ORDERING PROCESS OPTIMIZATION OF PAINT AT UW ONDERHOUDSPARTNER LENFERINK

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Bachelor Assignment for Industrial Engineering and Management, University of Twente Enschede

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Preface

Dear reader,

Before you lies my bachelor thesis on: ‘Ordering process optimization of paint’. This research was conducted at Uw Onderhoudspartner Lenferink (UOL) in Heino and was done as a bachelor assignment for the study Industrial Engineering & Management at the University of Twente in Enschede. This research focusses on optimizing the order strategy of paint at projects of UOL in order to reduce waste and costs.

I would like to express my gratitude towards everyone who has been involved with this thesis. First of all I would like to thank my first university supervisor, Dennis Prak, for always giving extensive and critical feedback and for helping me with brainstorming whenever a difficult problem arose. The sessions where we discussed the progress of this thesis have provided the backbone of the finalized version. Secondly, I would like to thank Marcos Machado, my second university supervisor. I am thankful for the critical feedback you provided on the general layout of the thesis and all other suggestions you made.

Furthermore, I would like to thank Jasper Neulen for introducing me to the company, getting me acquainted with my colleagues and for always being open and motivational when it came to my thesis. Moreover, I would like to thank Luc Lenferink, my company supervisor, for always being supportive of my research. Thank you for applying me with the necessary information and data if needed and being enthusiastic and interested in my research. Finally, I would like to thank all my colleagues for helping me out during this thesis and making me feel welcome at UOL.

Tijmen Prins

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Management summary

In this bachelor thesis, research is conducted regarding the return flow of paint towards the warehouse of Uw Onderhoudspartner Lenferink (UOL), which is a painting and maintenance company, located in Heino, the Netherlands. Their problem is that at the project sites lots of paint is sent return which they feel like could be reduced. However data for this is not present.

In order to track the current flow of paint which is sent return, data of the return flow of some of the projects is manually collected and counted during the period of this research. This way the return rate of three specific projects could be calculated. A problem cluster is created and the core problem is found to be that there is no check-up on how much paint is actually used compared to the pre-calculations at a project. This means that the personnel on the workplace has no guidance in terms of insights on how much paint should be ordered. As for the office staff they have no insight in whether the pre-calculations were accurate. The action problem is that there currently is an unknown wastage rate which is considered too high by UOL and thus should be decreased.

It was found that visualizing the data in an understandable way could help lead to a solution. A dashboard is a tool best fit for UOL, as the office staff already works with different dashboards. By means of interviews with the stakeholders of the ordering process and by letting them give scores to certain KPIs, crucial KPIs for a dashboard were indicated. The important KPIs are: expected future paint consumption, wastage rate and pre-calculated amount relative to actual amount ordered. On this dashboard these important KPIs are showcased. Since the project leader meets every week with the foreman of a project this meeting can be used to take a look at the dashboard and use it as a decision support-tool.

Now another bottleneck that is dealt with is helping the decision making. As there is now more data available there is also the possibility to improve the estimation of the paint that is still needed to finish off a project. This should help with reducing the wastage rate at the end of a project. For this matter a model is created in this thesis that is based on the Newsvendor Model and the concept of forecast evolution. The output given by this model are the order sizes per period, the expected wastage rate at the end of a project and ratios between the pre-calculations and the actual numbers. This model can help with estimating the litres of paint still needed for a project based on the current progression and the pre-calculations. There are three different scenarios from which one can choose, one more focussed on the pre-calculations, whereas the other is more responsive to the actual usage and one in between. At each period the dashboard can give insights on what each scenario would order for the current period as well as the subsequent periods and how it would impact the expected waste at the end of the project. The order sizes of the current period can be adjusted and based on these adjustments the model gives different order quantities for the subsequent periods, like this different order sizes can be tested. The model always makes a trade-off between ordering one litre of paint too much and sets this off against ordering one litre of paint too little. This way it is cost efficient while still looking to decrease the wastage rate as it tries to find the final litre usage by giving order size suggestions for the following periods of a project based on the weighing between the pre-calculations and the known data at that period.

With this model simulations were ran and it was found that the wastage rate can be decreased when following the suggested order sizes as presented by the dashboard. The model shows that in the beginning the order quantities could be bigger compared to the current situation while the orders that are placed towards the end should be smaller.

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In the first chapter of this thesis the company will be introduced as well as their problem and the assignment description. The core problem will be highlighted and a problem-solving approach will be presented.

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In the context analysis the current situation of UOL (Uw Onderhoudspartner Lenferink) has been described, as well as the negative effects of the current situation. The actors within the process of ordering are made clear and a visual representation is created.

3. Theoretical framework

In the theoretical framework visualization methods and ways to implement them will be discussed, this part is based on literature review. The stakeholders and their involvement are taken into account here. Furthermore a Newsvendor Model will be introduced and the concept of forecast evolution will be explained as these two models can help with finding a solution for UOL.

4. Solution design

In the solution design a model is represented based on the literature research. Here the model is is discussed in great detail and adjusted to the situation of UOL. Furthermore, three different scenarios are provided which can all be simulated to test the model.

5. Data analysis

In the data analysis the simulations of the different projects are ran and the different outcomes of the scenarios are discussed.

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In this chapter the findings of the research are presented and summarized, as well as a discussion about the research, recommendations for the company, limitations and further work.

Abbreviations

UOL	Uw Onderhoudspartner Lenferink
RQ	Research Question
SME(s)	Small and Medium Enterprise(s)
ICT	Information and Communications Technology
BPMN	Business Process Model and Notation
IEM	Industrial Engineering & Management
KPI(s)	Key Performance Indicator(s)
VvE	Homeowner association
MMFE	Martingale Model of Forecast Evolution

1. Introduction

The problem owner is Uw Onderhoudspartner Lenferink (UOL). UOL is a painting and maintenance company located in Heino and surroundings. It was established in 1949 as a painting company and has been in the hands of the same family ever since. Nowadays they focus on drawing up and executing smart maintenance plans for long-term partnerships with corporations and individuals. These partnerships are mostly over a period between 25-30 years and thus a good relationship with the customer is seen as crucial. UOL has around 80 employees, including craftsmen, maintenance consultants, plan preparers, project leaders and office staff and has been fast-growing in the past few years with the shift in vision (Uw Onderhoudspartner Lenferink, 2022). Whereas earlier the focus was mainly on one-time jobs, now they strive to only have customers who agree to a multi-year maintenance plan. This is their unique selling point and makes UOL stand out from its competitors in the same field. The company has an office with two separate divisions, one for individual and small jobs such as VvE's (Homeowner associations) and one for bigger projects often from corporations. The fast growth not only results in more employees and jobs for UOL but also in a return flow of material and especially paint which takes in a lot of storage space.

1.1 Problem identification

UOL has their own warehouse next to the office. Here materials from projects and jobs return when there is no need for them anymore or when they need to be temporarily stored. A part of these materials is paint that is not used anymore at the projects. Once it enters the warehouse it does not come out as useful product but mostly as waste which gets disposed of. For this reason the great quantities of paint that are sent return are seen as a problem by the company and are a matter that UOL wants to avoid as much as possible from a sustainable standpoint as well as a cost point of view. In order to give an overview of the cause and effects of the return flow of paint a problem cluster is made connecting them with each other. This way the core-problem and action problem are identified.

When the paint arrives at the warehouse it is often put away without much thought. In the first years of the company, when the return flow of paint was much less, the paint was arranged on the shelves in the warehouse by the use of the colour codes, since each colour has an unique code. Nowadays paint is put in randomly, making it hard to find the right paint when searching for it. After some time spent idle in the warehouse either the paint is thrown away due to expiry dates or it is used after it is found by one of the painters. In the warehouse there is no overview or database of the paint that is located within the warehouse. When the paint is thrown away UOL makes cost for the disposal of it. In an ideal situation no products are sent return from projects, however this is unlikely due to the fact that paint is ordered with a minimum of 0.5 litres. So small leftovers of a few centilitres are almost unavoidable when for example 0.25 litres are needed. However this is not the problem UOL wants to tackle. The problem is that the paint that is sent return is not only small amounts of a few centilitres but also whole unopened cans which should not have been ordered in the first place or cans of 2.5 litres where only 0.5 litres were used, while the supplier also sells cans of 0.5 litres. In order to find the source of the problem exploratory talks with the personnel at the office were set-up, talking about their job and how they view the problem of the paint sent return. This was done in a way of semi-conducted interviews with some of the plan preparers and project leaders. With the collected information the following problem cluster has been created:

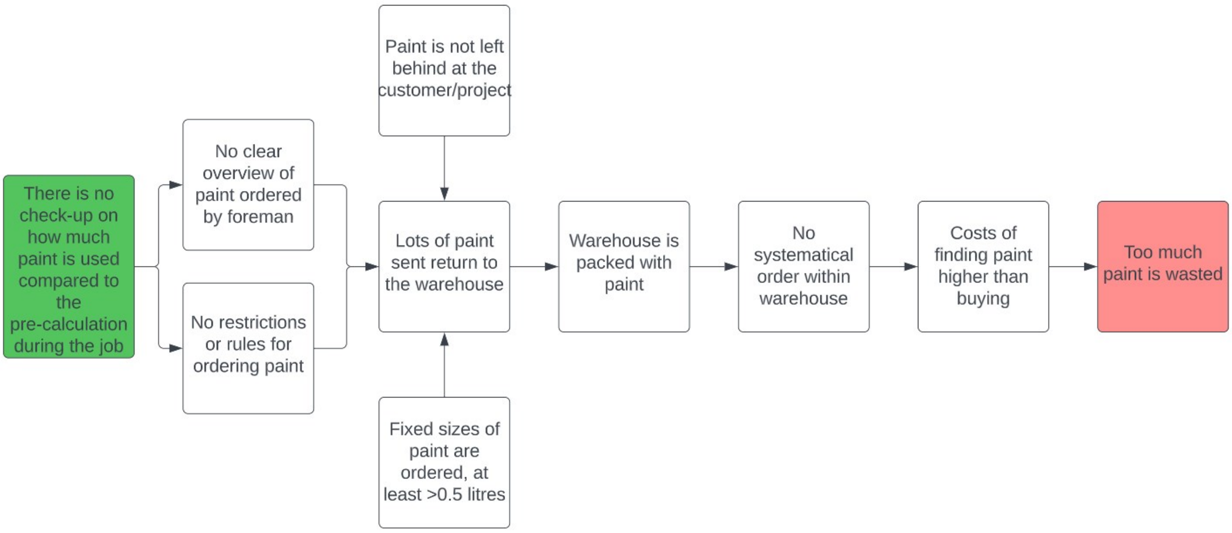


Figure 1 Problem cluster at UOL

1.2 Core- and action problem

As can be seen in Figure 1 The core problem here is that **there is no check-up on how much paint is used compared to the pre-calculation during the job**. During the interviews it came forward that the information of the pre-calculations, which predicts the expected litre usage of paint for a project, does not reach the actual workplace. Thus the foremen have no idea on how much paint is pre-calculated and whether they are ordering more than expected or not. Since roughly 80% of the costs consist of man-hours and 20% of the materials used the foremen prefer ordering too much rather than too little to prevent a standstill. The foremen do this purely based on experience and logically human errors can occur when estimating, resulting in ordering a litre or more too much. If some insight was given here into the expected litre usage it might be prevented, especially if there was a tool that supported decision making when it comes to ordering paint. So here lies the focus of the thesis.

When looking at the problem from a cost point of view there are certain costs attached to the paint at the beginning of each job but there is never a check on how much paint has already been used when the job is 50% done (or any other percentage). Even at the end there is no check whether the pre-calculation of the paint was right or if more or less paint was ordered. This problem then has a direct causal relationship with two other problems, namely:

- *No clear overview of paint ordered by foreman*
  No one at the company is tracking how much paint is ordered during the project, although it is registered in the database it is rarely checked and compared to the pre-calculations.
- *No restrictions or rules for ordering paint*
  Within the company there are no rules for ordering paint, when the painters need new paint they go to the foreman and tell him what to order, then the foreman makes the order for the painters without any form of check.

This and the fact that paint is not left behind at the customer or project results in the fact that a lot of paint is returning to the warehouse of UOL. So the core problem possibly leads to ordering more paint than actually needed which results in more paint coming back to the warehouse. Paint that arrives at the warehouse is put away, but the flow of incoming paint is way bigger than the outgoing flow. This results in the warehouse being packed with paint. Whereas in the first years of the company, a systematic order of placing paint within the warehouse was in place (shelves have a colour code), now it is not useable due to the shelves being full with paint already. Furthermore, the paint on the shelves is not always on the right place and due to a lot of different colour codes it can be hard to find the right paint. The fact that the shelves are mostly full results in the paint being placed in random places within the warehouse. This makes it hard for painters to find the right paint even when it should be in the warehouse and the costs of finding the right paint is said to be higher than just ordering new paint. Due to this, a lot of paint is not ever used again after being stored within the warehouse. As one can imagine this results in a lot of paint being wasted and high inventory costs, although unknown to the company itself.

Figure 1 also shows the action problem which results from all the issues listed in the problem cluster. The action problem here is that too much paint is wasted, meaning that there is a gap between the norm and reality. However, currently the waste is not monitored and there is no data collected. So in order to tackle the action problem this has to be made measurable by collecting data from running projects which are ending in the period of this research.

1.3 Problem-solving approach

In order to solve the core-problem, missing knowledge is collected through research questions. These research questions are needed to acquire information to work towards a solution for UOL. Five research questions have been formulated to do so. The research questions and their respective sub-questions will be mentioned briefly below:

RQ-1: How much waste of paint is there currently?

- *i. Where does this waste come from?*
- *ii. Where does this waste result in?*
- *iii. Why is there currently no solution?*

RQ-2: How can the data of paint usage be projected in an understandable way for everyone at the company?

- *i. How can the paint usage be tracked?*
- *ii. How can a visualization method be implemented?*
- *iii. What is the most efficient visualization method for the data?*
- *iv. How can it fulfil the needs of every stakeholder involved?*
- *v. How can the KPIs be projected properly?*

RQ-3: What is the impact of different order sizes and order intervals on the quantity of paint that comes retour?

- *i. How can the optimal order quantity be established per project?*

ii. *What is the most efficient interval to order paint?*

iii. *How can potential waste be indicated?*

RQ-4: What is the difference between the current situation and the outcome from the model?

i. *What can be learned from the model?*

ii. *Where can the most waste be prevented?*

iii. *How can the current situation be optimized?*

iv. *How can this be implemented in a dashboard?*

v. *What is the reason between the differences found?*

RQ-5: How can a new system for ordering paint be implemented at UOL?

i. *What are the different options?*

ii. *What are the costs related to the options?*

iii. *How reliable are the different options?*

iv. *What is the most feasible option for every division within the company?*

v. All the questions above are answered in the remainder of the thesis. RQ-1 is answered in Chapter 2, the Context Analysis. RQ-2 is answered in Chapter 3, the Theoretical Framework, RQ-3 is answered in the chapter 4, the Solution Design RQ-4 and RQ-5 are answered in Chapter 5 the data analysis. On the one hand the goal is to create insight in the order process for all involved staff and on the other hand to create a model which supports the decision making progress based on raw data.

2. Context analysis

In order to tackle the current problem it is necessary to comprehend its nature and origin. So the whole process from (re-)ordering paint till receiving it, the decision process along the way and the impact of the waste is of utmost importance. For this purpose, interviews with the different involved actors are conducted as to give an insight in their thought process and their contribution to the ordering process of paint and the resulting waste. Finally, the waste of paint also affects other processes at UOL. Thus, to understand the exact scope of the problem it is useful to explore the effects of the waste, which will be done later on in this chapter.

2.1 Ordering process

In order to map the process of ordering paint till the point that it is used or ends up as waste a flowchart is created of the current process. This map is used to give a better insight on how paint currently moves throughout the company and its respective projects/jobs. It all starts with determining the actors who are active in this process. For UOL these are the foremen, painters, the warehouse manager and the administrator. An external actor in this process is the supplier of the paint. As can be seen in Figure 2 the process starts with an order which is placed by the involved foreman. This order is placed by sending a message through the phone to the administrator of the company who processes all the orders and places them on the right order number. After doing so, the order automatically gets placed within the database of UOL. After the lead time of the respective supplier the paint gets delivered on the job and then the painters can start with the project and thus start with painting.

2.1.1 Re-ordering of paint

Reordering happens in either of the following two ways: the painter notifies the foreman when taking the last can of paint from a certain colour or the foreman himself checks the storage to see whether there is still enough paint and when this is not the case the foreman places an order for new paint. This order then again gets sent to the administrator working in the office of UOL who processes it and it gets placed in the database as well. As for the ordering itself there are a few restrictions that the foremen have to keep in mind. First of all the lead time of the supplier. UOL works closely with one paint supplier with whom they have a mutual agreement that when paint is ordered before 10AM it gets delivered on the same day, most of the time somewhere in the afternoon. So for this supplier the lead time is relatively short which makes ordering in small batches doable. However sometimes the lead time is longer due to distribution or location of the project and when a project has special needs, for example a specific supplier or specific paint then the lead time can become multiple days. So this is something the foreman at the project has to keep in mind. The longer the lead time, the further ahead in the future the orders need to be planned which makes it harder to estimate what is needed for the upcoming days since there is a higher uncertainty and they want to prevent standstill.

The second restriction is the storage facility at the projects location itself. Depending on how big the project is, how many painters there are working and the location of the project, the size of the storage and the type of storage unit get decided on. This can either be in a container or a small storage place besides the shack. In a densely built residential area there is often not enough space for a container, so smaller storage units are used here which results in less space for paint to be stored which is something the foremen have to keep in mind when ordering. This then directly influences the order sizes possible for the project since the storage space has to be kept in mind.

In the meantime, while paint is ordered, assuming there is still enough paint, the painters continue painting. When paint gets delivered by the supplier, the painter(s) continue with painting until they either finish or are in need of new paint again. When new paint is needed the foreman will order this again and the same loop will be activated. It is important to note that (re-)ordering does not have any extra costs attached to it.

2.2 Impact of inaccurate orders: Standstill & Leftovers

A standstill occurs when there is no paint left that can be used at that moment. So this means that too little paint is ordered or the paint is ordered too late. The reasoning for this can be that the foreman notices too late that there is not enough paint left to get through a working-day or a false estimation of the expected usage of paint resulting in no paint left at the end of the day. Some extra paint on hand is then also preferred. A result of a standstill is that the painters cannot continue with their tasks. In case of a standstill, the highest priority is to replenish the paint storage such that work can continue as soon as possible. As mentioned earlier, the costs of man-hours account for roughly 80% compared to the 20% of the materials making a standstill way more costly than a shortage of paint. In a decision supporting tool it is important to make considerations based on the costs of having either too little or too much paint at the end of a period, such that the most cost-efficient choice can be made.

When the painter is finished the foreman checks whether the paint might be useful for an upcoming project. However, most of the time it is not known what project is done next and which colours are needed for that project. So this only happens with standardized colours which come back more often in different projects. These standardized colours then get placed in the van which goes to the next project such that it can be used there. If the paint does not get used then it gets delivered back to the warehouse where it gets stored. All the other paint, which is project specific, gets sent return to the warehouse by the foreman. Here the warehouse manager stores it. The paint stays in the warehouse until one of the two following scenarios happens: Either one of the painters of an individual job uses the paint or, and this is often the case, the paint gets disposed of by a chemical disposal company for which UOL has to pay a certain fee. The flowchart outlines the situation at UOL and shines some light on where the waste comes from. The waste results from the ordering process itself, so in this case by ordering too much paint of a certain colour which in the end does not get used. This should not inevitably mean that it is waste. However at UOL the warehouse is rarely used for temporary stock but more as a place for storage until disposal, meaning that once paint enters the warehouse it barely comes out as useable product but most of the time as chemical waste. So this makes it that the preferable way is to decrease the paint that gets sent return such that the waste gets reduced and the extra costs made by ordering and storing too much paint decreases as well.

