Visualising supply versus demand at X Y Foods to prevent a stock-out situation: A holistic approach.

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Confidentiality

X Y Foods is a fictional name. The name of the company cannot be published due to confidentiality reasons. The name, actual data, or internal information must not be publicised. The quantitative data used is factored by ratio x to protect the company's data.

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Preface

I would like to gift this piece of work and, hence, my diploma to my mother – Siham. M.K. Awada, which is the least I could do to repay for all the sacrifices she had made.

I am honoured to present my thesis, which marks the culmination of my bachelor's degree in industrial engineering and management at the University of Twente. Although challenging, this journey allowed me to discover aspects of myself that have led to my academic, professional, and personal growth.

Essentially, my objective of completing a 20-week research project in 12 weeks was ambitious and unlikely. However, through discipline, careful planning, and accumulation of small but consistent wins, I managed to achieve it. This was all possible thanks to my supervisor, Dr. Dennis Prak. His critical feedback and trust have elevated my approach and commitment to producing a thesis that meets his high standards.

I extend my gratitude towards my company supervisor, Ms. Vitoria, and her team for their constant support and trust, which helped me apply my research in a real-life setting.

I conclude by thanking my family and friends for making this journey possible, and I look forward to sharing more moments with them. That being said, and as always, happy reading!

Thank you,

Mohamad Ibrahim

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Management Summary

This research was conducted at X Y Foods. X Y Foods is one of the world's leading food and beverage firms in the fast-moving consumer goods industry. With its large-scale operations, the company was challenged to calculate the volumes required for one of its most crucial raw materials – oil. The heart of the issue lies in the fact that the company was under-covered by its existing contracts with suppliers, meaning that the supply guarantees in the existing contracts are not enough to meet the demand. The main research question formulated to address this supply chain issue is:

"How can X Y Foods visualise the supply versus demand of oil and make procurement decisions to avoid a stock-out situation in its production facilities?"

A context analysis was executed to understand how X Y Foods tracks, manages, and sources the oil portfolio. The company carries a routine which involves comparing the supply with the demand of oil needed at a given period to produce product x via a "weekly routine" to address this supply security issue. However, this "weekly routine" contains several pitfalls, mainly unjustifiable assumptions, improper communication, and a lack of visibility regarding oil supply versus demand. In-depth discussions were held at the company to understand how the different oil actors operate. This was visualised by creating a Business Process Model.

To assist the X Y Foods procurement department, data analysis was carried out regarding the quality of the demand data sources. This was assisted using mathematical metrics such as Mean Squared Error and Mean Average Percentage Error. Further, an interactive dashboard was modelled and created based on a known data quality. The dashboard had profound results since it minimised the gap between supply and demand and offered detailed visibility regarding the oil portfolio. This included the creation of new metrics such as "carry-over volume", which replicated the reality of the situation and gave X Y Foods insight regarding volumes that were "lost". The dashboard was created with a holistic motivation so all actors can gather insight regarding their tasks. The company's buyers can now dive deep into the consumption of the contractual oil agreements to support them on whether more oil needs to be sourced to meet the factory's demand.

The dashboard results were used to give recommendations regarding the amount of oil that needs to be sourced based on an identified sourcing strategy motivated by a literature review. By creating the interactive dashboard, the main conclusions were drawn:

1. The demand requirement assumption turns out to be faulty for Dutch X Y Foods. Hence, there is a mismatch between the demand for oil-extracted Systems Applications Procedures(SAP) and the factory-communicated demand.
2. It is concluded that French X Y Foods has a better data quality overall than the Dutch facility.
3. The carry-over volume specification showed the negative implication of treating each month separately. The gap of a given month was minimised immediately by using the preceding month's surplus to cover the current month's demand.
4. The weekly oil consumption visibility gives detailed insight to the buyer regarding whether each factory is consuming its contractual volume with its suppliers.
5. There are five instances where there is an expected gap in both factories. This gap is covered with the *spot volume* specification volume created.
6. The interactive dashboard provides a breakdown on a weekly and monthly basis regarding the amount of oil on hand, the demand needed to fulfil the production of product x, and the potential gaps between supply and demand (if any). A further breakdown is available per factory, per supplier, and period.

Based on this research, the main recommendations for X Y Foods are as follows:

1. From August until January, there are five instances where a gap is expected. X Y Foods is recommended to use the decision tree created in this study to close the gap. The decision tree created considers which period of the month the gap is expected, lead time, distance from the factory, lot size, truck size, and carbon footprint impact. With the solution recommended in Sections 5.3.1 and 5.3.2. X Y Foods will close all the gaps and meet the demand requirements set by the production facilities
2. Eliminate the demand requirement assumption as there is a mismatch between the factory communicated data and SAP. Hence, a root cause analysis should identify why those discrepancies occur.
3. Use an efficient sourcing strategy that optimises the factory inventory levels. The dashboard allows for such a strategy as it gives detailed visibility over the supply chain and allows for long-term planning via the 6-month view. This strategy includes fulfilling the demand through contractual agreements. Spot volume should only be used in case of emergencies.

A limitation of this research study is choosing the data points with higher demand, which has a trade-off of increased costs. The reason behind this choice is to ensure that enough oil is procured to minimise the chance of a stock-out situation.

Given that this research aimed to make sourcing recommendations based on known data quality, it has been made clear that there are noticeable discrepancies between SAP and the factory communication data, which is another limitation of this thesis and presents future research opportunities to understand why those discrepancies occur and further solve this problem.

Due to its promise and improved visibility, the dashboard should be implemented, and future research should compare how X Y Foods operates with better visibility and more insight regarding the supply versus demand of oil.

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List of Abbreviations

BPM Business Process Model

CE Continental Europe

CPM Central Material Planners

NE Northern Europe

ERP Enterprise Resource Planning

FG Finished Goods

FMCG Fast Moving Consumer Goods

FSQ Food Safety & Quality

MAE Mean Absolute Error

MAPE Mean Absolute Percentage Error

MOQ Minimum Order Quantity

MSE Mean Squared Error

PO Purchase Order

SAP Systems Applications Procedures

SR Supply Risk

RMSE Root Mean Squared Error

1. Introduction

This chapter introduces the scope of the research and the problem faced at X Y Foods that the research is intended to solve. A general introduction to the company is given first, and the problem description is addressed in Section 1.1. From this, the research question is identified and discussed in Section 1.2. Then, the motivation behind the chosen problem-solving approach to solve the research question is discussed in Section 1.3. Lastly, a discussion regarding the validity and reliability of the research is found in Section 1.4, followed by Section 1.5, which concludes the introduction chapter.

1.1 Company & Problem Description

X Y Foods is one of the world's leading food and beverage firms. With offices in over 40 countries and a yearly revenue of 27,096 billion dollars as of June 2023 (The Kraft Heinz Company, n.d.), it is evident that X Y Foods is one of the largest in the food and beverage industry. X Y Foods operates globally, offering an extensive portfolio that caters to consumers of different tastes and preferences. As one of the pioneers in the fast-moving consumer goods (FMCG) industry, X Y Foods faces operational challenges to meet its high demands, leading to the problem description addressed in the following paragraph.

In the aftermath of the COVID-19 pandemic, X Y Foods faced a challenge in maintaining the efficiency and reliability of its supply chain. This challenge primarily revolved around accurately calculating the volumes required for one of its most crucial raw materials - oil. Oil is a fundamental ingredient in producing a wide range of products. This ingredient is sourced from five suppliers supplying two X Y Foods factories. The inadequacy in predicting the oil demand had significant implications for X Y Foods, affecting its ability to meet market demands efficiently. The heart of the issue lies in the fact that the company was under-covered by its existing contracts with suppliers, meaning that the supply guarantees in the existing contracts are not enough to meet the demand. As this problem unfolds, X Y Foods address this problem by the use of a "weekly routine". This routine involves comparing the supply with the demand of oil needed at a given period to produce product x. However, this solution has several limitations, which include a lack of visibility to the amount of oil being used, making decisions based on data with an unknown quality, and not managing or tracking the sourcing process of this fundamental raw material. A detailed analysis of the weekly routine is explained in Sections 2.2 and 2.3. As a result, the procurement of oil became a challenge, with a shortfall in supply that strained the company's ability to meet the high demand from its production facilities. This situation necessitated emergency measures, resulted in additional costs, and required manual interventions to source oil on short notice. Collectively, these factors led to operational inefficiencies and negatively impacted the organisation.

