An improvement of the refill process of vending machines.

A thesis about demand analysis, product range improvement and review period calculation.

Industrial Engineering and Management

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An improvement of the refill process of vending machines.

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Management summary

Healzzy2Go is a start-up in the industry of vending machines with healthy substitutes for the regular candy bars. Currently, they are struggling with their refill process. During this process, they often encounter one of two situations. On the one hand, machines tend to have less than two items of every product in stock when the operators arrive. On the other hand, products tend to replenish unevenly in the machines. This means that one product may be out of stock while another may not even be sold once.

To solve this, Healzzy2Go proposed a solution to base the allocation of rings on an equalization factor, a factor between the demand of product x and product y. Basing the allocation of rings on this factor would equalize the replenishment of the products in the machine. Therefore, it was decided that this was a promising solution, so it was worked out further. As a start, several interviews were conducted to have a good overview of the current refill process. Next, a data analysis was done on the sales of 154 products over 27 vending machines. From this analysis, the equalization factors and the demand distributions were computed. These two were then used in the third stage, in which a model was built in Excel VBA. The input for this model is the product range of a particular machine, the equalization factors and the demand distributions. The model outputs with what period in between Healzzy2Go should refill the particular machine that was used as the input.

After these stages were done, an assessment was made as to whether the proposed solution will improve the current situation. This was done mainly on a basis of two indicators: the cycle service level and the replenishment ratio. The former is the chance that the products do not run out of stock during a certain period. The latter is a ratio between the number of items of the most empty ring and the number of items in the fullest ring. However, also the changes in the number of products in a machine, the number of visits by an operator and the safety stock were taken into account. Although these are not necessarily indicators of (in)efficiency in the refill process, they indicate what possible effects an implementation of the built model would have.

Initially, the cycle service level was determined at 50% and the replenishment ratio at $\frac{1}{8}$. The goals for these two indicators were set at 90% and 1 respectively. When calculating these indicators using the built model, it results in a cycle service level of 90% and a replenishment ratio of 90%. Although this seems like an improvement, the other three indicators changed as well. The number of products per machine were almost halved, the number of visits of an operator has more than septupled and the safety stock is on average twice as large. These huge changes come with quite some monetary implications. Assuming the costs of one visit is €20.− and the average price of a product is €3.50, the profit per week will decrease from €9.23 to −€786.79. This shows that it is even loss-making when the model is implemented as it is. Therefore, the recommendation is that the model can be implemented if and only if the significant changes that come with it are acceptable.

If Healzzy2Go should decide to move on with this model, they should find an implementation strategy to make sure this model can be incorporated into their refill process. Next to that and most importantly, further research has to be done on the accuracy of the input for the model. Currently, the data analysis is constructed using slightly sub-optimal data. Although this reduced the accuracy of the outcome of the model a bit, it can be prevented by using different data. Therefore, Healzzy2Go should work on gathering the transactions made per machine per product and use that as the data for the data analysis. This will improve the accuracy of said analysis and, therefore, the accuracy of the model. This will also affect the considerable changes talked about in the previous paragraph, which may in its turn affect the decision to implement the model.

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Glossary

In this chapter, an alphabetised list of key terms used in this thesis with their definitions and, if possible, formulas is drawn up.

Key term	Definition	Formula
χ^2-test statistic	This statistic tests how well two distributions compare to each other. (Hayes, 2020) It is mostly used in an hypothesis analysis (see *'hypothesis analysis'*).	$\chi^2_{df} = \sum_i \frac{(O_i - E_i)^2}{E_i}$
Confidence interval	A confidence interval is an indication as to how (un)certain it is that a certain parameter of, for example, a distribution falls between two values. (Kenton, 2020a)	$CI = [\bar{x} \pm z * \sigma]$
Demand distribution	The demand distribution is the distribution of the demand. Examples of distributions are normal (see *'normal distribution'*), poisson and binommial distributions.	
Efficiency	Efficiency is to get the highest possible outcome of the lowest possible input (Banton, 2020). Increasing efficiency in, for example, a factory, would lead to more products produced with the same (or sometimes even less) effort put into them.	

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Key term	Definition	Formula
Equalization factor	The equalization factor shows how much better or worse product x is selling than product y. It is the ratio between the sales of product x and the sales of product y.	$EF_y^x = \frac{\mu_{sales_x}}{\mu_{sales_y}}$
Forecasting	Forecasting is the technique of predicting future trends based mainly on historical and present data. (Tuovila, 2019) It uses statistics to incorporate uncertainty into the prediction, which makes it more accurate.	
Hypothesis analysis	A hypothesis analysis in statistics is a way to assess the possibility of a hypothesis to be right. (Majaski, 2020) The exact test statistic used depends on the available data. An example of a possible test statistic is χ^2 (See 'χ^2-*test statistic*').	

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Key term	**Definition**	**Formula**
Inventory management model	Inventory management entails the process of ordering products or materials, storing said products or materials and the general usage of a company's inventory. (Hayes, 2019) An inventory management model is a methodology to improve/optimise said process.	
Lead time	Lead time is the amount of time that passes between the start of a process and the end of it. (Kenton, 2020b) It is often used in manufacturing and supply chain management, but it also addressed in inventory management.	
Normal distribution	The normal distribution is a distribution of data that shows that data near the mean occurs more frequently than data further from the mean. (Chen, 2020) This distribution shows a bell curve when looked at in a graph.	$X \sim N(\mu, \sigma)$

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Key term	Definition	Formula
Replenishment ratio	The replenishment ratio is a ratio that shows the equality of the replenishment of the products in a certain machine. It can be calculated by dividing the number of items left in the ring with the least products by the number of items left in the ring with the most products. This ratio will approach 1 when the replenishment grows more equal and will approach 0 when the replenishment is more out of balance.	$RR = \frac{n_{minprod}}{n_{maxprod}}$
Semi-structured questionnaire	A semi-structured interview is a data gathering method that allows for some spontaneous adjustments. This is an interview with a few preset specific questions and lets the interviewer steer the interview based on the responses from the interviewee. (Cooper & Schindler, 2013, p. 153)	
Cycle service level	The cycle service level is the the chance that the products do not run out of stock during a certain period (Silver et al., 2016, p. 249)	$CSL = \frac{n_{demandismet}}{n_{demand}}$

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Key term	**Definition**	**Formula**
Standard deviation	The standard deviation is a parameter that shows how much the data points differ from the mean of the data set. (Hargrave, 2020) This parameter is higher when the data points are further apart and lower when they are closer together. It is denoted by a σ.	$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

Table 1: Glossary.

1 Introduction

In this chapter, a couple of topics will be discussed. First, the background of this research will be addressed, including an introduction of the company and a description of the background of the situation in Sections 1.1 and 1.2 respectively. This will be followed by an explanation of the core problem in Section 1.3, the theoretical framework in Section 1.4 and a plan of approach in Section 1.5.

1.1 The company

The problem at hand is currently owned by Healzzy2Go. This company was founded in April of 2019 and is one that strives for healthiness among its customers. It produces customizable vending machines with healthy substitutes for the unhealthy snacks that are normally in there. An example of such a machine can be found in Figure 1. These machines can be found at schools, in gyms, at shopping malls and in office buildings. Heallzy2Go will discuss with its customer what they want to do regarding the size of the machine, the product range in the machine and the style of the machine. They currently have five sizes and about 200 products available. However, not all of these options are currently used due to the matter of popularity. Furthermore, they have six preset styles, all focused on an industry ranging from sports to education to healthcare, work, mobility and leisure time. Moreover, due to the fact that the coronavirus has quite the influence on their daily business, they expanded their company to vending machines filled with face masks, antibacterial gel and other products like these.

Figure 1: A Healzzy2Go vending machine.

At the end of 2019, Healzzy2Go took over another company. This company was also in the industry and was doing relatively well. However, due to lack of resources, they were unable to move forward. Healzzy2Go made the choice to acquire the company because of the fact that they had more knowledge about the market they are in. Unfortunately, it was administratively not that well organized, which made it difficult to use said knowledge. Therefore, during the months after the takeover, they organized it better and they are now looking for ways to improve.

1.2 Current refilling process

Currently, Healzzy2Go does not know what products will be out of stock when they arrive at the machine. As a result of this, they also do not know when they should refill. Therefore, they have set up a policy that every machine should be visited by an operator at least once every two weeks. Although this is their current policy, this is also part of the problem they are facing. They know this is not working, since when they arrive it often happens that the rings of products in the machines are in one of the two following situations. On the one hand, the rings are too empty for their taste, which means that a ring of products, that has a maximum number of six products, has less than two products on its ring. This minimum has not been calculated but is rather an estimation based on experience. On the other hand, rings of products are sold unevenly. This results in the fact that some types of products will be emptied out, while others are not sold at all. Because of this irregularity, they find it more difficult to determine when they should refill.

1.3 Core problem

During the first meeting with Healzzy2Go, they explained that the vending machines they produce are inefficiently filled. The supervisor from the company, Judith Temiz-van Alphen, explained that the struggles talked about in Section 1.2 are causing more problems every day, which makes it a priority to handle. In this section, the core problem will be discussed. This will be done by first looking at the problems to solve and then creating an understanding of the core problem. After this, the reality and the preferred situation (the norm) will be identified. Finally, the core problem will be formulated as the research question and the solution process will be split up into different steps. In each of these steps, a subquestion will be answered. This will all be done in Sections 1.3.1, 1.3.2, 1.3.3 and 1.3.4 respectively.

1.3.1 Problems to solve

After doing more interviews with Healzzy2Go, the conclusion was reached that the cause of the problem that is perceived is twofold. On the one hand, employees do not have an idea of when to refill the machines. As was explained in Section 1.2, their policy is not based on what they sell but is more a managerial policy. On the other hand, employees do not know what to fill. Healzzy2Go has little to no insight into which products are selling well and which products are being ignored more. As a result of this, it often happens that one of the two following situations occur. The first situation is that operators arrive at a machine and only half of the products are touched. The other half of the rings are then completely full and not touched at all. The second situation is that operators arrive and the machine is completely empty.

Concluding, two problems should be solved. First, the products in the machines are not emptying equally. Second, the machines are too empty when the operators arrive. In Section 1.3.2 these two problems will be further identified and in Section 1.3.3 the norm and the reality will be assessed.