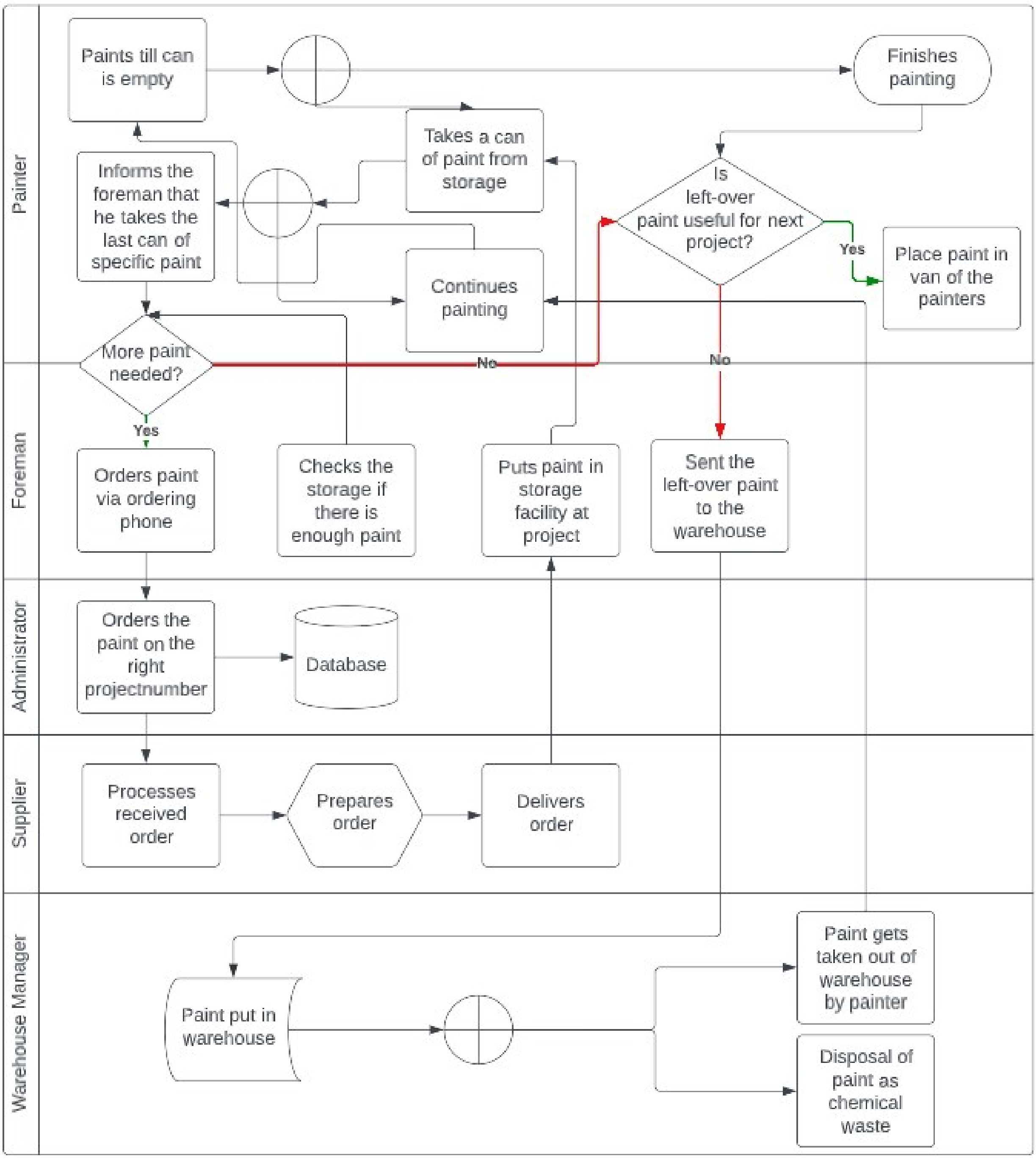


Figure 2 Flowchart of the ordering process of paint at UOL

2.3 UOL's order process and decision making

As can already be concluded from the flowchart in Figure 2, the waste results in the disposal of the paint from the warehouse where UOL has to pay for. Nonetheless this is not the only result of the waste. When looking at the macro-level, another waste disposal company has to travel to the warehouse and back in order to dispose of the paint which emits CO_2 which is bad for carbon footprint. Also when disposing paint certain costs are made. At UOL the disposal data of paint from the end of 2019 up and till now is known. The paint disposal company with whom UOL works has disposed of 1587 liters of paint since November 2019 which has cost the company €2111,36. Besides these costs UOL already paid for the paint and has not used it. The average price of a liter can differ a lot per sort and colour of paint. As from the data gathered from three projects from which the average liter price is known the price is somewhere around €40 per liter, of course it could differ depending on what kind of paint was stored in the warehouse but this is an educated guess. So when these costs gets multiplied with the amount of liters which UOL disposed of that's an extra ~€63.500 spent on paint for which no use case within the company was found. So in total UOL spent more than €65.000 on the paint that got disposed of alone, averaging a cost of €41 per liter of paint. Currently there is still a lot of liters of paint stored in the warehouse unaccounted for in the calculations so when this paint gets added the waste of paint in Euro's becomes even bigger.

If one looks at the flow chart, Figure 2, it becomes clear that decisions are made by employees within the company whom are trusted to do so. The current system trusts on its employees to make the right decision for every order. However mistakes can be made and sometimes an error of judgement can lead to an order which is too big resulting in waste. As some of the foremen and painters have said, they rather order too much paint than too little. This is a logical thought, especially considering the fact that roughly 80% of the costs are in man-hours, meaning that downtime is very costly. The downside of this approach is that this opens the door for ordering too much to be certain that downtime gets avoided. Furthermore the foremen do not necessarily see the need for improving the ordering system. They feel that they can estimate what quantity of paint is needed quite well due to experience and say that they just order what they expect to use. Also towards the end all foremen are more cautious when it comes to ordering. They check the paint that is available at the storage containers and how much is left at the painters' cans. The foremen also avoid ordering in big order sizes because of the small lead times. This makes it easy for the foremen to only order for a few days and re-order when necessary.

2.4 Focus of UOL

At UOL there are no rules when it comes to ordering paint, some of the foremen at UOL have set their own rules with their painters, for instance when a painter takes the last can of paint of a certain colour they have to tell the foreman about it such that the foreman can order it new or at least take it into consideration. However not every painter tells the foreman about it so sometimes they have to wait for the right paint. So for some painters the awareness on this matter is non-existing. There are weekly meetings between the project leader and the foreman, during these meetings the focus is on the progress of the project, the number of hours worked and whether they correspondent with each other, meaning that if a certain amount of hours are worked on the project then the progression has to match this amount of hours as it was pre-calculated. Otherwise there will be looked into what the reason for the difference is. However during these meetings materials are not talked about at all. So as of now there is no focus on the materials that get ordered during the projects and whether this matches the progress. Hereby the foremen might also not feel the need to specifically focus on the material usage and just order what they think is right, even though it might not always be the case. The lack of information and the fact that no time is devoted to the material costs and usage at a project could be the reason that there is no solution at the moment.

2.4.1 Tracking of paint usage

At this moment the paint usage during a project or job is not tracked at all. So a way to track how much paint is already used at any point of the job/project could help with seeing whether the pre-calculations are accurate and it could help with calculating how much paint would still be needed to finish the project. This might help the foremen with deciding on how much paint to order. Furthermore a clear overview could help the project leaders and plan preparers with an insight of how much costs are spent on paint specifically. When there are big differences between the pre-calculations and actual paint usage, this also becomes clear when the data is tracked. Then complementing this with a way to make it easy to read the data for the people involved could help with finding bottlenecks. First of all, thinking of methods to track the current paint usage is important. Because in the current situation this is not tracked and it is essential information for a visualization method. With the knowledge of the quantity of paint returned a decision support tool could possibly give recommendations and an insight in when to order the paint in what quantity to prevent waste.

Currently the orders that are placed are all stored in a database filtered per project. So it is already known what is ordered. However, it can be the case that not all paint ordered is getting used. So somehow this needs to be tracked in order to give an accurate estimation of the paint usage. When looking at UOL, the people who have, or at least should have, the most insight are the foremen. The foremen are placing the orders and in that way have an insight of what gets delivered on the workplace. However, talks with the foremen revealed that there is no overview for them of the total paint used at a project, the only way to get an insight is to keep the receipts of the orders they received. One could manually count what is used by the number of litres that fit in the empty cans. This could be one simple method of counting the paint and tracking its status. However this method does not take into account paint cans which are used but not empty yet. With a big project this could be the case for a lot of cans. So in order to be more accurate these should also be registered. The counting of the empty paint cans results in extra work for the foremen which is not planned in, resulting in extra work hours. As the foremen themselves indicate this would not be a desired option since it takes extra work and the planning is already tight, furthermore their job would become more administrative which is something they do not like. So this would mean extra tasks for either the painter(s) or the foreman on the job. Especially if one wants an accurate weight. A scale could solve this problem but has then to be bought and incorporated at every project side.

Another way of tracking the paint is through the orders that are placed in the database of UOL, however this will not be as accurate as counting it manually. For this method assumptions need to be made which will be clarified later on. The orders placed at a project get registered in the database automatically and this data can be extracted. This data then can show the total amount of paint ordered up and till the current date, simply by adding it up. However, here an assumption needs to be made that at the current date either all the paint or all the paint except the paint from the last order got used. Something in between could also be applied. This method will not be as accurate but costs less time and manpower and thus there are less costs attached to this method. Since here only the project leader has to extract the data, which should not take long. It can be concluded that manually counting the used cans at a project side and registering them is an administrative task that is not liked by the foremen and painters. Furthermore investments need to be made in the form of scales to weight the litres of paint left to make it accurate and extra man-hours for counting it. A simpler yet less accurate approach is using the database of UOL to count the litres of paint ordered and assuming that this paint gets used and then in the end count the left-over paint at a project. In such a process paint that is left-over during the running period of the project could even be subtracted in a model such that it takes this into account resulting in a more accurate decision support tool.

In conclusion, the problem of the UOL is that in general too much paint gets returned to the warehouse which ends up as waste. Some insight during the ordering process could help with the decision making, especially when there is a model that takes into account the costs of the ordering either too much or too little paint. The next chapter will discuss what kind of data visualization methods can help with creating a decision support tool for UOL. It also looks into different models that can support the decision making process by giving better insight based on the data that is present.

3. Theoretical framework

As there is now an outline of the problems at UOL and the causal relationships between these problems it becomes clear what components are needed in order to come to a solution. First of all a way to visualize the data of the ordering of paint in a clear and convenient overview, second of all a model that is based on the data from the pre-calculations of a project, as well as the progression during the project and can help with giving proper indications on the order quantities per period for the ordering process. There are a lot of different data visualization methods available. Therefore, in order to choose the appropriate method, it is important to take into account the needs of the company and the stakeholders involved. In this chapter a literature research is performed on different methods for the visualization and implementation of decision support tools for SMEs (Small and Medium Enterprise(s)) such as UOL, while bearing in mind the stakeholders. Furthermore, two models are researched for the purpose of implementing parts of them into a combined model (Solution Design, Chapter 4). These two models are the Newsvendor Model and forecast evolution, both concepts will be researched through existing literature on the matters.

3.1 Decision support tool and its KPIs

For SMEs such as UOL it can be difficult to invest a lot of capital into a decision support system. There are two important factors that need to be tackled, first of all the collection of the proper data and the use of suitable business and intelligence systems to process it. Secondly an overview of the economic situation, this way it is known how much capital can be spent on a decision support tool (Twongyirwe & Lubega, 2018). The data needed for UOL is stored in their database except for the return of paint which has to be collected manually during the research period and thereafter by themselves. When visualizing data, one of the methods that can be used is a dashboard, since it presents data in such a way that it visualizes the latest condition of the progress of the chosen KPIs (Orlando & Sunindyo, 2017).

It can occur that there are different stakeholders in a situation whom all have different needs for the dashboard. The stakeholders can be seen as the users of the dashboard and by identifying and analysing them, the expectations they have from a dashboard can be met (Orlando & Sunindyo, 2017). The involvement of stakeholders in the process of the design is often disregarded but it is important to understand the needs and abilities of the stakeholders for the visualization of the dashboard. This is done to ensure that the information the stakeholders need is present in the design of the dashboard (Kannan & Zapata-Rivera, 2022). With the help of a survey the KPIs for the heterogeneous stakeholders can be determined. Here the stakeholders can rate the importance of different KPIs for their decision making in the processes (Henri, Christoph, Järvenpää, & Niemi, 2016). Furthermore this can help with considering new KPIs not thought about by the stakeholders before and is a moment where the stakeholder can give input for KPIs they feel are missing. An ordinal scale can be helpful to give insight in the rating of the KPIs since an ordinal scale can be used as a scale of attitude and preferences (Cooper & Schindler, 2014). By doing this it can be determined what the different stakeholders deem as important information for their job to be visualized.

For the design of the dashboard there should not be any distracting elements. This can be realised by a single-screen with a static display. Furthermore, the placement of information is important. The centre of the screen and the left-top should contain the most crucial data for the dashboard. So on these planes the most important KPIs can be placed. The way of presenting information within the dashboard is also of interest, for example depending on the amount of information a tabular or graph can be chosen. With a lot of information a tabular form is preferred whereas if this is not a case a graph is easier to understand (Orlando & Sunindyo, 2017).

For the development of the dashboard, the methodology as displayed in Figure 3 can be applied. It consist of six different steps, starting with the requirement identification. In the requirement identification the strategic plan of the company, the dashboard type and the user groups are identified (Suryatiningsih, Hariyanto, & Ardiyanti, 2012). The user groups are the stakeholders mentioned before. The identification of KPIs process can be executed through interviews with the stakeholders. The functionality of the dashboard will be decided based on the needs of the stakeholders and what is placed where on the dashboard based on the importance of the information.

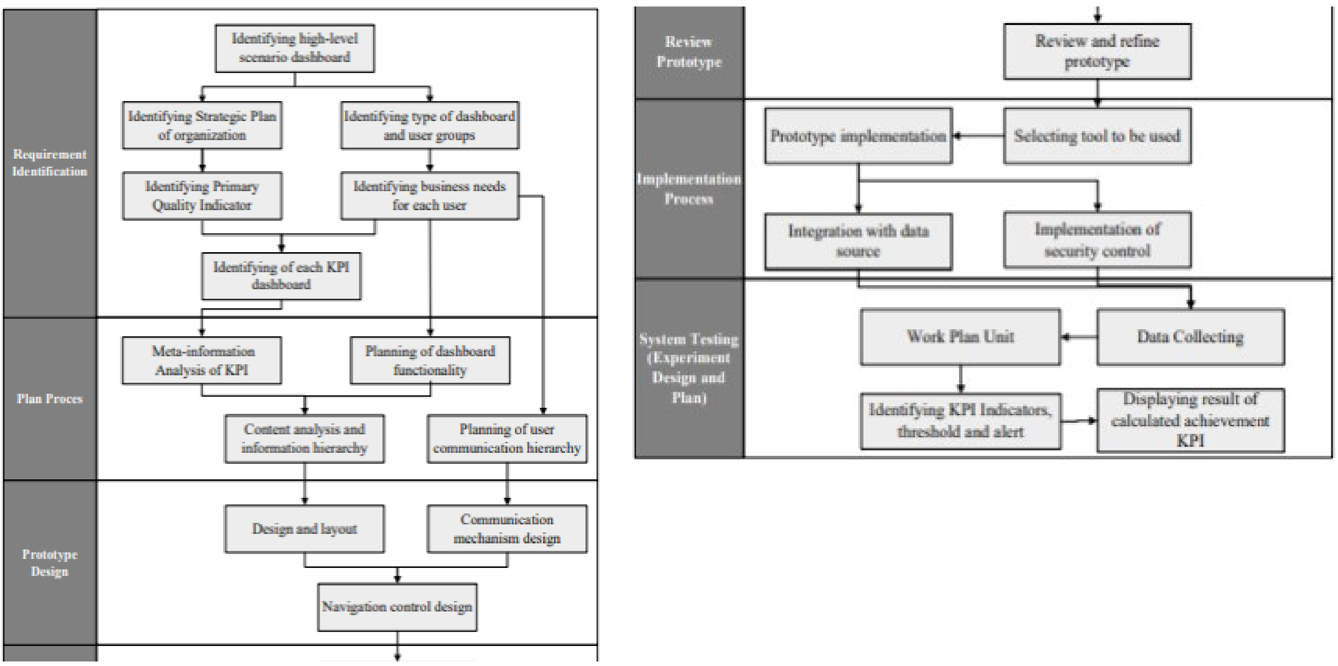


Figure 3 Research methodology for dashboard development (Suryatiningsih, Hariyanto, & Ardiyanti, 2012)

A strategic dashboard is a visual tool used to track and analyze KPIs related to a company's strategic goals and objectives. The dashboard typically displays data in real-time or near real-time, providing stakeholders with a quick and easy way to understand the current state of the business. The strategic dashboard can include a variety of different KPIs, depending on the needs of the business (Allio, 2012). Some common examples include financial metrics such as revenue, profit margins, and cash flow, as well as operational metrics such as lead time, productivity, and supply chain efficiency.

In addition to displaying the current status of KPIs, strategic dashboards often include trend analysis and forecasting tools, allowing decision-makers to predict future outcomes based on past performance. This can help stakeholders identify potential problems and opportunities and make data-driven decisions about how to allocate resources and pursue strategic goals. Overall, a strategic dashboard is a powerful tool for any company looking to keep track of certain KPIs and make informed decisions about how to achieve their long-term strategic objectives (Rahman, Adamu, & Harun, 2017). An operational dashboard is a dashboard that monitors the current activities of a company and their metrics connected to these activitities. This dashboard also displays the data in real-time or near real-time such that the stakeholders can act upon the KPIs visible to them. (Kristyanti, Kusumasari, & Alam, 2020)

For the prototype design phase there will be looked at the layout of the dashboard, including the structure and the order of information shown as well as the number of screens needed. Additionally a proper color design and visual clarity for the information that is relevant for the stakeholders such that it enhances the focus on it. Finally a review will be conducted of the design where the stakeholder can give feedback on the layout (Suryatiningsih, Hariyanto, & Ardiyanti, 2012).

In the implementation phase, a tool for the dashboard will be chosen that fits the data used for the dashboard and the design needed for it. Then in the system testing phase the data from the projects will be used and tested within the dashboard where the KPIs will be tested based on the data and their output. Furthermore this step requires the stakeholder to give feedback on whether the dashboard fulfills the needs it is supposed to fulfill (Suryatiningsih, Hariyanto, & Ardiyanti, 2012).

The projection of KPIs is of the utmost importance for the different stakeholders. Here it is essential to adhere to the needs of the stakeholders based on their scoring of the different KPIs and input received during the several interviews. For each different KPI the visual can differ depending on what is important for that KPI. Furthermore the design and clarity of the dashboard need to be kept in mind when implementing the KPIs. Since there are multiple KPIs which were indicated as important by the stakeholders it is crucial they all get a logical placement within the dashboard. As for the different stakeholders it is important to keep in mind the difference in data literacy between the users. For some users, data may be presented in a manner that is more difficult to comprehend than for others. By displaying data in diagrams it could be better understandable than just numbers for example (Verbert, Ochoa, Croon, Dourada, & Laet, 2020).

3.2 Newsvendor Model

The Newsvendor Model determines the inventory level of perishable products when the demand for a certain period is uncertain and the prices are fixed. It can help by providing a structured way to think through the decision making progress of choosing an order quantity. Therefore the optimal order quantity for a project can be established using a Newsvendor Model. This is a model that is used to make inventory decisions under uncertainty about demand. Here the costs of either buying too many are traded off against the costs of buying too few. Normally it involves choosing an inventory level when there is stochastic demand. At the beginning of each period a decision has to be made about the number of products to buy at a certain price. (Butters, 2019)

A single period Newsvendor Model often occurs in practice where there is a period for which demand only exists in that period. The factors that influence the decision are the price and costs of an item, the distribution of demand, the salvage value of the item and the loss of customer goodwill due to an inventory stock-out. The cost function of this model consist of the costs of overage and the costs of underage. The costs of overage is the costs of buying one product too many, whereas the costs of underage is the cost of buying one product too few and thus a trade-off has to be made. (Geunes, Ramasesh, & Hayya, 2001)

In this Newsvendor Model the company or organization has to make a decision about the quantity of products to order for the given period, this is denoted in the model with q. Then with a probability of P(D), a demand of D products occurs, where D is an non-negative integer. Based on the D and chosen q costs are made, these are either the cost of overage (C_o) or the cost of underage (C_u) mentioned earlier. The costs involved are either:

$$\begin{cases} c(D,q) = C_o q + conditions\ not\ involving\ q,\ when\ (D \leq q) \\ c(D,q) = C_u q + conditions\ not\ involving\ q, when\ (D \geq q+1) \end{cases}$$ (Winston, 2004)

In Table 1 an overview of the variables involved in the Newsvendor Model is presented.

P = Probability	*D = Demand*	*q = Products ordered*
C_u = Cost of underage	*C_o = Cost of overage*	*E(q) = Expected products ordered*

Table 1: Variables explanation of the Newsvendor Model

3.2.1 Costs minimization

The goal of the company or organization is to minimize the costs. This goal can be achieved by finding the q for which the costs of ordering are the smallest when the cost function can be described by c(D,q). As mentioned in Table 1, E(q) is the expected cost when q products are ordered. By applying marginal analysis the smallest q for which the $E(q+1) - E(q) \geq 0$ holds can be found.
When $D \leq q$ ordering q+1 units results in having ordered 1 product too much. This increases the cost by a factor C_o. The probability of this happening is given by $P(D \leq q)$. On the other hand $D \geq q+1$ results in having order one product too little, resulting in the increase of the cost by a factor of C_u. The probability of this happening is given by $1 - P(D \leq q)$

So, one can rewrite the formula $E(q+1) - E(q)$ into $C_o P(D \leq q) - C_u(1 - P(D \leq q))$

Which can be rewritten as well into $P(D \leq q) \geq \frac{C_u}{C_o + C_u}$ (Winston, 2004)

In this formula, the critical fractile is the balance between the two different types of costs:

$$\frac{Cu}{Co + Cu}$$

3.2.2 Standard loss function

In the case of a normal distribution the standard loss function can be found. Before that is possible the distribution is standardized by converting values to their z-score. A normal distribution with random variable *x* has a μ and σ^2 and a probability density function with: $P(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/(2\sigma^2)}$.