1.2 Derivation of Main Research Question

Heerkens and van Winden (2017) define an action problem as an inconsistency between the norm and reality as the problem owner perceives it. After analysing the problem description, we conclude that the action problem to be addressed is that X Y Foods are under-covered by their contracts. The production facilities face instances where it is impossible to produce goods because of insufficient raw materials (oil). Production shortages have severe impacts, including delayed orders and increases in costs due to the operation of production lines without output, resulting in high idle time of machines and potential customer dissatisfaction. Another consequence is the disrupted supply chain; being under-covered by raw materials contracts can disrupt the X Y Foods supply chain. Most noticeably, there is severe stress on operational inefficiencies. To elaborate, the need for last-minute alterations and extra effort to secure raw materials can disrupt daily operational activities and increase the workload. To conclude, after reviewing the definition of an action problem and identifying the challenges X Y Foods faces. The action problem is "X Y Foods are being under-covered by its contracts".

After exploration of the action problem at hand, we dive deeper to find the essence of the problem. Figure 1 shows an elaborate approach to why X Y Foods faces situations under-covered by its contracts.

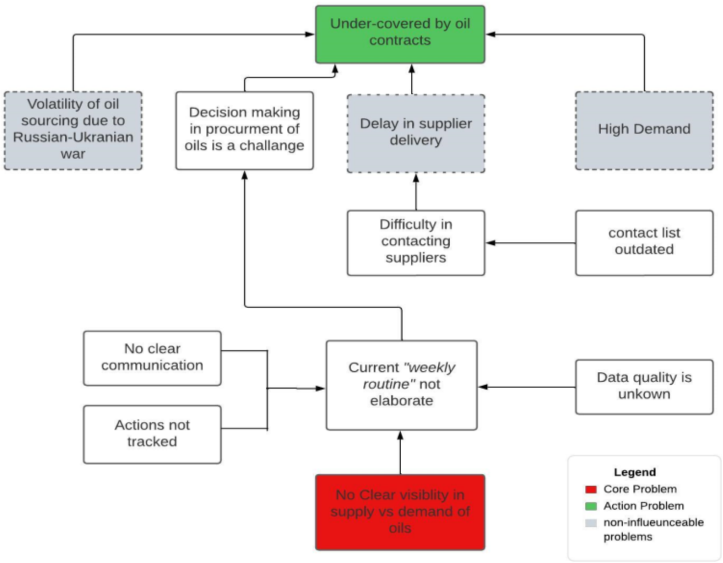

Figure 1: Problem Cluster

After further investigation, it was concluded that there are several reasons behind the factory being under-covered by their contracts. Some of the reasons included that there has been a noticeable trend in most suppliers delaying their shipments, which was due to the increased volatility in the sourcing of oil due to political instability. As the Russian-Ukrainian war emerged, sourcing oil has become more expensive and challenging to ship on time. However, this problem is non-influenceable and thus outside this project's scope.

The most sensible problem was that the current weekly routine needs to be more elaborate for several reasons, one being the unknown quality of the input source. The demand requirements for data quality are unknown. The demand requirements data is only extracted from an Enterprise Resource Planning (ERP) system called Systems Applications Processes (SAP). The responsible personnel (buyers) procure oil only based on the ERP data. However, this could have a negative impact as the actual demand requirements from the factories are not communicated in the weekly routine. Hence, an assumption is made that the demand requirements from the ERP system match what the factories need.

Additionally, the fact that the current weekly routine is not elaborate makes procuring oil difficult, hence the decision-making process. The weekly routine meeting updates all actors involved in sourcing oil and producing product x, for which the primary raw material is oil. Finally, this weekly meeting is supposed to give insight into oil consumption by production, what the factory requires, and how much is left. Even though this is the objective of the weekly routine, those exercises are not being practised.

Hence, the core problem behind being under-covered by the contracts and the severe consequences X Y Foods faces can be minimised if the core problem can be tackled. Namely, there is no concise and clear visibility on the respective factory's supply versus oil demand.

Having clear visibility via the use of an interactive dashboard helps the coordinators, buyers and all necessary actors have proper visibility over the demand of the factories, and then the procurement department can source enough oil in time; this means that the factories will always have insight and clarity on the required supply to meet the demands of the production facility, not needing any emergency measures; most notably the department will be covered by their contracts.

1.2.1 Main Research Question

After analysing the problem and creating a problem cluster, we conclude that the research question to investigate that aims to tackle the core problem of X Y Foods is:

"How can X Y Foods visualise the supply versus demand of oil and make procurement decisions to avoid a stock-out situation in its production facilities?"

The primary objective of this research is to provide the problem owner with a holistic approach and solution to address this critical supply chain issue. The goal is to develop a dashboard that enables the company to visualise the supply and demand for oil on a timely basis, offering foresight and a decision-making tool for the quantities that need to be sourced. By achieving this, the solution aims to minimise potential supply undercuts, reduce operational disruptions, and ensure that X Y Foods can consistently meet the demands set by its production facilities.

1.2.2 Knowledge Problems

To help solve the main research question, we will look at a list of sub-research questions that split the main research question into manageable components. With that being said, the sub-research questions to be addressed during this study are:

1. What are the current methods used by X Y Foods for tracking and managing oil supply and demand?
   - Who are the actors involved in procuring and sourcing oil for X Y Foods, and what are their roles?
   - What are the limitations of the current method?
   - What are the contractual agreements X Y Foods has with its five suppliers?

This research question aims to provide an in-depth understanding of the existing methods and practices used by X Y Foods' actors to monitor the demand requirements and supply of oil, which involves a comprehensive overview of the current weekly routine, data extraction process, and decision-making procedure to procure oil based on the demand requirements set by the production facilities. This part of the research aims to explore areas of data sources, current practices, and the actors' roles in supply and demand procedures. The data-gathering approach involves X Y Foods's current contracts with its suppliers and the oil allocation per factory. This knowledge serves as a guideline for assessment in which the proposed effectiveness of the dashboard can be assessed.

2. What methods are used to evaluate input data in supply chain management, and what tools are present to visualise supply and demand via a dashboard?
   - What relevant tests can be used to evaluate the data quality?
   - What existing tools are currently present from similar industries to visualise quantitative data via a dashboard?

This research question addresses the current methodologies present based on the literature review. This includes strategies X Y Foods can implement to enhance the trustworthiness of its data by analysing the demand requirements data. As explained earlier, information about the quality of the demand requirements data has yet to be discovered. This research question also aims to look at existing dashboards in similar fields or industries to discover the tools to visualise quantitative data via a dashboard.

3. What dashboard specifications are needed to create an adequate supply versus demand visualisation based on known data quality?
    - How might the availability and quality of demand requirements data influence the assessment of the demand requirement assumption?
    - What is needed so the dashboard can replicate the reality of the situation?
    - Which selected features will bring visibility to X Y Foods?

This research question addresses the dashboard solution's technical and feature specification aspects. It involves a detailed analysis of the specific features, functionalities, and elements required to develop a dashboard that visualises the supply and demand of oil in an extensive manner based on known input quality. This chapter will include elaborate reasonings behind the choice of data visualisation techniques, the dashboard user interface design to ensure user-friendliness, the ability to produce accurate real-time or near real-time updates, and a systematic approach X Y Foods can implement to make decisions based on known data quality. Additionally, this section will explain the reasoning behind choosing those features and how / why using a dashboard will help solve the problem of X Y Foods' lack of visibility in oil supply versus demand.

4. What recommendations could be made from the dashboard?
    - What are the decisions X Y Foods can make from the solution?
    - What are the limitations and future development opportunities for the dashboard?