1.3.2 Understanding of the core problem

Before the research can be started, a full understanding of the problem at hand should be acquired. During the conversations with Healzzy2Go about the possible problems they face, it was discussed that the two problems talked about in Section 1.3.1 both fall under one umbrella. This is the matter that the machines are inefficiently filled. This inefficiency is then twofold, namely the two problems discussed in Section 1.3.1. Due to the fact that it is about inefficiency, an understanding of what inefficiency is should be achieved. In the glossary in Table 1, the definition of efficiency can be found and in Appendix A, a systematic literature review of possible indicators for the inefficiency can be seen. This way, the inefficiency can be defined and quantified. To fully quantify the problems at hand, two indicators for inefficiency should be found. As can be seen in the appendix at hand, a suitable indicator for (in)efficiency is the cycle service level (Moons et al., 2019, p. 7) (Slack et al., 2016, p. 647), which is the fraction of demand which is properly met. (Silver et al., 2016, p. 249) Although this is an indicator of the first problem that has to be solved, it does not fit the second one. When only the cycle service level is used, it can still be the case that one product is empty while the other is barely touched. Therefore, a second indicator for the (in)efficiency to fully capture both problems is needed.

The second problem faced is about equality in the replenishment of the products. A ratio between the product that is the most empty at the time of arrival and the product that is the fullest will be a possible indicator for this part of the (in)efficiency. This ratio will be smaller than 1 and approaching 0 if the equality of the replenishment of the products is more out of balance. However, if it is in perfect balance, it will be 1 and the products will replenish equally.

1.3.3 Norm and reality

Using the indicators from Section 1.3.2, an estimation of the efficiency of the current situation (the reality) and the desired situation (the norm) will be provided. First, the estimation of the current situation is given. Due to the fact that Healzzy2Go has no real knowledge of the cycle service level of the machines at any given moment, they were asked to give an estimation of how often it happens that an operator arrives at a machine and it is too empty for their taste. This means that when an operator arrives, all products have less than 2 items in their rings. They replied by stating that it was about 50% of the time. This estimate indicates the cycle service level and will, therefore, be used as an indicator for the reality of the (in)efficiency.

Next, an estimation of the current situation of the second indicator, the replenishment ratio will be given. Presently, all products have only one ring. This means that there are only 6 items of every product in a machine. Due to the fact that 50% of the time on average one item is left of a certain product in a machine, which is explained in the previous paragraph, and 50% of the time on average 4 items are left in a machine, the calculation will be as follows: $RR = \frac{0.5}{4} = \frac{1}{8}$

Next, an estimation of the desired situation will be given. Of course, the situation that the machines will never be too empty again is desired most, but that would mean that the inventory should be infinite and that is not possible. Therefore, Healzzy2Go was asked what cycle service level they would be satisfied with to which they replied with 90%. This means that a cycle service level of 90% will be the norm for the first indicator. For the replenishment ratio, a value of 1 would be ideal, as has been explained before. This will, therefore, be the norm of the replenishment ratio.

1.3.4 Research question

When talking with Healzzy2Go about the problem, they proposed a possible way to solve it. They proposed to calculate a factor between the sales of product x and product y to indicate how much better product x is selling than product y. If this factor is calculated for every possible pair of products, it can be used to determine the number of rings product x should have relative to product y. All the factors combined can then be used to determine the distribution of rings among products. Due to the fact that this will equalise the time it takes before a product is empty, it will be called the equalization factor. The definition for this factor can also be found in the glossary in Table 1. Because this looks like a promising solution to the problem, the research question will be:

"Is using a replenishment strategy based on an equalization factor an improvement to the refill process of Healzzy2Go?"

To acquire a full understanding of this question a few themes should be worked out in advance. First, a view of the current situation should be achieved. Second, the factors talked about at the beginning of this chapter, the equalization factors should be computed. Also, an analysis of the demand distributions of the products should be done to indicate future sales. Both the equalization factors and the demand distributions will then be used in the proposed calculation of the length of the period between two refill moments. This results in the following subquestions:

- "What is the current situation with respect to the refill process?"
- "What are the equalization factors in the current situation?"
- "What are the demand distributions of the different products at Healzzy2Go?"

- “How can the period length between two refill moments be calculated?”

The plan of approach for these subquestions will be given in Section 1.5 and an answer to the research question will be given in Section 5.

1.4 Theoretical framework

In this section, the main concept of this thesis, which is inventory management, will be elaborated on. The purpose is to give the theoretical framework in which this thesis lies. This concept can be defined by four trade-offs: deterministic versus stochastic demand, continuous versus periodic review, minimal costs versus service level approach and backlog versus lost sales. (van der Wegen, 2018, p. 7) (van der Wegen, 2018, p. 92) These trade-offs will be elaborated on in Sections 1.4.1, 1.4.2, 1.4.3 and 1.4.4 respectively.

1.4.1 Deterministic versus stochastic demand

The first trade-off is about deterministic versus stochastic demand. These two concepts are both ways the demand can be defined. More specifically, these are two ways the demand can be known. To elaborate on the first one of the two, deterministic means that the demand is known in advance. (Winston, 2004, p. 846) This way, very specific decisions on inventory management can be made and there is no randomness involved. Moving on to the second concept of the two, stochastic demand is the demand of which the future value is not known precisely, which can also be called probabilistic. (Winston, 2004, p. 880) This means that there is randomness involved and that way precise decisions cannot be made. A particular certainty can be given that a decision will yield the desired situation when making a decision, but there is always a chance that events turn out different and the desired situation is not reached. Although this is not always the case, the chance that this happens can be minimized by, for example, using a safety stock. This is then a certain stock that is always on hand to ensure that the uncertainty in demand does not lead to stock-out. (Winston, 2004, p. 894)

1.4.2 Continuous versus periodic review

Secondly, an elaboration of the trade-off between a continuous and a periodic review will be given. A continuous review means that the inventory is constantly monitored and the assessment on whether to restock is made continuously. (Winston, 2004, p. 848) Although this may seem the best option, it can quickly become cost-intensive, due to the fact that the inventory is constantly monitored. Another option is reviewing the inventory only periodically. This means that the inventory is not monitored constantly, but only after a certain period. (Winston, 2004, p. 848) This period can be small like every day or week, but can also be larger like every month or quartile. When using periodic review, the costs will decrease, but it will also give you less control over the fact that there are always enough products in stock.

1.4.3 Minimal costs versus service level approach

Moving on to the third trade-off, which is one between aiming for minimal costs or for a high service level. The latter is the percentage of time of which the demand is met. (Winston, 2004, p. 898) These two concepts are mutually exclusive in such a way that a service level of 100% will come with an infinite number of products in stock and thus quite high costs. On the other hand, minimized costs will result in a lower service level, since then there are fewer products in stock and the chances are higher that with stochastic demand a stock-out will occur.

1.4.4 Backlog versus lost sales

Finally, the trade-off between the possibility of backlog and lost sales will be elaborated on. This is a trade-off that occurs when there is a stock-out. If that happens there are two options: either the item can be backlogged, which means that the demand from then on will be put on a list and these will be the first to be delivered once the stock is back in (Winston, 2004, p. 847), or the sales are lost and the company misses out on revenue. These two concepts are completely mutually exclusive and it depends on the market whether the demand can be backlogged.

1.4.5 Current situation

For the current situation, a few determinations can already be made. Looking at the trade-off between deterministic versus stochastic demand, it seems that the demand is stochastic. The demand is not known, but fluctuates, which causes uncertainty. When deciding between a minimal costs approach or a service level approach, Healzzy2Go is dealing with a service level approach. This is also reflected in having the cycle service level as an indicator for the (in)efficiency determined in Section 1.3.2. Finally, there is a trade-off between backlog and lost sales. In this situation, Healzzy2Go is dealing with lost sales. If a potential customer arrives at the machine and the product they want to buy is out of stock, he or she cannot place an order so that it will be provided later. It is rather that that person is out of luck and leaves empty-handed. This indicates a lost sales situation.

Following this train of thought, we can conclude that the model most representing the current situation is the (R, S)-model. When using this model, every R units of time, an order is placed in such a volume that the inventory level is raised to the order-up-to-level S. (Silver et al., 2016, p. 277) In this case, the operators bring the products along on their visit, which will result in a lead time of 0. Combining this all, the conclusion is that the inventory model that fits the situation best is an (R, S)-model with a lead time of 0.

1.5 Plan of approach

In this section, a plan of approach for the subquestions defined in Section 1.3.4 will be given. First, an approach to the acquisition of an understanding of the current situation will be given. Second, the approach for the determinations of both the equalization factors and the demand distributions will be stated. Third, how the period lengths will be calculated will be explained and it will end with an elaboration on the deliverables.

To answer the first subquestion, some interviews will be held with multiple people at Healzzy2Go. This will be done by using a semi-structured questionnaire that will be prepared beforehand. (Cooper & Schindler, 2013, p. 153) Both high level and low-level employees will be interviewed to get a full understanding of the situation. This means that the operators and the logistics manager will be interviewed. This will provide more different views on what is going on during the whole process. An elaboration on this part can be found in Chapter 2.

After this, the data provided by Healzzy2Go will be analyzed as a method to answer the second and third subquestion. The data that will be used is the transactions made by customers at the machines of Healzzy2Go. This will then be used to calculate the beforementioned equalization factors. Furthermore, a distribution to the demand that fits the data best will be applied, which will be used in a further stage of this research. The entire data analysis, along with examples can be found in Chapter 3.

After the completion of this analysis, the next stage of this research will begin. In this stage, the fourth subquestion will be answered by using the outcomes of the analysis to create a model that will forecast when Healzzy2Go must refill. First, the requirements for this model will be set and an inventory model based on this will be chosen. Then, the to be created model will be made in Excel VBA based on the chosen inventory model. The input will be the products in the vending machines, the distribution of the demand determined earlier and the equalization factors calculated in the previous stage. It will output what and when Healzzy2Go should refill its machines. This can be found in Chapter 4.

Finally, this will all be combined in a report and will provide a recommendation for Healzzy2Go regarding the research question. Furthermore, possible options for further research will be given.

The deliverables of this thesis will be the model built for the calculation of when and what to refill and the report including the literature research, the summary of the analysis, the recommendation for Healzzy2Go and the options to further research. This bachelor's thesis will be ended with a presentation on what has been done and what the results are.

2 Current situation

As can be seen in Section 1.5, the first step will be gathering information on the current situation with respect to the refill process from when the contract with the customer is signed until the point when all Healzzy2Go does is customer maintenance. First, it is described how this will be done and after that, the process is described. These are Sections 2.1 and 2.2 respectively.

2.1 Data gathering method

To gather information on the current process, a semi-structured questionnaire was drawn up that would be used during walk-ins with the operators and the logistics manager at Healzzy2Go. This questionnaire consists of five parts. First, an introduction of the interviewer and the goal of the research will be given. After that, some questions about the background of the interviewee will be asked. These include questions about his/her position within Healzzy2Go and how long he/she has worked there to get a sense of his/her experience with the process. Furthermore, questions are asked about the process to get a sense of what is currently going on. It begins with a question as to whether the interviewee can describe the process as indicated in the introduction of this chapter. Then it goes into depth about how the responsibilities of the interviewee fit in this process. After this, questions were asked about the faults in the current process. To keep the neutrality of this interview, it was aimed to ask the questions assumption-free as much as possible. Should a question with an assumption be asked, it would always be preceded by a question that checks whether that assumption is correct or not. The interview was completed by an explanation of what will be done with the results and the question to the interviewee as to whether they have questions.