The standard normal distribution, also called the z-distribution is a normal distribution where the μ has a value of 0 and the σ^2 has a value of 1. Any normal distribution can be transformed into the z-distribution by calculating the respective z-score. Here $z = \frac{x-\mu}{\sigma}$(Wolfram, 2023). With the use of the z-table the probability can be found that a value is either larger or smaller than the value of the z-score. This can be used in combination with the Newsvendor Model to find the expected overage or underage. In that case the x gets replaced with the order quantity q. Then with the standard loss function L(z) and the standard deviation of the demand, the expected underage can be given, namely using the following equation: $L(z) \times \sigma$. The expected overage can be given with the order size q and the expected lost sales. The expected lost sales can be represented by the standard loss function. Thus, expected overage = $q - (L(z)) \times \sigma)$. (Terwiesch & Cachon, 2012)

3.3 Multiple period Newsvendor Model

Besides the standard Newsvendor Model there also exists a model based on the Newsvendor Model but with multiple ordering periods instead of just one. This model is known as the Multiple period Newsvendor Model (Qiu, Sun, & Lim, 2017) and will be discussed in this paragraph. The main distinction between the single period and multiple period models lies in the fact that the latter can incorporate inventory leftovers or shortcomings from previous periods to make a better decision for the subsequent periods, resulting in a more elaborate determination of the optimal order quantities. A finite horizon and a single product system are considered. The demand in period t is given by $D_t \; for \; t = 1, \ldots, T$. Where T is the whole rolling horizon. Here the assumption is made that the demand D_t is independently distributed for each period t. The end state of period $t-1$ is taken into account for the next period t. Therefore the inventory level before making the next order decision is known and is given by x_t. This value can either be positive or negative. As positive integer means that there is left over product, whereas a negative integer means that there was a shortage. So if an overage occurs, an order for period t that is smaller than previously expected could happen. Whereas when it is the other way around and an underage occurs then the order quantity might become bigger in the upcoming period t. This is something that does not apply for the single period Newsvendor Model. The on-hand inventory level after the ordering decision is made is given by x^t. The formula for the state of the inventory is then given by:

$x_{t+1} = x^t - D_t, \; t = 1, \ldots, T$ (Qiu, Sun, & Lim, 2017)

This is an equation that can be implemented in situations where the inventory level has to be taken into account for the next period(s) t of the Newsvendor Model.

As there are multiple periods, holding costs can be incurred when left-overs are transferred to the next period. The holding cost can be formulated with: $h_t x_{t+1}, if \; x_{t+1} > 0$. There can also be backorder costs when the demand of a certain period was not satisfied, this can be formulated with: $-b_t x_{t+1}, if \; x_{t+1} < 0$. The demand is stochastic and can be given with $D_t \in \{D_t^1, D_t^2, \ldots, D_t^{K_t}\}$. Here K_t is a positive value which represents a possible value for D_t, which is considered a demand scenario for period t. Then the probability for each demand scenario D_t^k is given by: $p_t^k = (p_t^1, p_t^2, \ldots, p_t^{K_t})$. The costs per period are presented by c_t and the revenue per period with r_t.

Based on the presented equations above the formula for the costs can be defined. This formula is: $C_t(x^t, D_t^k) = -r_t D_t^k + max\{h_t(x^t - D_t^k), -(r_t + b_t)(x^t - D_t^k)\}$ (Qiu, Sun, & Lim, 2017).

In this equation the sales revenue is subtracted so that the minimization of the costs is equivalent to maximizing the profit. Furthermore two vectors can be created one for the costs per period and one for the optimal expected cost per period. The cost vector per period t can be given with: $C_t(x^t) = C_t(x^t, D_t^1), C_t(x^t, D_t^2), \ldots, C_t(x^t, D_t^{K^t})$. The optimal expected cost vector can be given with: $V^t(x_t) = min\{\kappa\delta(x - x_t) + c_t(x - x_t) + H^t(x)\}, for\ x \geq x_t$ (Qiu, Sun, & Lim, 2017).

Where κ is the fixed ordering costs whereas δ is either 0 or 1 depending on whether $x - x_t$ is > 0 or equal to 0. The value of δ is 1 when $x - x_t$ > 0 and it is 0 when $x - x_t$ is = 0. A boundary condition is added which is $V^{T+1}(x_{T+1}) \equiv 0, for\ all\ x_{T+1} \geq 0$. Such that there are no periods taken into account after the last period T even though if there is inventory left. In the $V^t(x_t)$ equation the variable $H^t(x)$ is still unidentified. This variable can also be calculated with the function that represents the expected revenue, the expected backorder cost, the expected holding cost and the optimal expected future cost. This equation is denoted by:

$H^t(x) = C_t(x)'p_t^k + \gamma V^{t+1}(x - D_t)'p_t^k, T = 1,2,\ldots,T$ (Qiu, Sun, & Lim, 2017).

In this equation γ represents a discount factor, where $\gamma \in [0,1]$. With the use of the $V^t(x_t)$ equation and the known $H^t(x)$ value for each period t it can be decided whether to order and how much to order. It is based on the variables of the Newsvendor Model, the expectations for the upcoming periods, the current state of the inventory level and the demand distributions p_t^k, which are assumed to not be specific and only belong to an uncertainty set which better presents the real-life situation (Qiu, Sun, & Lim, 2017).

From the paper (Qiu et al., 2017) the complexity of a multiple Newsvendor Model is shown as well as how it can be implemented. However there are a few differentiations. First of all this model states that demand is stochastic whereas for the situation of UOL the demand is normal distributed. Furthermore, there is involvement of holding costs for the cost of overage when products are transferred to the next period. It also tries to rectify any deviations from the real demand in the next period whereas for UOL this might not be necessary as long as the deviations are minimized towards the end. What can be learned from this model is that it is important to adjust the variables for each subsequent period when reviewing them such that the outcome at the end is as accurate as possible.

3.4 Forecast evolution

Forecast evolution is a method that can be applied when in each period a new forecast can be made based on updated data from the previous period(s). This way the accuracy should increase as the uncertainty factor decreases when each period comes closer to the end of the running period of a project (Forel & Grunow, 2022). The basis of forecasting lies in the belief that prior and current information can be utilized to anticipate future events. Forecast evolution refers to the process of updating a forecast as new information becomes available. This can involve adjusting the forecasted values, as well as the underlying assumptions and forecasting model used to generate the forecast. The goal of forecast evolution is to improve the accuracy of the forecast over time. This can be done by incorporating new data, adjusting for known biases, or using more advanced forecasting techniques. The process of forecast evolution can be automated or done manually, depending on the specific use case and the resources available (Petropoulos, 2022).

Before implementing the concept of forecast evolution in this thesis it can be insightful to look at real-life scenarios where forecast evolution was used. For this purpose papers where forecast evolution was implemented in a model are discussed in the next paragraph.

3.4.1 Implementations of forecast evolution

Forecast evolution has already been tested in some real-life cases. In this section, two case studies will be used to illustrate the opportunities that can arise when forecast evolution is incorporated into a model.

The first paper (Albey et al., 2015) is about the appliance of forecast evolution in demand modelling in an application to production planning. The study examines a dynamic production-inventory system that incorporates updates to demand forecasts through the Martingale Model of Forecast Evolution (MMFE). MMFE expresses the complete forecast uncertainty of a streamflow in a single future period by aggregating the forecast improvements across the intermediate periods (Zhao, Zhao, Yang, & Wang, 2013). This approach is then integrated into a probability-constrained stochastic optimization model. The overall objective is to optimize production planning by minimizing the expected total cost and ensuring that desired service levels are met. To evaluate the efficacy of the integrated model, a rolling horizon policy is implemented using data from a leading semiconductor manufacturer. The aim is to measure how the incorporation of forecast update information impacts system performance in terms of cost and service level achievement. The focus is on a model for a single product. For each period independent demand is assumed. The model derives a chance constraint that aims to ensure that a specified probability of no stockouts is retained.

The forecast evolution method makes use of the rolling horizon with T periods and each specific period t=1,…,T. It is assumed that the model looks for decisions for the next T periods, which is seen as the planning horizon. Furthermore a finite horizon is assumed with a periodic review setting. These settings, which are stages s in the model, represent the time of a period. Where stage s till s+1 is the time for which a decision has to be made in period t and the stage s-1 is the time in the past when the most recent decision was made. It is assumed that the periods in the model are of equal length. Moreover the forecast of demand is known for some periods in the future, which is seen as the forecast horizon. The demand forecast for period t, D_{st}, is made at the end of stage s, with forecasts generated for all stages from s to s+H. The realized demand in period t, $D_{tt}=D_t$, is known since the forecast is made after the actual demand is revealed. Forecasts for periods beyond s+H are set equal to a constant μ representing the mean demand. As time progresses to the next period s+1, new demand forecasts are generated based on additional available information, with ε_{st} denoting the random variable for the forecast update at the end of period s for period t, given s≤t. The forecast update vector received at the end of stage s is denoted by $\varphi_s=(\varepsilon_{ss},\varepsilon_{s,s+1},...,\varepsilon_{s,s+H})$, where $\varepsilon_{s,s+H}$ is the first update made to μ to form the H-period ahead forecast, and ε_{ss} is the final update that determines the actual demand.

According to the MMFE assumptions, the demand in period t is a random variable represented as the mean demand plus the sum of the forecast updates in the last H periods. The unconditional covariance of demands can be expressed as a sum of the covariance matrix of forecast updates and the unconditional covariance between demands.

As the remaining part of the paper (Albey et al., 2015) mostly focuses on the specific production planning model, which is not relevant for this thesis it will not be further discussed. The conclusion of the paper is that the computational results suggest that the inclusion of forecast evolution in the production planning model can enhance its performance, provided there is sufficient excess capacity that the planning model can utilize to leverage the advance demand information offered by the forecast evolution model. Thus, from this study it can be learned that forecast evolution can be effective in a multi-period setting as long as demand information is updated regularly and some kind of demand information is known at the beginning, given that the current situation is sub-optimal and there is room for improvement.

The second paper (Wang et al., 2012) is about a study that examines a Newsvendor Models behaviour as they update their forecast of market demand dynamically over a finite planning horizon, utilizing the MMFE mentioned earlier. To meet demand at the end of the horizon, the Newsvendor Model can place multiple orders, with each order incurring a higher cost than the previous one. The trade-off between improving demand forecast and increasing ordering cost is investigated, and it is demonstrated that the optimal ordering policy is a state-dependent base-stock policy. The base-stock level is characterized linearly for additive MMFE. Additionally, a comparison is made between the model and a benchmark model where the Newsvendor Model is only allowed to order once. By comparing the two models, the impact of the multi-ordering strategy on the Newsvendor Models expected profit and risk exposure is quantified.

The created model makes use of N+1 periods, numbered from 1 to N+1.The initial N periods are the ordering periods, indicating the N different opportunities for the Newsvendor Model to place orders at various times. In the final period, N+1, which is the selling season in this model, the sales occur. The model takes c_n as the cost of ordering one unit in period n and r as the retail price. It is then assumed that $0<c_1<c_2< \dots < c_N< r$. Which means that it is cheaper to order in earlier periods. If there exists $c_i \geq c_{i+1}$ or $c_i \geq r$, that period can be removed as the Newsvendor Model would never order in that period. Market demand is a variable that is randomly determined and becomes known in period N+1. As market information is gradually revealed over the planning horizon, the forecast of demand improves. We denote the forecast of demand in period n as D_n, assuming that the initial forecast D_1 is given and the final forecast D_{N+1} equals the actual demand realization D. The forecast process, represented by the MMFE, is modelled as $\{D_n, n=1, \dots , N+1\}$.

Both the additive and multiplicative MMFE are considered, here the difference lays in the way that the forecast are adjusted, the differences are described in Table 2.

Additive model (a-MMFE)	**Multiplicative model (m-MMFE)**
Updates are independent, distributed normally with a mean of 0 and variance $\boldsymbol{\sigma_i^2}$	Updates are based on ratios of consecutive forecasts, given by: $\frac{D_n}{D_{n-1}}$ = exp(ε_n), where ε_n is normally distributed with a mean of $-\frac{\sigma^2}{2}$ and variance σ_n^2
In period i = 1, the expected demand is: μ = D_1	In period i = 1, the expected demand is: Log(D_1) - $\sum_{i=2}^{N+1} \frac{\sigma_i^2}{2}$
The forecast of demand in period 2, … , N+1 is given by D_n = D_1 + $\boldsymbol{\varepsilon}_2$ + $\boldsymbol{\varepsilon}_n$, where $\boldsymbol{\varepsilon}_i$ portrays the forecast adjustments for period i = 2, … ,n	The adjustments of the forecast in period 2, … , N+1 is given by I_n = $\sum_{i=2}^{N+1} \boldsymbol{\varepsilon}_i + \frac{\sigma_i^2}{2}$ Then by combining D_n and I_n the evolution of the forecast demand is given

Table 2: Differences between the a-MMFE and m-MMFE model

From the study through numerical analysis the conclusion could be made that a multiple ordering policy in a Newsvendor Model is especially useful when the uncertainty at the start of the period is high, gets reduced through the forecast evolution throughout the periods and the ordering points are spread over the whole running period. Furthermore comparing a dynamic single order period to a dynamic multiple ordering period based on forecast evolution it can be concluded that the latter is far more beneficial in increasing the profits and reducing the risks as it can adapt itself better to the current market situation. When comparing the a-MMFE and m-MMFE models with each other both have a positive expected profit gap, however the expected average profit gap of the m-MMFE model is higher than that of the a-MMFE model (Wang, Atasu, & Kurtulus, 2012).

3.5 Conclusion

A decision support tool can be used to visualize data and one of the fittest methods to do so is a dashboard, since it can present data in such a way that it visualizes the latest condition of the progress of the chosen KPIs. Before choosing the KPIs, stakeholders of the dashboard need to be identified. Then these stakeholders can choose the KPIs that they deem important to have insight in for their role within the company. In the Solution Design chapter the KPIs will be introduced as well as a method to rate them for each stakeholder, furthermore the projection method of the KPI will be chosen. Regarding the models introduced, parts of them will be utilized in the Solution Design. The Newsvendor Model can be used to create the pay-off between ordering too much or too little paint. The multiple period Newsvendor Model can be used to split the running period of a project into smaller periods such that the output of the model is spread over the periods and can be adjusted when needed. As for the evolution forecasting it was shown that the method can increase performance in terms of profitability in a multi-period setting as long as demand information is known and updated regularly. It reduces the uncertainty of demand throughout the periods and thereby increases the expected profit by ordering closer to the actual demand. So by translating these concepts and models into one model for UOL it should help for creating a solution for UOL.

4. Solution design

In order to come to a solution it is important to take into account the shareholders perspective on different KPIs and the dashboard design. Furthermore for a model it is important to look at the costs, current progress and pre-calculations. All these variables influence the potential outcome of a project and can give an insight to the KPIs found important by the personnel. So in order to realize this a model has to be implemented which takes these different variables into account. In this chapter a model will be represented, which is based on the Newsvendor Model and the concepts of forecast evolution. Furthermore, it takes into account historical projects as their information can help with giving insight in how an 'average' project looks like which should help with the ordering process. Finally it tracks the current progression and whether this is in line with the pre-calculation.

In the case of UOL the project leader needs the information of the plan preparer and the foreman in order to know how much paint is planned on being used and how much is actually used. Also during the project, the project leader wants to know the current state of the progress as an indication. This information is obtained through the foreman who keeps track of the progress. For this a percentage is calculated for the amount of work that is already done. The foreman needs to know when the quantity of paint used is getting close to the amount that was calculated. Hereby it would be most efficient if the quantities per colour code are taken into account as there is not just one kind of paint. However in the database which is used to calculate the expected paint used it is only calculated in litres and not per specific sort and colour of paint. Thus only the total amount of litres will be used as this is only known at the point of the pre-calculations. For the plan preparer it is important to know whether the pre-calculation was accurate, if not the plan preparer can look into what impacted the differences. As can be read, the personnel at UOL all have different reasons and needs for the dashboard.

For UOL the strategic plan is to map the usage of paint during the project and prevent waste of paint. The dashboard type is an operational one since each dashboard presents the data of one project, based on the shown data decisions for that project can be made. The data shown on the dashboard involves the crucial KPIs and the general progression of the project in terms of paint usage.

The database that UOL currently works with interacts with Power BI and not with Excel, making it easier to obtain data when using a Power BI dashboard. However, the database UOL currently uses, does not provide all the necessary information for giving a proper overview of the data needed for the dashboard. First of all, there is no standard approach as to how to enter items in the database, so when extracting information out of the database there can occur multiple errors, for example the same product entered differently or the quantitative data entered in the wrong column. This will result in false information in Power BI. For the sake of this purpose this information is filtered out manually for the researched projects. Secondly, the return flow of paint is not stated within the database, meaning that it has to be added manually. Furthermore, the total costs for the paint are not given and have to be calculated based on the paint usage per meter in litres, the costs per meter and total meters painted per different operation and all have to be added together. In order to have a smooth transition of data transferring from the database to power BI these few things have to be adjusted accordingly. For the purpose of the prototype it will be created in Excel since all data is extracted manually already and this can give an example from things that are also possible in Power BI with the right adjustments. So, as to answer the question Power BI would be the most efficient visualisation method to use for UOL once the database is adjusted on the needs of the dashboard. However as of now this is not the case and thus Excel is more viable and will thus be used.

4.1 KPIs

The fact that there is a lack of information and no time devoted to the materials costs and usage at a project summarizes the need for a tool to help the personnel concerned with these matters such that they can act upon them. The stakeholders in this case are the plan preparers, project leaders and foremen. For the plan preparers it can be insightful to know how accurate their pre-calculations were when it comes to the costs and paint usage. When differences occur this could be an opportunity to investigate where this difference comes in order to learn from it and improve the system. For the project leaders it is important to know whether the paint usage is in line with progress and what percentage of paint gets wasted. Finally, for the foremen it could be a tool to help them with ordering the paint, especially in the last few weeks of a project it can be hard to estimate how much paint is needed when nothing about the pre-calculations is known. If a decision tool gives the expected paint usage the foremen could act upon it or at least take it into consideration.

Different KPIs are listed below with their documentation, all could be useful for stakeholders, the KPIs are invented by the thesis author, however later input is asked to the different stakeholders on whether they find the chosen KPIs important and their own input is asked as well.

The selected KPIs are:

- **Total paint ordered**
  Documentation: The total paint consumption shows the total quantity of paint ordered at a project in litres. The importance of this is to give an indication how much is ordered such that it can easily be compared to pre-calculations.
- **Expected future paint consumption**
  Documentation: This is the expected paint consumption for the remaining periods of a project. The expected future paint consumption will be shown in litres. The importance of this KPI is that it shows the paint usage which the company can expect for the upcoming weeks for which they can prepare themselves and keep it in mind when ordering paint.
- **Probability of waste (at a certain order)**
  Documentation: This is the chance that when an order gets placed with a certain size that it will lead to waste, meaning that the paint will not be used at the project. This will be shown as the probability that it leads to an overage, in percentage. The importance of this is to give insight to the person ordering that when a certain size is used that this could result in waste.
- **Current waste**
  Documentation: This is the amount of paint in litres that at period t in time can already not be used. This can be used to subtract from the paint used and make the model more accurate since it can take into account paint that will not be used.

- **Wastage percentage**
  Documentation: This indicates the percentage of waste of paint when comparing it with the total paint that is ordered, meaning the **total paint consumption** KPI. The formula for this is: $\frac{Leftover\ paint\ (litres)}{Total\ paint\ consumption\ (litres)} * 100\%$. This gives an indication of how much of paint is left compared to the total paint that is used, the importance of this is to give an insight on how big the waste is compared to the total size of the project. This way projects of different sizes can also be compared more easily on this matter since doing it by purely quantity would not be fair if the size of one project is much bigger than the other.
- **Order sizes**
  Documentation: Quantity of paint ordered per period. The model will suggest an 'optimal' order size based on the data known. This can change per period based on the progression so far and the pre-calculation. This could help with reducing the waste or giving an indication around what quantity to order.
- **Order intervals**
  Documentation: Time in-between orders in working days.
- **Leadtime**
  Documentation: Time between placing order and receiving the order in working days.
- **Average paint consumption per working day**
  Documentation: The quantity of paint in litres that gets used per working day on average. $\frac{Quantity\ of\ paint\ used\ (litres)}{Working\ days}$. The importance of this KPI is that it helps with deciding on the order interval since time stand still is very costly and needs to be avoided.
- **Total progress of the project**
  Documentation: Total progress of the project which uses indicators such as total houses/complexes already finished as a percentage of the total houses/complexes. The importance of this KPI is that it can be a tool for other KPIs and shows the total progression of the project for the stakeholders.
- **Total costs of the paint**
  Documentation: Total euros spent on paint during the project. The importance of the KPI is that it can be used to give an insight to the plan preparers as to whether their pre-calculations were accurate.
- **Pre-calculated quantity of paint needed with respect to actual quantity of paint ordered**
  Documentation: The factor between the quantity of paint which was needed according to the pre-calculations and what was exactly ordered in litres of paint. $\frac{Quantity\ of\ paint\ ordered}{Quantity\ of\ paint\ pre-calculated}$. This is an important KPI for plan preparers since it shows how accurate their pre-calculation is compared to the actual quantity of paint that is used. If there is a big difference the plan preparer can decide to look into it and find out the cause.
- **Total failure costs**
  Documentation: All the costs that are made due to the leftover paint. So the ordering costs and eventual waste disposal costs. The importance of this KPI is that it shows the waste for a project in terms of euros.

- **Pre-calculated costs of paint with respect to actual costs of paint**
  Documentation: Costs of paint in euros which were pre-calculated by the plan preparers compared to the costs actual made during the running time of the project in euros: $\frac{Costs\ spent\ on\ paint}{Pre-calculated\ costs\ paint}$. The importance of this KPI is that it shows the factor difference between what was pre-calculated for the paint and the actual costs spent on the paint. This shows the accuracy of the pre-calculations.

4.2 Stakeholders: Interview's set-up

Every stakeholders has different needs that comply with their respective tasks. A lot of data can be tracked, the question that then remains is whether it should be tracked. In order to find which KPIs are found important by the stakeholders interviews were held. In these interviews different KPIs will were presented to them with a scale from 1 – 5. Here the scale indicates the importance of the KPI for their respective task. Where 1 means that it is totally not important and 5 means it is very important. A rating of 3 means that the stakeholder is neutral about the KPI, meaning that the KPI could be represented on the dashboard but would not be that important. Based on the average ratings given for each KPI it can be found out what the different stakeholders find important for the dashboard. To make sure that it is as accurate as possible it is important to interview as much people as possible for each stakeholder. Now there are not a lot of people working at UOL so the benchmark here is to interview at least three persons per job. Then when averaging the KPIs it can be found out how important each KPI is for each stakeholder. A score less than 3 would mean that it is not important for the stakeholder and thus should not appear on the dashboard, where as a score of 5, or close to 5 means that the KPI is very important for the stakeholder and should have a significant place on the dashboard. So based on the output of the forms created to test the importance of the KPIs a prototype of the dashboard can be made.