After the dashboard solution has been created, this part of the research aims to identify the specific actions, decisions and strategic choices X Y Foods can derive from the insights provided by the dashboard. These decisions can incorporate a wide range of areas, including but not limited to resource allocation, supplier communication, demand visibility and, most notably, any potential supply gaps in a specific month and decisions to be made on how those gaps are to be covered to avoid a stock-out situation.

1.2.3 Intended deliverables

- A statistical study to verify whether X Y Foods's assumption is valid and for which time horizons to aid in the decision-making process. This deliverable involves a tool to test whether there is a significant statistical difference between two data sources.
- A tool (dashboard) that aims to ease the visualisation of the supply and demand of oil. This visual model will include all the necessary information to help X Y Foods actors base their decisions on how much oil needs to be procured.
- A sourcing strategy that allows X Y Foods to make decisions on the quantities and suppliers to procure oil from.

1.3 Problem-solving approach

To tackle the identified core problem of “no clear visibility in supply versus demand of oil”, we use the Managerial Problem-Solving Method (MPSM). As the problem cluster in Figure 1 shows, many factors play a role in our action problem, "Being under-covered by oil contracts". This approach aims to guide a tailored solution, adding value to X Y Foods. In this section, we demonstrate how the specific stages of the MPSM methodology will help us arrive at the intended deliverables of this research. As our core problem is that there is no visibility in the supply and demand of oil, we first need to conduct a root cause analysis to understand what led to this case, which would be understanding the current methods used by X Y Foods for tracking and managing oil supply and demand, followed by an extensive data collection and analysis practice to quantify the data quality of demand requirements.

Additionally, a study and look into existing literature to identify what the dashboard needs to show to achieve a visualisation that adds value to X Y Foods. This is then followed by the methodology used to develop the dashboard. After this, the dashboard will be created and motivated by the context analysis to ensure the research addresses and solves the core problem. Finally, the created solution will aid in the decision-making process. Hence, recommendations will be given to prevent a stock-out situation for this study, namely, from August to January. The sequence of this problem-solving approach is explained in more detail below to make this process more transparent.

Analysing the problem

This phase involves understanding X Y Foods actors' current methods to manage, track, and source the essential raw material used for oil production. To do that, we need to understand the actors involved in the mentioned activities and how they link, which will be done using a Business Process Model (BPM), followed by a detailed analysis of the weekly routine in place, which consists of an explanation of the weekly routine followed by addressing the limitations of the routine in practised by X Y Foods. To further understand the current situation, data extraction is made to gather the quantities of oil sourced from August to January.

Formulating (alternative solutions)

This phase involves conducting a literature review to arrive at the intended deliverables of this research. We first conduct a literature study to quantify the quality of the demand requirements since X Y Foods currently carries their sourcing strategy, assuming the demand for oil extracted from SAP matches the reality of the situation (factory communicated data). Hence, we look at current studies that evaluate whether two data sources are similar by utilising data analysis motivated by inferential statistics or mathematical metrics.

Next, we look at existing methods used by FMCG industries to visualise supply versus demand initiatives. Additionally, we conducted a theoretical study to understand the importance of having a model that envisions this initiative as concretely as possible. Formulating the alternative solution phase will conclude with looking at relevant sourcing strategies for producing materials.

Choosing and building the solution

This phase of the problem-solving approach will first be carried out by preparing the demand requirements data. The reason for preparing the data in this phase is that a choice regarding the source of demand data is made after deciding the method of data analysis and the interpretation of those results, which is done in consultation with the methods of evaluating two data sets conducted in the previous phase. Data preparation and analysis include motivating the choice of data analysis used, carrying out data analysis and finally, interpreting the results, which will then aid in deciding which data set will be chosen. Additionally, this phase elaborates on the specifications of the dashboard, followed by building the solution.

Evaluating the solution

The final phase of the problem-solving approach will discuss the key learnings of the solution. Additionally, recommendations will be given to X Y Foods regarding the amount of oil that needs to be sourced to prevent a stock-out situation. Additionally, the dashboard will be evaluated to see if it addresses the specifications needed to visualise supply versus demand at X Y Foods. The final solution will be sent and discussed at the company to see if expectations are met. However, the use and implementation of the dashboard are outside the scope of this research.

1.4 Reliability and Validity

The extent to which the research can be assessed as reliable or unreliable depends on the research approach used. The reliability of quantitative data is simple to maintain as one could use the same extraction methods from the ERP system, conduct the given data analysis method and achieve similar results. Throughout this study, we aim to analyse the data set extracted and compare it to another data set (from the factory) using a mathematical study. That said, we can conclude that the data is statistically significant/ insignificant with a certain percentage of certainty.

Our research design also includes specific data-gathering methods that involve interviews. One disadvantage of conducting interviews is that the answers differ from one person to another. To tackle this problem, structured questions were asked to ensure similar answers. This should make the study reliable. To assess the study's validity, we aim to triangulate the research as much as possible. This means the research will gather more than one answer for each question. For the case of the discussions made, the same questions will be asked to different actors, followed by an internal analysis of what answers to use to cross-verify the findings.

To conclude, the research questions were formulated so that the results, whether quantitative or qualitative, are reliable and could be reproducible. For the case of quantitative data, statistical testing or comparison of two different data sets will ensure that the data quality is known. As for qualitative data, a triangulation approach will be carried out to ensure the validity of the data. In general, we aim to remain consistent in data collection by using the same techniques and asking the same questions to avoid personal bias or variations in how questions are asked.

1.5 Conclusion

To conclude, this chapter introduced the company and its respective problems. Based on that, several research questions were constructed. This research aims to provide a holistic solution that addresses the critical supply chain issue with an interactive dashboard and quantifies the demand requirements data so that X Y Foods can make decisions based on known data quality. The solution aims to provide insight and a decision-making tool on the quantities that must be sourced on time to prevent a stock-out situation. Chapter 2 of this thesis dives into the current situation by identifying the actors involved in oil management and procurement, followed by an explanation of the weekly routine and its limitations, which gives contextual background on what is needed to address the problem currently faced by X Y Foods.

2. Context Analysis

This chapter will discuss the current methodology X Y Foods uses to address the supply and demand of oil. This chapter is related to the third phase of the MPSM cycle. The problem will be discussed and analysed in more depth. This chapter starts with identifying the roles of X Y Foods actors in oil management and procurement, which is explained in Section 2.1. This is followed by Section 2.2, which gives the reader contextual awareness of the current situation, which is essential for the overall solution and implementation of the dashboard. Section 2.3 explains the current limitations of the situation. Additionally, Section 2.4 addresses the current volumes of the contractual agreements with the suppliers. This chapter relates to solving the first research question. Finally, this chapter will end with the key conclusions and take-away messages addressed in Section 2.5. The research question addressed in this section is:

1. *What are the current methods used by X Y Foods for tracking and managing oil supply and demand?*

2.1 Roles of X Y Foods actors in oil management and procurement

This section identifies the key actors in sourcing, managing, and tracking oil. This section identifies the key actors and what their respective roles are. This part of the research is crucial as it helps understand who the dashboard is meant for such that the solution considers the actors and their different roles.

Buyers

Buyers are commercially responsible for relationships with suppliers. Buyers are responsible for booking volumes of oil at competitive pricing. They negotiate with X Y Foods suppliers and book the volumes of oil needed based on the gap – the difference between what is present in the inventories and the demand requirements set by the production facilities.

Material Schedulers

After the buyers book the volumes needed for a given month, the material schedulers (MS) place weekly orders, so-called purchase orders (PO), from the contractual agreements.

Central Material Planners

Central Material Planners (CMPs) are responsible for communicating the volumes of oil needed to fulfil the demand. Their job is to manage the current weekly routine. CMP extract data from SAP, leads the weekly meeting and flags any changes or anomalies that the X Y Foods actors should know.

Coordinators

The coordinators ensure that all actors (buyers, CMP, material schedulers) do what they should do. Additionally, their primary responsibility is to oversee the whole process and act in case escalation is needed. Hence, the coordinators need to have information regarding the whole sourcing and manage the process in case escalation is needed.

2.1.1 BPM

Figure 2 shows the process by which the relevant X Y Foods actors cooperate from when the demand planners communicate the demand until the finished goods are produced from the raw material "Oil".

