
total investment	**€ 581,404.84**	**€ 251,183.99**	**€ 253,004.23**	**€ 1,085,593.06**
capacity per year	37,000	17,000	20,000	
capacity over a 20 year period	740,000	340,000	400,000	
depreciation per ton	**€ 0.79**	**€ 0.74**	**€ 0.63**	

Table 9. Depreciation per ton per repacking option.

Energy costs

The energy costs per component of the new process can be found in Appendix A. The energy costs per hour are calculated with the assumption that an engine uses 80% of its power and with an electrical cost of 0.12 euro per kWh. For every repacking option we investigate which component is used in the process. Then we sum the energy costs up per component per hour to determine the energy costs per hour per repacking option. The energy costs per ton are calculated by dividing the energy costs per hour with the capacity per hour as shown in Table 7.

Repairs and maintenance costs

The repairs and maintenance costs are difficult to determine exactly. Therefore, we assume that the repairs and maintenance costs are approximately the same as last year. In order to prevent downtime in the new process, the service engineer advises to have one preventive maintenance day per month. Components will last longer, the downtime will decrease and defects will be detected in an early stadium. The repairs and maintenance costs of last year were 13,254.95 euro and the costs of 12 maintenance days per year will be 5,760.00 euro. Hiring a service engineer for a maintenance day costs 60 euros per hour and a maintenance day consists of 8 working hours. In Table 7 the costs are calculated per ton for every repacking option.

4.1.4 Conclusion

In this section we have explained the possibility of investing in a new repacking process. The new repacking process consists of a bag cutter which needs less staff than at the current repacking process. Further, the new bag cutter consists of a pallet stacker and of a bag press which saves also staff hours. The amount of waiting time of (dis)connecting trucks is negligible because of the implementation of silos. Since every output has two silos, the repacking process can continue with filling the second silo if the first silo is full. If the second silo is full, the first silo is already emptied. In that way there will always be at least one silo empty. In order prevent downtime, a service engineer needs to inspect and clean the process where needed at least once per month. The new repacking process consists of two inputs and two outputs. It is possible to operate these two inputs separately from each other. This is different from the repacking process currently used. Together with the decrease of idle time, this increases the capacity rapidly to a sufficient level with a buffer capacity for unexpected orders. The repacking costs per ton are significantly decreased for all three repacking options. The total repacking costs are between 3.82 and 5.20 for the different repacking options.

4.2 Improving the current repacking process

In this section we discuss the possibility to adapt the current process. We want to decrease the repacking costs per ton and increase the capacity of the current process. In Chapter 3 it became clear that the staff costs are the most important costs. We can reduce the staff costs per ton in two ways. The first way is to repack more tons in an hour to spread the staff costs over more tons. The second way is to repack the same number of tons with less staff. It is also required to have enough capacity with buffer capacity for peak demand. Firstly, we discuss the changes that we can make in the current process in Section 4.2.1. Secondly, we make the ABC-analysis of improving the current process in Section 4.2.2.

4.2.1 Improving current process

To repack more tons in an hour in the current process, we can decrease the idle time. The idle time consists of the time to (dis)connect the trucks and the downtime of the current process. We can repack more tons in an hour if we replace the filling station of the trucks with silos to waste no time with placing and connecting the truck to the filling station. The silos are too high to place inside. However, the current process is placed in the middle of the warehouse instead of against a wall close to the silos. The longer the distance to travel raw materials over, the more transport screws are needed. This means that there are many transport screws needed to connect the current process with the silos.

According to the steady state distribution, the repacking capacity per hour will decrease when the raw materials must travel through more transport screws. Every transport screw further in the process need to go a little faster to prevent accumulation. This means that the repacking capacity per hour will decrease with every extra transport screw the raw materials need to go through to repack the products. For short distances this is not a big problem but transporting a product to the other side of the warehouse will slow down the repacking process significantly. Therefore, we cannot use the silos in the current process.

We can repack more tons in an hour if we do something about the downtime that occurs. According to the current service engineer, preventive maintenance will decrease most of the downtime. Therefore, he advises to have one preventive maintenance day per month. This will bring the capacity up to the level of seven years ago, when Kommer installed the repacking process. This means preventive maintenance will increase the capacity from 12.5 ton per hour to 15 ton per hour.

To decrease the number of employees needed to repack the same number of tons, we can replace the current bag cutter with the bag cutter as explained in Section 4.1.1. This means we need one employee operating the bag cutter instead of two employees who are putting bags in, and this saves us one employee when we repack bags to big bags or bulk. The output of the bag cutter is placed above the funnel to connect the bag cutter with the rest of the process. The bags and pallets are sorted automatically with this bag cutter. The changes of the components of the old process can be found in Appendix A. If we compare the Value Stream Map of the current process in Figure 1 with the Value Stream Map of improving the old process in Figure 12, we can see that there are components removed. The removed components are the lift table, the assembly line, the current bag cutter, and the extractor above the current bag cutter. The numbers in the Value Stream Map in Figure 12 are referring to Table 20 in Appendix A of improving the old process.

In the future Kommer needs to repack 74.000 tons per year. A year has 260 working days. The capacity per hour is 15 ton. This means we need to be able to repack for 19 hours a day. 15 tons per hour is lower than when we invest in a new process. Investing in a new process will result in a capacity per hour of 25 ton. Since Kommer wants his employees to work no more than 10 hours on a day, Kommer can decide to work in 2 shifts of 8 hours. The remaining 3 hours will be done with a second repacking process. This process has some remaining capacity which can be used for the last 3 repacking hours and as buffer capacity.

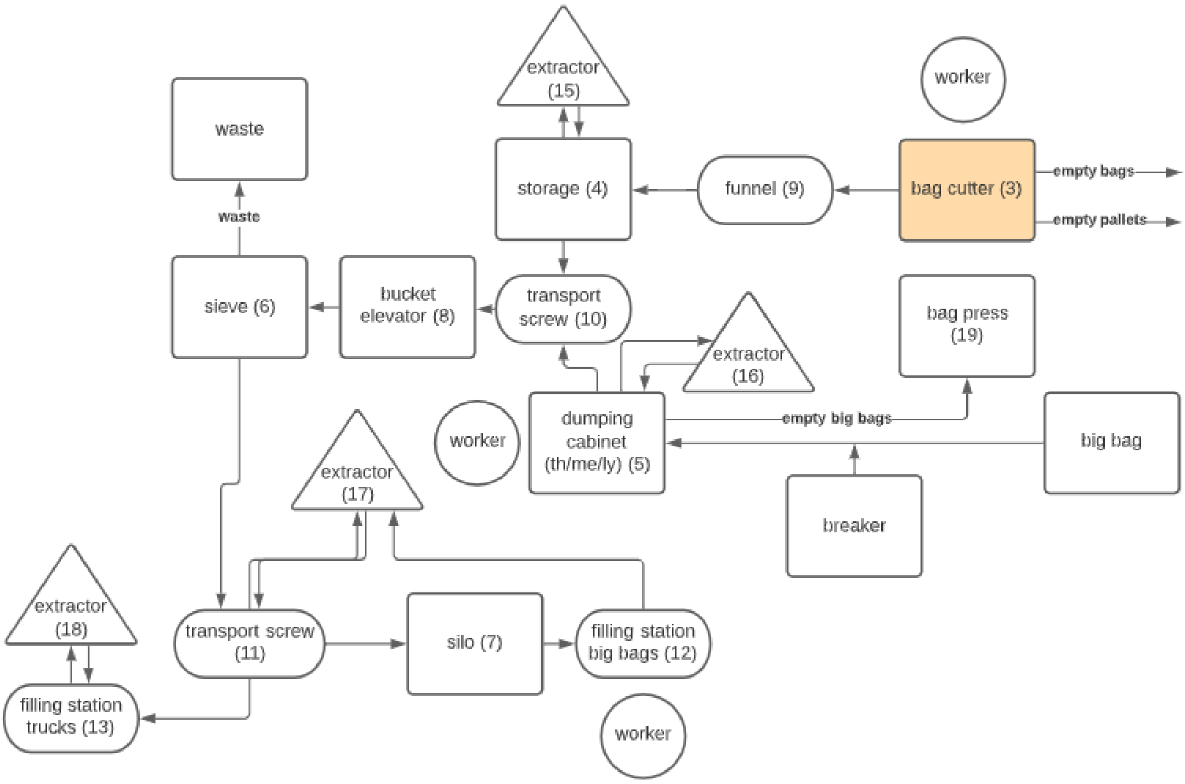


Figure 12. Value Stream Mapping of the raw materials improving the old repacking process.

4.2.2 Repacking costs improving current process

Activity-Based Costing (ABC) analysis renovating current situation		from bags to bulk	from bags to big bags	from big bags to bulk
forklift				
rent per year	€ 6,000.00			
electricity and external costs per year	€ 900.00			
current capacity	74,000			
total costs forklift per ton		€ 0.09	€ 0.09	€ 0.09
space costs warehouse				
rent of 1 square meter per year	€ 45.00			
number of square meters	229			
space costs per year	€ 10,305.00			
current capacity	74,000			
space costs per ton		€ 0.14	€ 0.14	€ 0.14
staff costs				
average staff costs per ton		€ 4.93	€ 7.07	€ 4.30
depreciation				
depreciation costs per ton current components		€ 0.39	€ 0.51	€ 0.37
investment new components	€ 380,500.00			
interest	€ 57,550.63			
capacity per year	74,000			
capacity over a 20 year period	1,480,000			
depreciation costs per ton new components		€ 0.22	€ 0.22	€ 0.00
total depreciation costs per ton		€ 0.61	€ 0.72	€ 0.37
energy costs				
energy costs per hour		€ 5.51	€ 5.51	€ 3.35
capacity per hour	15			
energy costs per ton		€ 0.37	€ 0.37	€ 0.22
reparations and maintenance				
reparations and maintenance costs per year	€ 13,254.95			
costs of 12 maintenance days per year	€ 5,760.00			
reparations and maintenance costs per ton		€ 0.18	€ 0.18	€ 0.18
repacking costs per ton		€ 6.32	€ 8.58	€ 5.30

Table 10. ABC-analysis changes (yellow) improving current process.