For the interviews with the stakeholders the requirement was made that the employee should have at least one year of working experience at UOL, so this criteria was followed when conducting the interviews. The reason behind this requirement is that this way they have had at least a few projects they ran in their role and thus multiple experiences. The interviews were conducted in a semi-structured way, meaning that there was a set of predetermined questions but during the interview spontaneous related questions were asked, depending on the answers. In the middle of the interview the different stakeholders were asked to fill in a form containing different KPIs which could be represented on a dashboard for paint consumption during a project, this form can be seen in Appendix 2. The KPIs all came with a brief description and if any questions arose during filling out the form they were answered such that it was known they were clear, furthermore the author of the thesis supervised it and tried to explain every KPI in detail. The stakeholders were asked to give a scoring from 1-5 with an interval with 1 on the matter of the different KPIs as to how important they are for their specific job. For each KPI the average was taken to decide the importance of them for the stakeholder in question. In this way the different KPIs can also be compared and it can be known which KPIs should have a significant place within the dashboard and which KPIs should not be portrayed on the dashboard. In Appendix 3 the results can be seen with all scores given, in Table 3 the average scores for the KPIs per role are shown with in the last column the average score given to the respective KPI where each stakeholder has a stake of 1/3 on the average.

KPIs	Foremen	Project leaders	Plan preparers	Average
Total paint consumption	3.75	3.50	4.33	3.87
Expected future paint consumption	4.50	4.00	4.00	4.17
Chance of wastage	3.50	3.50	5.00	4.00
Current waste	3.50	4.50	3.33	3.78
Wastage rate	3.75	4.00	4.33	4.03
Order sizes	3.25	1.50	3.33	2.69
Order intervals	2.50	3.00	3.33	2.94
Leadtime	4.75	4.00	3.33	4.03
Average paint usage per working day	1.50	2.00	3.33	2.28
Total progress	4.75	4.50	3.67	4.31
Total costs	3.00	4.00	4.67	3.89
Pre-calculated amount relative to actual amount	4.50	4.00	4.67	4.39
Total failure costs	3.50	4.50	5.00	4.33
Pre-calculated costs relative to actual costs	3.25	3.00	4.67	3.64

Table 3: Average scores given to the KPIs

4.3 Stakeholders: Interview's output

Four different foremen were interviewed for the purpose of indicating important KPIs for the dashboard and the process of ordering paint. For the foremen the most important KPIs are the total progress of the project and the lead time of the paint. However, the total progress can already be seen on a separate dashboard and thus should not be the only highlight of this dashboard but could work good in combination of the material aspect, since the interest is in paint usage compared to the total progress. The lead time is also seen as an important KPI since this gives the foremen a lot of information about the order sizes they can use such that standstill can be avoided. Since the delivery times can differ based on time, location and supplier this would be helpful to have on the dashboard. One could look at the percentage difference between the average score given to the KPIs and the specific KPI in order to decide whether they are needed on the dashboard or not. Answers given within the interviews could also give insight into the thoughts of certain KPIs and could help with the decision making. For example all the foremen said that they order whatever they think is needed for the job, not taking costs into account since they say: 'What is needed, is needed and has to be ordered'. So when reading this statement made by the foremen it can be derived that costs are not seen as the most important factor for their job but the progress and making sure enough paint is present at the project location is. So even though the scores given to costs related KPIs are close to the average, namely: 3.00; 3.50; 3.25 it might not be something the foremen would focus on once they have insight into this information. However this can not necessarily be seen when looking at the respective scores given to the KPIs, since they come quite close to the average. When looking at the KPIs with a score higher than the average, six KPIs remain. These should be the most important for the foremen. The six KPIs are: total paint consumption, expected future paint consumption, wastage rate, lead time, total progress and pre-calculated amount of paint relative to actual ordered amount of paint. Purely based on the subjectivity of the foremen these six KPIs should be the preferred indicators placed on the dashboard if focussed on the foremen. At the end of the form the foremen got the chance to add a KPI they felt was missing and one foreman said to be interested in the budgeted costs of paint for the project and the budget for tools or other equipment. The first KPI could be shown due to the pre-calculations, the second KPI named is out of the scope for this research but could be the next step in a follow-up research since it would cover all the material costs which is more complete.

Two project leaders were interviewed and asked about which KPIs they found important for their role within the company. The average score given to the KPI's was 3.57. Eight KPIs scored higher than the average score given to the KPI's. All these eight KPI's received an average score of 4.00 or higher. These KPIs are: expected future paint consumption, current waste, wastage rate, lead time, total progress, total costs, pre-calculated amount relative to actual amount of paint ordered and total failure costs. The highest scores were given to current waste, total progress and total failure costs respectively with a score of 4.50. Hence, these KPI's are seen as the most important by the project leaders at UOL and should have a leading position within the dashboard. As for the total progress this can already been seen as mentioned before and therefore has the purpose of supportive KPI for the other KPIs which are placed on the dashboard.

Three plan preparers were interviewed and asked about which KPI they found important for their role within the company. The average score given to the KPI's was 4.07. Seven KPI's scored higher than the average score given, namely a 4.33 or higher, these were: total paint consumption, chance of wastage, wastage rate, total costs, pre-calculated amount relative to actual amount of paint ordered, total failure costs and pre-calculated costs relative to the actual costs of the paint. Two KPI's even got the maximum score of 5.00, namely chance of wastage and total failure costs. So these KPI's are seen as very important by the plan preparers. Relative high scores are given to the KPI's that involve any costs. This is quite logical as the plan preparers make cost calculations based on the expected paint usage and when this differs from the reality, the cost KPIs could be an useful insight in how much this difference is and whether it is something that went wrong in the pre-calculations or at the job itself, as there currently is no insight into that. The plan preparers already indicated that when they have a clear overview of the paint used at the end of a project, the costs involved and the wastage rate they can look at projects which differ a lot from their pre-calculations and do an analysis on where the differences come from.

4.3.1 Summary of interviews' findings

During the semi-structured interviews with the stakeholder the form was filled in by all interviewees and thus gives a relevant view of the KPIs that are found important within UOL. When comparing the results between the different divisions there are a few KPIs which are seen as important by all. These

KPIs are: *expected future paint consumption, wastage rate and pre-calculated amount relative to actual amount ordered*.

So depending on whether one general dashboard will be made or a dashboard per division it is important to look what KPIs are seen as important. Since the foremen do not like administrative tasks in general and would like to keep it simple it is the question whether it would work to make a dashboard for them which is easy to use and read. There could also be chosen to create a dashboard for the office personnel only, which can be shared and explained with the foremen during the weekly meetings such that misinterpretations of the data is avoided. Furthermore it is encountered that the order sizes, order intervals and average daily paint usage are not seen as important by any of the personnel of UOL and therefore not important enough to be placed within the dashboard. This conflicts a lot with the theory when it comes to inventory control models. However it might have to do with the fact that there normally is a short lead time, which the stakeholders find important to know about and therefore do no focus that much on specific order sizes and order intervals. As for the paint usage this differentiates a lot per day depending on the tasks performed and therefore is not seen as important.

For the most important KPIs the following ways of displaying the data will be used:

- Expected future paint consumption
  Documentation: Integer representing the litres still needed. Here the used litres of paint will be subtracted from the pre-calculated litres of paint for every period *t* and based on the concept of forecast evolution adjustments on the pre-calculated amount can be made.
- Wastage rate:
  Documentation: Percentage rate of the paint left-over in litres as a percentage of the total quantity of litres ordered on the project. Attention can be given to this KPI based on a colour scheme, where a certain percentage which is seen as ‘okay’ by UOL is green, whereas a wastage rate which is not okay is yellow/orange and a really bad rate can even be red.
- Pre-calculated amount relative to the actual amount ordered:
  Documentation: Ratio, with colour pattern. Meaning that for different values of the ratio the cell containing the value changes of colour. For example from a ratio of 0-0,8 the colour could be green, then from 0.8-1 it could be orange, meaning that it becomes close to the expected paint usage and it is a sign that the foremen and project leaders should focus a bit more on the paint usage and from values greater than 1 it could be red meaning that more paint is used than expected.

Since the employees of UOL find the following KPIs important it is looked at whether this can be implemented into a decision support model. For this purpose a prototype of the dashboard has been designed as can be seen in Figure 4, it includes the displaying of the KPIs mentioned above.

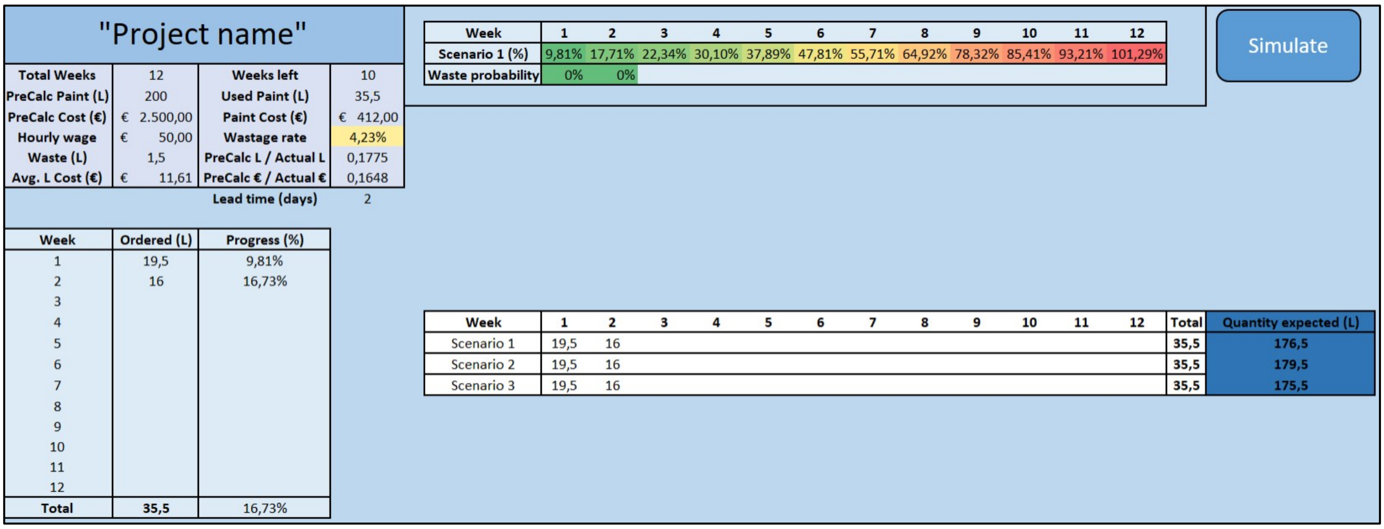


Figure 4: Prototype of the dashboard with the important KPIs

4.4 Dashboard prototype

In this prototype there is chosen to create one dashboard targeting the personnel at the offices (plan preparers and project leaders) and thus one general dashboard is made. The reasoning for this is that the project leaders and foremen have a weekly meeting where they update each other on the progress. Project leaders already indicated that this is a nice opportunity to show the dashboard to the foreman of a project and update it. Since the dashboard has a lot of numbers the project leader can explain them and help indicate with ordering if needed and warn the foreman when they are nearing towards the end of the paint needed according to the dashboard. In Figure 4, on the left top below “Project name”, certain KPIs can be found which were discussed with the personnel of UOL. These are: The current waste, wastage rate, lead time, total paint costs and the pre-calculated amounts in terms of litres and costs compared to the actual amounts in terms of litres and costs. In the table below this, the order sizes per period (week) can be found. As well as the progression measured by the foreman of the project. In the upper middle of the dashboard the progression per scenario is given as the expected progression by the implemented model, which will be explained later on in this chapter. Furthermore the chance of wastage per period is given here. Finally on the middle right side of the dashboard the expected future consumption is given as the total expected quantity in litres of paint that is needed for the project. When pressing the simulate button the output for the different scenarios is shown in the middle while taking into account the order sizes which are filled in the table on the left-side of the dashboard. This could be order sizes that were ordered in the real-situation or an order size for the subsequent period to test what the dashboard would give for outcome in terms of the different KPIs.

As one can see right now, in Figure 4, on the top left of the dashboard crucial data is placed. This is a mix between the basic information of a project and calculated KPIs based on the current progress. The basic information has to be filled in by the plan preparers before the dashboard can be utilized. The numbers shown in Figure 4 are imaginative and are not taken from a project of UOL but are merely used to showcase the possibilities of a dashboard. In the of the dashboard middle another important element of the dashboard can be seen. This is the simulation part where it calculates the expected quantity of litres still needed and the chance of waste based on the order sizes. The waste probability is shown at the top middle of the dashboard together with the expected progress based on the scenario chosen, a drop down list is implemented here such that the values of all scenarios can be seen including their waste probability. The three scenarios will later be described as well as the model that it is based on. On the left of the dashboard there is a table which has to be updated weekly in order for the dashboard to be up-to-date. Here the quantities ordered for each week as well as the progress according to the painting tasks done is recorded.

4.5 Newsvendor Model: Assumptions & Variables

Before continuing with laying out the model there are a few assumptions which have to be taken into account, these are:

1. The left-over paint does not get used anywhere else within UOL.
2. There is unlimited capacity for storing paint at the project side, in reality this is not always the case as there are storage units with a certain maximum capacity.
3. The running time of the project is known and does not change. The reasoning for this is that we can simulate our model with a certain known period.
4. The horizon is finite, since every project has its ending after a period of time.
5. The prices of the paint are not affected by buying in bulk.
6. Roughly 80% of the costs are manhours and 20% of the costs are material for projects, this can be used when not all variables needed for computing the underage and overage costs are known for a project.
7. No wrong paint is ordered on a project

Since the model makes use of a lot of different variables they are listed below in Table 4 with a concise description:

Variable	**Description**
n	Used to refer to a project
T_n	Total running time in weeks of project *n* as per the pre-calculations
Q_n	Total litres ordered at project *n*
μ_n	Total litres of paint pre-calculated at project *n*
t	Indication of a period (1-week)
σ^t	Standard deviation of the demand of project *n* for period *t*
$p_{n(t)}$	Percentage of paint tasks completed at project *n* for period *t*
$q_{n(t)}$	Litres of paint ordered at project *n* during period *t*
$L_{n(t)}$	Litre usage per percentage point of paint tasks completed at project *n* in period *t*
$\mu_{n(t)}$	Expected required paint in litres of project *n* during period *t*
$\sigma_{n(t)}$	Standard deviation of the order sizes of project *n* at period *t*

Table 4: Description of the variables used in the model

The proposed model consists of two parts, the first part is based on historical data from projects, whereas the second part is based on the current progress of the project. The reason for implementing both models into one new model is that in the beginning it is not known how the project will run, basing the orders on historical data can give a considered ordering policy. However since the projects are not homogenous it could be that one projects paint usage differs more from the pre-calculations than another either in positive or negative terms. For this reasoning in order to be more accurate a second model which makes use of the concepts of forecast evolution is taken into account. By combing the two models one can make a more educated estimation for the first few orders because it is based on historical data and the pre-calculation and one can adjust it based on the progress that is noticed at a project, making it project-specific and therefore more accurate.

4.6 Newsvendor Model Application

First of all, based on historical data and the pre-calculations a Newsvendor Model can be built up around a specific project. In this section the variables involved in a Newsvendor Model will be translated into specific application for UOL. In the case of UOL the salvage value of the paint and the loss of customer goodwill due to an inventory stock-out will be disregarded. This is because most of the paint once brought back to the warehouse is waste and does not have a residual value for the company. It is even the case that UOL has to pay for the disposal of it so in that sense it has a negative salvage value. For the sake of the research we will leave this out since some of the paint gets used, meaning it has a positive influence on the salvage value while the rest gets disposed having a negative salvage value. The true value of this cannot be known with certainty. As for the goodwill of the customer it could impact the relationship between UOL and the customer when there is a delay, however in the case of UOL it is not only one period where products get ordered so when there is a stillstand the paint can be ordered directly such that the work can continue as quickly as possible, which results in a delay but the company will still manage to deliver the final product. Furthermore, UOL only accepts customers for long-term relationships so it is unlikely once the contract is accepted that the customer will cancel it.

The total cost function for the paint is then: $C(D,q) = \{ \begin{matrix} q(L), \; if\ D = q \\ (D-q)Cu + q(L), \; if\ D > q \\ (q-D)Co + q(L), \; if\ D < q \end{matrix}$

Where L is the average litre price in Euro’s at project n.

4.6.1 Cost of overage (Co) & underage (Cu)

In the case of UOL the cost of overage occurs when too much paint is ordered which cannot be used, here overage costs are the costs of ordering a litre too much. Through the pre-calculations the costs for a litre of paint and a standstill can be calculated. The costs of a litre of paint leftover can be calculated by taking the total pre-calculated costs of buying the paint for UOL and dividing that by the total amount of litres pre-calculated on a project. This how the formula looks like:

$$\text{Average litre price at project n} = \frac{Total\ \ pre-calculated\ costs\ of\ paint}{Total\ amount\ of\ litres\ pre-calculated}$$

The disposal costs of a litre of paint are also known since there have been disposals of paint in the past by an outsourced company. Using the average price of this in the past it can be assumed that the costs in the future will be in the vicinity of the previous costs. So the overage costs can be written down in an equation as follows:

$C_o = Average\ litre\ price\ of\ paint\ at\ project\ n + disposal\ costs\ per\ litre\ of\ paint$

The underage costs occur when there is no paint left to use for the painters. This then results in a standstill. This assumes that painters cannot perform a different task in the meantime. The costs of underage can be calculated using the labour costs. The labour costs are given in at an hourly rate, whereas with a standstill it could be multiple hours up and till a day or more, depending on the lead-time of the paint and when the last order was placed. Since the cost of overage is in terms of costs per litre the underage costs should also represent this. Here the labour costs per litre are based on the expected usage of paint per hour, based on the hours that are anticipated in the pre-calculations. An example could be that if 0,5 litres are used per hour on average during a project then two hours are needed to use one litre of paint. Meaning that two hours of labour are needed. These two hours could have been prevented by buying one litre of paint extra. Then the following equation will be used:

$$C_u = \frac{Hourly\ wage}{Hourly\ litre\ usage\ at\ project\ n}$$

4.6.2 Demand (D) & Probability (P)

The demand is the quantity of paint needed for a project. At the start of the project the pre-calculations should be used for this. Since the pre-calculations estimate the litres of paint needed based on the measurements made and materials pre-described, here it takes into account the amount of metres that need to be painted and its usage per square meter. During each period this data should be updated based on the orders that are already placed. Therefore the demand decreases with the litres already ordered. Then for the following period based on the number of employees and the remaining demand a decision can be made for the order size, keeping uncertainty in mind by adding an uncertainty factor. The uncertainty factor will be based on the concept of forecast evolution. For UOL the products ordered is given in the amount of litres that are ordered within one period. The mean is the expected amount of litres needed for the project based on the pre-calculations and the standard deviation is calculated based on previous projects and their differences between the pre-calculations and what is ordered in total. The calculations for these two will be mentioned further in the report. A normal distribution is assumed since the projects real usage of paint lies around the pre-calculated mean. The pre-calculations for the litre usage of paint are based on pre-set norms. Since these pre-set norms were once measured manually it should not differ that much when the measurements of the dimensions of the buildings at the project side are made accurate. Furthermore every painter works differently, one uses a thicker layer than another for example which creates differences in paint usage and could affect the final ‘real’ paint usage of a project.

4.7 Multiple period Newsvendor Model

Now that all the variables are clarified for the Newsvendor Model it is important to shift it into a multiple period Newsvendor Model since UOL does not order their paint for the projects in one go and thus one period will not represent the real-life situation accurately. The length of the periods for UOL can best be presented in weeks since there is a meeting every week between the foreman of a project and the project leader where they can update each other on the progression. This is also the moment that the data is relevant for the current period since it only gets updated once a week. So for each project one has to look at the running period in weeks. This is also an understandable period length when looking at the plan preparers since it is really hard to estimate the running period in days for example.

Since there is a finite horizon with multiple periods the last period can be seen as the most important period because ordering too much in this period definitely leads to waste and all the paint that is left after this period is waste. So in principle the costs of overage (C_o) are only realized in the last period. While the cost of underage (C_u) can occur during each period since a standstill can happen in any period of the project. To improve the multiple periods Newsvendor Model the C_o is divided by the remaining periods the paint can be utilized. So for example if a project runs for T_n=10 and currently we are ordering for period t=6, then the C_o during that period will be divided by T_n-6+1 = 5. Since the overage can be remedied in 5 different periods. To calculate the optimal order quantity for the current period it is important to look at the progression so far. Here it is important to know how much paint is already ordered and what the current inventory level is at period t. This inventory level can be given by x_t and consist of the litres of paint leftover from the periods up and till t-1, so the order that gets placed in period t is not taken into account here. However as interviews with the different foremen indicated it is not doable to count and measure the specific certain litres that are left before the weekly meeting between the foreman and project leader of a specific project. So implementing the inventory level and adjusting the orders based on that integer, might it be a positive or negative integer, is not realistic for the case of UOL. However in an ideal situation the leftover paint is measured in litres or the hours of stillstand are measured and multiplied by the average expected paint usage per hour to know how much litres of paint it was short for period t. Which then can be taken into account for the next periods. As of now it will be assumed that the paint ordered during period t will also be used during that period t, such that every period solves a new Newsvendor Model. When there are still *t* periods left the optimal order quantity can be computed by subtracting the litres of paint ordered from the mean of the whole project and using the Newsvendor Model with the new mean and a standard deviation that is a fraction of the whole running period of the project, so multiplying it by a factor $\frac{1}{t}$. At the end of this chapter it will be explained how the new mean and standard deviation are calculated per period.