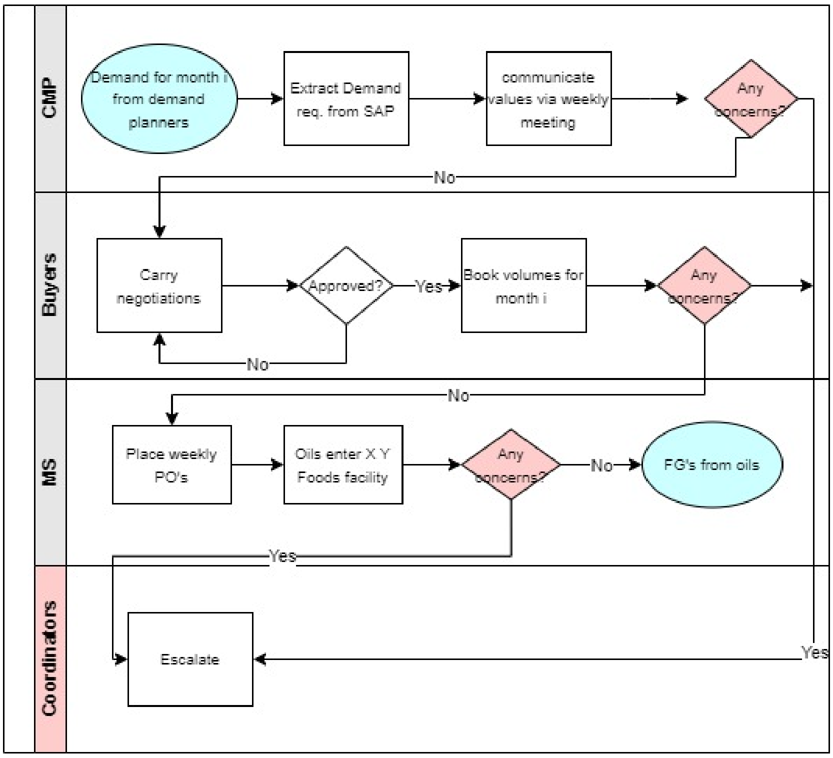

Figure 2: BPM of the weekly routine

Figure 2 shows how the roles of all relevant X Y Foods actors work together from start to finish. As the roles have already been explained in the previous section, this figure aids as a guide to visualise what has been said.

2.2 Weekly Routine

To tackle the problem addressed in Section 1.1, X Y foods currently carry out a weekly routine. The routine consists of extracting the production demand data from an ERP system called SAP and comparing it to how much oil is currently in the inventories. This is done by analysing the Excel file (shown below) weekly. Those values are then communicated to the coordinators and buyers to take action on how much oil needs to be sourced—two different X Y Foods Facilities source oil from five different suppliers to produce product x.

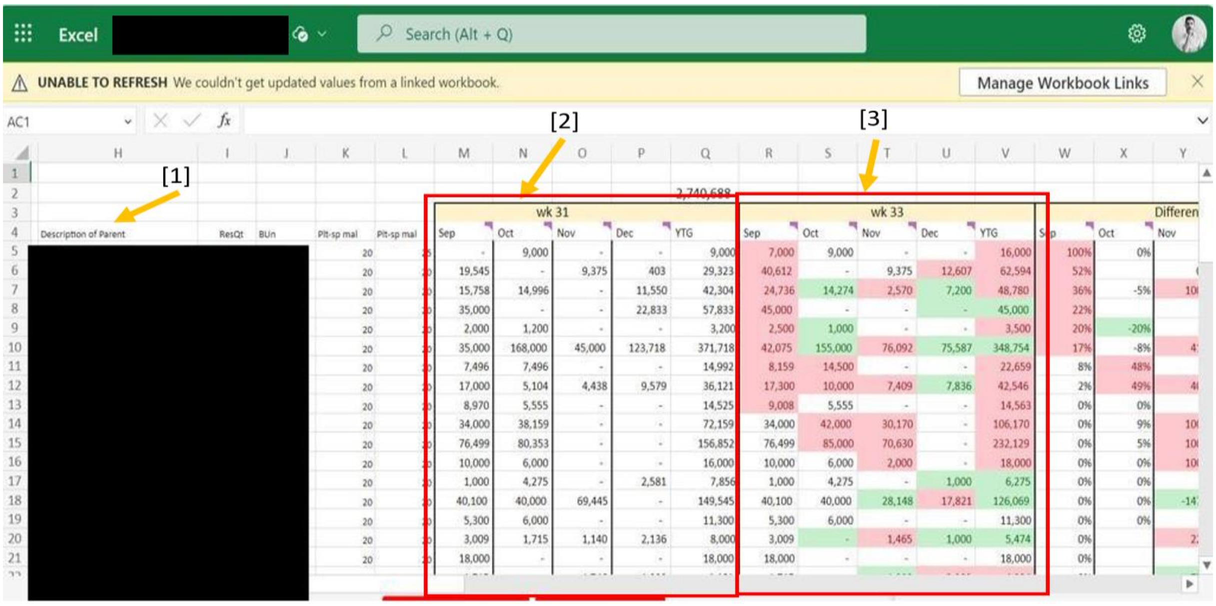

Figure 3: Current weekly routine

Figure 3 shows the projected weekly requirements of raw materials for factory "French X Y Foods" on only a 4-month horizon. [1] contains the weekly requirements of all raw materials and not only oil ("column: Description of Parent") for the given factory. This file is updated weekly and shows whether the factory is in surplus or deficit from September until December, meeting the production requirements based on how much raw material is on hand. The green and red cells depicted in [3] represent whether the factory can produce the products based on how much raw material is on hand. Moreover, the figure shows missing data (empty cells) in [2] and [3]; hence, the X Y Foods actors are unable to find whether the factories can meet the production requirements. The purpose of Figure 3 is to show the difficulty of reading and understanding the weekly routine of managing, tracking, and procuring raw materials based on the weekly routine.

2.3 Limitations of the Weekly Routine

This section addresses the limitations of the weekly routine explained in Section 2.2. Looking at Figure 3, it is challenging to visualise the requirements of oil specifically because the file contains the weekly requirements of all raw materials and not only oil ("column: Description of Parent"). Another issue in the current weekly routine is the data extraction method used. As stated, X Y Foods determines the demand requirements by extracting data from an ERP system. However, this data is currently not validated by the production schedulers at the factory. This strategy assumes that the demand requirements data from the ERP system matches what is required from the factory. This means that the decision-makers at X Y Foods are making decisions based on an unknown data quality.

The current situation makes it challenging to oversee what is being produced and how much of the contracted volumes are being consumed. It does not consider any external actions that the coordinators and buyers carry out to meet the demands of the production facility. This information cannot be deduced from the weekly routine, which has put X Y foods in various critical situations. The current situation does not predict supply versus demand effectively. To prove this, the plant coordinators have found themselves in situations where they did not have enough oil to meet the demands, leading to manual interventions and emergency orders, which has significantly increased the costs of this process. The implication goes back to the weekly routine currently followed by X Y Foods.

A critical limitation of the current solution (weekly routine) is that the visibility is only shown monthly. In other words, oil supply and demand are only shown by month. This is dangerous, as the oil supply is volatile. It is crucial to have a weekly view of the supply and demand of oil. With the current situation, it is impossible to foresee how much of the contracts (supply) is being used. With weekly visibility, X Y Foods actors can see how much of the contracts are consumed weekly. Finally, weekly visibility allows for better resource management, helping to avoid overproduction or underproduction. This leads to cost savings and resource efficiency.

Furthermore, the current routine does not consider any carry-over volume. To elaborate further, there are instances in which the factories required less than what was sourced for a given month. Naturally, this extra supply can fulfil the demand for the following month. However, this current routine does not consider this carry-over volume because each month is assessed separately, which shows that the current routine lacks clarity.