The results of these walk-in interviews will be generalized and elaborated on in Section 2.2. Should interesting struggles come up during these interviews that are not in the scope of this research, they will be mentioned in the recommendations as a possible subject for further research.

2.2 Current process

From the different interviews, the current situation and some precarious points were identified. This whole process can be seen in Figure 2 and will be explained in the upcoming paragraphs.

From the moment that the customer signs a contract, it is the responsibility of the logistics manager to coordinate the process until the installation of the machine at the customer's location. During the acquisition process, the specifications of the machine will be determined. The logistics manager will receive the choices for the product range, the size of the machine, the appearance and the deadline for the installation. These will then be communicated to their suppliers and delivered to their warehouse in Druten within a week. Once everything is in stock, the machine will be made ready. This means that the appearance will be taken care of and the software will be installed and linked to their ERP system. The machine will also be tested in Healzzy2Go's warehouse and once the machine has received clearance, it will be shipped to the customer. This process up until now has taken up most of two to three weeks.

Next, the installation will take place. One of the operators will go to the customer to set the machine up on location and it will be filled for the first time. From now on there is a difference between the two subscriptions Healzzy2Go offers. On the one hand, there is the self-service subscription. This means that after the operator has installed the machine, a certain stock will be left behind and the customer has the responsibility that the machine is refilled. He/she can order new products on the webshop Healzzy2Go has and these products will then be delivered within a few days. On the other hand, there is a full-service subscription. When a customer chooses for this subscription, it means that Healzzy2Go has full responsibility that the machines are properly filled. Since May of 2020, there has been a shift in how these subscriptions were handled. Before, once the machines were installed, the operators would initially return once every two weeks and would then assess if they should come more or less often. Now, they will estimate how often they should come based on similar machines. This will then also be reassessed every time they arrive. Although this is a step in the right direction, they are not there yet and the refill process, in particular, can still be improved.

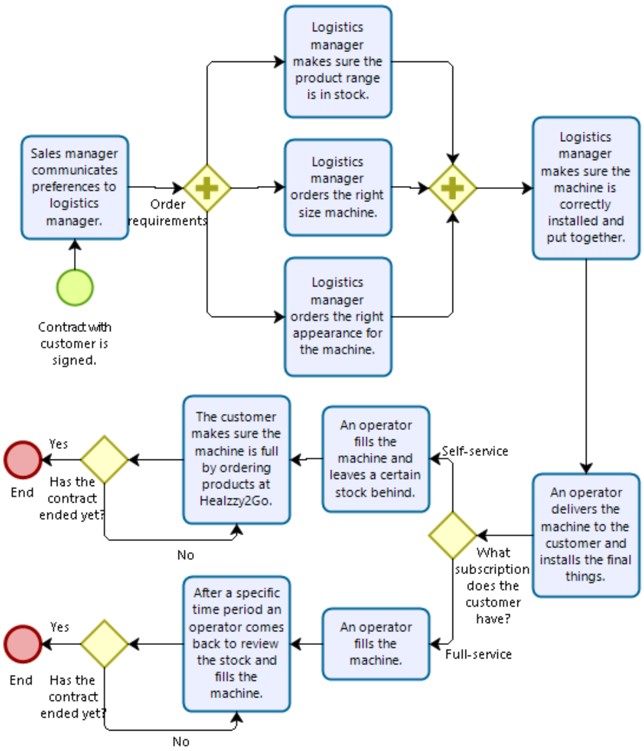

Figure 2: BPM of the current process.

2.3 Chapter summary

When answering the first subquestion stated in Section 1.3.4 about the current situation of the refill process, a few walk-in interviews were conducted. These were semi-structured interviews taken with the operators and the logistics manager as interviewees. During these interviews, their role in the refill process, the refill process itself and, if applicable, improvement points were discussed. The outcome, which is elaborated on in Section 2.2 and visualized in Figure 2, is that after the preferences are set, the logistics manager makes sure everything is set for the machine to be installed at the customer. When that happens, the customer can have the subscription of self-service, which means that the operator leaves a certain stock and from then on the customer is responsible for refilling the machine, or full-service, which means that Healzzy2Go stays responsible for refilling the machine. When the full-service subscription is chosen, an operator initially comes by the machine every two weeks and evaluates if that is long enough or if that should change.

3 Data analysis

In Section 1.5, it was stated that a data analysis will be done on the data provided by Healzzy2Go. With regards to this data, initially, the transactions per machines were asked as the preferred data. However, due to the unavailability of this dataset, it was chosen to use another dataset and transform that to usable data. Therefore, the first step in this data analysis will be the transformation of the provided dataset. After that, the data set will be analyzed and used for the determination of the demand distributions and the equalization factors. This will be done in Sections 3.1, 3.2 and 3.3 respectively.

3.1 Transformation of provided data set

As stated in the introduction of this chapter, the preferred data set, which is the different transactions per machine, was not available. Therefore, it was discussed with Healzzy2Go what alternative is available. Eventually, the conclusion was made that the records of how much has been refilled every time an operator arrives at the machines can be used as an input for the analysis. This should be transformed into estimations of how much has been sold per day, but then it is usable data. This process can be seen in Figure 3 below.

The transformation was done by establishing how many days there were between two refill moments in which the machine was turned on. This means that weekends and school holidays are reduced from the actual number of days between the two times. The reduction of school holidays only holds for schools, but weekends hold for all machines. When this process is done, the number of items refilled is divided by the number of days the machine is turned on and then assigned to the corresponding dates. This was done for all 31 weeks and it resulted in a division of how many items were sold per product per machine.

However, not all machines were turned on at the same time, there was still a small bridge to cross. Therefore, the number of items sold per product per machine was added for all machines. This resulted in the number of items sold per product. To ensure that all products and all time periods were equally treated by the upcoming analysis, these values were divided by the number of machines turned on that specific day. This division resulted in the number of items sold for an average machine per product per day.

Finally, these values were grouped. To achieve statistical significance, a minimum of 30 data points are needed. (Meijer, 2018) When grouped per week, in 31 data points remain, which is statistically significant. Therefore, the rest of this data analysis will be done with the data grouped per week for the 154 products that can be analyzed for the demand distribution and the equalization factors in Sections 3.2 and 3.3 respectively.

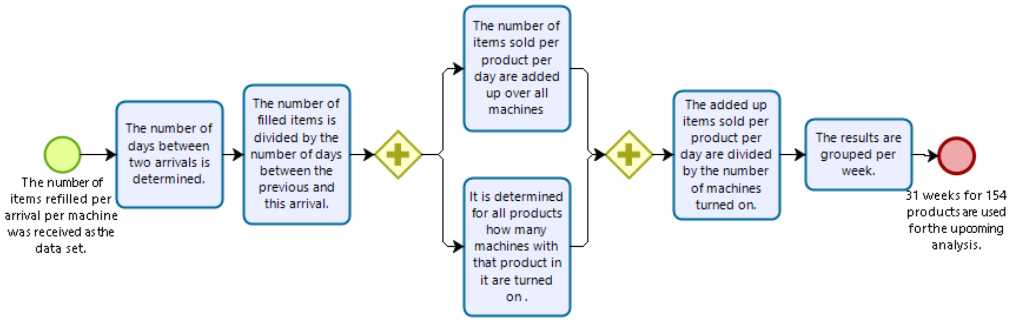

Figure 3: The transformation process of the data set.

3.2 Determination of demand distributions

To determine the demand distribution of the different products, an hypothesis analysis was conducted. As the hypothesis, the assumption of normality of the demand distribution was used. The parameters for the normality, being the mean and the standard deviation of the data points, were calculated by using the following formulas. First, the mean per product was computed by using

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad (1)$$

in which $\bar{x}$ is the mean of the product and n is the number of data points, which is 31 in this case. After that, the standard deviation is computed by using

$$\sigma = \sqrt{\frac{\sum_i^n (\bar{x} - x_i)^2}{n-1}} \qquad (2)$$

in which σ is the standard deviation, n is again the amount of data points and $\bar{x}$ is the mean of the specific product.

Then, using a χ-test was executed. This test calculates with a particular certainty how likely it is that the data points with the given parameters are normally distributed. To do this, the certainty and the degrees of freedom have to be used as input for this test. With 0.0125 as the certainty and the number of bins minus one as the degrees of freedom as the input for the χ-test, the normality of the demand distribution was tested.

For this χ-test, a histogram has to be made. To start this, the number of bins for the histogram has to be calculated by using the square root rule. This results in the formula:

$$num_{bins} = \lceil \sqrt{n} \rceil \qquad (3)$$

in which n is the number of data points, in this case 31, and the outcome is rounded up. Next, the data points have to be assigned to the bins in question. Every bin has a size, which is calculated by

$$size = \frac{max_i - min_i}{num_{bins}} \qquad (4)$$

in which min_i and max_i are the minimum and maximum value respectively of the data points for product i. The outcome of this formula will, in combination with the minimum and maximum value, result in the boundaries for every bin. These can then be used to assign all the data points to the several bins. This is then compared to the number of data points that should be in the bins when the sales of product i is normally distributed. To assess the similarity between the expected and the observed number of data points in a certain bin, the error for that bin is calculated by using

$$error = \sum_j \frac{(E_j - O_j)^2}{E_j} \tag{5}$$

in which O_j is the observed number of data points in bin j and E_j is the expected number of data points in bin j. The errors of all the bins are summed up to form the total error. Then, the value of χ with the before mentioned parameters was determined. If the total error is smaller than the value of χ, the hypothesis can be accepted and the product's demand can be considered normally distributed. If this is not the case, it does not mean that the demand is not normally distributed, but it cannot be said with the preferred certainty that it is.

Using this approach, 88% of the product's sales can be considered normally distributed. Although for 12% it cannot be concluded with 97,5% certainty that the demand is normally distributed, it does not mean that it is not. Therefore, for the sake of simplicity, it will be considered normally distributed with the parameters computed at the beginning of this section.

3.3 Determination of equalization factors

Finally, the equalization factors will be determined. As described in Section 1.5, these factors will be calculated by dividing the mean of one product by the mean of the other, as shown below.

$$EF_y^x = \frac{\mu_{sales_x}}{\mu_{sales_y}} \tag{6}$$

Since 154 products are analyzed, this results in a matrix of 154 by 154. However, not for all these products the equalization factor can be computed. Due to the fact that some of these products were not sold at all and, therefore, have a mean of 0, computing the equalization factors will result in either 0 or ∞. Both of these results are not usable in the upcoming model, so that is why the decision has been made to exclude these from the computations.