First of all for project specific calculations one should look at the litres of paint pre-calculated and the running period of the project in weeks.

$\frac{Litres}{T} = \frac{\text{PreCalc(n)}}{T(n)}$ is the average litre usage per period t, where period t is in weeks. PreCalc_n is the total amount of litres pre-calculated by the plan preparers and T_n is the running period of the project n in weeks.

4.8 Normalization methods applied to UOL's projects

Every project has a different running period, total litre usage and wastage rate. For this reason it is important to normalize projects in order to compare the different projects and make them compatible. For this purpose, research data of three projects were collected such that calculations can be made based on their data. To normalize the projects the following procedure is used with the example of project n, Each project n has the following data available:

Project n:

- T_n (Total number of running weeks as per the pre-calculation)
- Q_n (Total litres of paint used)
- μ_n (Total litres of paint as per the pre-calculation)

This is done for all three projects for which the data is specifically collected for this research but should be done by the company in order to improve the accuracy of the model. In order to calculate the standard deviation between the paint ordered and the paint pre-calculated. Unfortunately the data is known for three projects only meaning that the accuracy could be improved a lot by extra data from projects. If more datasets were known this standard deviation would be more accurate and give better outcomes in the model itself. For UOL, once this model is implemented, it would be important to start collecting the data in an efficient matter, such that it can easily be added to the standard deviation. The T_n is already known for each project. However the total litres of paint used and the total litres of paint pre-calculated are not added up somewhere and have to be calculated manually which takes a lot of time, this would be a process that has to be automated otherwise it is not cost efficient enough.

In order to know the values of project n per period t, one has to divide it by the running period (T) of the project, thus:

Normalized project n(t):

- $NormQ_n = \frac{Q_n}{T_n}$
- $Norm\mu_n = \frac{\mu_n}{T_n}$

This then gives the data per period, which can be used to calculate the standard deviation.

$$\sigma^t = \sqrt{\sum_{n=1}^{N} \frac{(NormQ_n - Norm\mu_n)^2}{N}}$$

Where σ_t is the standard deviation of the litres of paint used per period *t* for an 'average' project. N is the number of projects for which the normalized data is known. When the N increases, the standard deviation of the distribution becomes more accurate since there are more observations and it becomes closer to the true distribution. This causes a decreasing spread, resulting in a more accurate representation of an average project.

This standard deviation can be used for future projects. However it does not take into account the fact that the weeks are not homogenous and that the pre-calculations can be inaccurate. For this reason an uncertainty factor will be built in based on the current period of the project. This is $T_{project}$, where it represents the remaining weeks of the project. Then the formula for the standard deviation of a project is: $\sigma_n = T_n * \sigma^t$. The expected usage of litres of paint, is the litres of paint as per the pre-calculations, this will be the μ_n. With help of this μ_n, one can also calculate this value per period t by dividing it by a factor t.

If a project has a running period of 10 weeks then the T_n is 10, one week later it is 9, decreasing with a factor 1 for each period that passes. This can be written down as follows: T_n = (T+1)-t. Where *t* is the number of the current week, starting with value 1 in the first week. The σ_T can get updated weekly based on the current $NormQ_n$ and $Norm\mu_n$. This decreasing factor of T_n factors in the uncertainty that is present at each project. In the beginning the factor is higher and it decreases each week. The period for which decisions have to be made are (t = 1, …, T). Where q_{t-1} is the quantity of litres of paint ordered up and till period $t-1$. For the next period the mean can be updated based on what is already ordered on the project (q_{t-1}), the updated μ_n and σ_n. So for period t, the μ_n can be calculated using $(\mu_n - (q_t - 1))$. Then it is known what still needs to be ordered for the periods $(T-(t+1))$.

4.9 Forecast Evolution application with variables involved at UOL's projects

Sometimes it might be the case that a project has a pre-calculation where the amount of litres used is way off compared to reality. In these cases it is important that the current progress of the projects is related to the amount of paint used. Here forecast evolution could be a solution. In the instance of UOL these updates are based on the total progress of the project which is given as a percentage after each period and the litres of paint ordered up and till the period.

During each period, the paint ordered is retrievable in the database. Furthermore the project leaders have a document in which the progress of a project is registered, in this document there are multiple tasks that need to be done before completing the project with its respective hours. In order to find what the progress of the painting part is it is necessary to filter the tasks involving the painting and let them represent 100% of the total progress. Once this is done it can be measured what the progress of the painting is at a project. With this information it is possible to create a more accurate forecast and decrease the uncertainty for future periods.

Since the first order is purely based on the pre-calculation and historical data, there is chosen to create a period 0. Which is the start of the project, this then has a $\mu_0 = \frac{\mu n}{T}$. The progress of painting tasks can be tracked during each period with the variable $p_{n(t)}$ = x% of paint tasks completed. For $p_{n(0)}$ this can be calculated based on the running period T and the fact that all tasks combined are 100% of the project. The formula is then: $p_{n(0)} = \frac{100\%}{T}$. This basically represents the expected paint usage and progression per period t and will purely be used as an expected state for further calculations. $\mu_p = \mu_{n(0)} * p_{n(0)}$. This then gives the expected paint usage per percentage point (1%) of the project finished. The comparative litres of paint ordered is already known with $q_{n(t)}$. Since one wants to compare the current progression with the expected progression based on the pre-calculation another variable combining the litres ordered and the progression is needed. This would then be: $L_{n(t)} = \frac{q_{n(t)}}{p_{n(t)}}$, which gives the litres usage per percentage of the painting tasks completed.

Assuming that the paint usage is normally distributed over the periods t, one can create a mean and standard deviation based on the data points obtained. Here it is important to note that the average paint usage per period t is taken and since periods are not homogenous it can differ per period t. For this instance and the fact that each period should have an equal weight it is important to give the periods a weight based on the percentage done. The μ_n has a weight of 100% at the beginning since the first order is purely based on the pre-calculations as data for project n is not known yet. For the second period there is already new information available, namely that of period t = 1. This information can be used to create a more accurate order for the upcoming periods.

Since normal distribution is assumed the mean of the project can be calculated based on the current data received from the current periods. So $\mu_{n(t)}$ (t= 1, …,t) = $\frac{\sum_1^t(\frac{q_{n(t)}}{p_{n(t)}})}{t}$. This is the mean of project n at period t as litres of paint used per percentage point of progress finished.

The standard deviation can also be computed from period t=2 and onwards with the following formula: $\sigma_{n(t)} = \sqrt{\frac{(\frac{q_{n(1)}}{p_{n(1)}} - \mu n(t))^2 + (\frac{q_{n(2)}}{p_{n(2)}} - \mu n(t))^2 + \ldots (\frac{q_{n(t)}}{p_{n(t)}} - \mu n(t))^2}{t-1}}$.

So the paint usage is normal distributed per percentage point ~N($\mu_{n(t)}$, $\sigma_{n(t)}$). Since a pre-calculation is made based on pre-set norms as to how many litres of paint should be used by certain action and the actions are done in an arbitrary order not known beforehand in this model, it could be the case that actions in the first week performed use a lot of litres compared to other actions which will be done later on the project. This would then suggest a higher mean than the μ_0 based on the pre-calculations. It is possible to add the $\mu_{n(0)}$ in the calculations for the $\mu_{n(t)}$ and $\sigma_{n(t)}$ going forwards, however the impact of the pre-calculation would then decrease drastically with every upcoming period and this might not be realistic. Therefore it might not be sensible to apply this. Adding a weight to the pre-calculations and a separate weight to the current progress and adding them together later on might be an option to address this. When doing this, the pre-calculation will have more impact throughout the running-time of the project, while also adjusting to eventual differences due to the current progress. However a simulation would give a better insight on this matter.

4.10 Simulations: Proposed scenarios

So for the purpose of showing the different impacts this has on the calculations at the end of the project three different scenarios will be worked out, these are:

- **Scenario 1:** The $\mu_{n(0)}$ and σ from historic projects will be used for the first order, then from period t=1…T the $\mu_{n(t)}$ and $\sigma_{n(t)}$ will be used. Here the impact of the pre-calculations will decrease with every order and the orders will be based mostly on the current progress of the project. The more periods a project has, the less the impact of the pre-calculations since it takes in a lesser fraction of the formula.
- **Scenario 2:** The $\mu_{n(0)}$ and σ from historic projects will be used for the first order, the $\mu_{n(0)}$ and its respective σ will have a weight of 100 throughout the whole project. Then from the following periods the $\mu_{n(t)}$ and $\sigma_{n(t)}$ will be calculated. Their weight will be based on the progress of the project in percentage, thus $p_{n(t)}$. So when 20% of the project is done at period

t=2, $p_{n(2)}$ will be 20% and the weight will be 20. Then the formula used will be: $\frac{100 * \mu p}{100 + p_{n(t)}} + \frac{p_{n(t)} * \frac{\sum_1^t (\frac{q_{n(t)}}{p_{n(t)}})}{t}}{100 + p_{n(t)}}$ for the mean and $\frac{100 * \sigma n}{100 + p_{n(t)}} + \frac{p_{n(t)} * \sqrt{\frac{(\frac{q_{n(1)}}{p_{n(1)}} - \mu n(t))^2 + (\frac{q_{n(2)}}{p_{n(2)}} - \mu n(t))^2 + \ldots (\frac{q_{n(t)}}{p_{n(t)}} - \mu n(t))^2}{t-1}}}{100 + p_{n(t)}}$ for the standard deviation. This will mean that the pre-calculation will always have at least 50% impact on the next order, its impact still decrease but much more slightly compared to scenario 1.

- **Scenario 3:** The $\mu_{n(0)}$ and σ from historic projects will be used for the first order, the μ_0 and its respective σ will have a weight of 100 at the start which will be decreasing with $p_{n(t)}$ each period. So from period 2 the $\mu_{n(t)}$ and $\sigma_{n(t)}$ will be calculated. Their weight will be based on the progress of the project in percentage, thus $p_{n(t)}$. So when 20% of the project is done at period *t* =2, $p_{n(2)}$ will be 20% and the weight will be 20. Then the formula used will be: $\frac{(100 - p_{n(t)}) \mu p}{100} + \frac{(\frac{\sum_1^t (\frac{q_{n(t)}}{p_{n(t)}})}{t}) p_{n(t)}}{100}$ for the mean and $\frac{(100 - p_{n(t)}) \sigma n}{100} + \frac{p_{n(t)} * \sqrt{\frac{(\frac{q_{n(1)}}{p_{n(1)}} - \mu n(t))^2 + (\frac{q_{n(2)}}{p_{n(2)}} - \mu n(t))^2 + \ldots (\frac{q_{n(t)}}{p_{n(t)}} - \mu n(t))^2}{t-1}}}{100}$ for the standard deviation. This will infer that the pre-calculation has a decreasing impact but the decrease will not be as steep as scenario 1. However it will still have less impact, especially in the later stages compared to stage 2.

With the simulations of the three projects and the three different scenarios it is hoped to conclude whether one or multiple scenarios are realistic and give a better outcome then the real situation when implemented. It is also considered whether one scenario works better for one project than another or that one of the scenarios is the better pick. The reason for adjusting the scenarios based on the pre-calculation and the current progress is to check what factor is more important, the pre-calculation of a project or the way a project is currently running? Since the real values are known already, it can be compared to the real situation. This will then be done in the next chapter.

4.11 Waste indicator: Proposal of a metric for paint waste

The dashboard can be used as a tool by the foremen and project leaders when it comes to ordering paint. The goal is to give them a proper indication of the paint usage at their project so far and to warn them whenever there is a chance of possible waste. It should stimulate the awareness of the foremen, specifically at the end of the project where the most waste is created and help them with ordering. It also helps with giving the foremen some insight in what the plan preparers estimate for the usage of paint such that they can act upon this. In an ideal situation this is done per sort of paint, however this is out of scope for this research and could be an interesting aspect for an eventual follow-up research. When this is done per sort of paint it gives a better indication for the foremen since they know what kind of paint to order and what quantity is estimated for this. In this dashboard there is only looked at the total litres of paint pre-calculated.

The potential waste can be indicated with the model which is presented earlier in this chapter. With each subsequent period, the uncertainty factor of the model decreases, which results in a more accurate estimation of the litres of paint needed to finish the project. For this it is important that data gets recorded for every period. Since the forecast evolution method uses the data collected in past periods to make a more accurate forecast of the future periods. The relevant data here is the paint ordered per period and the progress of that period. The progress is recorded by the percentage of the painting tasks at the project that is already done, an indicator for this is the percentage of certain tasks that are completed from the houses/complexes/apartments done within one project and relating them to the litres of paint that are currently ordered.

The uncertainty factor can be seen as the standard deviation from the current progress, as the more periods passed, the smaller the standard deviation becomes and the more accurate the indication of paint needed becomes. This factor also becomes more influential with each consecutive period due to the fact that the weight assigned to it in all of the different scenarios presented earlier increases. This should lead to a more accurate forecast of the total paint usage at a project. In the dashboard the progress of the project should be trackable. Furthermore, an option for a hypothetical order placement in terms of litres could help with identifying potential waste, here the dashboard should then warn if there is a possibility on waste with a certain order size. The closer to the end of the project the higher the chances of waste become, so here it can be utilized to check what order size presents the best trade-off between stillstand and ordering too much paint. In the end the foremen can decide for themselves what the best option is, as they are the once working on the workplace. This decision could be made with help of the concerned project leader.

To create this indication the standard loss function can be implemented. The z-score has to be calculated and when this is done it can be multiplied by the standard deviation of the specific period, in this case that will be the calculated $\sigma_{n(t)}$ or σ, depending on the period but since it becomes more and more important towards the end of a project it will most likely be calculated with the $\sigma_{n(t)}$. The use of this variable means that per period a different outcome will be presented, since the more data is known, the smaller the standard deviation and the more accurate the loss function becomes. Finally the expected overage can be calculated for each order size as well which could help the foreman and project leader with deciding on the order quantity. This can be done with the following equation: $q_{n(t)} - (L(z)) \times \sigma_{n(t)})$. Where $z = \frac{q_{n(t)-\mu_{n(t)}}}{\sigma_{n(t)}}$ and $L(z)$ is the standard loss function.

5. Data analysis

Now that a model is presented it is time to test the different scenarios that have been proposed. With the data that is collected manually simulations of the three different projects will be run. The simulations will be coded in VBA and the output will be displayed in Excel. Unfortunately the historical progress of the projects cannot be extracted per period as the intermediate calculations (weekly meeting between project leader and the respective foreman) are processed in the same document which is updated weekly, thus it is not known what the progress was each week. Therefore, in order to give an indication of the progress per week the assumption is made that the total work hours booked on the project represents the expected progress, assuming that each hour the same quantity of paint is used. In reality this might differ, depending on the tasks performed each week, however in general the more hours worked during a period the more progress is booked.

For the sake of this research data was collected from three different projects which ended in the period of this research (approximately end of 2022). From those three projects the left-over paint was counted and the useful information was extracted from the database. The useful data extracted from the database includes: pre-calculation values for costs and litre usage as well as the orders and the man-hours booked on the project. The projects names are known to the supervisors but are called *project X*, *project Y* and *project Z* in this thesis and all differ in the running time, critical fractile and difference between the pre-calculation and real usage. This indicates that throughout UOL there are a lot of different projects and they do not all look the same. In the Appendices A4-A9 the pre-calculations and actual orders for the three different projects can be found as well as the costs. The costs as seen in the appendices are multiplied with a factor known to the supervisors and do not represent the real values.

5.1 Standardizing & Critical Fractile

With the aim of standardizing projects the formula in Figure 5 and data in Table 5 are used to give a standard deviation per period t of a project. First the paint usage per period t was calculated by the actual usage and the pre-calculations. Since the data of only three projects is known the standard deviation is still relatively uncertain. When more data gets collected it is likely that the standard deviation decreases and becomes more accurate, however as of now no more data is available and the following standard deviation will be used in all three project simulations.

NormPaint(n)	NormPreCalc(n)
12.00	18.9895
10.85	11.0900
37.80	49.6298

Table 5: Calculation of standard deviation of historical projects

$$\sigma_T = \sqrt{\sum_{n=1}^{N} \frac{(NormPaint_n - NormPreCalc_n)^2}{N}}$$

Figure 5 Standard deviation calculation of standardized projects

Co and Cu from the Newsvendor model are calculated with the help of the pre-calculations as this gives the best indication for the respective project beforehand. The Co is calculated by:

$avg. costs\ per\ litre + disposal\ costs\ per\ litre$

The Cu is calculated by: $\frac{Hourly\ wage}{avg.\ litre\ usage\ per\ hour}$.

Then the critical fractile is calculated by: $\frac{Cu}{Co+Cu}$.

As mentioned earlier the overage will be divided by the remaining periods it can be remedied in. Then with the respective Cu and Co the critical fractile can be calculated, which is used for the calculations of the order sizes in litres. The values for the critical fractile can be found in Table 6. When considering these values it is peculiar that the wastage rate of Project X is rather high, namely 11.52%. Since when one looks at the costs for overage and underage and applies a Newsvendor Model for the whole running period of the project the wastage rate should be around ~4%. Because when running it once with the known values of the critical fractile, pre-calculated litres of paint and the standard deviation for the standardized project (σ^t), the model gives an output of 231 litres of paint whereas the pre-calculations are 222 litres of paint. This is a wastage rate of ~4,1% if the pre-calculations are accurate. With simulating Project X it should be able to reduce the wastage rate to at least below this number by decreasing the uncertainty of the final paint usage. For Project Z and Project Y the pre-calculations differed to much compared to the actual paint usage to create an indication of the wastage rates that can be achieved via a simulation but due to the concept of forecast evolution acquired in the model it should shift its paint usage towards the real value throughout the subsequent periods.

Project name	Co	Cu	Critical fractile
Project X	43.06	172.79	0.8005
Project Y	29.16	205.08	0.8755
Project Z	52.32	87.08	0.6247

Table 6: Calculations of the critical fractile for each project

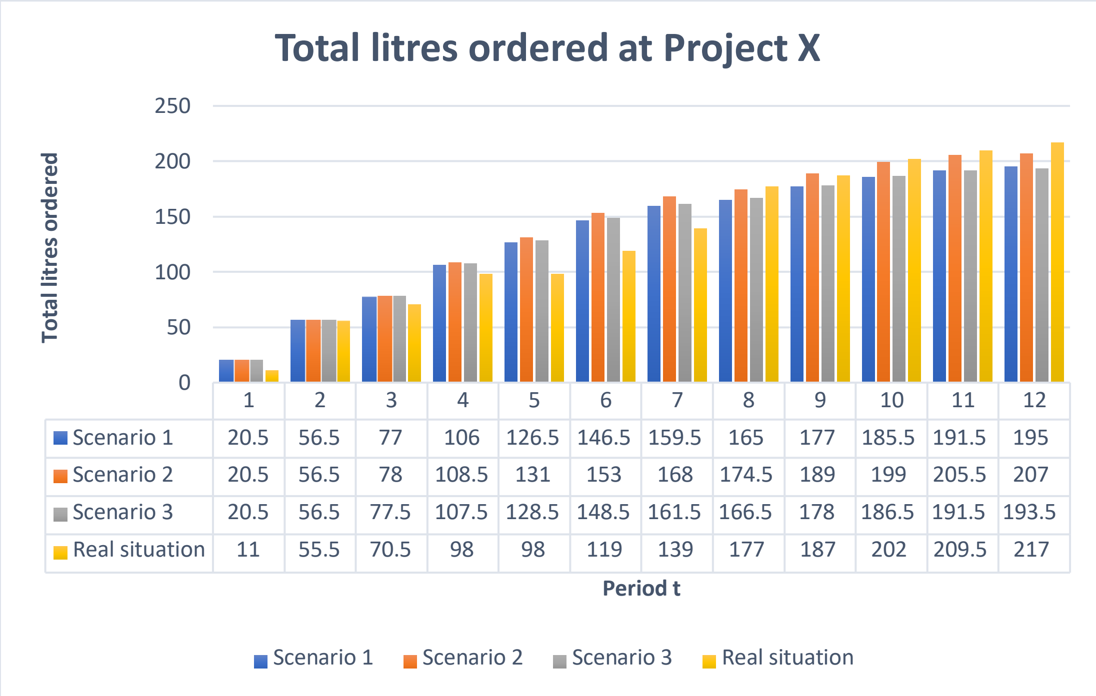
5.2 Application cases: UOL's projects X, Y & Z

In Figure 6 the dashboard for the simulations of the Project X project can be seen. As mentioned before the first order is based on historical data for each scenario, thus in each case it is the same quantity. As for the other periods the way the expected progress at that point is calculated is different. In the first scenario the fractional impact of the pre-calculations decreases with a factor $\frac{1}{t}$ for each progressing period, meaning that the impact of the current progress increases, thus the impact of L(t) increases on the μ_t. Since the total value which is needed for this project is already known it also means that the litre usage becomes closer and closer to the 1.92 litre per percentage point. In the second scenario the pre-calculations keep having an impact of at least 50%, this then follows that the end total of litre used is in the middle of what is needed and what is pre-calculated. For the third scenario the impact of the pre-calculation decreases with a factor of $100\% - p(t)$. This can also be seen back as the impact of the pre-calculations are stronger in the beginning of the project (higher quantities of paint ordered in the first few periods compared to scenario 1), however in the end drastically less litres of paint are ordered compared to the first scenario, meaning that the impact of the current progress is higher in the end. This all results in different order amounts as can be seen in the graph of Figure 7.