In this section we provide an ABC-analysis to calculate the repacking costs per ton per repacking option if Kommer wants to improve the current process. The ABC-analysis, as shown in Table 10, distinguishes the costs between the different repacking options. There are six different costs that occur: The costs are about the forklift, the space of the process, the staff costs, the investment and depreciation costs, the energy costs and the repairs and maintenance. Four of these costs are going to change if we choose this solution. We will explain the way we calculate these costs. The first and second costs are not going to change and therefore we will not discuss these costs.

Staff costs

The third cost item is the staff costs. In Table 11 the average staff costs per ton per repacking option is listed. We calculate the average staff costs per ton per repacking option by calculating the weighted average of the staff cost per ton of the improved process and the second process. We need one less employee on the bag cutter. This decreases our staff costs. To calculate the average staff costs per ton we will use the following information:

- 19 hours needed for repacking on a day
        - (Required capacity 285 ton/day) /(available capacity of 15 ton/hour)
    - 16 hours (2 shifts of 8 hours) at the current repacking process
        - 32.63 euro per employee per hour (30 euro per employee per hour with 8.75% allowances for working in shifts)
    - 3 hours at a second repacking process
        - 30 euro per employee per hour

As shown in Table 11, we can calculate the staff costs per ton per repacking option on both processes by multiplying the staff costs per hour per employee with the number of employees and dividing the result with the capacity in tons per hour. Then we calculate the average staff costs per ton per repacking option by taking the weighted average of the staff costs per ton of the two repacking processes based on the working hours.

staff costs		**from bags to bulk**	**from bags to big bags**	**from big bags to bulk**
staff costs shifts per hour per employee	€ 32.63			
number of employees (incl. forklift driver)		2	3	2
capacity per hour	15			
staff costs per ton		€ 4.35	€ 6.53	€ 4.35
working hours	16			
staff costs second repacking machine per hour per employee	€ 30.00			
number of employees (incl. forklift driver)		4	5	2
capacity per hour	15			
staff costs per ton		€ 8.00	€ 10.00	€ 4.00
working hours	3			
average staff costs per ton		**€ 4.93**	**€ 7.07**	**€ 4.30**

Table 11. Average staff costs per ton per repacking option improving current process.

Depreciation

The fourth cost is the depreciation of the components. We take the depreciation costs per ton to calculate the component costs. However, the bag cutter needs an investment to be placed in the process. Therefore, we need a mortgage which will have the same conditions as explained in Section 4.1.3. The investment is 380,500 euros. The conditions are that the mortgage will be paid back over a ten-year period against 0.25% interest per month. This results in 57,550 euro of interest costs. Since there are some components removed in the improved process, the depreciation will be a little bit lower. We calculate the depreciation by dividing the depreciation costs per component over the number of tons the current process uses as explained in Chapter 3. The depreciation per component can be found in Appendix A.

The total depreciation costs of the investment consist of the investment and the interest over a ten-year period. The repacking process will last at least 20 years, so we divide the investment over the capacity for 20 year. The total investment costs are calculated the same way as explained in Section 4.1.3. The capacity stays the same. The company can repack more in an hour when there is preventive maintenance, but the company also no longer wants his employees to work 12 hours a day. In the current situation, Kommer was able to repack 150 tons in 12 hours. Due to preventive maintenance Kommer will be able to repack 150 tons in 10 hours in the improved process. This means the available capacity increases from 150/12=12.5 ton per hour to 150/10=15 ton per hour. Repacking 15 tons for 10 hours has the same result as repacking 12.5 tons in 12 hours. In both cases there will be 150 tons repacked on a day. This means the current capacity is still 39,000 tons per year.

Energy costs

The fifth cost is the energy costs. The new bag cutter cost more on energy per hour than the old components. The total energy costs are calculated the same way as in Section 4.1.3. The energy costs per component can be found in Appendix A. We calculated the energy costs per ton by dividing the energy costs per hour with a repacking capacity of 15 tons per hour. The results can be found in Table 10.

Maintenance costs

The sixth costs are the repairs and maintenance costs. The repairs and maintenance costs are approximately the same for improving the old process as for investing in a new process. Therefore, we take the same costs as calculated in Section 4.1.3. However, we add the costs of 12 preventive maintenance days per year.

4.2.3 Conclusion

In this section we have explained the possibility of improving the current repacking process. The corresponding costs per ton for every repacking option are shown in Table 10. To decrease the amount of manual work at the current repacking process, we have the possibility to change the bag cutter with the bag cutter explained in Section 4.1.1. In that way we can decrease the amount of manual work. Because the current process is placed in the middle of the warehouse and the silos need to stand outside, the distance is too far to use the silos. Therefore, we cannot decrease the amount of waiting time of (dis)connecting trucks. If the service engineer maintains the current repacking process at least once a month, the downtime can be decreased to almost 0 hours per day. The capacity can only be increased to a sufficient level if Kommer decides to work in shifts.

4.3 Solution choice

The goal of our assignment was to answer our research question:

"Which repacking process has the lowest costs of the raw materials per ton while having sufficient capacity to handle orders?"

ABC-analysis repacking costs per ton	from bags to bulk	from bags to big bags	from big bags to bulk
current process	€ 9.46	€ 12.19	€ 6.67
improving current process	€ 6.32	€ 8.58	€ 5.30
investing in a new repacking process	€ 4.00	€ 5.20	€ 3.82

Table 12. ABC-analysis repacking costs per ton per repacking option at the current process and for the two solutions.

In Sections 4.1 and 4.2 we have made an analysis to calculate the repacking costs per ton per repacking option. The first analysis was made to calculate the repacking costs per ton per repacking option if Kommer decides to invest in a new repacking process. The second analysis was made to calculate the repacking costs per ton per repacking option if Kommer decides to improve the current process. In Chapter 3 we have made an ABC-analysis to calculate the repacking costs per ton per repacking option in the current situation. The results can be found in Table 12. In the current situation it is for all three repacking options the most expensive to repack raw materials in comparison to the two solutions. Therefore, we are going to choose one of the two solutions. When we identify the three different repacking options, we see that for all three repacking options the best option is to invest in a new repacking process. This will result in the lowest repacking costs per ton. However, if we want to invest in a new repacking process, we need to meet two constraints. We need to be sure that there is enough repacking capacity to serve the customer and we also need to be sure that the hurdle rate is met. Firstly, we calculate if there is enough capacity available in Section 4.3.1. Secondly, we investigate if the solution is profitable enough in Section 4.3.2.

4.3.1 Capacity constraint

If we want to invest in a new repacking process, we need to be sure that there is enough repacking capacity in order to serve the customer without letting the customer wait too long before repacking orders are processed. The new process distinguishes between orders of repacking bags and orders of repacking big bags. Firstly, we explain how we calculate the waiting time before an order is repacked. Secondly, we provide an example calculation of how we calculated the average waiting time before an order is repacked. Thirdly, we discuss the results of our calculation of the waiting time of repacking bags. Fourthly, we discuss the results of our calculation of the waiting time of repacking big bags.

Waiting time

If Kommer wants to invest in a new process, there must be sufficient capacity to repack the orders. The repacking orders are divided over two sub-processes. There are two inputs in the new process. The first input is a bag cutter. The two repacking options who are starting at the bag cutter are "from bags to big bags" and "from bags to bulk", because for these two repacking options bags need to be cut open. The second input is to cut the big bags. The repacking option that is using the big bag cutter is "from big bags to bulk", because for this repacking option big bags need to be cut open. Both sub-processes can repack 250 ton per day. This means that in total they can repack 500 ton per day.

To investigate if the capacity of a sub-process is enough, we calculate what the expected average waiting time in days is before an order can be repacked. It can be the case that repacking orders are not ordered evenly throughout the year but are clustered together around certain days. This can have the result that the process has on some days almost nothing to repack, and on other days too much repacking orders to process that day. This with the result that the waiting times before an order is repacked increases. Because we do not want the waiting times to be too high, we use the expected capacity per day to find out whether the orders are spread out good enough over a year.

We calculate the expected capacity per day by multiplying the demand of every day of 2020 with the expected growth. First, we sort the orders of the year 2020 of repacking bags by the orders of repacking big bags. Then we multiply the repacking orders with a growth rate of 1.02, as calculated in Equation 6 in Section 2.3. We used for the calculations the unrounded number calculated by 74,000/72,317. 74,000 is the expected demand and 72,317 is the current demand. This growth rate is the expected growth rate of the total amount of tons repacked in the process in the year 2020. For simplicity we assume that this growth rate per year for the whole process is the same per day per sub-process. Now we have calculated with data of the year 2020 the expected capacity per day per sub-process. At the big bag line, big bags are cut manually. At this line it is also possible to cut bags. However, for bags it is more expensive to be cut manually than to be cut by an automatically bag cutter. Therefore, we assume that for our calculation bags are not cut manually at the big bag input.

With help of a waiting list, we can calculate the expected waiting time per day. Everyday repacking orders come in. We collect the orders of a day and plan them for the next day. We schedule the orders a day later because we have no data available at which moment of the day an order arrive. If an order arrives at the end of the day, it is unrealistic to assume that the order is repacked at the same day. If the arrived orders are in total less than 250 ton and there is no waiting list, then every order can be repacked one day later. This does not result in any extra waiting time above the standard waiting time of 1 day. It can be the case that there are more than 250 tons of orders coming in on a day. This means that the surplus is put on the waiting list. If this is the case, then the orders that arrive tomorrow must wait to be scheduled until the waiting list is empty. This can result in a case that less than 250 tons of orders arrive on a day, but because of a waiting list some orders cannot be scheduled. These orders are then put on the waiting list. Every day we investigate how many tons are on the waiting list and so we can determine what the average waiting time is. To make our calculation more understandable we provide an example calculation. In order to determine the maximum waiting time and to provide insight in how often a certain waiting time occurs, we also determine per day the length of the waiting list in days. Every 250 ton can be processed in 1 day, so we divide the number of tons on the waiting list by 250 to get the waiting time in days. We round this number up to whole days to get a clear overview.