3.4 Example calculations

To provide more clarity of the process of calculating the demand distributions and equalization factors, an example will be given in which for a product both calculations will be done. In Sections 3.4.1 and 3.4.2 respectively, these calculations will be done for a certain product in the entire product range Healzzy2Go offers.

3.4.1 Example calculation of the demand distribution

To calculate the demand distribution, the hypothesis analysis with the hypothesis that the demand is normally distributed is conducted. To start that, the parameters of the distribution should be known. For a normal distribution, only two parameters are necessary, which are the mean and the standard deviation. For the product at hand, these two parameters are calculated using Formulas 1 and 2 respectively, which results in a mean of 0.872... and a standard deviation of 0.639... based on the demand depicted in Figure 4. Next, the number of bins and the bin size will be computed for the histogram. Using Formulas 3 and 4 respectively, it was calculated that 6 bins with a size of 0.418... would be needed. This would result in bins as shown in Table 2 and the histogram shown in Figure 5. For these bins, the frequency of data points that lie between the lower and upper limit is determined and shown in the most right column of Table 2. These values will, later on, be compared to the expected values for these bins.

Bin number	Upper limit	Frequency
1	0.42	9
2	0.84	10
3	1.25	5
4	1.67	2
5	2.09	4
6	2.51	1

Table 2: The bins for this example.

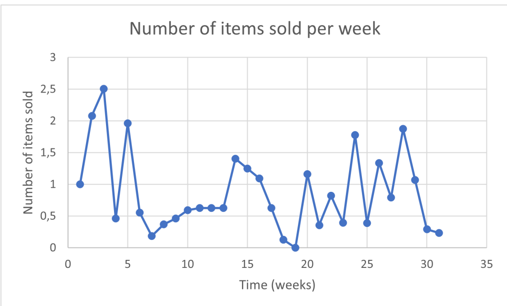

Figure 4: A graph of this example's demand.

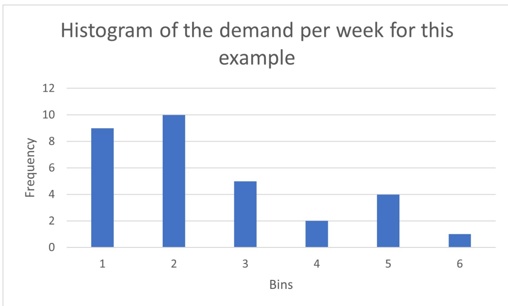

Figure 5: Histogram of this example's demand.

Moving on, the expected values for the bins will be determined. Due to the fact that the assumption was made at the beginning of this calculation that the demand is normally distributed, these values will be derived from the normal distribution. To do this, the cumulative density function (CDF) will be computed with the previously calculated parameters as input. The expected percentage of the total data points per bin will be derived from this by subtracting the CDF value of the previous bin from the CDF value of the current bin. This will then be multiplied by the number of total data points to find the expected number of data points per bin. For the product at hand, this can be seen in Table 3.

Bin number	CDF	Per bin	Expected number of data points
1	0.24	0.24	7.39
2	0.48	0.24	7.40
3	0.72	0.25	7.67
4	0.89	0.17	5.26
5	0.97	0.08	2.39
6	0.99	0.02	0.72

Table 3: The expectations for the bins in this example.

Now, the two values per bin will be compared by using Formula 5. In Table 4, the error per bin will be denoted and added up to form the total error. This total error will then be compared to the value of χ^2. This value of χ^2 indicates what the maximum error may be for the demand to still be normally distributed. For the determination of the value of χ^2, two parameters must be known: the certainty with which the demand can be categorized as normally distributed and the degrees of freedom. The former cannot be calculated but is usual to be set at 95% certainty. The latter is computed as follows:

$$df = bins - 1 - num_{parameters} \tag{7}$$

With two parameters in the normal distribution and a total of 6 bins, the degrees of freedom will be $df = 6 - 1 - 2 = 3$. Using these two parameters for the determination of the value of χ^2, 9.348... will be the value of χ^2. Comparing this to the total error of 5.412, it can be concluded that the total error is smaller than the value of χ^2. This means that with 95% certainty the conclusion can be drawn that the demand for the product "Charlie's Natural Soda Black Currant Acai" is normally distributed with a mean of 0.872... and a standard deviation of 0.639....

Bin number	Observations	Expectations	Error
1	9	7.39	0.35
2	10	7.40	0.91
3	5	7.67	0.93
4	2	5.26	2.02
5	4	2.39	1.09
6	1	0.72	0.11
Total			5.41

Table 4: Comparison between observations and expectations.

3.4.2 Example calculation of the equalization factor

Moving on to the equalization factors, it can be noted that then the value relies on two products, rather than one as with the demand distribution. For that sake, two other products will come into play for this example. The second product will be "Active O2 Apple/kiwi" with a mean of 8.333... and a value of 2.995... as the standard deviation. The third product will be "Cawston Press Sparkling Apple Rhubarb" with a mean of 0.066... and a value of 0.102... as the standard deviation. For the sake of simplicity, the products are renamed product 2 and product 3 respectively. For the same reason is the product "Charlie's Natural Soda Black Currant Acai" renamed to product 1. These can also be seen in Table 5.

Product	Mean	Standard deviation
1	0.87	0.64
2	8.33	3.00
3	0.07	0.10

Table 5: The products with parameters for this example.

For the equalization factors, only the means will be used, as can be seen in Formula 6. This means that the mean sales of product x will be divided by the mean sales of product y to have an indication of how much better product x sells than product y. In Table 6, this is done for the products at hand. In this table, some sells are marked with an 'x', which means that for that cell products x and y are the same product. To show

Product\product	1	2	3
1	x	0.10	13.03
2	9.55	x	124.37
3	0.08	0.01	x

Table 6: The products with parameters for this example.

what has been done, the equalization factor between product 1 and product 2 will be elaborated on. As can be seen in Table 5, the mean of product 1 is 0.873 and the mean of product 2 is 8.333. Following Formula 6, results in $EF_2^1 = \frac{0.873}{8.333} = 0.105$, which is the same as in Table 6.

3.5 Chapter summary

For the answer to the second and third subquestion stated in Section 1.3.4 about the equalization factors and demand distributions, the rough data received from Healzzy2Go was transformed into workable data by spreading the data points over the time it represented. Furthermore, the data was altered to cancel the fact that some machines are not turned on all the time, which would result in a bad representation of the situation. It was then clustered per week and two analyses were conducted: the calculation of the equalization factors and the fitting of a normal distribution. For the former, Formula 6 was used to calculate the equalization factors. The latter, however, required some more steps. First, assuming the data were normally distributed, the parameters $\bar{x}$ and σ were computed. These were then used as input for a hypothesis analysis to test the data for normality. This was done for all products and the result is that 88% of the products are normally distributed with computed parameters $\bar{x}$ and σ. For the sake of simplicity, it was assumed that all products are normally distributed with the computed parameters.

4 Model

In Section 1.5 it was written that after the data analysis, a model will be constructed. First, there will be looked at the specifications of the model, after which the model itself will be built. Finally, the calculations will be done on a sample machine. These segments are Sections 4.1, 4.2 and 4.4 respectively.

4.1 Specifications of the model

As described in Section 1.5, the idea of this model is to have a composition of products as the input for the model and have the refill periods, meaning the number of days a machine can go without needing a refill of products, and the distribution of the rings between products as the output of the model. This will be done by using the distributions determined in Section 3.2 and the equalization factors determined in Section 3.3. Furthermore, Healzzy2Go provided a couple of requirements regarding the capabilities of the model. First, it should take the safety stock into account. They normally have a safety stock of 2 products per ring, but should something else improve the process' performance, it will be considered. This means that the safety stock should be calculated in the model to offer the eventual user the option to use another safety stock.

The fact that Healzzy2Go works with a safety stock also means that the inventory management model that will be used should work with safety stock. Furthermore, there is a choice between a continuous and periodic review of the inventory level. Due to the fact that Healzzy2Go only checks the products that are still in the machine when an operator goes to the customer's location, they are working with a periodic review. (Winston, 2004, p. 907) However, when using a periodic review, the inventory level is looked at and an order will be placed for the remaining products with a certain lead time. In this case, the operators bring the products along on their visit, which will result in a lead time of 0. Combining this all, the conclusion is that the inventory model that fits the situation best is an (R, S)-model with a lead time of 0.

4.2 Building of the model

After the determination of the specifications, the model itself was constructed. This has been done in Excel VBA, which results in the fact that the model is an Excel file. To start with, the outline of the model was built, followed by a check of whether the selected products fit in the chosen machine when using the equalization factors. After this, the inventory management model was built and the desired calculations were done. Last, the results were presented in a sheet to give a clear overview. These stages will be explained upon in more detail in Section 4.2.1 and an overview is given in Figure 6. Also, a user guide to the model will be given in Appendix C.

4.2.1 Technical stages

First, the outlining of the model will be elaborated on. To start this stage, the output of the data analysis is imported into the Excel file. These sheets will then be hidden, so the data cannot be altered anymore. Furthermore, an input sheet will be made. This includes a list of 72 products, which is the maximum amount of different products that can be in the largest machine Healzzy2Go offers, and a button that shows a window in which the size of the machine and the desired safety stock can be indicated. Finally, a results sheet will be created. In this sheet, there will be an overview of the product chosen in the input sheet, with the necessary amount of rings next to it. It also shows a graph of the forecasted demand using the suggested policy and it shows the suggested policy. However, the data that will be put in the results sheet, will be calculated at a later stage.

Next, we move on to the check as to whether the selected products fit in the chosen machine using the equalization factors. To compute this, the sheet with the equalization factors, the size of the machine and the selected products are the necessary input. Healzzy2Go currently has five different machines: Compact Standard, Medium Standard, Medium Premium, Max Premium and Max+ Premium. These machines have a size ranging from 24 rings to 72 rings. The output will be the number of rings allocated to each product. First, the model will look if the products are sold at all. If this is not the case, an equalization factor could not be made, since a division by zero is impossible. This then means that these products cannot be included in further stages of the model.

After that, the actual check as to whether it fits will take place. It will look for the least sold product in the list of selected ones and allocate one ring to that product. Then it will look for the equalization factors that are in the column of the least sold product and allocate the rings to the other products. This will be done by giving every product the rounded version of the respective equalization factor. However, not all products fit into one ring. Products that are cookies or crisps need two rings for one product, so for these products, the equalization factor is doubled and then rounded as well. If the sum of the allocated rings exceeds the size of the machine, a window will pop up with an error stating this problem and a suggestion on which products to eliminate from the product range. These selected products to eliminate are the three least selling products. Otherwise, if the sum of the allocated rings is less than the maximum size of the machine, the model will move onto the next stage.