Project X				Progress (t)	1	2	3	4	5	6	7	8	9	10	11	12
				Scenario 1	9,23%	27,44%	38,30%	53,34%	64,10%	74,58%	81,47%	84,49%	90,80%	95,31%	98,51%	100,42%
				Scenario 2	9,23%	25,79%	36,32%	50,99%	62,22%	73,13%	80,73%	84,12%	91,23%	96,31%	99,63%	100,47%
				Scenario 3	9,23%	25,82%	36,32%	51,17%	62,51%	73,43%	81,09%	84,50%	90,77%	95,92%	99,19%	100,67%
VC Paint (μ)	222	Waste	25	€ 43,06												
Weeks (T)	12	Total needed	192													
STDEV (σ)	11	Z-score	0,843443													
Co	€ 43,06	Waste	9,277872													
Cu	€ 172,79	μ0	18,5													
Cf	0,80050961	q0	19,5													
NORMINV	231,277872	h1	8,33%													
First order	19,273156	5,73%	23,18%	7,81%	14,32%	0,00%	10,94%	10,42%	19,79%	5,21%	7,81%	3,91%	3,91%	113,02%		
	t	1	2	3	4	5	6	7	8	9	10	11	12	Total		
Real situation	Ordersize	11	44,5	15	27,5	0	21	20	38	10	15	7,5	7,5	217		
Scenario 1		20,5	36	20,5	29	20,5	20	13	5,5	12	8,5	6	3,5	195		
Scenario 2		20,5	36	21,5	30,5	22,5	22	15	6,5	14,5	10	6,5	1,5	207		
Scenario 3		20,5	36	21	30	21	20	13	5	11,5	8,5	5	2	193,5		
Per t	Hours	101,5	176	111	177,75	143	161	120,5	50,5	151	129	117	104,5	**1542,75**		
	% Per t	6,58%	11,41%	7,19%	11,52%	9,27%	10,44%	7,81%	3,27%	9,79%	8,36%	7,58%	6,77%	100,00%		
	Cum. %	6,58%	17,99%	25,18%	36,70%	45,97%	56,41%	64,22%	67,49%	77,28%	85,64%	93,23%	100,00%			
t	1	2	3	4	5	6	7	8	9	10	11	12	Total			
Scenario 1	20,5	56,5	77	106	126,5	146,5	159,5	165	177	185,5	191,5	195	195			
Scenario 2	20,5	56,5	78	108,5	131	153	168	174,5	189	199	205,5	207	207			
Scenario 3	20,5	56,5	77,5	107,5	128,5	148,5	161,5	166,5	178	186,5	191,5	193,5	193,5			
Cumulative																

Figure 6 Dashboard of Project X simulations

When comparing the scenarios to the real situation of Project X all the scenarios have less waste than the current situation. Project X was a project with a high wastage rate (11.52%!), one of the things that stood out here was that 5 litres of paint were wrongly ordered, which the simulation does not take into account. However, there is still a decrease in waste when following the quantities that the simulation presented based on the working hours. The simulation also does not order any more litres of paint once the expected progress surpasses the 100%, which results in no orders in the last period. Since the model could decide it rather orders more litres of paint to prevent a standstill, the expected progress can proceed 100%. If Scenario 3 was followed and no wrong paint was ordered and the quantities matched perfectly then only 1.5 litres of paint would be wasted. Which would result in a wastage rate of only $\frac{1,5}{192} \times 100\% \ = \ 0,8\%$. The biggest difference between the scenarios and the real situation is that the orders in the beginning of the project are bigger than in the real situation, while towards the end in the real situation the orders are bigger while they tend to flatten more in the simulations. This is the result of the Newsvendor Problem, since in the beginning the Co is very low compared to the Cu and the Co increases with every subsequent period, as the chance of overage increases as well.



	1	2	3	4	5	6	7	8	9	10	11	12
Scenario 1	20.5	56.5	77	106	126.5	146.5	159.5	165	177	185.5	191.5	195
Scenario 2	20.5	56.5	78	108.5	131	153	168	174.5	189	199	205.5	207
Scenario 3	20.5	56.5	77.5	107.5	128.5	148.5	161.5	166.5	178	186.5	191.5	193.5
Real situation	11	55.5	70.5	98	98	119	139	177	187	202	209.5	217

Figure 7 Total litres ordered at Project X

The simulations of project Y do not differ that much compared to the Project X' simulations. The biggest difference is that the running period is three periods longer and that the difference between the pre-calculations and actual usage is a lot bigger. This does then also result in scenario 2 not being more cost-efficient than the real situation as it always follows the pre-calculation for at least 50%. However, scenario 1&3 where the impact of the pre-calculations becomes stronger with each progressive period would result in less waste than the real situation. The biggest difference is in the beginning where all the scenarios order more paint than in the real situation. This might be the case cause no more paint was needed and more progress was booked towards the end of the project but this cannot be said with certainty. In Figure 9 the total litres ordered at Project Y throughout the periods is presented in more detail.

Project Y				Progress (t)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Scenario 1	6,92%	11,03%	13,52%	18,80%	24,79%	36,84%	47,13%	55,24%	63,36%	73,09%	81,13%	88,20%	92,48%	97,47%	100,47%
				Scenario 2	6,92%	9,42%	11,01%	14,89%	19,55%	29,03%	38,29%	46,20%	54,28%	64,46%	73,74%	82,56%	88,68%	95,78%	101,57%
				Scenario 3	6,92%	9,50%	11,12%	15,09%	19,91%	29,82%	40,05%	49,32%	59,08%	71,31%	82,71%	92,42%	97,89%	100,99%	101,82%
VC Paint (μ)	744,5	Waste	21																
Weeks (T)	15	otal neede	546																
STDEV (σ)	11	Z-score	1,152802																
Co	€ 29,16	Waste	12,68083																
Cu	€ 205,08	μ0	49,63333																
Cf	0,8755042	q0	50,5																
NORMINV	757,18083	h1	6,67%																
First order	50,478722	11,08%	1,83%	0,00%	0,18%	15,57%	17,86%	6,87%	17,40%	24,73%	0,00%	5,49%	0,64%	1,10%	0,73%	0,37%	103,85%		
	t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL		
Real situation	Ordersize	60,5	10	0	1	85	97,5	37,5	95	135	0	30	3,5	6	4	2	567		
Scenario 1		51,5	18	11,5	29	33	67,5	57	44,5	44,5	53,5	44	38,5	23	27	16	558,5		
Scenario 2		51,5	17	11	27,5	32	65	59,5	49	50	63	55	52	34,5	42	33	642		
Scenario 3		51,5	17,5	11	28	32,5	66,5	62	51,5	52,5	64	52	40	16,5	9	0	554,5		
Per t	Hours	91,25	111,25	61,5	172	186	366	283	203	189,5	220	168,5	141,5	78,5	98	64	2434		
	% Per t	3,75%	4,57%	2,53%	7,07%	7,64%	15,04%	11,63%	8,34%	7,79%	9,04%	6,92%	5,81%	3,23%	4,03%	2,63%			
	Cum. %	3,75%	8,32%	10,85%	17,91%	25,55%	40,59%	52,22%	60,56%	68,34%	77,38%	84,31%	90,12%	93,34%	97,37%	100,00%			
t	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total			
Scenario 1	51,5	69,5	81	110	143	210,5	267,5	312	356,5	410	454	492,5	515,5	542,5	558,5	558,5			
Scenario 2	51,5	68,5	79,5	107	139	204	263,5	312,5	362,5	425,5	480,5	532,5	567	609	642	642			
Scenario 3	51,5	69	80	108	140,5	207	269	320,5	373	437	489	529	545,5	554,5	554,5	554,5			
Cumulative																			

Figure 8 Dashboard of Project Y simulations

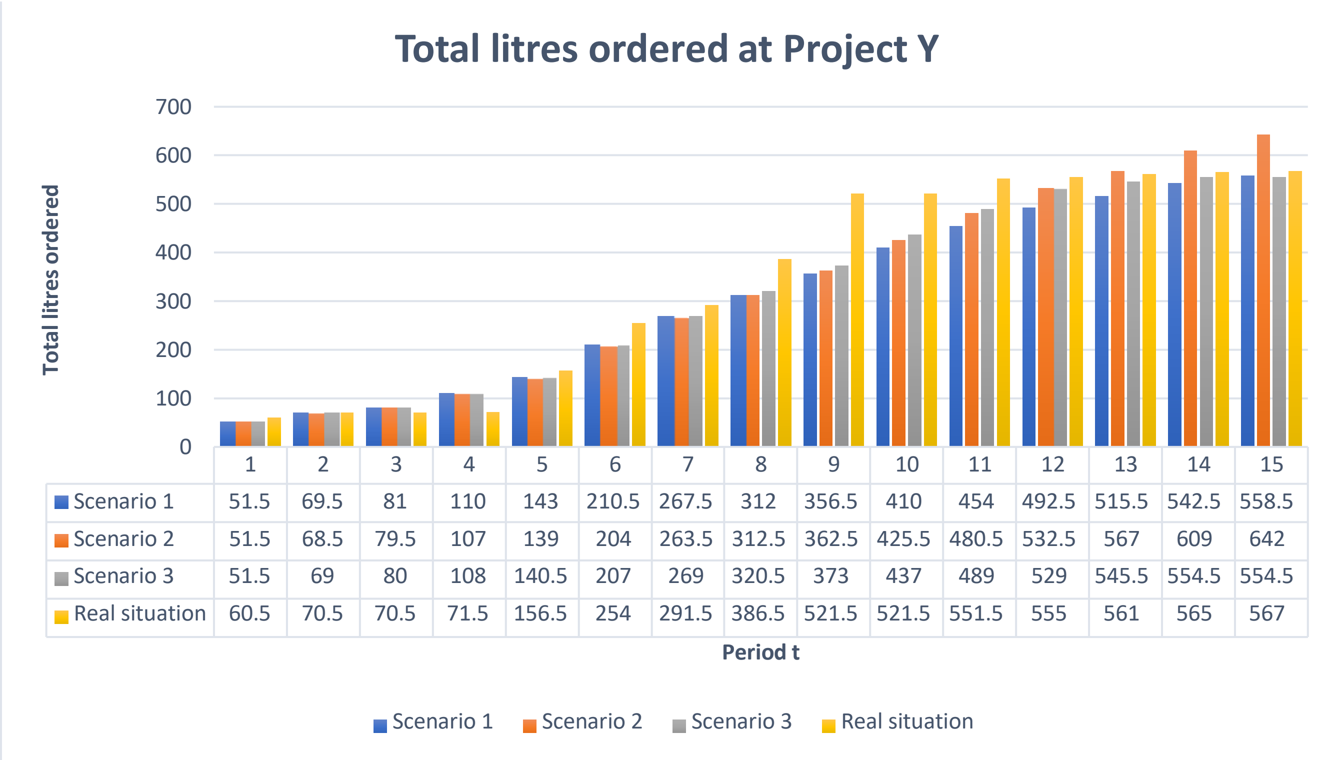


Figure 9 Total litres ordered at Project Y

The simulations of the Project Z did not give any useful results. The first order is logical and not a big quantity, especially taking into account that the critical fractile is rather high in the first period due to the fact that the cost of overage play a smaller role compared to the last period, this results in a higher critical fractile which then results in a higher order size than simply dividing the pre-calculation by the number of periods. The reason why the output is much higher than the quantity of litres that is actually needed is partly due to the fact that the first order is purely based on the pre-calculations and these are way off, namely 38 litres of paint whereas 17 litres of paint are used in reality. This results in the fact that the first order almost fulfils all the paint that is needed. However at this point the model does not know that the pre-calculation is not accurate. In the second period it takes the progression into account from the first period. The reasoning that the order quantity still became larger in the second period is the fact that it still takes into account the pre-calculation for at least 50% in all scenarios and the fact that in the second period more hours are worked. Because there are only a few periods, each one has a major impact and also contains quite a big percentage of the total work hours worked. Since one focuses on the progress and hereby takes the expected progress and the current progress into account it could be that the big differences here lead to orders which would not have been placed in a real-life situation. As one can see in the dashboard in Figure 10, in the real situation no orders bigger than 10 litres are placed, while in the simulation at period 2 an order of 14.5 litres is placed. Another variable that could have impacted this result is the fact that the pre-calculations for the paint indicate a more than double amount of litres needed than the quantity that was actually used. Since this was a rather small project it could be the case that these big differences impact the simulations way too much and thus are not viable for such situations.

Project Z				**Progress (t)**	**1**	**2**	**3**	**4**	**5**
				Scenario 1	27,63%	104,30%	117,57%	124,21%	128,19%
				Scenario 2	27,63%	83,38%	125,35%	135,41%	137,29%
				Scenario 3	27,63%	88,25%	154,01%	213,86%	268,35%
VC Paint (μ)	38	Waste	7						
Weeks (T)	5	otal neede	17						
STDEV (σ)	11	Z-score	0,317727						
Co	€ 52,32	Waste	3,494993						
Cu	€ 87,08	μ0	7,6						
Cf	0,624654	q0	8,5						
NORMINV	41,49499	h1	20,00%						
First order	8,298999	58,82%	29,41%	41,18%	0,00%	11,76%	141,18%		
	t	**1**	**2**	**3**	**4**	**5**	**Total**		
Real situation	**Ordersize**	10	5	7	0	2	24		
Scenario 1		10,5	14	0	0	0	24,5		
Scenario 2		10,5	14,5	5,5	0	0	30,5		
Scenario 3		10,5	14,5	3	0	0	28		
Per t	**Hours**	87	119,5	156	87,5	60,75	510,75		
	% Per t	17,03%	23,40%	30,54%	17,13%	11,89%	100,00%		
	Cum. %	17,03%	40,43%	70,97%	88,11%	100,00%			
t	**1**	**2**	**3**	**4**	**5**	**Total**			
Scenario 1	10,5	24,5	24,5	24,5	24,5	24,5			
Scenario 2	10,5	25	30,5	30,5	30,5	30,5			
Scenario 3	10,5	25	28	28	28	28			
Cumulative									

Figure 10 Dashboard of Project Z simulations

5.3 Application cases: Summary of results

Based on the model introduced in this thesis and the different scenarios represented it was expected that depending on the accuracy of the pre-calculations the model would order less paint, especially towards the end of the project as forecast evolution should give a more accurate estimation of the litres of paint still needed. When the pre-calculations are accurate scenario 2 should give the best outcome since it always focusses 50% on the pre-calculations and 50% on the forecast evolution estimation. When the pre-calculations are less accurate scenario 1 should give the best outcome since it takes the pre-calculations into account with a decreasing factor based on the progress with each subsequent period. When the pre-calculations are way off scenario 3 should give the best outcome since its estimations are purely based on the concept of forecast evolution and the estimations are thus based on the progress, except for the first order.

When looking at the different projects one can see that these expectations were closely met. The only difference is that for project X, where the pre-calculations are pretty close to the real-life situation, scenario 3 still gave the best outcome, instead of scenario 1. However the differences are very small and both of the scenarios lead to a great decrease in the wastage rate. As for scenario 2, it is not tested whether it would give the best outcome when the pre-calculations are very accurate. However it is shown that when they are not that accurate that scenario 2 is less trustworthy than the other scenarios. This is clearly evident with Project Y where the second scenario gives a higher paint usage than the real situation since the differences between the pre-calculations and the actual usage are really high here. Upfront this information is not known so it is hard to estimate what scenario is the most cost efficient. From what is currently seen one would say scenario 3 as it has the lowest wastage rate in both project X as Y. However more data needs to be collected in order to rule this out. Most importantly it should be applied to a project from the start and not only a simulation at the end.

In order to test whether the simulations give accurate results or are useful for UOL it is important to test them on more historical projects or more importantly try them on an actual project. What is learned from these simulations just now is that they tend to be more accurate when the project is bigger and more paint is used. For small projects it might not be viable or even optimal to use simulations but it can be tried on a live project. In the simulations most of the time it orders more paint in the beginning of the project and decreases the quantity of the orders towards the end where each order could lead to waste, which is something that is impactful and could be implemented in a real-life situation. As for the different scenarios it is hard to say which one works best. This also means that the progress at that point, which can get recorded is of real importance. Then it only depends on how accurate the pre-calculations are to know which scenario works best. The safe choice would then be scenario 2 as this always takes the pre-calculations into account for at least 50% but also looks at the current progress. With Project X this method has already proven to decrease the waste, although slightly less than scenario 1 and scenario 3, with Project Y it was not successful but this is mostly due to the fact that the pre-calculations were way off from the actual usage. Yet, there is also no case of a project where the actual usage was higher than the pre-calculations and how the different scenarios react on that. Running more tests on different projects should give a better insight in what scenario is the most useful.

Technically the simulations can be ran before the start of a project but only when it is known how the man-hours are divided, however this first simulation would then not include the updates for each period, therefore this model is only useful when it gets updated each period. So implementing the simulations is not possible. Therefore a dashboard can be build, like the prototype shown earlier, where the project leaders can give the current progress of a project and compare it with the litres of paint used. Then it can be calculated with either of the three scenarios in mind what the expected paint usage is for the rest of the project, it could even give an indication of the order sizes based on the principles of the different scenarios.

6. Conclusion

Estimating the litres of paint that are still needed to finish off the work can be hard, especially when there is a big project with multiple painters walking around. In order to find a method that can help the foremen with deciding on the order quantities interviews and literature research were conducted. Furthermore from three projects the data was manually collected during the research period of this thesis. The goal here is to reduce the quantities of litres that return to the warehouse of UOL from the project sides. Based on the information found during the research an approach was created. This approach consists of finding out the important KPIs of the stakeholders involved in the ordering process and creating a dashboard to visualize these important KPIs. Furthermore a model is created, which helps with deciding the order quantity at any period t of the project. It is based on the pay-off between ordering a litre too much against ordering a litre too little. Finally it takes into account the current progress and the expected future progress by means of forecast evolution.

The indicated stakeholders were the plan preparers, project leaders and foremen. Quickly it was discovered that the foremen are not used to handle and interpret data and therefore a dashboard has to be simplistic or it should be explained to them, the latter was chosen such that the dashboard can be focussed on the office staff of UOL and during weekly meetings between the project leader and foreman the details can be discussed and the dashboard can be updated based on the tracked progress. It was found through a scoring card that the most important KPIs were: expected future paint consumption, wastage rate and pre-calculated amount relative to the actual amount ordered. These KPIs are crucial and have to be displayed on the proposed dashboard.

Since a decision is posed on the order quantity, basically the question that the foremen should ask themselves is should I order one litre more, yes or no? This can be hard to estimate without any data or purely based on experience. Hence a model that takes this pay-off into account, which is the Newsvendor Model, was implemented. Based on the data available from the pre-calculations and the projects these costs can be calculated and a trade-off can be made. However the Newsvendor Model only looks at one period which would be the whole running period of a project. In the case of UOL they order multiple times throughout the project, thus multiple Newsvendor Models might be a better tool to be used at UOL. Therefore research was conducted on the multiple Newsvendor Model and it was found that for each period a Newsvendor Model calculation can be done based on the expected litres of paint still needed and an increasing chance of overage through subsequent periods. The concrete difference between the multiple Newsvendor Model which was researched and the one implemented in this thesis is that the in the research model cost of overage are equal throughout the running period of the model and holding costs are incurred when too much is ordered, whereas in the model presented in this thesis the cost of overage are incurred in the very last period and there are no holding costs. By dividing the cost of overage by the number of periods still left these costs are made lower such that in earlier periods there is less punishment when more paint is ordered than might be necessary.

However as UOL does not check whether the pre-calculations match the actual paint usage and from the data collected from the projects it can be seen that this is not always the case the model should also update its expected paint usage based on the current progress such that it becomes more accurate and learns from its own progression. A concept that takes this into account and that is researched in this thesis is forecast evolution. In forecast evolution data that is gathered during the finished periods of a project is used to improve the forecasts for the leftover periods. Thereby an uncertainty factor is involved which decreases as the project progresses towards the end and the remaining of the forecasting only addresses a few periods. This means that the forecast evolution has less impact in the beginning of the project and more impact towards the end of it, since one can be more certain about the expected demand towards the end of a project through the updated mean and standard deviation which is used per period. Comparing it to the forecast evolution papers which were studied in this thesis the biggest difference is found in the fact that for UOL the demand is given for the project as a whole and after that the order interval is set to a week, here the demand per period is not known whereas in the papers studied each period has its specific demand distribution.

By combining the two models (Newsvendor Model and concept of forecast evolution), a new model is created. Here the concepts of forecast evolution are implemented to increase the accuracy of the expected paint usage for the remain of the project, while the Newsvendor Model keeps taking into account the trade-off in costs between ordering either too much or too little paint and adjusts the cost of overage per period. The two models are intertwined by updating the mean and standard deviation of the Newsvendor Model with the mean and standard deviation calculated on basis of known data of the progression and litres of paint ordered. Three different scenarios were introduced with all a different weight for the pre-calculations and the forecast evolution part of a project. Simulations were ran and from these simulations it can be concluded that less paint can be wasted when the model gets to decide on the order quantities. Purely based on the raw data the model tends to order higher quantities in the first few periods of the project and less paint in the last few periods of the project. Especially when following scenario 3 where the forecast evolution has the most impact the decrease in wastage rate is significant compared to the real-life situation. For the stakeholders the model can be applied per period where they fill in the order amount in litres and the progression so far and then based off of that information the model should give order sizes for the subsequent periods as well.