Example calculation waiting time

We illustrate the way how we calculate the average waiting time of the orders by means of an example. Table 13 shows the calculation of the waiting list of four consecutive working days. Each day has the same amount of available capacity of 250 ton.

daynumber	required capacity	available capacity	shortage	reserve	waiting list	waiting days
1	325	250	75	0	75	1
2	471	250	221	0	296	2
3	70	250	0	180	116	1
4	130	250	0	120	0	0

Table 13. Waiting list to calculate waiting time.

The waiting list indicates the number of tons we take with us to the next day because these could not yet be scheduled. We do not consider the individual order size. It is therefore possible that one day there is still room to schedule 10 tons and the next order to be scheduled has a size of 25 tons. In our calculation, we then assume that 10 tons of this order will be scheduled, and the other 15 tons are put on the waiting list. The reason for this assumption is that we do not have any information about the individual order size. The average waiting time of the waiting list in days can be determined by dividing the sum of the waiting lists by the total number of tons repacked. We assume that orders arriving on day "n" are scheduled and repacked on day "n+1" if these orders are not put on the waiting list. We do not include this day in our calculation of the waiting list. For our calculation we assume that at the start of day 1 the waiting list is empty.

On day 1, a total of 325 tons of repacking orders are ordered by various customers. These orders are scheduled for day 2. Because there is only room to repack 250 tons on each working day, we have a shortage of 75 tons. This means these 75 tons can not be repacked on day 2 and therefore these tons are put on the waiting list. This means that these 75 tons will be moved to day 3. As there is room per day to repack 250 ton, the extra waiting time for these 75 tons will be between 0 and 1 day. To provide insight in how often a certain waiting time occurs, we provide in the last column the length of the waiting list in days. These waiting times are rounded up to whole days. This means that the orders on the waiting list have to wait 1 day extra before these orders can be repacked.

On day 2, a total of 471 tons of repacking orders are ordered by various customers. These orders are scheduled for day 3. However, because there is only room to repack 250 tons on a working day, we have a shortage of 471-250=221 ton. There are also 75 tons on the waiting list. The orders who came in first are repacked first. This means that the orders on the waiting list first need to be scheduled before we start scheduling the orders that arrived on day 2. This means that the shortage increases from 221 to 75+221=296 ton. These orders are put on the waiting list. Because there is on a single day room to repack 250 ton, there is between 1 and 2 days of work on the waiting list.

On day 3, a total of 70 tons of repacking orders are ordered by various customers. These orders are scheduled for day 4. However, because there are orders on the waiting list, we have to repack first the orders on the waiting list. The orders on the waiting list are good for 296 tons. The waiting list contains more than 250 tons, which means that there is work enough for 1 day. This means that 250 ton on orders can be put of the waiting list and the 70 ton on orders of day 3 can be placed on the waiting list. This means that the waiting list decreases with 180 ton. The total number of tons on the waiting list decreases to 296-180=116 ton. This amount is more than 0 and less than 250 ton. This means that there is between 0 and 1 day of work on the waiting list.

On day 4, a total of 130 tons of repacking orders are ordered by various customers. These orders are scheduled for day 5. The waiting list contains 116 ton of orders. This means that the total amount of ton on repacking orders is 130+116=246 ton. Since this number is less than 250, we can schedule both the orders on the waiting list as the orders on day 4 on day 5. This means that every order can be scheduled for the next day and that the waiting list is empty. We even have 4-ton repacking capacity left. As we can start working on an order after an order is placed, we cannot use these 4 tons of remaining capacity.

We calculate the average waiting time for an order in the following way: the total amount of tons ordered in the first 4 working days is 325+471+70+130=996 ton. The sum of the waiting lists is 75+296+116=487 ton. This means that the average waiting list is 487/996=0.5 day. If there is no waiting list the orders are scheduled one day later. This means a standard waiting time of 1 day. Therefore, the total waiting time is the sum of the standard waiting time and the waiting time on the waiting list. This is 1+0.5=1.5 day. The spread of the waiting days is as follows: 1x 2 days, 2x 1 day and 1x 0 days. This means that if a customer orders on a random day, he has a chance of 25% on a waiting time of 2+1=3 days, 50% on a waiting time of 1+1=2 days and 25% on a waiting time of 0+1=1 day.

Waiting time repacking bags
The sub-process that repacks the bags need to be able to repack an expected required capacity of 53,123 ton per year. This means that there is on average 53,123 ton/258 days=206-ton capacity needed per day to fulfill demand. With an available capacity of 250 ton per day this is enough. However, it can be the case that orders are not spread out evenly over the year but are clustered together around certain days. If this is the case, this has the result that on some days the process has a few orders to repack and on other days the process has too many orders to repack on that day. This with the result that waiting times for orders will increase. Because we do not want the waiting times to be too high, we use the expected capacity per day to find out if the spread of the orders is good enough. The total expected waiting list is 109,183 ton. As calculated in Equation 15, this means that 1 ton stands on average 109,183/53,123=2 days on the waiting list. Orders have a standard waiting time of 1 day. This means that the average waiting time for a bag repacking order is 2+1=3 days.

$$average\ waiting\ time\ in\ days\ repacking\ bags = \frac{total\ waiting\ list}{total\ required\ capacity} + 1 = \frac{109{,}183}{53{,}123} + 1 = 3$$

Equation 15. Average waiting time in days repacking bags.

In Figure 13 we show the expected required capacity per day. In Appendix D the required capacity per day of 2020 is listed. When we multiply this data with the growth rate, we get the expected required capacity per day. The available capacity is 250 ton per day, which is shown by the orange line.

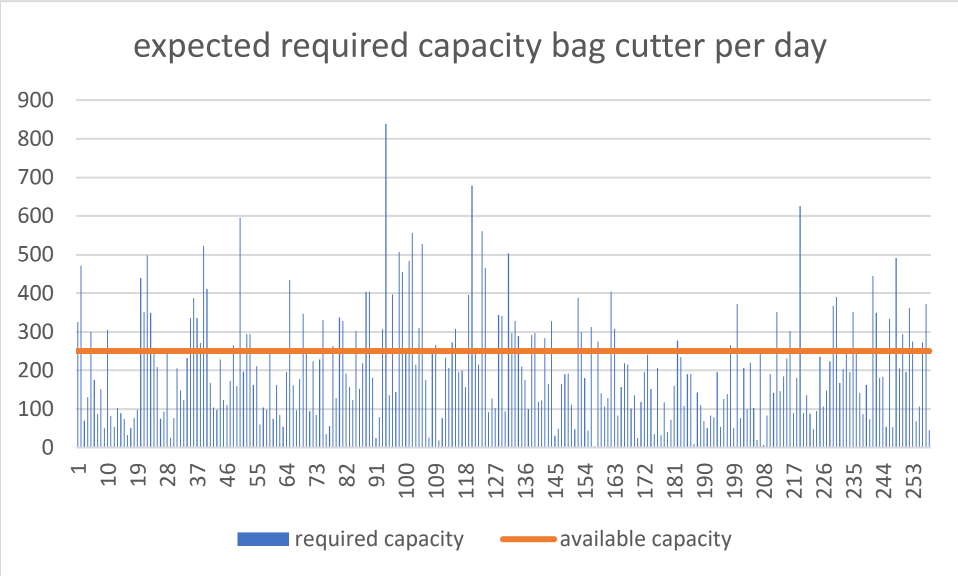


Figure 13. Expected required capacity of the bag cutter per day.

We now know the average waiting time before an order to repack bags is processed. However, we want to know how the waiting times per day are spread out. We can find in the third column in Table 14 the waiting times in days before an order is repacked. The waiting time is the sum of the length of the waiting list in days (column 1) and the day the order is repacked (column 2). In the fourth column we can see how often we expect that a certain waiting time occurs in a year according to our calculation. In Figure 14 we can see that the longer the waiting time is, the less we expect this waiting time to occur. In the fifth column in Table 14 we can see how often a waiting time happens cumulative. In column 4 we can see that at 99 working days orders are repacked within 1 day and that at 62 working days orders are repacked within 2 days. This means that on 99+62=161 days, orders need at a maximum two days before they are repacked. In column 6 we have translated this in a percentage of the total amount of days. So, there is a chance of 161/258=62% that an order is repacked within 2 days. What stand out is that, according to our calculation, we expect 80% of the orders repacked within 5 working days and 100% within 10 working days. Therefore, we assume that the chance that orders need more than two weeks before they are repacked is negligible. According to Kommer, an average waiting time of 3 days, where 80% of the orders can be repacked within a week, is fast enough. Therefore, we meet the condition to have enough repacking capacity to repack bags without waiting too long before an order is repacked.

length waiting list in days	standard waiting day	total waiting time	number of times	cumulative	cumulative %
0	1	1	99	99	38%
1	1	2	62	161	62%
2	1	3	26	187	72%
3	1	4	14	201	78%
4	1	5	6	207	80%
5	1	6	14	221	86%
6	1	7	4	225	87%
7	1	8	16	241	93%
8	1	9	13	254	98%
9	1	10	4	258	100%

Table 14. Expected waiting times in days to repack bags.