Finally, all the resources needed to decide how much oil needs to be sourced or to track the supply and demand of oil are currently scattered throughout the company. For instance, Figure 3 only shows the demand requirements for oil. If the coordinators want to analyse the recourse allocation of oil- then a manual data extraction from SAP should be carried out. Additionally, the actors cannot see how much oil the buyers procure. Lastly, there is no decision-making tool to manage and track decisions.

To conclude, X Y Foods actors currently find it challenging to manage and track the raw material oil as information about the supply, demand, decisions, and action points concerning oil are scattered along the company. A holistic approach mentioned in Chapter 1 ensures that all the information needed to manage, track, and procure oil is validated in one place. The weekly routine is a solution that lacks the mentioned holistic approach properties.

2.4 Contractual Agreements: Supply of oil

This section aims to help understand the quantities of oil sourced and the complexity of this supply chain process. This thesis project concerns two factories that use oil as a raw material to produce various products; oil is sourced from five different suppliers. It is important to note that not all five suppliers supply to both factories, as some suppliers are specifically designated to a particular factory. We denote the suppliers as supplier i ($i \in \{A, \ldots,$ E$\}$) for confidentiality purposes. The situation from August until January will be used to test the solution to show a six-month vision.

Table 1 below shows cases of which suppliers deliver to what factory.

Factory name	Supplier name (supplier i)
Dutch X Y Foods	A, B, C
French X Y Foods	A, B, D, E

Table 1: Supplier Split

As can be seen, $supplier\ A$ and $supplier\ B$ have contracts with both factories, and hence, they are the only two suppliers that supply both factories. The upcoming section showcases the contractual agreements of each supplier to each factory at a given month.

		Supplier A	Supplier B	Supplier C	Supplier D	Supplier E
Aug						
	French X Y Foods	487	112	-	300	247
	Dutch X Y Foods	727	262	375	-	-
Sep						
	French X Y Foods	487	112	-	300	247
	Dutch X Y Foods	727	262	375	-	-
Oct						
	French X Y Foods	487	112	-	300	247
	Dutch X Y Foods	727	262	375	-	-
Nov						
	French X Y Foods	500	100	-	250	200
	Dutch X Y Foods	700	240	400	-	-
Dec						
	French X Y Foods	600	150	-	360	290
	Dutch X Y Foods	750	289	460	-	-
Jan						
	French X Y Foods	0	0	-	0	0
	Dutch X Y Foods	0	0	0	-	-

Table 2: Contractual agreements in metric tonnes (MT)

The data in Table 2 was retrieved after consultation with the buyers – the personnel responsible for oil sourcing. The quantities sourced monthly are denoted in Table 2. Cells filled with "-" mean no contractual agreement between the factory and $supplier\ i$. The supply of January is yet to be populated as the buyers have not decided on how much oil needs to be sourced. This input is crucial in implementing the solution as it can be used in line with the demand requirements of the respective plants, and hence, the gap between supply and demand can be identified.

2.5 Conclusion

The current solution X Y Foods uses (weekly routine) to address the problem has been explained in depth. Although it addresses the oil supply, it contains substantial discrepancies and inaccuracies. The main limitations of the weekly routine include making procurement decisions based on unknown data quality, negligence of carry-over volume, which is essential as it replicates the reality of the oil inventory, and poor management and tracking of the oil portfolio overall, which leads to a lack of visibility over the supply versus demand of oil. Hence, this will be a starting point when implementing the solution to ensure that the dashboard is created to tackle all the limitations of the current weekly routine. Additionally, this section has identified the critical actors involved in sourcing, managing, and tracking oil. This is important as it helps provide a solution that meets the different requirements of the actors. Finally, the contractual agreements have been extracted and seen after consultation with the buyers. This is a crucial input in analysing the supply and demand of oil. Chapter 3 aims to provide the theoretical knowledge needed from current literature studies to help visualise the supply and demand of oil via a dashboard, evaluate sourcing strategies, and review current theories that help quantify the quality of quantitative data.

3. Relevant Literature

This chapter reveals the respective theory needed to help visualise the supply and demand via a dashboard and the relevant theory needed to quantify quantitative data quality. First, Sections 3.1 and 3.2 investigate existing studies that quantify the data quality by statistical tests or mathematical metrics. Next, Section 3.3 discusses how supply versus demand is visualised in the FMCG industry and discusses sourcing strategies to procure raw materials. This will be done by looking at theory to construct the dashboard and looking at relevant sourcing strategies. This chapter is part of the third and fourth MPSM cycle – analysing the problem and formulating alternative solutions and aims to address the second research question:

2. *What methods are used to evaluate quantitative data, and what tools are present to visualise supply and demand via a dashboard?*

3.1 Statistical tests to quantify the quality of the data

X Y Foods currently bases its procurement decisions on the amount of oil sourced based on the demand requirements data extracted from SAP. The actual requirements communicated by the factory are neglected in the weekly routine. With this information, X Y Foods assumes that the demand requirements of SAP match the factory's requirements. Using inferential statistics, X Y Foods can clarify the quality of their data and whether this assumption holds. Several tests could be used to quantify the quality of the data. Each test has its strengths and limitations. Most statistical tests work best based on assumptions and the nature of the data present. This section evaluates the most relevant statistical tests.

The t-test is a commonly used statistical test to compare the means of two groups (Kim, 2015). The statistical method in question is a parametric approach that assumes that the data follows a normal distribution and has equal variances (Lumley et al., 2002). Following the assumption of a normal distribution, the t-test can provide more reliable results than non-parametric tests. However, it is imperative to verify that the data satisfies the assumptions of the test prior to its application. In cases where the data does not adhere to a normal distribution, exploring alternative non-parametric tests, such as Wilcoxon's rank test, is advisable.

Another test looked at was Wilcoxon's rank test. This non-parametric test could be used when the data does not comply with assumptions of normality or equal variances. It is based on the ranks of the differences between paired observations. The test involves the following steps: 1. Rank the absolute differences between the paired observations, ignoring the signs. 2. Assign positive ranks to the positive differences and negative ranks to the negative differences. 3. Calculate the sum of the ranks for each group. 4. Use the smaller sum of ranks as the test statistic. 5. Determine the critical value or p-value from the appropriate distribution (e.g., normal approximation or exact distribution). One of the notable benefits of employing Wilcoxon's rank test is its flexibility in the face of deviations from distributional assumptions. This approach proves particularly advantageous in cases where the data does not correspond to a normal distribution or when outliers are present. What makes Wilcoxon's rank test powerful is that the test is less affected by outliers than parametric tests. This test involves ranking the data rather than relying on the actual data values. By assigning ranks, extreme outliers do not have as much influence on the test statistic as they might have on a parametric test. As Wilcoxon's rank test compares the sum of ranks between two groups rather than the actual data, this test is less affected by outliers because it deals with relative ordering. In brief, the Wilcoxon rank test is a non-parametric statistical test utilised to assess the difference in medians between two correlated samples.

In order to determine whether a parametric or non-parametric test can be used, an F-test could be used to determine if the two data sets have equal variances at a chosen level of certainty. To test for normality, Wilk Shapiro's test is a tool used to test whether the data follows a normal distribution. If the test turns out to be non-significant, it tells us that the data is not significantly different from a normal distribution and vice versa.

As an ending note, the chosen statistical test will be conducted using an 8-step hypothesis test, which is as follows (Cote,2021):

1. Give the probability model and statistical assumptions.
2. State the null hypothesis (H0) versus the alternative hypothesis (H1)
3. Compute the test statistic
4. State the distribution of the test statistics if H_0 is true
5. Compute the observed value of the test statistic.
6. State the test and the choice of α followed by determining the rejection region.
7. Compute the p-value
8. Draw the conclusion and the outcome of the statistical study

3.2 Metrics to quantify the quality of the data

The mean squared error (MSE) is a commonly used measure for assessing the accuracy of models across different domains, such as machine learning, statistics, and engineering (Chai & Draxler, 2014). "mean squared difference" refers to a statistical measure quantifying the average squared discrepancy between predicted and actual values. The mean squared error is computed by obtaining the mean of the squared discrepancies between the predicted and observed values.