Moving on to the third stage, which will be the construction of the inventory management model. As you can see in Section 4.1, an (R, S)-model with a lead time of 0 will be used. Furthermore, as can be seen in Section 3.2, the products were considered normally distributed with all their own mean and standard deviation. The input for this stage will, therefore, be the selected products, the distributions of all products and the allocated rings from the previous stage. First, the most critical product will be determined. This is done by evaluating every product on the difference between the rounded equalization factor and the unrounded equalization factor. The product with the lowest value of Formula 8, which will be negative when the equalization factor is rounded down and positive if the equalization factor is rounded up, will be the most critical product and will be used as the base for the safety stock calculation.

$$nint(EF_j) - EF_j \tag{8}$$

In this formula, $nint(EF_j)$ is the rounded equalization factor of product j and EF_j is the equalization factor of product j. The product that has the lowest value of this formula is marked as the most critical product in the product range. For this product, the standard deviation for the number of allocated rings to that product will be calculated by using the following formula.

$$\sigma = \sqrt{\sigma^2 * r_i} \tag{9}$$

In this formula σ is the standard deviation of the joint distribution, n is the total number of different products in the machine, σ_i^2 is the square of said standard deviation or the variance of product i and r_i is the number of rings allocated to that product. This will then be used for the calculation of the safety stock. For this, the formula

$$SS_i = \frac{z * \sigma_i}{n} \tag{10}$$

will be used. Here, SS is the safety stock, z is the inverse of the standard normal cumulative distribution with a probability of 90%, which is the cycle service level, and n is the number of rings allocated to the most critical product. If the calculated safety stock is different from the desired safety stock indicated in the pop-up window, the user will get the choice to change it. The original safety stock can also be kept and then the calculations will move on with the original one.

After this, the length of the cycle will be computed. To start this, the mean sales of the whole product range must be computed by using the formula:

$$\bar{x} = \sum_{i=1}^{n} \bar{x}_i * r_i \tag{11}$$

In this formula $\bar{x}$ is the joint mean, n is the total number of different products in the machine $\bar{x}_i$ is the mean of product i in the machine and r_i is the number of rings allocated to that product. Next, the period length will be calculated. This will be done by using the following formula:

$$SS = S - E(D_R) \tag{12}$$

In this formula, SS is the total safety stock of the machine based on the safety stock calculated before, S is the total number of products in a machine at maximum capacity and $E(D_R)$ is the expected demand during a certain review period. The expected demand per week is known and calculated using Formula 11, so the expected demand during a certain review period should be:

$$E(D_R) = E(D_{week}) * R \tag{13}$$

Here, $E(D_{week})$ is the expected demand per week and R is the review period in weeks. Using Formula 13 in Formula 12, the following formula comes up:

$$SS = S - E(D_{week}) * R \tag{14}$$

When this formula is rewritten such that the review period is before the equal sign and the rest is after it, Formula 15 appears.

$$R = \frac{S - SS}{E(D_{week})} \tag{15}$$

This value will then be multiplied by five to accommodate the number of working days between two visits. Finally, these results will be presented in the results sheet. This means that there will be an overview of the selected products with their allocated rings. The previously created graph will be filled with the computed data points and the length of the period in working days will be shown.

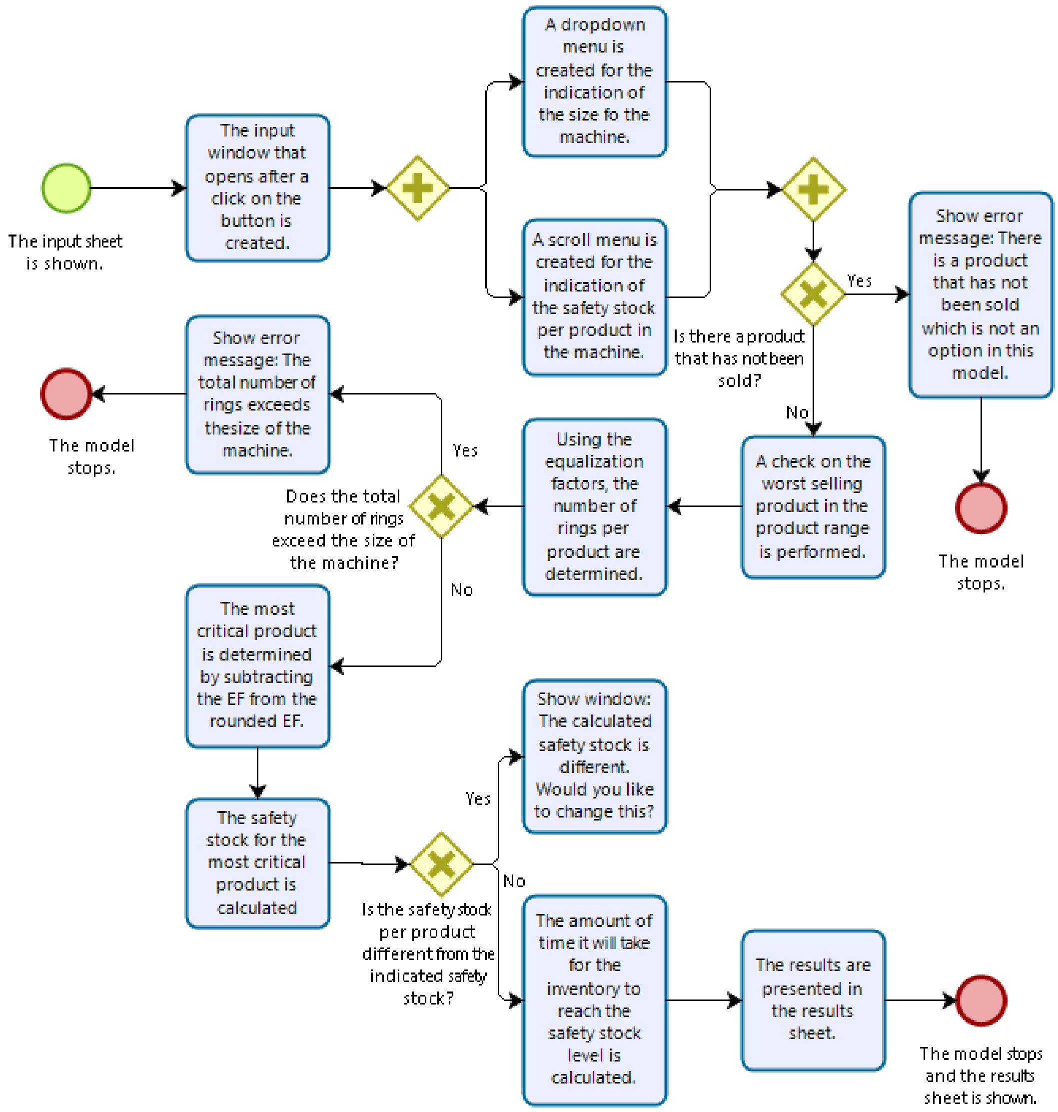

Figure 6: The process the model goes through.

4.3 Commercial implications of the model setup

Here, the commercial implications of the model setup will be elaborated on. Two major implications will be discussed. First, the consequences of eliminating a product will be talked about, followed by the possibility of the model not filling all the rings in the machine. These are discussed in Sections 4.3.1 and 4.3.2 respectively.

4.3.1 Elimination of a product

To start, the commercial implications of the elimination of a product from the product range will be discussed. As stated in Section 4.2.1, once the rings required for a certain product range exceed the maximum capacity of the selected machine, the three worst-selling products in the product range are highlighted and a choice will be given. Either another size machine should be chosen or at least one product should be eliminated from the product range. The product that will be eliminated, should not necessarily be one of the highlighted ones, but that is recommended. This is because if worse selling products are eliminated, it means that better selling products stay, which will increase customer satisfaction and in the end yield more revenue. Although it seems that because of that reason this is not a problem, it will become one when a product has to be eliminated that the customer wants in the product range. When this happens, it is recommended to go into conversation with the customer and talk about the situation. The alternative is to eliminate a better selling product, which is not beneficial for either party. There is always the option of choosing another size machine, but that should also be discussed with the customer.

4.3.2 Fewer products than rings in a machine

Another situation that may occur, is one when the total number of allocated rings is less than the maximum capacity of the machine. When this happens, there are three options to choose from when continuing. The first option is to do nothing with the leftover rings and leave them empty. Although this will not disturb the composition of allocated rings, it will also not yield any more revenue. The second option is to fill those rings with a product that is already in the product range. This may yield more revenue and the customer will probably be okay with it since the product is already in the product range. However, it is unnecessary and when the choice has been made to fill these rings and it may be better to look at the third option. This option results in filling the leftover rings with products that are not already in the product range. It is then wise to add a product that does not completely change the allocation of rings of the other products. This means that when, for example, a product is added that sells quite bad, it will affect the number of rings the other products are allocated. On the other hand, if a product sells well, it may require more rings than are leftover in the machine. A good choice will be to add a product that sells about just as well as or a bit better than the worst-selling product in the product range. This will result in a number of allocated rings of one or two, which will probably fill the gap.

4.4 A sample machine

In this section, an example will be given on how to come to the result when using this model. For this example, the model itself will not be used, but the calculations will be done by hand. For the sake of clarity, not all calculations will be done, but only unique ones. This means that there will not be any repetitiveness. In Section 4.4.1 the check will be done as to whether the product range fits in the chosen machine. Section 4.4.2 will focus on the determination of the safety stock and Section 4.4.3 will end this section with the final calculations.

To start off, the specifications of the example will be provided. For this example, a real machine will be used that is located in Heerlen. In the current machine, 27 different products are present. It is the smallest machine possible, which is the "Compact Standard" machine with a maximum capacity of 36. Furthermore, an initial safety stock of 2 is chosen.

4.4.1 Rings check

The check as to whether the current product range fits in the machine at hand consists of two parts. First, the check as to whether the product has been sold at all has to be done and second, the check as to whether the current product range does not take up too many rings has to be done.

In Table 7, it can be seen that there are no products that have a mean of 0. This means that all products currently in the product range have been sold at least once, resulting in the fact that the first part of the rings check has come to an end with no products that should not be in the product range. Moving on to the second part, which is the check on if the required division of rings exceeds the number of rings in the chosen machine.