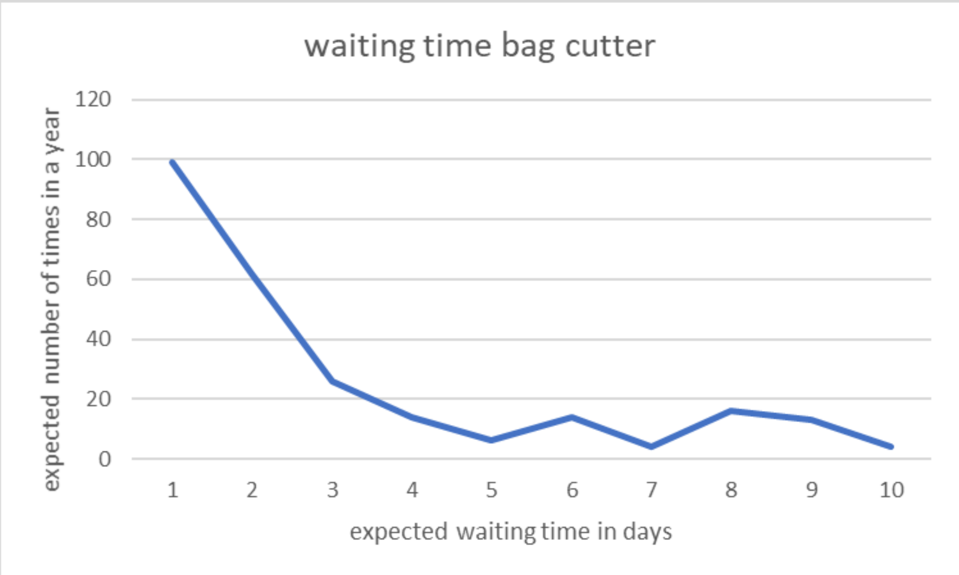


Figure 14. Expected spread of the waiting times in days to repack bags.

Waiting time repacking big bags

The sub-process that repacks big bags need to be able to repack an expected required capacity of 20,879 ton per year. This means that there is on average 20,879 ton/258 days=81-ton capacity needed per day to fulfill demand. With an available capacity of 250 ton per day this is enough. However, it can be the case that orders are clustered together around certain days instead of spreading out evenly over the year. If this occurs, this has the result that on some days the process has a few orders to repack and on other days the process has too many orders to repack within one day. This will have the result that waiting times for orders increase. We do not want the waiting times to be too high defined. Therefore, we use the expected capacity per day to find out if the spread of the orders is good enough. The total expected waiting list is 5,814 ton. As calculated in Equation 16, this means that 1 ton stands on average 5,814/20,879=0.3 days on the waiting list. Because orders have a standard waiting time of 1 day, the average waiting time for a big bag repacking order is 1+0.3=1.3 days.

$$average\ waiting\ time\ in\ days\ repacking\ big\ bags = \frac{total\ waiting\ list}{total\ required\ capacity} + 1$$
$$= \frac{5{,}814}{20{,}879} + 1 = 1.3$$

Equation 16. Average waiting time in days repacking big bags.

In Figure 15 we show the expected required capacity per day. In Appendix E the required capacity per day of 2020 is listed. We get the expected required capacity per day when we multiply this data with the growth rate. The available capacity is 250 ton per day, which is shown by the orange line.

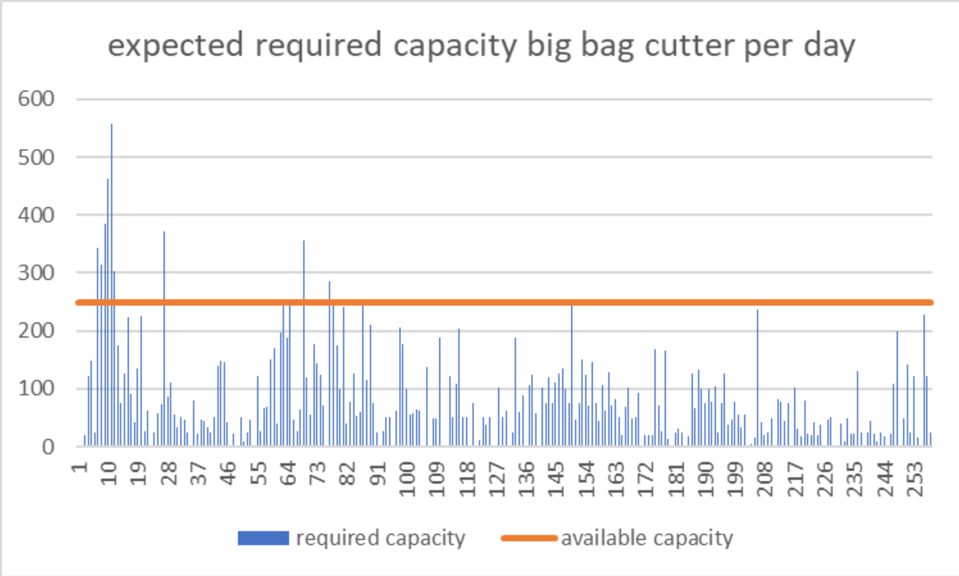


Figure 15. Expected required capacity big bag cutter per day.

We now know the average waiting time before an order to repack big bags is repacked. However, we are also interested in how the waiting times per day are spread out. In the third column in Table 15 the expected waiting times in days are listed before an order is repacked. The waiting time is the sum of the length of the waiting list in days (column 1) and the day the order is repacked (column 2). In the fourth column we can see how often we expect that a certain waiting time occurs in a year according to our calculation. In Figure 16 we can see that waiting times of 2 days or more are less expected to happen than a waiting time of 1 day. In the fifth column in Table 15 we can see how often a waiting time happens cumulative. In column 4 we can see that at 242 days orders are repacked within 1 day and that at 7 days orders are repacked within 2 days. This means that we expect that at 249 days, orders need a maximum of 2 days before they are repacked. In column 6 we have translated this in a percentage of the total amount of days. So, there is a probability of 249/258=97% that an order is repacked within 2 days. What stand out is that, according to our calculation, we expect 94% of the orders repacked within 1 working day and 100% within 5 working days. Therefore, we assume that the chance that an order needs more than 1 week to be repacked is negligible. According to Kommer, an average waiting time of 1.3 days, where 94% of the orders are repacked within 1 day, is fast enough. Therefore, we meet the condition to have enough repacking capacity to repack big bags without waiting too long before an order is repacked.

length waiting list in days	standard waiting day	total waiting time	number of times	cumulative	cumulative %
0	1	1	242	242	94%
1	1	2	7	249	97%
2	1	3	4	253	98%
3	1	4	2	255	99%
4	1	5	3	258	100%

Table 15. Expected waiting times in days to repack big bags.

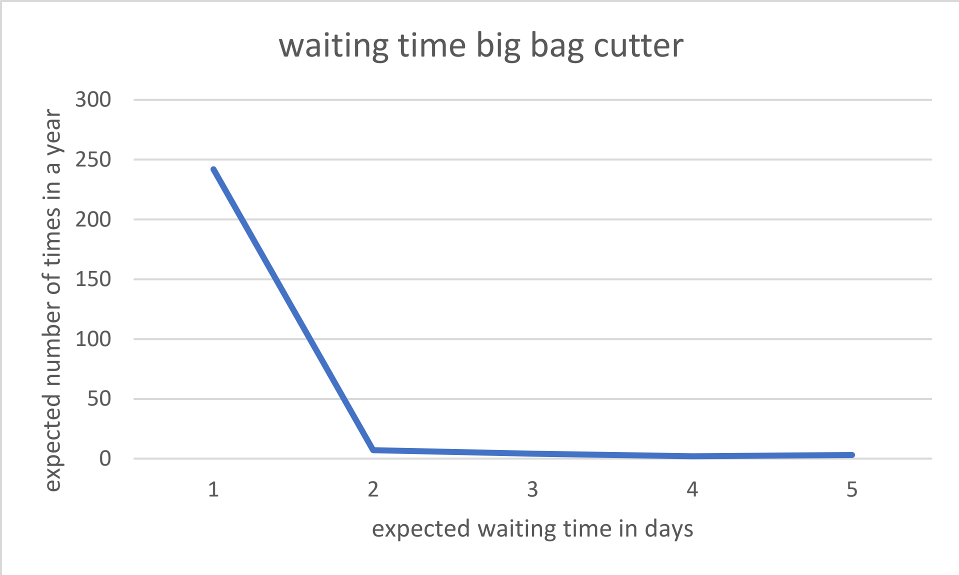


Figure 16. Expected spread of the waiting times in days to repack big bags.

Conclusion
In order to calculate the average waiting time, we distinguish between two sub-processes. The reason for this is that the new process has two different inputs. The first sub-process repacks bags and the second sub-process repacks big bags. Both sub-processes can repack 250 ton per day. The sub-process that repacks bags needs to repack on average 206 ton per day. If there is no waiting list, repacking orders are scheduled 1 day later after the order is placed. Orders are placed on the waiting list if there is no room to schedule them directly. The longer the waiting list, the longer the waiting time. The average waiting time in days before a bag repacking order is repacked, is 3 days. This consist of 1 standard waiting day and two extra waiting days because of the waiting time on the waiting list. According to the spread of the waiting days, we expect that around 80% of the repacking orders are repacked within 5 days. The average waiting time in days before a big bag repacking order is repacked, is 1.3 days. This consist of 1 standard waiting day and 0.3 extra waiting days because of the waiting time on the waiting list. According to our calculation, we expect that around 94% of the orders are repacked within 1 working day.

4.3.2 Costs constraint
If Kommer choose to invest in a new repacking process, a hurdle rate should be met of 10% per year. First, we determine the decrease in repacking costs per year. The money we save on repacking will turn into profit if the selling price stays the same. Then we discount future cashflows back to the present with the NPV. If the NPV is positive, the hurdle rate is met, and the investment is worth taken.