The MSE is frequently used in combination with other assessment measures, including the mean absolute error (MAE), root mean square error (RMSE), and mean absolute percentage error (MAPE). These metrics offer supplementary data regarding the precision and efficiency of the models.

The root mean square error, derived from the mean square error, is a widely used metric in assessing the average magnitude of errors within a model (Chai & Draxler, 2014). This method proves to be particularly advantageous in cases where the errors are anticipated to follow a normal distribution, which leads to more accurate interpretations. However, this metric should not be used because the data distribution is unknown. The RMSE provides a quantitative assessment of the average magnitude of the errors, making it a commonly employed metric for comparing the efficacy of various models.

In addition to the MSE and RMSE, alternative evaluation metrics, including the MAE, MAPE, and R-squared, are frequently employed to evaluate the efficacy of models (Tudose et al., 2021). The Mean Absolute Error quantifies the average absolute discrepancy between the predicted and observed values, thereby indicating the average magnitude of the errors. The MAPE is a metric that quantifies the average percentage deviation between predicted and actual values. It is a valuable tool for assessing the precision of the data to relative errors.

In general, the Mean Squared Error is a commonly employed metric in model evaluation to quantify the average squared discrepancy between predicted and observed values. It is commonly employed with other evaluation metrics, such as the RMSE, MAE, and MAPE, to evaluate the precision of models across diverse domains.

3.3 Supply versus demand visualisation in FMCG industries

A dashboard is crucial in enhancing the visualisation of supply versus demand within FMCG sectors. This is achieved by offering up-to-date insights and facilitating decision-making based on data analysis. According to Yang and Zhang (2019), dashboards provide a comprehensive and appealing visual representation of key performance indicators, enabling stakeholders to effectively monitor, analyse, and respond to fluctuations in supply and demand. In the FMCG sector, dashboards have become essential tools for decision-making due to the need for real-time monitoring and analysis in response to the dynamic nature of demands (Mahdzir et al., 2023).

Dashboards have emerged as valuable instruments for tracking and monitoring supply chain trends in the FMCG industry as a supply security measure. Likewise, dashboards have played a crucial role in enhancing resource allocation and response strategies within the healthcare industry amidst the pandemic (Colicchia et al., 2017). In addition, the dynamic nature of dashboards enables prompt reactions to fluctuations in demand patterns and disruptions in the supply chain, thereby enhancing operational agility and responsiveness (Yang & Zhang, 2019).

The dashboard development process involves solving performance measurements to ensure that the dashboard's content effectively transforms data into meaningful indicators that cater to the diverse needs of various users (Yang & Zhang, 2019). The importance of this matter is particularly evident within the FMCG sector, where the precision of demand planning holds significance. In this context, dashboards serve as valuable tools for visualising forecast discrepancies and assisting in their resolution, ultimately enhancing accuracy (Yang & Zhang, 2019).

In summary, implementing a dashboard within the FMCG sectors offers a timely and graphical depiction of the relationship between supply and demand. This empowers relevant actors to make well-informed choices, adapt to fluctuations in the market, and enhance operational efficiency.

3.3.1 Existing tools present to create a dashboard

Several essential components are considered to develop a supply versus demand dashboard. Firstly, it is essential to have trustworthy and accurate data relating to supply and demand. Subsequently, adhering to a structured procedure for developing a dashboard is essential. The typical procedure encompasses five stages: data collection, data processing and analysis, visualisation design, dashboard implementation, and dashboard adoption and utilisation (Pauwels et al., 2009).

According to Pauwels et al. (2009), ensuring that the dashboard design effectively presents the supply and demand data clearly and intuitively is crucial. This will enable users to understand and evaluate the information quickly. Regarding the attributes of the dashboard, it is fundamental to incorporate visual representations that effectively show current supply and demand levels, along with any emerging trends or patterns. The visual representations employed in this context may encompass line charts, bar graphs, or heat maps, depending on the characteristics of the data (Pauwels et al., 2009). Furthermore, the dashboard must allow users to dig deeper into the data to obtain more comprehensive and specific information. This can be achieved by enabling users to filter the data based on product category or geographic region, as Pauwels et al. (2009) suggested. In order to guarantee the precision and dependability of the data. Ensuring the accuracy and currency of the data utilised in the dashboard involves various activities such as data validation, data cleansing, and data integration (Zhu et al., 2018).

Several specifications should be considered to create an effective dashboard for visualising demand requirements in the context of supply versus demand. Rabiei & Almasi (2022) discuss the requirements and challenges of hospital dashboards. Although the focus is on hospital dashboards, the findings can be applied to this case to understand the specifications that can be created within the dashboard that add value to X Y Foods. This paper emphasises the significance of reporting, reminders and tracking as functional requirements for effective dashboards. The study stresses the importance of developing a dashboard that can fit various dynamic requirements to visualise situations and help decision-making processes based on different user needs. An effective dashboard should provide a visual representation of critical metrics, allow for the examination of correlation between variables, and have low requirements for computing resources. Additionally, the dashboard should reflect real-time data and trend analysis. These specifications can be applied to supply versus demand visualisation to ensure the dashboard is informative and user-friendly (Randell et al., 2022).

3.3.2 Matching supply versus demand: A sourcing strategy

When developing a sourcing strategy, it is essential to consider a range of metrics to improve the visualisation of supply versus demand. The performance of a supply chain is impacted by risks associated with both supply and demand. It is essential to acknowledge the relationships between these risks (Wagner & Bode, 2008). The evaluation of demand quality in supply chains depends on the metrics of demand visibility and demand variability, which substantially influence sourcing decisions (Lehtonen et al., 2005). Moreover, it is crucial to consider the effects of disruptions on both the demand and supply sides and the integration of demand and supply disruptions in decision-making processes when formulating sourcing strategies (Guo et al., 2016).

Matching the supply and demand is crucial in better sourcing decisions as it directly impacts supply chain performance and risk management. According to Wagner and Bode (2008), a strong alignment between supply and demand results in enhanced supply chain performance by contributing to optimised inventory levels. By aligning supply and demand, sourcing decisions can be tailored to maintain optimal inventory levels while meeting the demands. Additionally, sourcing decisions can be made in advance with suppliers, which enhances the overall relationship between the firm and the supplier. Finally, this sourcing strategy helps avoid unnecessary costs, either withholding excess inventory or rushing to source raw materials due to unforeseen spikes in demand. Hence, the implementation of efficient procurement strategies has the potential to minimise supply disruptions (Li & Zhang, 2023).

The decision to mono-source or dual-source is crucial in the FMCG industry and depends on multiple factors. The FMCG industry, known for its dynamic market conditions, necessitates careful evaluation of sourcing strategies to guarantee the supply chain's resilience and optimise operational efficiency (Simba et al., 2017). Mono-sourcing, the practice of procuring a product or service exclusively from a single source, can provide advantages such as reduced expenses and streamlined supplier monitoring. Nevertheless, it also presents potential hazards concerning supply chain disruptions and reliance on a single supplier (Simba et al., 2017). Alternatively, dual sourcing, a strategy that entails procuring a product from multiple sources, can reduce risk and enhance adaptability within the supply chain.

When deciding whether to rely on a single source or multiple sources in the FMCG industry, it is essential to consider factors such as managing supply chain risks and product characteristics. Moreover, the attributes of FMCG products, such as their limited duration of usability, necessitate the evaluation of sourcing choices with product availability and market responsiveness (Kuzmina et al., 2019)

3.4 Conclusion

This chapter has started by discussing relevant and necessary theories needed to conduct a statistical study. This involved looking at the relevant tests and metrics to quantify the quality of the demand data requirements so a conclusion could be reached on whether it is justifiable for X Y Foods to assume matching data. The tests that were discussed were the parametric T-test and the non-parametric Wilcoxon's rank test, which can be used when the data does not follow the assumptions of a parametric test. Next, several metrics were discussed to assess whether statistical assumptions hold or not based on the data type. Finally, the mean squared error (MSE), which can be used to assess models' accuracy, was examined. The next part of the chapter looked at the relevant theory needed to help visualise the supply and demand of our problem using an interactive dashboard. This included studies from similar industries that use a dashboard to address supply security issues. Finally, sourcing strategies such as mono / dual sourcing and procuring supply by matching it with the demand were examined. Chapter 4 includes the methodology and a step-by-step method to assess the data's accuracy and build the dashboard based on a chosen data set.