In the end the employees working on the project sides have the most impact on ordering the paint and reducing the waste. Creating and increasing consciousness is the most important factor to prevent waste, as mentioned earlier not all the painters tell the foreman when their paint can is empty, so the foreman do not always have a clear overview. A dashboard can be a supportive tool to validate certain orders, especially towards the end of a project but in the end it will not be leading. With the dashboard displayed in this thesis it becomes even easier as it suggests order sizes for the subsequent periods based on the progression so far and it will become more accurate throughout time. Furthermore an order size can be filled in and the expected waste can be calculated with it. However ,the fact that there is no check-up on the quantity of paint that is used compared to the pre-calculations can be solved by a simple dashboard following both KPIs in combination with the progression of the project. The differences that would occur by implementing the dashboard would be that it would create continuous consciousness about the waste prevention since it comes back during every weekly meeting. As well as a supporting decision tool to which one can give their own input and check the output when it comes to waste and help the decision making process based on it, as well as check on whether the pre-calculations themselves are done accurately. Since if there are differences between the real-life situation and the pre-calculations they become clear by means of the dashboard and data collection.

6.1 Discussion & Recommendations

How useful is the model presented in this thesis? The results might seem hopeful but it is still hard to say whether it reflects the reality. For only three known projects the simulations were ran and for one of them the simulation did not give an useful outcome. In these simulations the standard deviation used for the first order and for the subsequent orders but with decreasing impact is also purely based on these three historical projects, whereas in a real-life situation this data would not be known beforehand. Furthermore the simulations were performed on finished projects and not running projects. This has influence on the results as there is calculated on basis of the known final paint usage. While in a real-life scenario this is only known with certainty at the end of a project. This might also be the reason that scenario 3 outperforms the other scenarios as it has the highest weight attached to the forecasted evolution part of the model. One would prefer to see the impact of the models when a project is running and check how it makes it decisions then. Now it was already known what the final paint usage was and in the simulation there was also calculated with this value. So, before implementing the dashboard it should first be tested on a few projects in order to see what the outcomes are and how the employees of UOL react to it. Furthermore, it is not known in the simulations which tasks are performed in which week and since the different tasks have a different paint usage this can also change the effect of the forecast evolution part of the model. The model could be improved if it was known beforehand how much litres are needed for which tasks and when they are performed. Finally it was also shown that for projects with a significant difference between the pre-calculations and the real usage the simulation did not give any useful output, in this thesis one of the projects had a pre-calculation which was twice as high as the actual usage but it is not known from what exact difference it results in the simulation not giving an useful output. Furthermore the influence of the number of periods on this is not tested. As for the multiple Newsvendor Model part of the model it now takes into account the cost of overage by dividing the costs of overage by the fraction of the periods still left, however in an optimal situation this is based on the probability of an overage at an order of a certain quantity.

It is suggested for UOL to further test the model and its scenarios proposed but this time on a few running projects such that the stakeholders can test with the dashboard and see if it works for them. It is preferred to test it on projects with a somewhat larger pre-calculation of the litres of paint since these projects have shown to adjust well to the model whereas the only project with a rather small pre-calculation did not give an useful output due to the fact that there was an enormous difference between the pre-calculation and actual usage. Additionally more data needs to be collected for the purpose of getting a conclusion on what scenario can best be applied and on whether the model decreases the wastage rate.

Within the database that UOL uses unification is needed in order to implement the model and extract the right information. The orders are not always processed in the same way which results in having to go through the data manually in order to check whether the data was put into the database correctly, so this has to be adjusted. Furthermore, automatically calculating the total litres and costs of the paint specifically by simply adding an extra column in the pre-calculations and orders within the database such that this can be extracted easily into the model.

In order to improve the proposed model it is important to keep gathering data. By gathering data of historical projects the first order which is purely based on historical data becomes more accurate, as well as the other orders throughout the project but with lesser effect. This is because the first order is based on the mean and standard deviation of historic projects and with each extra project the sample size increases.

As for the return flow of the paint it is important to check whether the paint was ordered on the project or is a left-over from another project. As not all paint gets returned to the warehouse immediately after a project is finished this can cause confusion. By immediately returning it to the warehouse with the respective project number the office staff can analyse the projects in the most accurate way. Here they can check on the costs and litres used compared to the pre-calculations and the actual use, as well as the wastage rate.

Within the company it is important that the focus is on reducing waste and that the dashboard becomes a tool to visualize the progress of the project and can be used to indicate waste with certain order sizes. Therefore, it is important that the dashboard is easy to use for the office staff at UOL and it should be reviewed and refined based on the experiences of the staff.

6.2 Limitations & future work

Some limitations are identified. For the quantitative data a problem that might occur is that the data collected for the waste of paint is not a big enough dataset. Since the data is not collected at the beginning of the research and is only tracked for 10-15 weeks it might not give the most accurate data compared to when it is tracked for multiple years, so this has to be taken into hindsight. As already seen in the data from the three projects observed, is that they differ a lot in terms of accuracy of the pre-calculations and the critical fractile which all impact the outcome of the presented model. By collecting data of more projects over the years outliers in data should not have as much effect as they potentially have now in this thesis. Furthermore, the assumption is made that when a project gets accepted and gets carried out that it is known how long their duration is. However this duration can of course change in some circumstances, for example, due to weather, or the dependence of other parties. This will not impact the paint usage directly but will add another period for the multiple Newsvendor Model which impacts the model in total as some parts are divided by the total periods. But for the sake of keeping it simple and due to the fact that there is limited time to execute the thesis there is chosen to only look at the fixed interval. Finally the only paint that is counted is the paint returned to the warehouse, it is known that some paint gets left behind in the bus of the painter for later use, so it does not give the exact waste for all projects and jobs. Although this might not count as waste since the paint will likely be used in another project, it will not be taken into account at the pre-calculations and billing.

Due to its promise and possibilities further research into a dashboard combined with a forecast of demand should be proposed. Here the focus can be enlarged by taking all the materials instead of just the paint into account as this only is a small part of the material costs and there is more to gain. Furthermore now there is only focused on the litres of paint, once it is known what type of paint is needed, as well as the colour the estimations can be made even more accurate and appropriate for the company as litres is very broad when talking about paint. But before this is possible the pre-calculations should be adjusted such that the colours needed as well as the paint type are known within the database. Finally different percentages of influence of the pre-calculations and the forecast evolution should be tested throughout the projects, not just the percentages presented in the scenarios in this thesis. Since the percentages presented in this thesis are the most obvious once they do not have to be the most optimal choices. So a range between 0-100 for the percentages of either forecast evolution and the pre-calculation part can be researched. The implementation of this dashboard could be the first step to giving insight for the order process and collecting data for future use and improvements along the way.

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Appendices

Date	Description	Quantity (L)	Costs (€)
29/11/2019	Paint/ink sludge water based; Euralcode 08 01 11; processing method C03	596	953,60
29/11/2019	UN barrel 200L	2x200 = 400	59,50
09/07/2020	Paint waste; Euralcode 08 01 11; processing method C03	558	563,58
09/07/2020	UN barrel 200L	2x200 = 400	59,50
18/11/2021	Paint waste; Euralcode 08 01 11; processing method C03	433	415,68
18/11/2021	UN barrel 200L	2x200 = 400	59,50

A1: Waste disposal of paint at UOL

KPI's	How important is this KPI for my job? My job: Foreman/Project leader/Plan preparer
Total paint consumption	1 2 3 4 5 Unimportant <-----------------> Neutral <---------------> Very important
Expected future paint consumption	1 2 3 4 5 Unimportant <-----------------> Neutral <---------------> Very important
Chance of wastage in an order (Too much paint ordered)	1 2 3 4 5 Unimportant <-----------------> Neutral <---------------> Very important
Current waste (Paint that cannot or will not be used anymore)	1 2 3 4 5 Unimportant <-----------------> Neutral <---------------> Very important
Wastage rate: $(\frac{Leftover\ paint}{total\ orderered\ paint} * 100\%)$	1 2 3 4 5 Unimportant <-----------------> Neutral <---------------> Very important
Size of the orders (In liters of paint)	1 2 3 4 5 Unimportant <-----------------> Neutral <---------------> Very important
Interval of the orders (Time in days between the orders)	1 2 3 4 5 Unimportant <-----------------> Neutral <---------------> Very important

Leadtime of the paint → Number of days between the placement of the order and the receivement of the order	① ② ③ ④ ⑤ Unimportant <----------------> Neutral <--------------> Very important
Average paint usage per working day (in litres)	① ② ③ ④ ⑤ Unimportant <----------------> Neutral <--------------> Very important
Total progress of the project (e.g. percentage of houses completed or other indicator)	① ② ③ ④ ⑤ Unimportant <----------------> Neutral <--------------> Very important
Total costs of the paint	① ② ③ ④ ⑤ Unimportant <----------------> Neutral <--------------> Very important
Pre-calculated amount of paint compared to final amount of paint ordered: $\frac{\textit{Amount of paint ordered}}{\textit{Pre} - \textit{calculated amount of paint}}$	① ② ③ ④ ⑤ Unimportant <----------------> Neutral <--------------> Very important
Total failure costs or surplus costs (Cost of the remaining paint) + possible disposal costs	① ② ③ ④ ⑤ Unimportant <----------------> Neutral <--------------> Very important
Pre-calculated costs of the paint relative to the actual costs of the paint: $\frac{\textit{Cost spent on the paint}}{\textit{Pre} - \textit{calculated cost of the paint}}$	① ② ③ ④ ⑤ Unimportant <----------------> Neutral <--------------> Very important
Other KPI, namely:	① ② ③ ④ ⑤ Unimportant <----------------> Neutral <--------------> Very important

A2: Form used during interviews for the dashboard

$^{KPI}/_{Scoring\ (\boldsymbol{n})}$	**Foremen (4)**	**Project leaders**	**Plan preparers**	**Total (Avg)**
Total paint consumption	$\frac{3+4+4+4}{4}$ = 3.75	$\frac{3+4}{2}$ = 3.50	$\frac{4+4+5}{3}$ = 4.33	3.87
Expected future paint consumption	$\frac{5+4+5+4}{4}$= 4.50	$\frac{4+4}{2}$ = 4.00	$\frac{3+4+5}{3}$ = 4.00	4.17
Chance of wastage	$\frac{4+4+1+5}{4}$ = 3.50	$\frac{4+3}{2}$ =3.50	$\frac{5+5+5}{3}$ = 5.00	4.00
Current waste	$\frac{4+4+4+2}{4}$ = 3.50	$\frac{4+5}{2}$ = 4.50	$\frac{1+5+4}{3}$ = 3.33	3.78
Wastage rate	$\frac{3+3+4+5}{4}$ = 3.75	$\frac{4+4}{2}$ = 4.00	$\frac{4+5+4}{3}$ = 4.33	4.03
Order sizes	$\frac{3+5+1+4}{4}$ = 3.25	$\frac{1+2}{2}$ = 1.50	$\frac{3+4+3}{3}$ = 3.33	2.69
Order intervals	$\frac{5+1+1+3}{4}$ = 2.50	$\frac{4+2}{2}$ = 3.00	$\frac{3+4+4}{3}$ = 3.33	2.94
Leadtime	$\frac{5+4+5+5}{4}$ = 4.75	$\frac{5+3}{2}$ = 4.00	$\frac{1+5+4}{3}$ = 3,33	4.03
Average paint usage per working day	$\frac{1+1+1+3}{4}$ = 1.50	$\frac{1+3}{2}$ = 2.00	$\frac{3+4+3}{3}$ = 3.33	2.28
Total progress	$\frac{5+5+5+4}{4}$ = 4.75	$\frac{5+4}{2}$ = 4.50	$\frac{5+4+2}{3}$ = 3.67	4.31
Total costs	$\frac{1+3+4+4}{4}$ = 3.00	$\frac{4+4}{2}$ = 4.00	$\frac{5+5+4}{3}$ = 4.67	3.89
Pre-calculated amount relative to actual amount	$\frac{5+4+4+5}{4}$ = 4.50	$\frac{3+5}{2}$ = 4.00	$\frac{5+4+5}{3}$ = 4.67	4.39
Total failure costs	$\frac{4+4+4+2}{4}$= 3.50	$\frac{4+5}{2}$ = 4.50	$\frac{5+5+5}{3}$ = 5.00	4.33
Pre-calculated costs relative to actual costs	$\frac{3+4+4+2}{4}$ = 3.25	$\frac{3+3}{2}$ = 3.00	$\frac{5+4+5}{3}$ = 4.67	3.64
Other KPI: Amount of paint budgeted	By foreman			
Other KPI: Tools or other equipment budget	By foreman			
Overview for the foreman per colour and sort	By project leader			

A3: Scoring results of the KPI from the scorecard

Date	Product	Quantit	Costs	Litre(s)	Tlitres
11-05-22	1 x 1 L Sigmafix Universal	1	21,54 €	1	1
11-05-22	1 x Sigma Facade Topcoat mat wit 10l	1	313,11 €	10	10
18-05-22	1x Sigma Multiprimer 7040	1	44,86 €	1	1
18-05-22	2 x Sigma S2U allure gloss 2,5l kleur Ral 5009	2	383,91 €	2,5	5
18-05-22	2 x Sigma S2U allure primer 2,5l kleur Ral 5009	2	310,69 €	2,5	5
18-05-22	2x 2,5 L Sigma Multiprimer 2 EP RAL 1004 2K EP RAL 1004	2	205,34 €	2,5	5
18-05-22	4x 2,5L Sigma Multifinish 2K PU Semi-Gloss RAL 1004	4	695,29 €	2,5	10
18-05-22	4x 2,5l Sigma Multifinish 2k PU SG RAL 5009	4	818,00 €	2,5	10
18-05-22	Sigma Multifinish 2K PU Semi-Gloss RAL 1004	1	87,37 €	1	1
18-05-22	Sigma Multiprimer K EP RAL 1004	1	148,08 €	2,5	2,5
18-05-22	Sigma S2U allure gloss 2,5l S710-G10Y	1	191,95 €	2,5	2,5
18-05-22	Sigma S2U allure primer 2,5l S7010-G10Y	1	155,35 €	2,5	2,5
25-05-22	1x 2,5l sigma s2u allure gloss ral 1015	1	191,95 €	2,5	2,5
25-05-22	1x 2,5l sigma s2u allure primer ral 1015	1	155,35 €	2,5	2,5
25-05-22	2,5 L Sigma S2U Allure Primer s 7010 g10y	2	310,69 €	2,5	5
25-05-22	Sigma S2U allure gloss 2,5l kleur 7070 g10y	2	383,91 €	2,5	5
31-05-22	1x 2,5l sigma s2u allure gloss ral 1015	1	191,95 €	2,5	2,5
31-05-22	1x 2,5l sigma s2u allure primer ral 1015	1	155,35 €	2,5	2,5
31-05-22	3x 2,5l sigma multifinisch 2k pu sg ral 5009	3	521,48 €	2,5	7,5
31-05-22	6x 2,5l sigma multifinisch 2k pu sg ral 1004	6	1.042,94 €	2,5	15
15-06-22	1x 2,5l Sigma S2U allure gloss s 7010 g10y	1	205,38 €	2,5	2,5
15-06-22	2,5l Multiprimer 2k ep base ral 1004	1	120,54 €	2,5	2,5
15-06-22	6x 2,5l Multifinisch 2k pu base semi gloss ral 1004	6	1.224,25 €	2,5	15
15-06-22	Sigma S2U Allure Primer S 7010 G10Y	1	67,07 €	1	1
22-06-22	2,5l Sigma multifinisch 2k pu base semi gloss ral 1004	1	204,04 €	2,5	2,5
22-06-22	2,5l Sigma multifinisch 2k pu base semi gloss ral 5009	7	1.428,29 €	2,5	17,5
29-06-22	5x Multifinish 2k pu base semi gloss base z RAL 1004 (goldgelb)	5	1.020,21 €	2,5	12,5
30-06-22	RAL 7036 s2u satin 1x0,5L	1	44,05 €	0,5	0,5
30-06-22	RAL 1015 1x sigma tex Matt 5L	1	128,69 €	5	5
30-06-22	RAL 1013 Façade Topcoat Matt 2x 10L	2	670,01 €	10	20
06-07-22	4x multifinish 2k pu base z RAL 1004 goldgelb	4	816,16 €	2,5	10
13-07-22	3x 2.5 liter sigma multifinish 2k pu base semi gloss ral 1004	3	612,12 €	2,5	7,5
13-07-22	3x 2.5 liter sigma multifinish 2k pu base semi gloss ral 5009	3	612,12 €	2,5	7,5
20-07-22	1x multifish 2k pu base z RAL 1004	1	204,04 €	2,5	2,5
20-07-22	1x multifish 2k pu base z RAL 1004 goldgelb	1	204,04 €	2,5	2,5
20-07-22	1x multifish 2k pu base z RAL 5009	1	204,04 €	2,5	2,5
27-07-22	2x multifish 2k pu base z RAL 5009	2	408,08 €	2,5	5
31-07-22	2.5 liter multifinish 2k pu base ral 1004	1	204,04 €	2,5	2,5
		Total costs:	**14.706,29 €**	**Litres:**	**217**