Return on investment (ROI)
What would our return on investment be if we invest in a new repacking process? In the current situation, Kommer already makes a profit on its repacking services. When the income stays the same and the repacking costs will decrease, the profit will increase. In Table 16 we can see that the return on investment (ROI) is per year between 28% and 52%. We calculate the ROI per year by dividing the total costs of investment with the decrease of the repacking costs per year as shown in Equation 17.

$$ROI = \frac{Net\ Return\ on\ Investment\ of\ one\ year}{Cost\ of\ Investment} * 100\%$$

Equation 17. Formula of ROI (Beattie, 2021).

Notice that we have subtracted the investment costs from the new repacking costs in order to calculate the ROI. When we investigate the entire investment, the ROI is 40% per year. The payback time of the investment is between 1.9 and 3.6 years for the different repacking options. In total, the investment will be earned back one time in 2.5 years. Calculations can be found in Table 16.

investment	from bags to bulk	from bags to big bags	from big bags to bulk	total
investment over a 10 year period	€ 505,020.49	€ 218,183.70	€ 219,764.81	€ 942,969.00
interest over a 10 year period	€ 76,384.35	€ 33,000.28	€ 33,239.43	€ 142,624.06
total costs of investment	**€ 581,404.84**	**€ 251,183.99**	**€ 253,004.23**	**€ 1,085,593.06**
repacking costs per ton old situation	€ 9.46	€ 12.19	€ 6.67	
repacking costs per ton new situation	€ 4.00	€ 5.20	€ 3.82	
decrease repacking costs per ton	**€ 5.47**	**€ 6.99**	**€ 2.85**	
repacking costs of investment per ton new situation	€ 0.79	€ 0.74	€ 0.63	
decrease repacking costs per ton without investment costs	**€ 6.25**	**€ 7.73**	**€ 3.48**	
capacity per year	37,000	17,000	20,000	74,000
decrease repacking costs per year without investment costs	**€ 231,316.10**	**€ 131,415.61**	**€ 69,619.09**	**€ 432,350.81**
payback time investment in years	2.5	1.9	3.6	2.5
return on investment (ROI) per year	**40%**	**52%**	**28%**	**40%**
lifespan new repacking process in years	20	20	20	20

Table 16. Return on investment (ROI) per year.

Since the lifespan of the new repacking process is at least 20 years, this investment will be earned back 8 times. After subtracting the initial investment the total savings on repacking costs would be 7 times the investment of 1,085,593 euro over a time horizon of 20 year.

Net Present Value (NPV)

After the solution is implemented and the investment is made we expect positive cashflows for a period of 20 years. As shown in Table 16 we expect a decrease in costs per year of 432,350 euros. However, money earned in the future is less worth than money earned today, due to its potential earning capacity. Therefore, we need to discount future cashflows back to the present. The hurdle rate (discount rate) we use is 10%, as explained in Chapter 2. We discount the cashflows back to the present with the NPV. If the NPV is positive, the investment is worth taken.

$$NPV = \sum_{i=1}^{n} \frac{Cash\ Flow_i}{(1+r)^i} - Initial\ Investment$$

Where:

$r = discount\ rate.$

$i = number\ of\ periods\ to\ discount.$

Equation 18. Formula to calculate NPV (Fernando, 2021c).

investing in a new repacking process	
decrease in costs per year (cash flow)	€ 432,350.81
discount rate (r)	10%
number of years to discount (i)	20
initial investment (without interest)	€ 942,969.00
NPV	**€ 2,737,877.13**
IRR	**46%**

Table 17. Discounting cashflows.

Equation 18 gives the formula we can use to calculate the NPV (Fernando, 2021c). In Table 17 the input values are listed and the outcome is given. The NPV is positive. This means the investment is worth taken. Remember that we take the initial investment without interest, because for calculating the NPV the interest is part of the hurdle rate.

With a hurdle rate of 10% the investment is worth taken. However, what if the hurdle rate becomes higher because circumstances changed? Therefore, we compute the Internal Rate of Return (IRR). The IRR sets the NPV equal to zero and compute the highest hurdle rate possible.

$$0 = NPV = \sum_{i=1}^{I} \frac{C_i}{(1 + IRR)^i} - C_0$$
$$C_i = Net\ cash\ inflow\ during\ the\ period\ i.$$
$$C_0 = Total\ initial\ investment\ costs.$$
$$i = The\ number\ of\ time\ periods.$$

Equation 19. Formula of calculating IRR by setting NPV equal to 0 (Fernando, 2021b).

Equation 19 gives the formula we use to calculate the IRR (Fernando, 2021b). In Table 17 we find the input values. The maximum hurdle rate possible without having a negative NPV is 46%. This means as long as the hurdle rate is not higher than 46%, the investment is still worth taken.

Conclusion
If Kommer decides to invest in a new repacking process, a hurdle rate of 10% should be met. In order to compute if the investment is profitable enough, we have calculated the decrease in repacking costs. After having computed the NPV, we concluded that the investment is profitable enough. In order to determine the maximum hurdle rate, we have calculated the IRR. The maximum hurdle rate is 46%. This means as long as the hurdle rate is not higher than 46%, the investment is still worth taken.

4.3.3 Conclusion

As solution we want to choose the investment in a new repacking process. We can choose this solution if the capacity constraint is met, and the costs constraint is met. If we invest in a new repacking process, we consider two sub-processes. The first sub-process repacks bags and the second sub-process repacks big bags. Both sub-processes can repack 250 tons per day. The first sub-process needs to repack on average 206 tons per day. For the second sub-process this is 81 tons per day. The average waiting time in days before an order is repacked is for the first sub-process 3 days and for the second sub-process 1.3 days. This consist of 1 waiting day to repack the order and 2 respectively 0.3 waiting days because of the waiting time on the waiting list. We expect that around 80% of the orders of the first sub-process are repacked within 5 days. For the second sub-process we expect that 94% of the orders are repacked within 1 day. In order to meet the costs constraint a hurdle rate of 10% should be met. We have calculated the decrease in repacking costs in order to compute if the investment is profitable enough. If the repacking costs per ton decrease and the selling price of the repacking service stays the same, the decrease in costs will turn into profit for every ton repacked. After computing the NPV, we find out that the investment is profitable enough. To determine how high the hurdle rate could be while still having a positive NPV, we have calculated the IRR. The maximum hurdle rate possible without having a negative NPV, is 46%. This means if for any reason Kommer wants a higher hurdle rate, the investment is still worth taken as long as the hurdle rate is not higher than 46%. Because both constraints are met, we can choose as solution the investment in a new repacking process.

4.4 Conclusion

In this chapter we have provided two solutions and we have searched to the best solution which will answer our research question:

"Which repacking process has the lowest costs of the raw materials per ton while having sufficient capacity to handle orders?"

The two solutions we have compared are:

- Investing in a new repacking process.
- Improving the current repacking process.

What we want as a result are lower repacking costs per ton and enough capacity in order to fulfil demand with a buffer capacity for peak demand. Therefore, we have made an ABC-analysis of the two solutions in order to calculate the repacking costs per ton of the different repacking options. We get insight in which solution gives us the lowest costs per ton. The solution is chosen based on the required capacity and on the repacking costs per ton per repacking option. We have chosen the solution with the lowest repacking costs per ton per repacking option. We were able to do so because this solution has enough repacking capacity available. When Kommer would invest in a new process, the repacking costs per ton are for all three repacking options the lowest. The components of this new repacking process have a lifespan of 20 years. We have calculated if there is enough capacity available if Kommer decides to invest in a new repacking process with a buffer capacity for peak demand. According to our calculation, there is enough capacity available. Also, according to the NPV calculation, the hurdle rate of 10% is met. Therefore, we advise Kommer to invest in a new repacking process.

5. Conclusion and further recommendations

To be able to implement and evaluate the solution, we provide the thesis with an implementation and evaluation plan. The implementation plan has as goal to give Kommer a guideline of how to implement the given solution. The evaluation plan has as goal to solve mistakes and other issues of the implemented solution. Firstly, we provide a conclusion regarding this thesis in Section 5.1. Secondly, we discuss the implementation plan in Section 5.2. Thirdly, we discuss the evaluation plan in Section 5.3.

5.1 Conclusion

In this thesis we have carried out an investigation regarding a repacking process at Kommer. We were able to identify two action problems:

- The repacking costs per ton are too high.
- The current repacking process has a too low repacking capacity.

With help of the problem cluster, we were able to identify the core problem:

"Core problem: The repacking process is outdated"

Based on our action problems, we have defined the following research question:

"Which repacking process has the lowest costs of the raw materials per ton while having sufficient capacity to handle orders?"

In order to solve our action problems, we need to solve our core problem. Therefore, we created the following sub questions:

1. How to decrease the amount of manual work needed for repacking?
2. How to decrease the waiting time to (dis)connect trucks?
3. How to decrease the amount of downtime?
4. How to increase the capacity (in tons) to a sufficient level with buffer capacity for unexpected orders?

In order to solve our core problem, we evaluated two solutions:

- Invest in a new repacking process.
- Improve the current repacking process.

In order to solve the problems, we measured the current repacking capacity and the current repacking costs. The repacking process consist of three repacking options. In order to identify the most important costs we have created an Activity-Based Costing analysis. It became clear that approximately 80% of the costs can be assigned to staff costs. Therefore, the focus was on the staff costs, and we designed Question 1. In order to answer Question 1, we made two Value Stream Maps of the two solutions to identify the number of employees needed to repack the raw materials per solutions. It became clear that if Kommer invests in a new repacking process, the number of employees needed at the new repacking process will be the lowest.