Product	Mean	Product	Mean
1	2.85	15	5.89
2	2.08	16	5.62
3	0.75	17	2.49
4	1.66	18	1.23
5	1.31	19	8.61
6	0.75	20	6.03
7	0.83	21	3.89
8	0.75	22	1.93
9	8.30	23	1.60
10	5.97	24	1.78
11	1.14	25	0.48
12	1.94	26	0.64
13	4.00	27	0.41
14	4.01		

Table 7: Means of the product range.

To do this, the least sold product will be chosen as a first step. If you take a look at Table 7, it can be seen that product 27 is the least sold product with a mean of only 0.414 products sold per week. This means that the base for this check will be product 27. In Table 8, a sorted overview of the machine will be given with the equalization factors (EF) based on the base product. This means that the equalization factor for product 27 will be 1 and all the other products will be based on that. As can be seen in the table, the equalization factors are quite disparate. There is a factor of 20, but also one of 1.15. In the same table, the rounded values of said equalization factors are given.

Product	EF	Rounded EF	Product	EF	Rounded EF
27	1	1	12	4.68	5
25	1.16	1	2	5.02	5
26	1.55	2	17	6.01	6
3	1.81	2	1	6.89	7
6	1.82	2	21	9.39	9
8	1.82	2	13	9.65	10
7	1.99	2	14	9.68	10
11	2.76	3	16	13.56	14
18	2.97	3	15	14.22	14
5	3.17	3	10	14.42	14
23	3.86	4	20	14.55	15
4	4.01	4	9	20.02	20
24	4.30	4	19	20.79	21
22	4.67	5			

Table 8: EF and rounded EF of the product range with product 27 as the base.

When all these equalization factors are rounded and added up, the total number of rings required will be 260. Note that this is not the same number as when you round and add up all the numbers from the table. This is because some products require two rings due to their size. In this product range, this is the case with 8 products, which results in the difference. With a maximum capacity of 36 rings in the chosen machine, the conclusion has to be drawn that the current product range does not fit in the machine at hand. To solve this, some products have to be eliminated from the product range. Another option can be to choose another machine size, but since this is the machine chosen by the customer, this is not an option in this case.

Product	EF	Allocated rings
17	1	1
1	1.15	1
21	1.56	2
13	1.61	2
14	1.61	2
16	2.26	2
15	2.37	2
10	2.40	2
20	2.42	2
9	3.33	3
19	3.46	3

Table 9: Division of rings among the product range.

When eliminating products from the product range, the three worst-selling products are looked at. In the model, those products will be highlighted, but for now, they will be drawn from Table 7. As stated before, the worst-selling product is product

27. As can be seen in the table, the other two are products 25 and 26 respectively. Eliminating these from the product range and following the same steps as elaborated on before, results in a total required number of 139 rings. This has already decreased quite a lot, but it is still almost four times the number of rings at maximum capacity. Therefore, this procedure is repeated until the total required number of rings is smaller than the maximum capacity. After this has been done, the division of rings will be as shown in Table 9. As can be seen in the table, there is a total of 33 required number of rings, which fits in the maximum capacity of 36.

4.4.2 Safety stock determination

Coming to the determination of the safety stock. This part has to be done in two phases. First, the most critical product in the product range will be determined. This will be done by checking for which product there is the greatest risk of the rings being empty before the others are empty. In other words, it is determined for which product formula 8 yields the lowest value. After that, the safety stock for this critical product will be determined by using Formula 10.

Product	Rounded EF	EF	Difference
17	1	1	0
1	1	1.15	−0.15
21	2	1.56	0.44
13	2	1.61	0.39
14	2	1.61	0.39
16	2	2.26	−0.26
15	2	2.37	−0.37
10	2	2.40	−0.40
20	2	2.42	−0.42
9	3	3.33	−0.33
19	3	3.46	−0.46

Table 10: Difference between the rounded EF and the original EF.

In Table 10, the result of Formula 8 is shown for every product left in the product range. It can then be seen that product 19 has the lowest value for the difference and is, therefore, the most critical product. The parameters for this product can be seen in Table 11. In Table 9, it can be seen that this product has an allocated number of rings of 3, which means that the standard deviation denoted in Table 11 should be adjusted to this. To do this, Formula 9 is used. This results in $\sigma = \sqrt{6.05^2 * 3} = 10.47$.

Product	$\bar{x}$	σ
19	8.61	6.05

Table 11: Parameters for the most critical product.

To come from the parameters of product 19 to the safety stock, the z value is first calculated. This value is the inverse of the standard normal distribution with a certain probability. In the case of the calculation of the safety stock, this probability will be the cycle service level stated in 1.3.3. With a cycle service level of 90%, the value for z will be 1,282.

After this, the safety stock will be computed. Following Formula 10, the safety stock for the most critical product in this product range will be $1.282 * 10.47 = 13.43$. Dividing this by the number of rings allocated to product 19 results in a safety stock of 4.48 products per ring. To be safe, this value is rounded up, which means that the safety stock, which is by default on 2 products per ring, has to be increased to 5 products per ring.

4.4.3 Final calculations

Once the safety stock is calculated, the final stage of this calculated starts. In every ring, there is space for 6 items. Due to the fact that several products take up two rings instead of one, there is 16 times a row with products. This means that in total there are 96 items at max capacity. With a safety stock of 5 per product, 80 items are needed as a safety stock. This means that in the calculation of the period it takes to reach the safety stock, these items may not be taken into account. This leaves 16 items to be sold over a certain time period. Following Formula 11 to calculate the mean demand of the product range per week, it results in a mean of 126.89 products sold per week. This means that it takes $16/126.89 = 0.126 weeks$ for the inventory level to reach the safety stock. This means that it takes $0.126 * 5 = 0.63$ working days. To make sure Healzzy2Go is on the safe side, the period is normally rounded down. However, since this is a period of less than 1 working day, Healzzy2Go should refill the machine every day. The final result is that with an adjusted product range and rings division as shown in Table 9 and a recalculated safety stock of 5 products per ring, Healzzy2Go has to refill this machine every working day.

4.5 Implications of the model

Looking at the calculations done in Section 4.4, it can be seen that some variables change as a result of the model. First, the number of different products in the machine decreased. It is only logical that this happens, since instead of one ring per product, some may be allocated more than that, which causes the machine to be too small for the product range. Second, the number of times an operator arrives at the machine to refill it changes. This is exactly what was needed since Healzzy2Go noted that the way they do it now does not fit the situation right. Therefore, it has to change. Third, the safety stock changes. This is not necessarily the case. Initially, the safety stock is set at two products per ring, but in the new situation, it may change.

These three variables are not immediately connected to the answer to the research question stated in Section 1.3.4, but it may affect the recommendation on the implementation of the model. If one or more of these variables change significantly, the commercial and monetary implications will be influenced quite a lot. This can be positive or negative, but either way, it should be taken into account when providing a recommendation.

4.6 Chapter summary

To answer the fourth subquestion stated in Section 1.3.4 about the calculation of the period length between two refill moments, the specifications for the inventory model were elaborated on. The result is that an (R, S)-model is the most compatible one for this situation. Furthermore, a model was created to implement the proposed solution to the core problem. Using the equalization factors and demand distributions from Chapter 3, rings were allocated to the product range at hand and it was determined if the current product range fits the selected machine. If this is not the case, the choice was given to change to another machine size or to eliminate products from the product range. This was then repeated until there was a product range that fit the machine size. After this, the safety stock and the refill period were computed and the results were shown clearly in a results sheet. To show this process more understandably, an example was given in Section 4.4 and fully worked out.

5 Conclusion, recommendation and discussion

In this chapter, the conclusions, recommendations and a discussion will be given. In Section 5.1, an answer to the question *"Is using a replenishment strategy based on an equal replenishment factor an improvement to the refill process of Healzzy2Go?"* will be given. Furthermore, in Section 5.2, a recommendation will be provided on how to move forward. Finally, in Section 5.3, a discussion will be provided on the limitations of the research.

5.1 Conclusion

5.1.1 Core problem

Healzzy2Go indicated that the problem at hand is twofold. On the one hand, products do not deplete evenly. On the other hand, products deplete too quickly. This means that when an operator arrives at the machine to refill it, one of two cases happens. Either some rings of products are empty while others are barely touched or all rings have less than 2 products in them.

5.1.2 Research question

To solve this, Healzzy2Go came with a proposed solution. This solution entails to calculated factors between the sales of every product and determines the number of rings allocated to a certain product based on that. Furthermore, a model can be constructed to find how long it takes before the machine is at the set minimum of the safety stock and Healzzy2Go must refill a machine. This sounded like a promising solution, which means that the research question for this thesis is:

"Is using a replenishment strategy based on an equal replenishment factor an improvement to the refill process of Healzzy2Go?"

This research question was split up into subquestions, which will be discussed in Section 5.1.3.

5.1.3 Answering the subquestions

To answer the research question, the four set subquestions must be answered first. The first subquestion is about the current process. As can be seen in Chapter 2, the current process starts at the warehouse in Druten, where everything is put together such that the machine is good to go for the customer to receive. This process takes about 3 weeks. Afterwards, an operator will ship it to the customer and install the machine there. After that, the operator fills the machine and from there on there are two subscriptions. The full-service subscription ensures the customer that the machine is constantly filled by Healzzy2Go. Next to that, the self-service subscription gives the customer full responsibility that the machine is filled. They can do this by ordering products from Healzzy2Go's webshop.

The second and third subquestion were both answered in Chapter 3. Here, the data provided was transformed into workable data and grouped per week to ensure statistical significance. After that, the demand was determined to be normally distributed and the parameters for that were calculated. Finally, the equalization factors were determined.

Coming to the fourth and final subquestion, which looks into the calculation of the refill period. This was done by building a model in Excel VBA which can be used by Healzzy2Go to calculate the refill period of their own machines. It takes the demand distributions, the equalization factors and the product range as input and outputs the allocation of rings and the refill period.

5.1.4 Answering the research question

To assess whether an improvement can be made, when the proposed solution of a combination of equalization factors and cycle length calculation is implemented, the two indicators described in Section 1.3.2 have to be evaluated. First, the cycle service level will be reassessed. Due to the fact that the cycle service level is used in the calculation of the safety stock in Section 4.2.1, the cycle service level will increase from 50% as stated in 1.3.3 to 90%, assuming the option is always accepted to alter the safety stock when running the model.

Second, the replenishment ratio will be re-evaluated. In Section 1.3.3, it states that this ratio is currently $\frac{1}{8}$. Due to the implementation of the equalization factor will this ratio grow to about 1. However, if this factor is exactly followed, fractions of rings should be assigned to products. Since this is not possible, the number of rings allocated to a product are rounded to the nearest integer. This causes that this ratio will not be exactly 1, but rather 0.9.