4. Methodology

This chapter describes the methodology used to reach our intended deliverable. This chapter includes the steps taken to implement the solution. Section 4.1 shows the data gathering protocol of the demand requirements data and explains the chosen statistical tool used. Next, Section 4.2 shows an extensive data analysis procedure used to quantify the quality of the demand requirement data. Section 4.3 showcases the specifications of the dashboard based on the theoretical knowledge gained in Chapter 3 and the context analysis of Chapter 2. The dashboard modelling is shown step-by-step, described in Section 4.4. The methodology part of this thesis was developed after a concrete and in-depth understanding of the current solution and sufficient theoretical knowledge to help provide a solution to X Y Foods that adds value and solves its problem. This chapter is part of the fifth and sixth MPSM cycle – choosing and implementing the solution and aims to address the third research question:

3. *What dashboard specifications are needed to create an adequate supply versus demand visualisation based on known data quality?*

4.1 Gathering demand requirements data

The first part of the data analysis is to gather the data. The requirements of how much oil is needed per factory per month are collected for this. The two data sets are gathered from SAP and the database of the demand requirements communicated from the factories. The factory demand requirements were gathered after consultation with the material planners. After the data has been gathered, it has to be set up accordingly on Microsoft Excel for testing later.

French X Y Foods			Demand requirments per week in MT	
	Month	Week no.	SAP	Factory
	August	*Week 31*	244.5	252.75
		Week 32	344.25	365.25
		Week 33	426	482.25
		Week 34	371.25	377.25
	Septembe	*Week 35*	440.25	450.75
		Week 36	243	274.5
		Week 37	0	0
		Week 38	0	0
	October	*Week 39*	0	0
		Week 40	288	284.25
		Week 41	150	180
		Week 42	88.5	90
		Week 43	292.5	232.5
	November	*Week 44*	400.5	480
		Week 45	120	232.5
		Week 46	382.5	435
		Week 47	205.5	352.5
	December	*Week 48*	54	63.75
		Week 49	348	360.75
		Week 50	207.75	217.5
		Week 51	0	0
		Week 52	0	0
	January	*Week 1*	0	0
		Week 2	294	317.25
		Week 3	205.5	204.75
		Week 4	214.5	244.5

Dutch X Y Foods			Demand requirments in MT	
	Month	Week No.	SAP	Factory
	August	*Week 31*	*260.25*	*176.625*
		Week 32	*399*	*230.063*
		Week 33	*113.25*	*63.5625*
		Week 34	*423.75*	*302.625*
	September	*Week 35*	*117*	*101.25*
		Week 36	*255.75*	*196.875*
		Week 37	*825*	*569.25*
		Week 38	*504.75*	*358.875*
	October	*Week 39*	*426*	*306.563*
		Week 40	*457.5*	*341.438*
		Week 41	*276*	*200.25*
		Week 42	*312*	*135.563*
		Week 43	*231*	*317.813*
	November	*Week 44*	*412.5*	*326.25*
		Week 45	*48*	*29.8125*
		Week 46	*258.75*	*192.938*
		Week 47	*377.25*	*279*
	December	*Week 48*	*306.75*	*192.375*
		Week 49	*480.75*	*268.875*
		Week 50	*223.5*	*213.188*
		Week 51	*198.75*	*172.688*
		Week 52	*0*	*0*
	January	*Week 1*	*0*	*0*
		Week 2	*84*	*37.6875*
		Week 3	*384*	*79.3125*
		Week 4	*286.5*	*174.938*

Figure 4: Demand requirement for French & Dutch X Y Foods

Figure 4 shows the demand requirements for the French and Dutch X Y foods factories. Column *"SAP"* denotes the required demand as shown in SAP, and column *"Factory"* denotes the factory-communicated demand. Weeks that show the demand being 0 are because of production stoppage; hence, no oil is needed for the factory for that given week. To conclude, data analysis will be conducted after the demand requirements data has been gathered and set up accordingly. This data serves as a basis to foresee the gap between supply and demand for a given month and hence offers visibility to X Y Foods on how much oil needs to be sourced to avoid a stock-out situation.

4.1.1 Chosen statistical tool

After careful investigation of the theoretical perspective, the chosen statistical tool to evaluate the demand requirement data is the mean squared error. The strength of this tool lies in how it evaluates the data. Unlike statistical tests such as the t-test, MSE can give insight into each input alone before giving an overall value. Hence, discrepancies between the ERP and factory communicated demand can be visualised separately. This means X Y Foods can understand for which given weeks the difference between SAP and factory communicated data is significant. Additionally, the MSE metric can be utilised without examining the distribution of the data. Unlike the RMSE where it is better to use if the data follows a normal distribution.

$$MSE = \frac{1}{n} * \sum_{i=1}^{n} (SAP_i - F_i)^2$$

$MSE: Mean\ Squared\ error$

$n: number\ of\ data\ points$

$SAP_i: Demand\ from\ SAP\ for\ week\ i$

$F_i\ : Demand\ from\ Factory\ for\ week\ i$

Additionally, the MSE will be used with the MAPE, which measures the accuracy of the SAP system compared to the factory-communicated data.

$$M = \frac{1}{n} * \sum_{i=1}^{n} \frac{SAP_i - F_i}{F_i}$$

$M: MAPE$

$n: number\ of\ data\ points$

$F_i: Demand\ from\ Factory\ for\ week\ i$

$SAP_i\ : Demand\ from\ SAP\ week\ i$

4.2 Implementation of the mathematical metric

The MSE and MAPE are used to analyse how much the SAP demand requirement differs from the factory-communicated data. This is done by analysing two cases, French X Y Foods and Dutch X Y Foods. The code shown in Appendix F has been written to develop a function in Excel that could be used to calculate both the MSE and MAPE. This was done to ensure reproducibility and can be applied to any data set that meets the requirement of having equal range sizes without having to do the manual calculations. After the implementation of the MSE and MAPE, the following results were achieved:

French X Y Foods		Demand requirments per week in MT					
Month	Week no.	SAP	Factory	difference	% Change		
August	Week 31	244.5	252.75	8.25	3%		
	Week 32	344.25	365.25	21	6%	n:	26
	Week 33	436.25	482.25	46	10%	MSE:	1824.5
	Week 34	371.25	377.25	6	2%	MAPE:	11.1
Septembe	Week 35	440.25	450.75	10.5	2%		
	Week 36	243	274.5	31.5	11%		
	Week 37	0	0	0	-		
	Week 38	0	0	0	-		
October	Week 39	0	0	0	-		
	Week 40	288	284.25	3.75	1%		
	Week 41	150	180	30	17%		
	Week 42	88.5	90	1.5	2%		
	Week 43	292.5	232.5	60	26%		
November	Week 44	400.5	480	79.5	17%		
	Week 45	150.75	232.5	81.75	35%		
	Week 46	382.5	435	52.5	12%		
	Week 47	205.5	352.5	147	42%		
December	Week 48	54.25	63.75	9.5	15%		
	Week 49	348	360.75	12.75	4%		
	Week 50	207.75	217.5	9.75	4%		
	Week 51	0	0	0	-		
	Week 52	0	0	0	-		
January	Week 1	0	0	0	-		
	Week 2	294	317.25	23.25	7%		
	Week 3	205.5	204.75	0.75	0%		
	Week 4	214.5	244.5	30	12%		