The current process has a lot of idle time caused by downtime of machinery and waiting time of (dis)connecting silos. The less idle time there is in the repacking process, the more tons can be repacked in an hour. Since staff is paid per hour, the staff costs per ton decreases. When we investigated the process by observations and interviews with the staff, it became clear that there are two factors that are responsible for the amount of idle time. The first factor is the waiting time to (dis)connect trucks. Trucks need to be connected to the filling station before the repacking process can start and they need to be disconnected after the repacking has find place. In the meantime, the repacking process cannot operate. The second factor is the downtime of the repacking process because of failures of components. This is costing a lot of repacking capacity. In order to decrease the idle time, we created Questions 2 and 3. In order to answer Questions 2 and 3 we calculated the amount of idle time in the process. Therefore, we also calculated the available capacity of the process. We can identify the idle time by subtracting the repacking capacity of the process in tons per hour by the actual tons repacked per hour. It became clear that the idle time decreases the available repacking capacity with 50% compared with the repacking capacity of the process without idle time. With the implementation of silos (storage units) we have no more waiting time of (dis)connecting trucks. The staff starts with filling the first silo. When this silo is full, the staff starts filling the second silo. It takes longer to fill a silo than to empty a silo. When the second silo is full, the first one is already emptied and can be filled again. At the new repacking process it is possible to work at two orders at the same time. Because at the new repacking process there are four silos connected to the new repacking process, the employees have always an empty silo to fill. Trucks will empty the silos after they are filled without disturbing the repacking process. However, the current repacking process cannot have silos. This is because the current repacking process is in the centre instead of a side of the building. This means that, according to the service engineer, the distance to the silos (that need to be placed outside the building) is too far to transport raw materials over. If the current repacking process has preventive maintenance, the downtime will decrease significantly. This will be the same for the new repacking process. This means the idle time is negligible for the solution of investing in a new repacking process. The idle time is only partly solved if the current repacking process is improved, because this process cannot have silos.

In the current situation there is a lack of repacking capacity. The repacking process is used for 12 hours a day, the remaining capacity of another and more inefficient process is completely used and in some cases, there is not even a repacking process used to repack the materials. The goal is to use the repacking process for 10 hours a day without the use of another process or repacking without using a repacking process. In order to solve the shortage of repacking capacity, we created Question 4. We identified the solution we have chosen has enough capacity to serve the orders including a buffer capacity to serve also by peak demand. The costs per ton per repacking option are for all three repacking options the lowest when Kommer decides to invest in a new repacking process. This process consists of two sub-processes. The first sub-process is used for the two repacking options that involves repacking bags; the second sub-process is used for the repacking option for repacking big bags. The mean required capacity is 206 tons per day for the first sub-process. For the second sub-process this is 81 tons per day. The available capacity per sub-process is 250 ton. This means that we have in both cases a buffer capacity, which lead in an average waiting time of respectively 3 and 1.3 days.

After having measured the core problem with help of the four sub questions we investigated the two solutions. We have chosen to advise Kommer to invest in a new repacking process. The hurdle rate of 10% will be easily met, because the IRR is 46%. If Kommer decides to invest in a new repacking process, the return on investment is 40% per year. The return on investment is measured by calculating the decrease in costs. The revenue the repacking service generates stays the same, so a decrease in costs means an increase in profit. The payback period is 2.5 year. The repacking process will last for 20 years. In this time the investment can be earned back 8 times. When we subtract the initial investment then the total generated positive cashflow in 20 year is 7 times the investment of 1,085,593 euro (investment is including interest) and this is more than 7.5 million euro.

5.2 Implementation plan

The implementation plan consists of the steps needed to implement the given solution. Firstly, we provide shortly the steps and secondly we provide some explanation.

- Request the offers officially of the engineering companies.
- Discuss the mortgage with the bank.
- Discuss the installation of the new repacking process with the two engineering companies.
- In addition to the three already purchased silos, Kommer needs to purchase a fourth silo.
- Create room in the warehouse for the new repacking process.
- Install the new repacking process.
- Appoint someone of the existing staff to operate the process on a daily basis.

Firstly, we will officially request the offers. As shown in Section 4.1, Kommer has two offers from the past which forms, with the silos, together the new repacking process. If Kommer decides to invest in a new repacking process, the offers have to be requested officially to make the offers up to date. Otherwise, Kommer cannot get a mortgage from the bank.

Secondly, the director and the financial manager of Kommer need to discuss the mortgage with the bank. The investment can be financed with a mortgage, because Kommer can provide the components of the new repacking process as a collateral.

Thirdly, the director of Kommer will discuss the installation with the two engineering companies. The installation needs to be planned. The important thing is that both installed parts will fit perfectly to each other. Both engineering companies need to appoint a service engineer to maintain the process. The engineering company that delivers the discharge bellows for the silos will also install the silos.

Fourthly, Kommer needs to purchase a fourth silo. For the new process, Kommer needs four silos in order to have no waiting time of (dis)connecting trucks. Kommer has already bought three silos in the past. This means a fourth silo still needs to be bought. To be able to repack orders continuously, Kommer needs at least four silos. This is because the two inputs in the new repacking process needs each 2 silos as output. If one silo is full, the process operator can start filling the second silo. Before the second silo is full, the first one is already emptied by the truckdriver. In that way, there will always be one silo available, and the repacking process can operate continuously.

Fifthly, Kommer needs to create room in the warehouse before the installation takes place. At the moment, the reserved space for the new process is used for storage. Therefore, the forklift driver needs to replace the pallets from the reserved space. When the place is empty the installation can take place.

Sixthly, the installation itself will take place. The two engineering companies will install the new process and they will test if everything is working. If the installation is working Kommer can appoint a process operator who will operate the repacking process.

Seventhly, Kommer will appoint a process operator to operate the repacking process. The process operator will stand at the bag cutter, because from there the rest of the process can be overseen easily. He will monitor the process, decides which orders are repacked and makes sure that the valves are put the right way in order to fill the right silos.

5.3 Evaluation plan

When the process is running, Kommer will evaluate the solution. The evaluation is needed to compare the affected situation with the desired situation.

We recommend the following research questions. The direction has to ask these to themselves when evaluating the implemented solution:

- Have the goals been met? Measure whether the problem has been reduced without looking at its causes.
- What are the causes of the effects? Which problems are generated by the implemented solution?
- Are there any possible improvements still to be made? Are there still problems in the operation on a daily basis?

The evaluation needs to find place with at least the process operators of the new process, with the two engineering companies and with the director of Kommer.

Firstly, Kommer needs to evaluate whether all the problems are solved or whether there are still problems left to solve. Kommer needs to measure whether the problems have been reduced. It is important to involve the employees at the repacking process within this evaluation in order to find problems that at first sight cannot be seen.

If Kommer decides to invest in a new repacking process, less staff is needed to operate the repacking process for a repacking option. We want to know if the costs of manual work is decreased to the estimated costs. We recommend to calculate the new staff costs per ton and compare the results with the estimated results.

If the new repacking process is installed, the amount of idle time should be reduced to almost zero minutes per order. With the use of silos, the waiting time of (dis)connecting trucks should be taken away. With preventive maintenance there is almost no downtime at the new repacking process. What we want to know is if the idle time is reduced enough.

Secondly, the target goals need to be evaluated. The two target goals are:

- Enough repacking capacity to serve the repacking orders.
- The repacking costs per ton are decreased to the forecasted costs.

We recommend to calculate the average waiting time and the repacking costs per ton and compare these results with the estimated results.

Thirdly, the process operators can share their problems about operating the process on a daily basis. Maybe the target goals are reached, but other problems appeared in place of the old ones. If there are still problems left, a plan needs to be made to solve these problems.

After implementing and evaluating the solution, it is important to recommend maintaining the process regularly to prevent downtime. Further, it is important to evaluate after a couple of months again to identify problems that are not identified on the short term.

5.4 Discussion

In this thesis we have chosen the solution of investing in a new repacking process. When it comes to capacity or costs, investing in a new repacking process is the best decision to make. However, for computing the calculations we made a lot of assumptions.

For the formulation of the solutions, we have analysed the costs that occur in the current process. We needed information about the components. Because of a loss of information, the information we used was based on offers of new machinery, old bills, and interviewing people. This means this information is estimated. The offers of the new machinery are offers who are not yet requested officially. This means when their prices are changed in the main time, the offers are changed as well. This means there is a chance the prices are changed a bit in the meantime.

The required capacity in the future is based on the required capacity of the past and a growth rate. The growth rate is calculated with the use of the growth between 2017 and 2020. This means the measured period is 3 years. This is not a lot. This means there is a chance that in the future the growth will differ from the estimation.

Because the investment in a new repacking process has a huge return, it is not likely that if the cost estimation differs a bit from practice that the solution is not worth taken. The difference between the required and the available capacity of the first sub-process is 250-206=44 ton per day, which is a realistic buffer capacity. However, for the second sub-process this is 250-81=169 ton. This means that the second sub-process has very much buffer capacity. However, because the input for the second subprocess consists of a dumping cabinet of 16,604 euro, we cannot change the input with a cheaper alternative in exchange for some capacity loss.