A4: Project X actual orders retrieved from database

Date	Product	Qnt.	Costs	Litre(s)	Tlitre
22-06-22	Wijzonol LBH SDT Ultra Hg lak 2,5l ral 5011	1	€ 204,12	2,5	2,5
22-06-22	Wijzonol LBH SDT Ultra Hg lak 2,5l ral 3005	1	€ 204,12	2,5	2,5
22-06-22	Wijzonol LBH SDT Grondlak Ultra 2,5l lichte kleur	1	€ 139,50	2,5	2,5
22-06-22	Wijz. Industrielak Zijdegl. 2,5 L	6	€ 814,71	2,5	15
22-06-22	Wijzonol Uniprimer Kleur 1 L	1	€ 45,00	1	1
22-06-22	Wijzonol Uniprimer 2,5 L	1	€ 92,92	2,5	2,5
22-06-22	Wijzonol LBH SDT Ultra Hg lak 2,5l ral 9010	2	€ 408,24	2,5	5
22-06-22	Hechtrpimer 1l ral 3005	1	€ 55,44	1	1
22-06-22	Hechtprimer 1l ral 5011	1	€ 55,44	1	1
22-06-22	Wijzonol LBH SDT Ultra hoogglans lak 2,5l lichte kleur	1	€ 204,12	2,5	2,5
25-06-22	Sikkens BL ventura Satin 2,5 ltr apeldoorn@pointcenter.nl	4	€ 508,76	2,5	10
29-06-22	Wijz. watergedragen primer 2,5l 9010	6	€ 136,23	2,5	15
06-07-22	2,5 L Wijz. LBH SDT Ultra Hg lak 9010	1	€ 204,12	2,5	2,5
06-07-22	2,5 L Wijz. LBH SDT Ultra Hg lak 5011	1	€ 204,12	2,5	2,5
20-07-22	2,5 L Wijz. LBH SDT Ultra Hg lak 9010	2	€ 408,24	2,5	5
24-08-22	Wijzonol LBH Grondlak HV 1l ral 3005	1	€ 45,95	1	1
31-08-22	2,5l Wijz. Lbh Sdt Hoogglans Ultra 9010	2	€ 408,24	2,5	5
31-08-22	10x Wijzonol Uni Primer Ral 9001	10	€ 929,20	2,5	25
31-08-22	2,5l Wijz. Lbh Sdt Hoogglans Ultra 3005	2	€ 408,24	2,5	5
31-08-22	6x wijzonol Industrielak zijdeglans Ral 9001	6	€ 814,71	2,5	15
31-08-22	Wijz. Industrielak Zijdeglans Ral 9001	5	€ 678,93	2,5	12,5
31-08-22	Sikkens de Rubbol bl ventura satin 10l T0.23.48	4	€ 543,61	2,5	10
31-08-22	2,5 L Wijzonol Uniprimer Ral 9001	5	€ 464,60	2,5	12,5
03-09-22	7,5l Sikkens Rubbol BL Ventura Satin 3base T0.23.48	1	€ 407,72	7,5	7,5
07-09-22	5x Wijzonol Uni Primer Ral 9001	5	€ 464,60	2,5	12,5
07-09-22	20 liter s7.05.75 wijzoplex eiglans	1	€ 540,55	20	20
07-09-22	20liter wijzoplex7047	1	€ 659,56	20	20
07-09-22	2,5L Wijz. LBH SDT hoogglans Ultra 9010	2	€ 408,24	2,5	5
07-09-22	9x wijzonol Industrielak zijdeglans Ral 9001	9	€ 1.222,07	2,5	22,5
07-09-22	7,5l Industrielak 9001	3	€ 407,36	2,5	7,5
07-09-22	2,5L Wijz. LBH SDT hoogglans Ultra 5011	1	€ 204,12	2,5	2,5
14-09-22	2,5l Wijz. Lbh SDT Hoogglans Ultra 9010	3	€ 612,36	2,5	7,5
14-09-22	10l Wijzonol Wijzoplex eiglans S7.05.75	2	€ 540,55	10	20
14-09-22	2,5L Wijz. Aqua Hechtprimer 9010	1	€ 136,23	2,5	2,5
14-09-22	2,5l Wijz. Aqua Zijdeglans F6.06.74	2	€ 337,61	2,5	5
14-09-22	1 x 2,5 liter ral 9001 wijzonol industrie lak zijdeglans.	1	€ 135,79	2,5	2,5
17-09-22	2 x 2,5 liter Sikkens BL Ventura satin kleur nr T0.23.48	2	€ 271,81	2,5	5
21-09-22	10 liter wijzonol wijzotex extra mat kleur nr ral 9016	3	€ 667,58	10	30
21-09-22	2,5l Industrielak Zijdeglans 9001	5	€ 678,93	2,5	12,5
21-09-22	2,5l Industrielak Zijdeglans 9001	5	€ 678,93	2,5	12,5
21-09-22	Wijzonol Aqua zijdeglans 2,5l kleur	2	€ 337,61	2,5	5
21-09-22	2,5l Wijz. Aqua Zijdeglans ral 3005	2	€ 337,61	2,5	5
21-09-22	2,5l Wijzonol Uni Primer 9001	10	€ 929,20	2,5	25
28-09-22	Wijzonol Aqua zijdeglans 1l kleur UO.15.65	1	€ 67,97	1	1
28-09-22	2,5 liter wijzonol industrie lak zijdeglans ral 9001	2	€ 271,57	2,5	5
28-09-22	2,5l Wijz. Lbh sdt Hoogglans Ultra 9010	1	€ 204,12	2,5	2,5
28-09-22	Wijzonol Aqua zijdeglans 2,5l kleur F6.06.74	1	€ 168,81	2,5	2,5
28-09-22	Wijzonol LBH SDT Ultra hoogglans lak 2,5l 3005donkere kleur	1	€ 204,12	2,5	2,5
28-09-22	10 liter wijzonol wijzotex extra mat kleur nr - ral 9016	3	€ 667,58	10	30
28-09-22	Wijzonol Aqua zijdeglans 2,5l kleurV8.23.44	1	€ 168,81	2,5	2,5
28-09-22	2,5 liter wijzonol aqua zijdeglans kleur nr F6.06.74	1	€ 168,81	2,5	2,5
30-09-22	10l Wijzonol tex extra mat 9016	6	€ 1.335,16	10	60
30-09-22	Wijzonol Aqua zijdeglans 1l WO.07.77	1	€ 67,97	1	1
30-09-22	Wijzonol Aqua zijdeglans 1l Z1.10.70	1	€ 67,97	1	1
30-09-22	Wijzonol Aqua zijdeglans 1l ZO.20.50	1	€ 67,97	1	1
30-09-22	uniprimer wijzonol ral 9001 2,5L	5	€ 464,60	2,5	12,5
30-09-22	2,5 liter wijzonol industrie lak zijdeglans ral 9001	1	€ 135,79	2,5	2,5
30-09-22	Wijzonol Aqua zijdeglans 1l F2.05.55	1	€ 67,97	1	1
30-09-22	industrielak zijdeglans wijzonol ral 9001 2,5L	3	€ 407,36	2,5	7,5
12-10-22	10l Wijzotex extramat 9016	2	€ 317,90	10	20
12-10-22	2,5l Industrielak 9001 zijdeglans	1	€ 135,79	2,5	2,5
12-10-22	Wijzonol Aqua zijdeglans 1l kleur WO.20.40	1	€ 91,28	1	1
12-10-22	Wijzonol Aqua zijdeglans 1l kleur WO.20.40	1	€ 67,97	1	1
12-10-22	Wijzonol LBH SDT Ultra hoogglans lak 2,5l donkere kleur 3005	1	€ 204,12	2,5	2,5
12-10-22	Wijzonol Aqua zijdeglans 1l kleur AO.20.40	1	€ 91,28	1	1
12-10-22	Wijzonol Aqua zijdeglans 1l kleur EO.50.50	1	€ 67,97	1	1
12-10-22	Wijzonol Aqua zijdeglans 1l kleur AO.20.40	1	€ 67,97	1	1
19-10-22	Wijzonol Aqua zijdeglans 1l kleur F6.06.74	1	€ 67,97	1	1
19-10-22	2,5l Wijz. Aqua Zijdeglans F2.05.55	1	€ 168,81	2,5	2,5
26-10-22	Wijzonol LBH SDT Ultra hoogglans lak 1l donkere kleur 5011	1	€ 83,23	1	1
26-10-22	Wijzonol Aqua zijdeglans 1l kleur AO.20.40	1	€ 95,21	1	1
26-10-22	Wijzonol Aqua zijdeglans 1l kleurF6.06.74	1	€ 67,97	1	1
26-10-22	Wijzonol Aqua zijdeglans 1l kleur, kleur A0.20.40	2	€ 135,94	1	2
26-10-22	Wijzonol Aqua zijdeglans 1l kleur WO.20.40	1	€ 95,21	1	1
31-10-22	Wijzonol Aqua zijdeglans 1l kleur UO.15.65	1	€ 67,97	1	1
31-10-22	Wijzonol Aqua zijdeglans 1l kleur WO.20.40	2	€ 135,94	1	2
02-11-22	Wijz. Aqua Zijdeglans Kleur TR 1 L Z1.10.70	1	€ 67,97	1	1
09-11-22	Wijzonol Aqua zijdeglans 1l kleuR 0777	1	€ 67,97	1	1
23-11-22	1l WIjz. Aqua Zijdeglans FN.02.88	1	€ 67,97	1	1
		T costs:	€ 24.659,99	Total litres:	567

A5: Project Y actual orders retrieved from database

Date	Product	Quantity	Costs		Litre(s)	Tlitres
12-10-22	1x 2,5 liter Sigma S2U Primer in de kleur ON0021	1	€	150,18	2,5	2,5
12-10-22	1x 2,5 liter Sigma S2U Primeri n de kleur F60585	1	€	150,18	2,5	2,5
12-10-22	1x 2,5 liter Sigma S2U Allure Gloss in de kleur F60585	1	€	205,38	2,5	2,5
12-10-22	1x 2,5 iter Sigma S2U Allure Gloss in de kleur ON0021	1	€	205,38	2,5	2,5
19-10-22	Sigma S2U allure gloss 2,5l kleur ON 00 21	1	€	205,38	2,5	2,5
19-10-22	Sigma S2U allure gloss 2,5l kleur F6 05 85	1	€	205,38	2,5	2,5
26-10-22	2,5l Sigma S2U Allure Gloss F6.05.85	1	€	205,38	2,5	2,5
26-10-22	Sigma rapid primer 1l kleur 0N.00.21	1	€	54,84	1	1
26-10-22	Sigma rapid primer 1l kleur f6.05.85	1	€	54,84	1	1
26-10-22	2,5l Sigma S2U Allure Gloss F6.05.85	1	€	205,38	2,5	2,5
09-11-22	1l Sigma S2U Allure Gloss F6.05.85	1	€	82,70	1	1
09-11-22	1L Sigma Torno Aqua primer 9001	1	€	53,48	1	1
		Total costs	€	1.778,53	**Total litres:**	24

A6: Project Z actual orders retrieved from database

Product	Application	Meters	Liter/m	Costs/m		Tliter	Tcosts	
Muurverf buiten/binnen waterg.	1.1.21	326,1	0,08	€	1,53	26,088	€	499,78
Muurverf buiten/binnen waterg.	1.1.21	26	0,08	€	1,53	2,08	€	39,85
Muurverf buiten/binnen waterg.	1.1.21	1296	0,08	€	1,53	103,68	€	1.986,25
Alkydhars Houtprimer sneldrogend	1.3.7	213,5	0,02	€	0,85	4,27	€	182,16
Grondverf	1.1.1	1930,39	0,013	€	0,70	25,09507	€	1.342,01
Alkydhars Dekverf dekkend	1.1.1	1930,39	0,011	€	0,96	21,23429	€	1.860,51
Alkydhars Dekverf dekkend	1.1.1	1930,39	0,011	€	0,96	21,23429	€	1.860,51
Grondverf	1.1.6	97	0,08	€	4,27	7,76	€	413,80
Alkydhars Dekverf dekkend	1.1.6	97	0,07	€	6,10	6,79	€	591,58
Grondverf	1.1.1	102	0,013	€	0,70	1,326	€	70,91
Alkydhars Dekverf dekkend	1.1.1	102	0,011	€	0,96	1,122	€	98,31
Alkydhars Dekverf dekkend	1.1.1	102	0,011	€	0,96	1,122	€	98,31
						Total litres	**Total costs**	
						221,8017	€	9.043,97

A7: Project X pre-calculations for litres usage and costs

Product	Tmeter	Liter/m	Costs/m	Tliter	Tcosts
Grondverf	1569,6	0,004	€ 0,24	6,2784	€ 235,44
Wijzonol Snelgrond 1l kleur	31,8	0,016	€ 1,17	0,5088	€ 23,53
Wijzonol Snelgrond 1l kleur	10,38	0,016	€ 1,17	0,16608	€ 7,68
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	10,38	0,07	€ 8,63	0,7266	€ 56,67
Grondverf	1330	0,004	€ 0,24	5,32	€ 199,50
Wijzonol Snelgrond 1l kleur	85	0,016	€ 1,17	1,36	€ 62,90
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	85	0,07	€ 8,63	5,95	€ 464,10
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	5,76	0,07	€ 8,63	0,4032	€ 31,45
Wijzonol Uniprimer 1l kleur	300	0,02	€ 0,85	6	€ 162,00
Wijzonol Uniprimer 1l kleur	300	0,01	€ 0,43	3	€ 81,00
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	300	0,08	€ 6,64	24	€ 1.260,00
Wijzonol Uniprimer 1l kleur	492,5	0,02	€ 0,85	9,85	€ 265,95
Wijzonol Uniprimer 1l kleur	492,5	0,01	€ 0,43	4,925	€ 132,98
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	492,5	0,03	€ 2,50	14,775	€ 778,15
Wijzonol Uniprimer 1l kleur	323,93	0,08	€ 3,41	25,9144	€ 699,69
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	323,93	0,08	€ 6,64	25,9144	€ 1.360,51
Grondverf	31,2	0,004	€ 0,24	0,1248	€ 4,68
Grondverf	28	0,004	€ 0,24	0,112	€ 4,20
Wijzonol Uniprimer 1l kleur	192,2	0,08	€ 3,41	15,376	€ 415,15
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	192,2	0,08	€ 6,64	15,376	€ 807,24
Grondverf	54	0,004	€ 0,24	0,216	€ 8,10
Grondverf	352	0,004	€ 0,24	1,408	€ 52,80
Wijzonol Snelgrond 1l kleur	197	0,016	€ 1,17	3,152	€ 145,78
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	197	0,07	€ 8,63	13,79	€ 1.075,62
Wijzonol Uniprimer 1l kleur	644	0,02	€ 0,85	12,88	€ 347,76
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	644	0,08	€ 6,64	51,52	€ 2.704,80
Wijzonol Uniprimer 1l kleur	391	0,01	€ 0,43	3,91	€ 105,57
Wijzonol Uniprimer 1l kleur	52,17	0,08	€ 3,41	4,1736	€ 112,69
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	52,17	0,08	€ 6,64	4,1736	€ 219,11
Grondverf	394,4	0,004	€ 0,24	1,5776	€ 59,16
Grondverf	92,6	0,004	€ 0,24	0,3704	€ 13,89
Grondverf	30,4	0,004	€ 0,24	0,1216	€ 4,56
Wijzonol Snelgrond 1l kleur	3,93	0,016	€ 1,17	0,06288	€ 2,91
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	3,93	0,07	€ 8,63	0,2751	€ 21,46
Wijzonol Snelgrond 1l kleur	54,3	0,016	€ 1,17	0,8688	€ 40,18
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	54,3	0,07	€ 8,63	3,801	€ 296,48
Wijzonol Snelgrond 1l kleur	21,01	0,02	€ 0,93	0,4202	€ 12,40
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	21,01	0,08	€ 6,64	1,6808	€ 88,24
Wijzoplex Elastdecor 10l kleur	309,66	0,03	€ 11,04	9,2898	€ 216,45
Wijzonol Aqua zijdeglans 1l kleur	500,98	0,015	€ 0,96	7,5147	€ 305,60
Wijzonol Aqua zijdeglans 1l kleur	39,46	0,04	€ 2,59	1,5784	€ 64,71
Wijzonol Aqua zijdeglans 1l kleur	26	0,015	€ 2,59	0,39	€ 42,64
Wijzonol Aqua Hechtprimer 1l kleur	15,2	0,09	€ 4,74	1,368	€ 45,60
Wijzonol Aqua zijdeglans 1l kleur	15,2	0,08	€ 5,17	1,216	€ 49,70
Wijzonol Aqua Hechtprimer 1l kleur	54	0,01	€ 0,52	0,54	€ 17,82
Wijzonol Aqua zijdeglans 1l kleur	54	0,012	€ 0,77	0,648	€ 26,46
Wijzonol Aqua Hechtprimer 1l kleur	13,6	0,09	€ 4,74	1,224	€ 40,80
Wijzonol Aqua zijdeglans 1l kleur	13,6	0,08	€ 5,17	1,088	€ 44,47
Wijzonol Aqua Hechtprimer 1l kleur	25,98	0,09	€ 4,74	2,3382	€ 77,94
Wijzonol Aqua zijdeglans 1l kleur	25,98	0,08	€ 5,17	2,0784	€ 84,95
Muurverf binnen watergedragen	250,2	0,301	€ 4,41	75,3102	€ 698,06
Kwartshoudende verf buiten	85,624	0,4	€ 7,03	34,2496	€ 381,03
Muurverf binnen watergedragen	244,64	0,301	€ 4,41	73,63664	€ 682,55
Muurverf binnen watergedragen	398,24	0,301	€ 4,41	119,8702	€ 1.111,09
Muurverf binnen watergedragen	57	0,301	€ 4,41	17,157	€ 159,03
Relius R1 PRO 12,5lt RAL 9010	40	0,05	€ 5,72	2	€ 11,58
Primer watergedragen	47,04	0,008	€ 0,32	0,37632	€ 9,41
Wijzonol Aqua zijdeglans 1l kleur	47,04	0,08	€ 5,80	3,7632	€ 172,64
Primer watergedragen	147,7	0,008	€ 0,32	1,1816	€ 29,54
Wijzonol Uniprimer 1l kleur	147,7	0,03	€ 1,28	4,431	€ 119,64
Wijzonol Aqua zijdeglans 1l kleur	147,7	0,03	€ 1,94	4,431	€ 181,67
Primer watergedragen	118,08	0,008	€ 0,32	0,94464	€ 23,62
Wijzonol Aqua zijdeglans 1l kleur	118,08	0,08	€ 5,17	9,4464	€ 386,12
Primer watergedragen	73,6	0,001	€ 0,03	0,0736	€ 1,47
Wijzonol Aqua zijdeglans 1l kleur	73,6	0,008	€ 0,52	0,5888	€ 24,29
Wijzonol Aqua Hechtprimer 1l kleur	46,8	0,004	€ 0,21	0,1872	€ 6,08
Wijzonol Aqua zijdeglans 1l kleur	46,8	0,015	€ 0,96	0,702	€ 28,55
Wijzonol Aqua zijdeglans 1l kleur	4	0,04	€ 2,59	0,16	€ 6,56
Wijzonol Aqua Hechtprimer 1l kleur	6,06	0,09	€ 4,74	0,5454	€ 18,18
Wijzonol Aqua zijdeglans 1l kleur	6,06	0,08	€ 5,17	0,4848	€ 19,82
Waterafdunbare Vernislak	5	0,01	€ 0,49	0,05	€ 1,55
Wijzonol Aqua Hechtprimer 1l kleur	21,2	0,017	€ 0,90	0,3604	€ 12,08
Wijzonol Aqua zijdeglans 1l kleur	21,2	0,015	€ 0,96	0,318	€ 12,93
Wijzonol Aqua Hechtprimer 1l kleur	16	0,09	€ 4,74	1,44	€ 48,00
Wijzonol Aqua zijdeglans 1l kleur	16	0,08	€ 5,17	1,28	€ 52,32
Wijzonol Aqua Hechtprimer 1l kleur	584,4	0,01	€ 0,52	5,844	€ 192,85
Wijzonol Aqua zijdeglans 1l kleur	584,4	0,012	€ 0,77	7,0128	€ 286,36
Wijzonol Aqua Hechtprimer 1l kleur	152,8	0,09	€ 4,74	13,752	€ 458,40
Wijzonol Aqua zijdeglans 1l kleur	152,8	0,08	€ 5,17	12,224	€ 499,66
Wijzonol Aqua Hechtprimer 1l kleur	4	0,04	€ 2,10	0,16	€ 5,32
Wijzonol Aqua zijdeglans 1l kleur	4	0,08	€ 5,17	0,32	€ 13,08
Relius R1 PRO 12,5lt RAL 9010	49,92	0,05	€ 5,72	2,496	€ 14,46
				744,448	**€ 20.890,82**

A8: Project Y pre-calculations for litres usage and costs

Product	Meters	Liter/m	Costs/m	Tliter	Tcosts
Wijzonol LBH Grondlak HV 1l kleur	351	0,004	€ 0,24	1,404	€ 83,19
Wijzonol LBH Grondlak HV 1l kleur	351	0,011	€ 0,63	3,861	€ 221,83
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	351	0,011	€ 1,06	3,861	€ 371,57
Wijzonol LBH Grondlak HV 1l kleur	130	0,004	€ 0,24	0,52	€ 30,81
Wijzonol LBH Grondlak HV 1l kleur	130	0,011	€ 0,63	1,43	€ 82,16
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	130	0,011	€ 1,06	1,43	€ 137,62
Wijzonol LBH Grondlak HV 1l kleur	176	0,004	€ 0,24	0,704	€ 41,71
Wijzonol LBH Grondlak HV 1l kleur	176	0,011	€ 0,63	1,936	€ 111,23
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	176	0,011	€ 1,06	1,936	€ 186,31
Wijzonol LBH Grondlak HV 1l kleur	65	0,004	€ 0,24	0,26	€ 15,41
Wijzonol LBH Grondlak HV 1l kleur	65	0,011	€ 0,63	0,715	€ 41,08
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	65	0,011	€ 1,06	0,715	€ 68,81
Wijzonol LBH Grondlak HV 1l kleur	18	0,09	€ 5,23	1,62	€ 94,14
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	18	0,08	€ 7,68	1,44	€ 138,22
Wijzonol LBH Grondlak HV 1l kleur	14,4	0,09	€ 5,23	1,296	€ 75,31
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	14,4	0,08	€ 7,68	1,152	€ 110,57
Wijzonol LBH Grondlak HV 1l kleur	24	0,004	€ 0,24	0,096	€ 5,69 €
Wijzonol LBH Grondlak HV 1l kleur	24	0,011	€ 0,63	0,264	15,17
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	24	0,011	€ 1,06	0,264	€ 25,41
Wijzonol Snelgrond 1l kleur	4,2	0,09	€ 6,37	0,378	€ 26,74
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	4,2	0,08	€ 10,76	0,336	€ 45,18
Wijzonol Gevelcoat 10l kleur	16,5	0,015	€ 4,53	0,2475	€ 74,82
Wijzonol LBH Grondlak HV 1l kleur	112	0,004	€ 0,24	0,448	€ 26,54
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	112	0,011	€ 1,06	1,232	€ 118,56
Wijzonol LBH Grondlak HV 1l kleur	75	0,004	€ 0,24	0,3	€ 17,78
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	75	0,011	€ 1,06	0,825	€ 79,40
Wijzonol LBH Grondlak HV 1l kleur	7	0,016	€ 0,93	0,112	€ 6,53 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	7	0,08	€ 7,68	0,56	53,75
Wijzonol Snelgrond 1l kleur	1,2	0,02	€ 1,42	0,024	€ 1,71 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	1,2	0,08	€ 9,57	0,096	11,49
Wijzonol LBH Grondlak HV 1l kleur	117,8	0,004	€ 0,24	0,4712	€ 27,92
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	117,8	0,011	€ 1,06	1,2958	€ 124,70
Wijzonol LBH Grondlak HV 1l kleur	70	0,004	€ 0,24	0,28	€ 16,59
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	70	0,011	€ 1,06	0,77	€ 74,10
Wijzonol LBH Grondlak HV 1l kleur	5	0,016	€ 0,93	0,08	€ 4,66 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	5	0,08	€ 7,68	0,4	38,39
Wijzonol LBH Grondlak HV 1l kleur	5,9	0,02	€ 1,15	0,118	€ 6,81 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	5,9	0,08	€ 7,68	0,472	45,30
Wijzonol Snelgrond 1l kleur	2,7	0,02	€ 1,42	0,054	€ 3,84 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	2,7	0,08	€ 9,57	0,216	25,85
Wijzonol LBH Grondlak HV 1l kleur	12	0,004	€ 0,24	0,048	€ 2,84 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	12	0,011	€ 1,06	0,132	12,70
Wijzonol LBH Grondlak HV 1l kleur	3,8	0,004	€ 0,24	0,0152	€ 0,90 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	3,8	0,011	€ 1,06	0,0418	4,02 €
Wijzonol LBH Grondlak HV 1l kleur	137,5	0,004	€ 0,24	0,55	32,59
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	137,5	0,011	€ 1,06	1,5125	€ 145,56
Wijzonol LBH Grondlak HV 1l kleur	38,6	0,004	€ 0,24	0,1544	€ 9,15 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	38,6	0,011	€ 1,06	0,4246	40,86
Wijzonol LBH Grondlak HV 1l kleur	6	0,016	€ 0,93	0,096	€ 5,59 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	6	0,08	€ 7,68	0,48	46,07
Wijzonol LBH Grondlak HV 1l kleur	4,8	0,02	€ 1,15	0,096	€ 5,54 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	4,8	0,08	€ 7,68	0,384	36,86
Wijzonol LBH Grondlak HV 1l kleur	7	0,004	€ 0,24	0,028	€ 1,66 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	7	0,011	€ 1,06	0,077	7,41 €
Wijzonol Snelgrond 1l kleur	3,2	0,02	€ 1,42	0,064	4,55 €
Wijzonol LBH SDT Ultra hoogglans lak 1l kleur	3,2	0,08	€ 9,57	0,256	30,64
				37,98	**€ 3.073,84**

A9: Project Z pre-calculations for litres usage and costs