KPI	**Outcome**
The percentual change in the number of products.	-51.84 %
The number of times an operator arrives more often.	7.56
The percentual change in the safety stock.	114.29 %

Table 12: Outcomes when running the provided machines through the model.

Looking at the two indicators when using the proposed solution, they both make quite the improvement. However, when running the provided machines through the model and analyzing the results, the outcomes as can be seen in Table 12 come forward. As can be seen in that table is that there are also some disadvantages to implementing this model. A huge detriment is that Healzzy2Go must go to its customers on average about 7.5 times more. This means that

Machine	Number of visits per week	Costs per week
1	1.48	€ 29.69
2	0.61	€ 12.24
3	0.27	€ 5.38
4	0.27	€ 5.43
5	1.61	€ 32.14
6	1.67	€ 33.33
7	1.78	€ 35.56
8	0.80	€ 16.00
9	0.50	€ 10.00
10	0.53	€ 10.53
11	0.53	€ 10.67
12	1.00	€ 20.00
13	0.57	€ 11.36
14	1.22	€ 24.49
Total		**€ 256.82**

Table 13: Cost calculation of the visits to the customer for the current situation.

their costs of visiting the customer will also more than septuple. Next to that, the number of unique products in a machine will be less than half of what it was before. This means that there is less variation and this will affect the customer satisfaction. Finally, when looking at the safety stock, it will have to increase with more than 100%. This then also affects the refill period, which results in a high number of times an operator arrives more.

When putting these changes in a monetary perspective, it results in the following. Assuming that a visit to a customer costs around €20, −, it means that in the current situation the visits to the customer will cost €256.82 per week in total for all analyzed machines. The calculation for this can be found in Table 13. Similarly, for the situation that occurs when using the built model, it will cost €1975, − per week in total for all analyzed machines.

On the other side of these costs, we have the revenue of the machines. This revenue can be computed by multiplying the number of sellable products per week by the price of the products. Assuming that the average price of the products is €3.50, it can be calculated that in the current situation, the revenue would be €266.05 per week. For the situation in which the model is used, the revenue would be €1188.21. In Table 14, an overview is given of the estimated monetary implications of the implementation of the built model. In this table, also the estimated profit per week is given. As can be seen in this overview, in the second situation not only the costs but also the revenue increases. However, the costs increase significantly more than the revenue. If the assumptions stated before are correct, there will be a loss of €786.79 when the built model is used.

	Current situation	Model is used
Costs	€ 256.82	€ 1975,-
Revenue	€ 266.05	€ 1188.21,-
Profit	**€ 9.23**	**-€ 786.79**

Table 14: Monetary implications.

Because of these changes, the answer to the research question is not that simple. Although all the indicators set in Section 1.3.2 improved, the side effects are not that positive. However, if Healzzy2Go thinks the advantages are worth more than the disadvantages, the model can be implemented. If this is the case, the recommendations in Section 5.2 will describe what to do from now on.

5.2 Recommendation

In this section, two recommendations will be made to move forward.

5.2.1 Implementation strategy

Since the model can be used to improve their refill process, it is recommended that they implement it into their process. However, there is currently not yet a good implementation strategy. Therefore, the first recommendation is to do further research on such a strategy. This will ensure a smooth transition from the current process to the new and improved one.

5.2.2 Integration strategy

Although an implementation strategy will ensure a smooth transition for now, there is still something that will cause a problem in the future. This is the staticity of the model. This means that the data analysis can currently only be updated when it is done manually. It is desirable to do this automatically. Therefore, further research has to be done on how to connect this model to Healzzy2Go's ERP system and with that automatically update the data analysis of the model. This will then give more accurate results from the model, which will be more profitable for Healzzy2Go.

5.3 Discussion

Finally, some limitation due to the method and the provided data will be addressed. First, due to the fact that the data provided was not the preferred data, it had to be transformed into workable data. This means that there may be some inaccuracy with regards to the reality.

To solve this, Healzzy2Go should find a way to get more accurate data to improve the accuracy of the model. Finding more accurate data will also affect the outcomes in Table 12. This is because, as can be seen in 10, the safety stock strongly depends on the standard deviation. When more accurate data is found, the standard deviation will decrease and with that the safety stock. This will in its turn affect the refill period, since there are more products available to replenish, so Healzzy2Go can visit less often. Concluding, finding more accurate data will improve the outcome of this model.

Second, with regards to the demand distributions, more research has to be done as to which distribution the demand has exactly. As stated in Section 3.2, 88% of the products are normally distributed and for the sake of simplicity, it was assumed that the rest is that as well. However, this is not necessarily the case. Therefore, more research has to be done as to what distribution the other 12% of the products' demand has.

Finally, the model could be approached differently. Currently, the least selling product is given one ring and the others are scaled to that. However, one could also approach this by stating that the equalization factors of the product range should be added up and a product would the receive the fraction of total equalization factors it has as rings. This is one other approach, but there may be others. These approaches should also be researched to find the best way of dealing with the model.

References

Banton, C. (2020). Efficiency Definition. https://www.investopedia.com/terms/e/efficiency.asp

Chen, J. (2020). Normal Distribution.

Cho, D. W., Lee, Y. H., Ahn, S. H. & Hwang, M. K. (2012). A framework for measuring the performance of service supply chain management. *Computers and Industrial Engineering*, *62*(3), 801–818. https://doi.org/10.1016/j.cie.2011.11.014

Cooper, D. R. & Schindler, P. S. (2013). *Business Research Methods* (12th ed.). McGraw-Hill/Irwin.

Hargrave, M. (2020). Standard Deviation. https://www.investopedia.com/terms/s/standarddeviation.asp

Hayes, A. (2020). Chi-Square (χ2) Statistic Definition. https://www.investopedia.com/terms/c/chi-square-statistic.asp

Hayes, A. (2019). Inventory Management Definition. https://www.investopedia.com/terms/i/inventory-management.asp

Kenton, W. (2020a). Confidence Interval. https://www.investopedia.com/terms/c/confidenceinterval.asp

Kenton, W. (2020b). Lead time. https://www.investopedia.com/terms/l/leadtime.asp

Lerdwiwatchaiyaporn, S., Kongpoung, P. & Someran, L. (2020). Efficiency increase in storehouse management: The case study of ABC company limited. *International Journal of Innovation, Creativity and Change*, *12*(11), 309–321. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85084491133&partnerID=40&md5=abcd6ed9de5bbd47fda0a82b98ea2a26

Majaski, C. (2020). Hypothesis testing. https://www.investopedia.com/terms/h/hypothesistesting.asp

Meijer, D. ((2018). *Statistics for Engineers*.

Moons, K., Waeyenbergh, G., Pintelon, L., Timmermans, P. & De Ridder, D. (2019). Performance indicator selection for operating room supply chains: An application of ANP. *Operations Research for Health Care*, *23*, 100229. https://doi.org/https://doi.org/10.1016/j.orhc.2019.100229

Nallusamy, S. (2016). Overall performance improvement of an small scale venture using critical key performance indicators. *International Journal of Engineering Research in Africa*, *27*, 158–166. https://doi.org/10.4028/www.scientific.net/JERA.27.158

Silver, E. A., Pyke, D. F. & Peterson, R. (2016). *Inventory management and production planning scheduling*.

Slack, N., Brandon-Jones, A. & Johnston, R. (2016). *Operations management*. https://doi.org/10.1201/b13747-10

Tuovila, A. (2019). Forecasting Definition. https://www.investopedia.com/terms/f/forecasting.asp

van den Berg, J., van Heck, G., Davarynejad, M. & van Duin, R. (2012). Inventory management, a decision support framework to improve operational performance, In *Organizational integration of enterprise systems and resources: Advancements and applications*. https://doi.org/10.4018/978-1-4666-1764-3.ch015

van der Wegen, L. (2018). Slides OR IM. *Enschede*.

Van Heck, G., Van Den Berg, J., Davarynejad, M., Van Duin, R. & Roskott, B. (2010). Improving inventory management performance using a process-oriented measurement framework. https://doi.org/10.1007/978-3-642-16402-6{_}30

Winston, W. L. (2004). *Operations Research* (Vol. 4). Brooks/Cole.

A Systematic literature review on indicators for (in)efficiency

A.1 Research question

As explained in section 1.3.2, I will try to provide an answer to the question: *"What are possible quantitative indicators for (in)efficiency?"*. If I answer this question I will be a step closer to answering the bigger question, which will result in a full understanding of my core problem.

A.2 Inclusion and exclusion criteria

To optimally select suitable scientific papers, certain papers need to be included or excluded. The question that remains is then when this should be done. What are the criteria to include or exclude certain papers? In table 15 the inclusion and exclusion criteria for the question described above can be seen.

Criteria	**Comments**
Inclusion criteria	
Papers should be focused on an inventory management setting.	If the paper is focused on other things, for example the care paths in a hospital, (in)efficiencies will be different.
Papers can be both English and Dutch.	Both these languages are a fluency of mine, so that is why papers may be written in both languages.
Theories can also be written in books used for university education.	Many courses regarding this subject are included in my studies, so there may be some interesting theories written there.
Exclusion criteria	
The article may not be written in a magazine.	Articles written in a magazine often have insufficient scientific research, so a good enough answer cannot be built on that.

Table 15: Inclusion and exclusion criteria SLR 1.

A.3 Database

To find an answer to the to be researched knowledge question, Not only Scopus and Web of Science will be used to find articles that may answer the research question, but also the books used during my studies will be looked at to see if they provide a possible answer.

A.4 Search terms and results

Search term	Result	Sufficiency
efficien* AND "inventory management"	2082	No, the term is too broad.
efficien* AND "demand management"	1995	No, the term is too broad.
inefficien* AND "inventory management"	135	No, nothing is said about indicators.
inefficien* AND "demand management"	101	No, nothing is said about indicators.
indicat* AND efficien* AND "inventory management"	156	Yes
indicat* AND efficien* AND "demand management"	171	Yes.
indicat* AND inefficien* AND "inventory management"	14	No, the term is too narrow.
indicat* AND inefficien* AND "demand management"	8	No, the term is too narrow.

Table 16: Search terms and results SLR 1.

For the answer to the knowledge problem, the following articles/books will be used:

- A framework for measuring the performance of service supply chain management (Cho et al., 2012)
- Efficiency increase in storehouse management: The case study of ABC company limited (Lerdwiwatchaiyaporn et al., 2020)
- Improving inventory management performance using a process-oriented measurement framework (Van Heck et al., 2010)
- Inventory management, a decision support framework to improve operational performance (van den Berg et al., 2012)
- Operation Management (Slack et al., 2016, p. 647)
- Overall performance improvement of an small scale venture using critical key performance indicators (Nallusamy, 2016)
- Performance indicator selection for operating room supply chains: An application of ANP (Moons et al., 2019)

A.5 Conceptual matrix

In the table below, I will elaborate on the different characteristics of the inventory models used.