Reference list

Barone, A. (2020, 13 November). *Understanding Bottlenecks*. Investopedia. https://www.investopedia.com/terms/b/bottleneck.asp

Beattie, A. (2021, 14 January). *How to Calculate Return on Investment (ROI)*. Investopedia. https://www.investopedia.com/articles/basics/10/guide-to-calculating-roi.asp

Beleggen.info. (2021). *Gemiddeld rendement met beleggen*. https://beleggen.info/beleggen/gemiddeld-rendement

Bragg, S. (2021, 3 December). *Throughput definition*. AccountingTools. https://www.accountingtools.com/articles/throughput-definition-and-usage.html

Buscaglia, R. S. D. L. (2020, 8 December). *Chapter 5 Confidence Intervals for \(\mu\) | Introduction to Statistical Methodology, Second Edition*. bookdown.org. https://bookdown.org/dereksonderegger/570/5-confidence-intervals-for-mu.html

Chen, J. (2020, 1 June). *How the Valuation Process Works*. Investopedia. https://www.investopedia.com/terms/v/valuation.asp

CED (Collins English Dictionary). (2021, 1 December) Continuous process definition and meaning |. Collins Dictionaries. https://www.collinsdictionary.com/dictionary/english/continuous-process

Davis, S. (2021, 6 June). *What Are the Types of Costs in Cost Accounting*. Finimpact. https://www.finimpact.com/types-of-costs-in-cost-accounting/

Devault, G. (2020, 2 January). *Surveys Research: What Is a Confidence Interval?* The Balance Small Business. https://www.thebalancesmb.com/surveys-research-confidence-intervals-2297097

Fernando, J. (2021a, 20 February). *Time Value of Money (TVM) Definition*. Investopedia. https://www.investopedia.com/terms/t/timevalueofmoney.asp

Fernando, J. (2021b, 7 April). *Internal Rate of Return (IRR)*. Investopedia. https://www.investopedia.com/terms/i/irr.asp

Fernando, J. (2021c, 9 April). *Net Present Value (NPV)*. Investopedia. https://www.investopedia.com/terms/n/npv.asp

Haughey, D. (2011, 19 December). *Understanding the Project Management Triple Constraint*. Project Smart. https://www.projectsmart.co.uk/understanding-the-project-management-triple-constraint.php

Hayes, A. (2021, 5 March). *Empirical Rule*. Investopedia. https://www.investopedia.com/terms/e/empirical-rule.asp

Heerkens, H., & Winden, A. (2017). *Solving Managerial Problems Systematically* (1st edition). Wolters-Noordhoff.

Hoffmann, P. (2018, 17 December). *Capacity management & lean operations (PowerPoint OS lecture 6)*. https://signon.utwente.nl/oam/pages

IPG-Math (2020, 20 July). *Area of a circle | Questions and Answers | Formula*. Ms IPG. https://www.msipg.com/area-of-circle/

Kagan, J. (2021, 16 March). *Payback Period Definition*. Investopedia. https://www.investopedia.com/terms/p/paybackperiod.asp

Kanbanize (2020). *7 Wastes of Lean: How to Optimize Resources*. Kanban Software for Agile Project Management. https://kanbanize.com/lean-management/value-waste/7-wastes-of-lean

Kenton, W. (2020a, 10 February). *Activity-Based Costing (ABC)*. Investopedia. https://www.investopedia.com/terms/a/abc.asp

Kenton, W. (2020b, 28 November). *Idle Time*. Investopedia. https://www.investopedia.com/terms/i/idle-time.asp

Kenton, W. (2021, 22 March). *Hurdle Rate Definition*. Investopedia. https://www.investopedia.com/terms/h/hurdlerate.asp

Koo, J. (2021, 6 April). *Cycle Time vs Lead Time vs Takt Time*. Tulip. https://tulip.co/blog/lean-manufacturing/cycle-vs-lead-vs-takt/

Kooijman, B. (2021, 15 March). *Alle 35 Lean tools op een rij, het ultieme artikel over Lean*. Bureau Tromp. https://bureautromp.nl/lean-manufacturing/

Mansa, J. (2021a, 8 April). *Return on Investment (ROI) Definition*. Investopedia. https://www.investopedia.com/terms/r/returnoninvestment.asp

Mansa, J. (2021b, 1 June). *Cost Accounting Method: Advantages and Disadvantages*. Investopedia. https://www.investopedia.com/ask/answers/041515/what-are-main-advantages-and-disadvantages-cost-accounting-method.asp

Manutan B.V. (2021). *Superdunne heftafel - Laadvermogen 2000 kg | Hymo | Manutan*. https://www.manutan.nl/nl/mnl/extra-platte-ergonomische-en-vaste-handbediende-heftafel-mx-20-hefvermogen-2000-kg

Meijer, D. (2019). *Statistics for Engineers*. University Twente.

Mukhopadhyay, S. (2021, 22 June). *Weighted Average Cost of Capital*. WallStreetMojo. https://www.wallstreetmojo.com/weighted-average-cost-capital-wacc/

Munday, T. (2016). The Pareto principle - Something for hydrogeophysical practitioners to remember when employing geophysical data in groundwater resource assessment? *ASEG Extended Abstracts*, *2016*(1), 1. https://doi.org/10.1071/aseg2016ab278

NSR (Nederland Staatsobligaties Rendementen) (2021, 23 June). Investing.com. https://nl.investing.com/rates-bonds/netherlands-government-bonds?maturity_from=40&maturity_to=290

NU (2014, 7 July). *Vijf vragen over staatsleningen*. https://www.nu.nl/nuzakelijk-overig/3546589/vijf-vragen-staatsleningen.html

Orue, A., Lizarralde, A., Amorrortu, I., & Apaolaza, U. (2021). Theory of constraints case study in the make to order environment. *Journal of Industrial Engineering and Management*, *14*(1), 72. https://doi.org/10.3926/jiem.3283

Poortema, K. (2019). *Statistics Reader part 1*. https://canvas.utwente.nl/courses/3236/pages/tables-formulas-sheets-and-test-procedure-in-8-steps?module_item_id=75247

Rodriguez, D. (2020, 18 September). *Lean Tools, Principles, and Applications*. invensislearning. https://www.invensislearning.com/blog/lean-methodology-tools-principles-applications/

Schaik, P. (2021, 7 January). *Theory of Constraints*. Bureau Tromp. https://bureautromp.nl/theory-of-constraints/

Taboga, M. (2017). *Empirical distribution*. https://www.statlect.com/asymptotic-theory/empirical-distribution

Thakur, M. (2021, 22 June). *Hurdle Rate*. WallStreetMojo. https://www.wallstreetmojo.com/hurdle-rate/

Tuovila, A. (2021a, 31 August). *What Is Overhead in Business?* Investopedia. https://www.investopedia.com/terms/o/overhead.asp

Tuovila, A. (2021b, 15 July). *Depreciation Definition*. Investopedia. https://www.investopedia.com/terms/d/depreciation.asp

Wille, A. (2021). *What is a KPI? Definition, Best-Practices, and Examples*. Klipfolio.Com. https://www.klipfolio.com/resources/articles/what-is-a-key-performance-indicator

Winston, W. L., & Goldberg, J. B. (2004). *Operations Research*. Thomson Brooks/Cole.

A. Cost analysis

number	old machine part	capacity (ton/hour)	new price	lifespan	depreciation	energy consumption (kWh)	energy costs per hour
1	lift table	25	€ 6,000	15	€ 400	3	€ 0.29
2	assembly line	59	€ 2,000	10	€ 200	0.75	€ 0.07
3	bag cutter	47	€ 100,000	25	€ 4,000	1.1	€ 0.11
4	storage	_	_	_	_	_	_
5	dumping cabinet	_	€ 25,000	20	€ 1,250	_	_
6	sieve	_	€ 25,000	25	€ 1,000	5.5	€ 0.53
7	silo	_	€ 20,000	50	€ 400	_	_
8	bucket elevator	62	€ 51,000	20	€ 2,550	5.5	€ 0.53
9	transport screw 1 (funnel)	39	€ 15,000	15	€ 1,000	4	€ 0.38
10	transport screw 2 (transport to bucket elevator)	26	€ 15,000	15	€ 1,000	3	€ 0.29
11	transport screw 3 (transport to filling stations)	44	€ 17,475	15	€ 1,165	5.5	€ 0.53
12	transport screw 4 (filling station big bags)	33	€ 15,825	15	€ 1,055	5.5	€ 0.53
13	transport screw 5 (filling station trucks)	54	€ 18,850	15	€ 1,257	5.5	€ 0.53
14	extractor 1	_	€ 10,000	40	€ 250	2.2	€ 0.21
15	extractor 2	_	€ 10,000	40	€ 250	2.2	€ 0.21
16	extractor 3	_	€ 10,000	40	€ 250	2.2	€ 0.21
17	extractor 4	_	€ 10,000	40	€ 250	2.2	€ 0.21
18	extractor 5	_	€ 10,000	40	€ 250	2.2	€ 0.21
19	bag press	_	€ 18,025	20	€ 901	5.5	€ 0.53

Table 18. Specifications of the Value Stream Mapping of the raw materials current repacking process.

number	new machine part	new price	lifespan	depreciation	energy consumption (kWh)	energy costs per hour
1	bag cutter	€ 380,500	25	€ 15,220	5.5	€ 0.53
	dust exhaust system	_	_	_	7.5	€ 0.72
	bag press	_	_	_	5.5	€ 0.53
2	dumping cabinet	€ 16,604	20	€ 830	_	_
3	sieve	€ 47,795	25	€ 1,912	4	€ 0.38
4	sieve	€ 47,795	25	€ 1,912	4	€ 0.38
5	bucket elevator	€ 71,190	20	€ 3,560	7.5	€ 0.72
6	bucket elevator	€ 71,190	20	€ 3,560	7.5	€ 0.72
7	silo with discharge bellow	€ 40,776	25	€ 1,631	_	_
8	silo with discharge bellow	€ 40,776	25	€ 1,631	_	_
9	silo with discharge bellow	€ 40,776	25	€ 1,631	_	_
10	silo with discharge bellow	€ 40,776	25	€ 1,631	_	_
11	bunker (filling station big bags)	€ 20,615	50	€ 412	_	_
12	transport screw	€ 14,600	20	€ 730	3	€ 0.29
13	transport screw	€ 16,691	20	€ 835	3	€ 0.29
14	transport screw	€ 16,691	20	€ 835	3	€ 0.29
15	transport screw	€ 14,600	20	€ 730	3	€ 0.29
16	transport screw	€ 14,600	20	€ 730	3	€ 0.29
17	transport screw	€ 14,600	20	€ 730	3	€ 0.29
18	transport screw	€ 14,600	20	€ 730	3	€ 0.29
19	transport screw	€ 17,795	20	€ 890	3	€ 0.29
20	bag press	€ 18,025	20	€ 901	5.5	€ 0.53
total		€ 960,994		€ 41,039	71	€ 6.82

Table 19. Specifications of the Value Stream Mapping of the raw materials investing in a new repacking process.