Literature	Concept(s)
A framework for measuring the performance of service supply chain management	• The utilization of products when providing a pre-specified level of customer satisfaction.
Efficiency increase in storehouse management: The case study of ABC company limited	• Index of staff satisfaction and security • Efficiency of shipping • The accuracy of product storage • Quality and waste of warehouse product • Accuracy of storage area • Effective use of the area • The productivity of staff and tools • Returned products • Unqualified products • Cost of warehouse management • Cost of shipping • Cost rate of shipping in competitive time

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Literature	Concept(s)
Improving inventory management performance using a process-oriented measurement framework	• Order cycle time • Frequency of delivery • Safety stock usage • Number of different items in stock
Inventory management, a decision support framework to improve operational performance	• Order cycle time • Frequency of delivery • Safety stock usage • Number of different items in stock

Continued on next page

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Literature	Concept(s)
Operation Management	• Level of customer complaints • Mean time between failures • Customer satisfaction score • Order lead time • Frequency of delivery • Cycle time • Proportion of products in stock • Mean deviation from promised arrival • Time needed to develop new products/services • Range of products/services • Machine changeover time • Average batch size • Time to increase activity rate • Average capacity/maximum capacity • Minimum delivery time/average delivery time • Variance against budget • Utilization of resources • Labor productivity • Added value • Cost per operation hour

Continued on next page

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Literature	**Concept(s)**
Overall performance improvement of an small scale venture using critical key performance indicators	• Inventory level • Average non-moving stock • Inventory days of supply
Performance indicator selection for operating room supply chains: An application of ANP	• Inventory service level (ISL) • Inventory visibility (IV) • Inventory accuracy (IA)

Table 17: Conceptual matrix SLR 1.

A.6 Integration of the theory

As can be seen in Table 17, there are a couple of concepts that occur more often. These are cycle time, frequency of delivery, safety stock usage, number of different items in stock and service level/customer satisfaction score (see Table 1). These are all good indicators for the efficiency of the situation, but since the service level is embedded in one of the two problems stated in Section 1.3.1, this will be the indicator to focus on. However, the other ones should also be used. Therefore, those will be used as a secondary assessment as to whether the solution is an improvement to the problems stated in Section 1.3.1.

Concluding, the cycle service level will be used as the indicator for the (in)efficiency of the situation. The norm and reality in Section 1.3.3 will also be based on this.

B Screenshots of the model

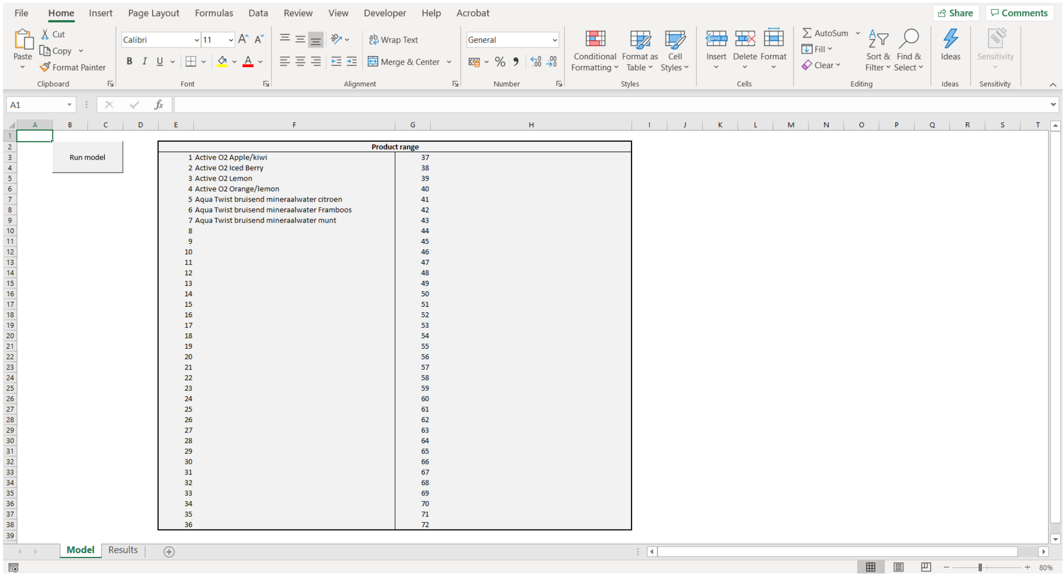

Figure 7: Input sheet.

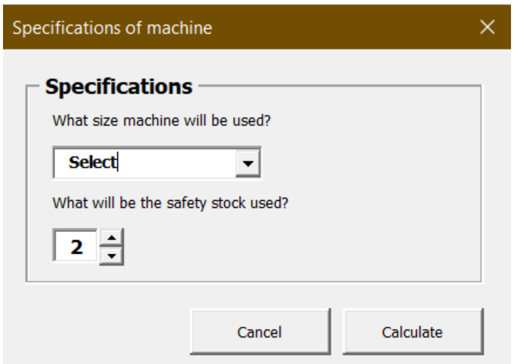

Figure 8: Specifications window.

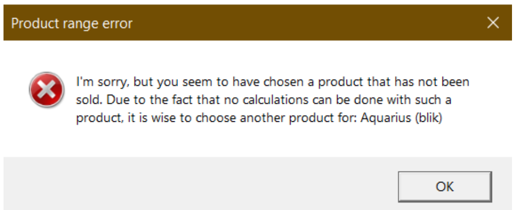

Figure 9: Error window product not sold.

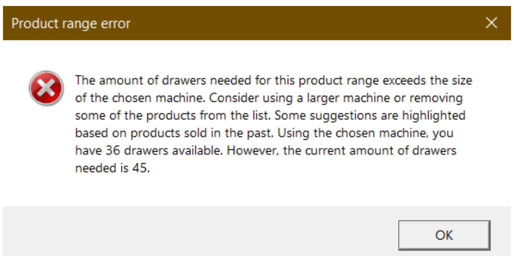

Figure 10: Error too many rings needed.

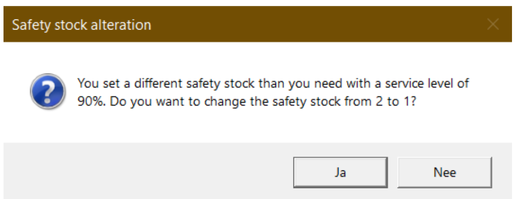

Figure 11: Choice for another safety stock.

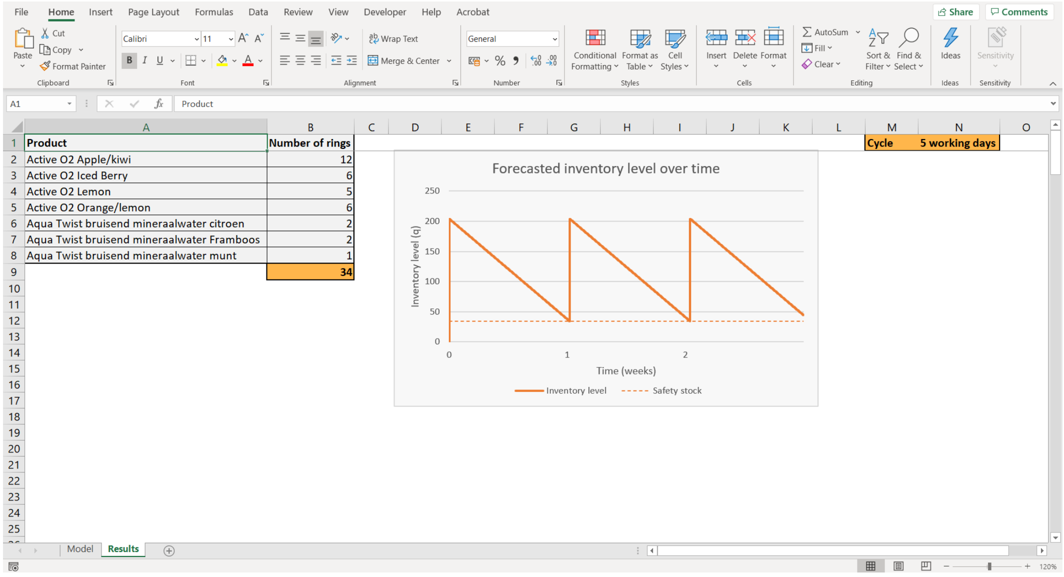

Figure 12: Results sheet.

C User guide

Now, a user guide for the model will be provided. This is a step-by-step guide to the model including screenshots. These screenshots can be found in Appendix B.

When using the model, the first view that can be seen, is shown in Figure 7. There is a grey table in which all cells have a drop-down menu where products can be chosen. After the selection is made, a click on the button on the top left saying "Run model" will pop up a window, shown in Figure 8. Here, two more parameters have to be selected. First, the selection for the machine size has to be made. As stated in Section 4.2.1, there is a choice for five machines, which are presented in a drop-down menu. Second, the selection for the desired safety stock needs to be chosen. As a standard this is set at two, since Healzzy2Go almost has a safety stock of two, but it can be altered using the up and down buttons. Once all parameters are put in, the button on the bottom right that says "Calculate" can be pressed to start the model.

After this press on the button, a couple of errors may occur before the results are shown. First, a window may pop up which states that a product has been chosen that has not been sold, such as in Figure 9. Due to the fact that further calculations cannot be done when this is the case, this product has to be excluded from the product range. In the window, it also states which product causes this error, so it can easily be excluded. Second, a window may pop up that indicates that the amount of rings needed for this product range exceeds the size of the machine, like in Figure 10. When this is the case, some products have to be excluded from the product range to ensure an improved situation. Three suggestions have been done to exclude, which are highlighted in yellow. Once the "OK" button in either of these cases is pressed, the model will stop. The products can then be excluded and the model can be restarted.

Last, a window shown in Figure 11 may pop up with a suggestion about the safety stock. At the beginning of the model, a desired safety stock is indicated. However, this may not be the best solution. The model calculates a safety stock with which the cycle service level will be 90%. If this differs from the indicated safety stock, the choice will be given to change it. It is not a necessity to change it for the rest of the model, but it will improve the overall process.

If everything runs smoothly, the results sheet will become active and the results will be shown as in Figure 12. On the top left, the selected products and the amount of needed rings are indicated. Please note that these are the total amount of rings per product type, so if the product type is a cookie or a bag of crisps, it will show double the amount of rings, since those products need two rings per product. In the top middle, a graph of the forecasted inventory level will be shown with next to that the cycle length. The cycle length is the amount of time it takes for the inventory level to reach the safety stock level. This is also the amount of time that needs to be between to refill moments.