number	renovating old machine part	new price	lifespan	depreciation	energy consumption (kWh)	energy costs per hour
1	lift table	€ 6,000	15	€ 400	3	€ 0.29
2	assembly line	€ 2,000	10	€ 200	0.75	€ 0.07
3	bag cutter	€ 100,000	25	€ 4,000	1.1	€ 0.11
3	bag cutter	€ 380,500	25	€ 15,220	5.5	€ 0.53
	dust exhaust system	_	_	_	7.5	€ 0.72
	bag press	_	_	_	5.5	€ 0.53
4	storage	_	_	_	_	_
5	dumping cabinet	€ 25,000	20	€ 1,250	_	_
6	sieve	€ 25,000	25	€ 1,000	5.5	€ 0.53
7	silo	€ 20,000	50	€ 400	_	_
8	bucket elevator	€ 51,000	20	€ 2,550	5.5	€ 0.53
9	transport screw 1 (funnel)	€ 15,000	20	€ 750	4	€ 0.38
10	transport screw 2 (transport to bucket elevator)	€ 15,000	20	€ 750	3	€ 0.29
11	transport screw 3 (transport to filling stations)	€ 17,475	20	€ 874	5.5	€ 0.53
12	transport screw 4 (filling station big bags)	€ 15,825	20	€ 791	5.5	€ 0.53
13	transport screw 5 (filling station trucks)	€ 18,850	20	€ 943	5.5	€ 0.53
14	extractor 1	€ 10,000	40	€ 250	2.2	€ 0.21
15	extractor 2	€ 10,000	40	€ 250	2.2	€ 0.21
16	extractor 3	€ 10,000	40	€ 250	2.2	€ 0.21
17	extractor 4	€ 10,000	40	€ 250	2.2	€ 0.21
18	extractor 5	€ 10,000	40	€ 250	2.2	€ 0.21
19	bag press	€ 18,025	20	€ 901	5.5	€ 0.53

Table 20. Specifications of the Value Stream Mapping of the raw materials improving old process; red=component removed, green= component added.

B. Survey

What is the weight of bags and big bags?

- The weight of a big bag is 1 ton (1000 kg)
- The weight of a bag is 25 kg. One pallet contains 40 bags. This means one pallet has the weight of 1 ton.

What is the capacity of the current repacking process?

- One truck is loaded in 2 hours. This means the repacking capacity is 12.5 ton per hour. This is the same for filling big bags.

How many working hours are there on a working day?

- 12 working hours

How many working days are there in a year?

- 260 working days per year
  - 5 days a week
  - 52 weeks a year

What is the required capacity of the past years?

- I got excel-files with the orders from the customers of the past

Which problems do occur at the repacking process? (partly answered by observing myself)

- Capacity process is too low
- Full bags are manually put on the assembly line
- A worker is needed to put the bags in a bag press
- Empty bags are manually removed at the end of the machine
- Health and safety problems (already partly solved)
- Components of process gets stuck
- Problems occur too long

C. Daily capacity 2020

317	154	663	217	195	252	202	267	69
460	492	203	126	166	464	695	103	81
88	314	119	247	252	380	618	191	104
247	507	236	172	327	131	349	267	489
437	341	688	306	456	173	527	360	124
196	292	361	125	350	281	599	381	99
419	171	145	419	311	311	272	204	434
456	202	392	107	554	146	365	208	141
426	406	222	256	436	180	516	297	148
750	346	344	98	188	115	305	213	157
625	116	392	219	151	116	25	366	199
350	218	35	116	232	212	292	370	275
271	351	335	250	367	256	307	162	295
161	277	503	289	265	169	203	85	87
197	394	296	27	148	198	75	183	113
249	139	427	104	169	271	228	115	484
139	171	556	235	280	56	322	456	182
117	293	226	139	156	277	316	350	77
228	283	229	423	632	52	407	201	
650	261	245	219	202	70	390	197	
369	350	348	224	312	181	244	53	
548	91	208	299	334	302	203	347	
341	452	456	295	159	252	386	157	
278	439	506	187	325	106	738	675	
261	297	600	208	84	204	253	200	
145	112	251	629	166	310	220	334	
455	449	48	166	163	73	597	330	
325	77	326	154	394	270	491	379	
134	313	870	105	239	204	138	388	
374	232	129	178	164	240	383	388	

Table 21. Data used for Chi-square test; tons repacked on a daily basis of the year 2020.

D. Daily capacity repacking bags 2020

1	317	61	159	121	253	181	156	241	435
2	460	62	83	122	210	182	271	242	341
3	68	63	53	123	547	183	229	243	177
4	127	64	191	124	455	184	106	244	179
5	292	65	424	125	89	185	186	245	53
6	172	66	158	126	124	186	187	246	326
7	85	67	93	127	99	187	9	247	52
8	148	68	173	128	335	188	140	248	480
9	49	69	339	129	333	189	107	249	200
10	298	70	244	130	92	190	68	250	287
11	79	71	92	131	492	191	50	251	191
12	53	72	218	132	289	192	81	252	354
13	101	73	83	133	322	193	76	253	269
14	87	74	223	134	283	194	192	254	66
15	73	75	323	135	205	195	53	255	104
16	32	76	35	136	171	196	124	256	266
17	50	77	55	137	98	197	135	257	365
18	75	78	257	138	285	198	259	258	44
19	96	79	127	139	289	199	50		
20	429	80	330	140	116	200	364		
21	343	81	320	141	119	201	75		
22	487	82	188	142	277	202	202		
23	341	83	153	143	161	203	98		
24	253	84	121	144	320	204	215		
25	204	85	296	145	30	205	101		
26	73	86	149	146	48	206	19		
27	91	87	214	147	160	207	248		
28	241	88	394	148	185	208	7		
29	25	89	395	149	188	209	81		
30	74	90	177	150	109	210	187		
31	200	91	24	151	46	211	139		
32	145	92	77	152	379	212	343		
33	120	93	299	153	292	213	144		
34	227	94	820	154	176	214	179		
35	327	95	132	155	43	215	226		
36	379	96	388	156	306	216	295		
37	327	97	141	157	3	217	87		
38	265	98	495	158	269	218	177		
39	511	99	445	159	137	219	612		
40	403	100	251	160	103	220	87		
41	164	101	473	161	126	221	132		
42	101	102	543	162	395	222	86		
43	96	103	211	163	301	223	47		
44	223	104	303	164	81	224	93		
45	121	105	516	165	153	225	230		

46	108	106	170	166	213	226	103
47	169	107	25	167	210	227	145
48	259	108	244	168	98	228	218
49	156	109	260	169	132	229	360
50	582	110	18	170	24	230	381
51	192	111	75	171	116	231	165
52	287	112	228	172	192	232	199
53	287	113	202	173	236	233	248
54	159	114	266	174	149	234	192
55	206	115	301	175	34	235	344
56	59	116	192	176	202	236	242
57	102	117	194	177	31	237	137
58	95	118	153	178	114	238	85
59	248	119	386	179	40	239	159
60	73	120	663	180	70	240	71

Table 22. Daily capacity repacking bags of the year 2020; red is the day number, black is the required capacity on that day.

E. Daily capacity repacking big bags 2020

1	0	61	40	121	0	181	24	241	21
2	0	62	192	122	10	182	31	242	9
3	20	63	242	123	50	183	23	243	25
4	120	64	184	124	36	184	0	244	18
5	145	65	239	125	50	185	18	245	0
6	25	66	46	126	0	186	123	246	21
7	334	67	25	127	0	187	64	247	105
8	308	68	63	128	99	188	130	248	195
9	377	69	349	129	50	189	96	249	0
10	452	70	117	130	62	190	74	250	47
11	546	71	53	131	0	191	98	251	139
12	297	72	174	132	25	192	77	252	25
13	170	73	140	133	185	193	102	253	119
14	74	74	121	134	58	194	25	254	15
15	124	75	69	135	87	195	73	255	0
16	218	76	0	136	0	196	123	256	223
17	89	77	280	137	104	197	37	257	119
18	42	78	246	138	122	198	47	258	25
19	132	79	170	139	57	199	75		
20	221	80	98	140	0	200	55		
21	26	81	235	141	99	201	32		
22	61	82	38	142	73	202	54		
23	0	83	76	143	117	203	0		
24	25	84	124	144	74	204	5		
25	57	85	52	145	109	205	15		
26	72	86	59	146	123	206	231		
27	364	87	242	147	132	207	41		
28	84	88	112	148	98	208	20		
29	109	89	206	149	73	209	23		
30	55	90	74	150	242	210	48		
31	31	91	24	151	45	211	0		
32	50	92	0	152	73	212	79		
33	46	93	27	153	147	213	75		
34	25	94	50	154	121	214	44		
35	0	95	50	155	69	215	73		
36	78	96	0	156	143	216	0		
37	23	97	62	157	74	217	100		
38	46	98	201	158	44	218	31		
39	43	99	173	159	104	219	17		
40	33	100	98	160	61	220	79		
41	24	101	53	161	126	221	22		
42	50	102	56	162	69	222	20		
43	137	103	62	163	79	223	40		
44	144	104	62	164	50	224	20		
45	144	105	0	165	20	225	36		

46	40	106	135	166	68	226	0
47	0	107	0	167	101	227	46
48	21	108	48	168	48	228	49
49	0	109	47	169	49	229	0
50	50	110	185	170	91	230	0
51	10	111	0	171	0	231	40
52	25	112	0	172	20	232	9
53	47	113	120	173	20	233	48
54	0	114	50	174	20	234	21
55	119	115	107	175	164	235	22
56	25	116	198	176	69	236	128
57	64	117	50	177	25	237	24
58	68	118	50	178	162	238	0
59	146	119	0	179	12	239	24
60	166	120	75	180	0	240	44

Table 23. Daily capacity repacking big bags of the year 2020; red is the day number, black is the required capacity on that day.