Dutch X Y Foods		Demand requirments in MT					
Month	Week No.	SAP	Factory	difference	% Change		
August	Week 31	160.25	156.625	3.625	2%		
	Week 32	399	360.063	38.9375	11%		
	Week 33	103.25	83.5625	19.6875	24%	n:	26
	Week 34	323.75	302.625	21.125	7%	MSE:	4201.4
September	Week 35	117	103.25	13.75	13%	MAPE:	15.4
	Week 36	255.75	258.875	3.125	1%		
	Week 37	825	769.25	55.75	7%		
	Week 38	504.75	358.875	145.875	41%		
October	Week 39	426	306.563	119.4375	39%		
	Week 40	457.5	341.438	116.0625	34%		
	Week 41	276	200.25	75.75	38%		
	Week 42	312	235.563	76.4375	32%		
	Week 43	231	317.813	86.8125	27%		
November	Week 44	412.5	326.25	86.25	26%		
	Week 45	41.75	29.8125	11.9375	40%		
	Week 46	258.75	192.938	65.8125	34%		
	Week 47	377.25	279	98.25	35%		
December	Week 48	306.75	292.375	14.375	5%		
	Week 49	380.75	268.875	111.875	42%		
	Week 50	223.5	213.188	10.3125	5%		
	Week 51	198.75	172.688	26.0625	15%		
	Week 52	0	0	0	-		
January	Week 1	0	0	0	-		
	Week 2	41	37.6875	3.3125	9%		
	Week 3	294	279.313	14.6875	5%		
	Week 4	186.5	174.938	11.5625	7%		

Figure 5: MSE and MAPE for French & Dutch X Y Foods

The MAPE quantifies the average deviation between the demand requirements extracted from SAP and the factory. A lower Mean Absolute Percentage Error is favoured due to its indication that, on average, the SAP data exhibit a higher degree of closeness to the values expressed by the production facilities, expressed as a percentage of the actual values. French X Y Foods data exhibits a lower Mean Absolute Percentage Error of 11.1% in contrast to Dutch X Y Foods, which has a MAPE of 15.4%. This implies that, on average, the forecasts generated by the French factory exhibit a lower percentage error, suggesting better accuracy in relative terms.

Likewise, a low mean squared error is generally favoured as it indicates that the SAP data exhibit more excellent proximity to the values communicated by the factory regarding squared errors. French X Y Foods exhibits a significantly lower MSE of 1,824.5, in contrast to Dutch X Y Foods, which has a higher MSE of 4201. This observation suggests that the French Factory demand requirement data extracted from SAP is closer to the factory communicated data when compared to the Dutch facility, indicating superior accuracy regarding squared errors.

French X Y Foods demonstrates better performance compared to Dutch X Y Foods in terms of both MAPE and MSE, suggesting improved accuracy in terms of percentage errors and enhanced accuracy in terms of squared errors. A lower MAPE and MSE indicate that French X Y Foods offers more precise predictions and exhibits a minor overall error compared to the latter. After consultation with the central material planners at X Y Foods, it was suggested that a difference of less than 15% is natural. This is because of the method of calculation of the demand requirement data, which is out of the scope of this research. Hence, any percentage change more significant than 15%, which is marked in red in Figure 5, means the data needs to be fixed. Diving deeper, the MSE of Dutch X Y Foods is approximately 250% larger than that of the French factory and has many percentage differences more significant than 15%, especially between October and November.

To answer the question, "Is the demand requirement assumption justifiable?". After careful analysis, the situation depends on the associated factory. As for French X Y Foods, the SAP and factory data are relatively similar, with a MAPE of 11.1%, less than the 15% threshold. Additionally, only weeks 43-45 have severe discrepancies, and hence, we conclude that the demand requirement assumption is justifiable for French X Y Foods. Dutch X Y Foods has severe discrepancies in the overall demand requirements, especially over October and November. Out of the 26 pairs of data analysed, 13 had a difference of more than 15%, which is highlighted in red in Figure 6, and nine showed a difference of over 30%. Hence, we conclude that the assumption is not justifiable for Dutch X Y Foods because the MAPE is 15.4%, which is higher than the threshold of 15%.

4.2.1 Chosen Data Set

Data analysis has been carried out to help decide whether the SAP and factory communicated demand data match. We have concluded that this is not the case because of the discrepancies between the two data sets. Hence, a decision must be made whether the SAP or factory communicated data will serve as input of demand to help develop a dashboard that visualises the supply and demand of the situation.

The goal of this thesis is to provide a solution that aims to minimise the chance of a stock-out situation happening. Despite having a higher cost, we chose the data set with higher demand requirements for supply security reasons. Choosing the data with higher demand means that X Y Foods must source more oil to meet this demand. This safety measure should minimise the stock-out risk in theory and practice. When supply closely matches demand, there are fewer instances where the production line runs out of oil, leading to uninterrupted production and, most importantly, addressing the action problem "being under-covered by contracts". Having a higher demand input to develop the dashboard by providing visibility to X Y Foods means more oil needs to be sourced to match the high demand of the factory despite this approach having a higher cost. The newly proposed solution (dashboard) considers carry-over volume; hence, if there are instances where X Y Foods procured more oil for a given month for security measures, the extra volume (if any) will be used to match the demand of the next month, which in principle saves costs for the commencing month.

To motivate this choice further from a consumer point of view, X Y Foods is known for its high-quality products and its premium prices. This is motivated by their high brand reputation. Hence, stock-outs can damage the brand's reputation because of the perceived unreliableness if the customer encounters unavailable products due to the shortage in supply because of procuring fewer oil based on the demand. Hence, using the data with higher demand is a security measure to ensure enough oil is procured in times of mismatching demand data.

4.3 Dashboard Requirements

Based on the conducted literature review, context analysis and the problem X Y Foods faces, the following dashboard requirements will achieve the visualisation X Y Foods is aiming for and additionally reduce the probability of having a stock-out situation due to the interactive dashboard specifications:

Specification nr.	**Specification**	**Added value to X Y Foods**
1	Gap between supply versus demand	Visibility
2	Weekly overview of oil consumption	Visibility, in-depth insight
3	Carry-over volume	Minimisation of gap, cost reduction
4	Ability to dig deeper into values	Insight
5	Filter data based on category and region	Improved visualisation
6	Represent data visually	Visibility, Ease of use
7	Represents up to date data	Validity, accuracy
8	Action point & reminder tracker	Decision making, sourcing strategy
9	Decision-making tool based on dashboard	Sourcing strategy
10	User friendly	Ease of use
11	Cover page	Ease of use

Table 3: Dashboard Specifications

Section 2.2 explains the current weekly routine that aids as a sourcing tool to avoid a stock-out situation. Section 2.3 explained the limitations of the current weekly routine. Hence, the following specifications aim to address the limitations of the weekly routine that have been explained in depth.

4.4 Modelling the Dashboard

This section implements the knowledge gained in the previous sections and considers Section 4.3, where the dashboard specifications are addressed. Consequently, the dashboard will be developed in this section.

4.4.1 Data Preparation: Monthly Demand

We will use the "max" function in Excel to choose the higher demand requirement for a given week, as seen in Figure 6.

	Demand requirments per week in MT							
Week no.	**SAP**	**Factory**	**difference**	**% Change**			**Month**	**final demand req.**
Week 31	*137.53125*	*252.75*	*115.21875*	*46%*			*August*	G3)
Week 32	*344.25*	*365.25*	*21*	*6%*	***n:***	26		365.25
Week 33	*436.25*	*482.25*	*46*	*10%*	***MSE:***	2332.5		482.25

Figure 6: Selecting demand requirement procedure.

After this, we summed up the demand values of each given week to gain insight into how much product x would be produced per month. The monthly requirement for French X Y Foods can be seen in Table 4. When combined with the monthly contractual volumes, the monthly demand represents the gap between supply and demand, which can then be used to recommend the amount of oil needed monthly to prevent a stock-out situation.

Month	**Demand Requirement (MT)**
August	1477.5
September	725.25
October	786.75
November	1500
December	642
January	766.5

Table 4: Monthly Demand Requirement for French X Y Foods

The same is done to the other factory, as shown in Table 5, namely, Dutch X Y Foods

Month	**Demand Requirement (MT)**
August	986.25
September	1705.6
October	1789
November	1090.25
December	1109.75
January	521.5

Table 5: Monthly Demand Requirement for Dutch X Y Foods

Now that the monthly demand requirement is on hand, after concluding which data set to select, we can develop an overview of the supply and demand of oil, which is constructed with an interactive graph. This addresses specifications 1 and 9 of Table 3.

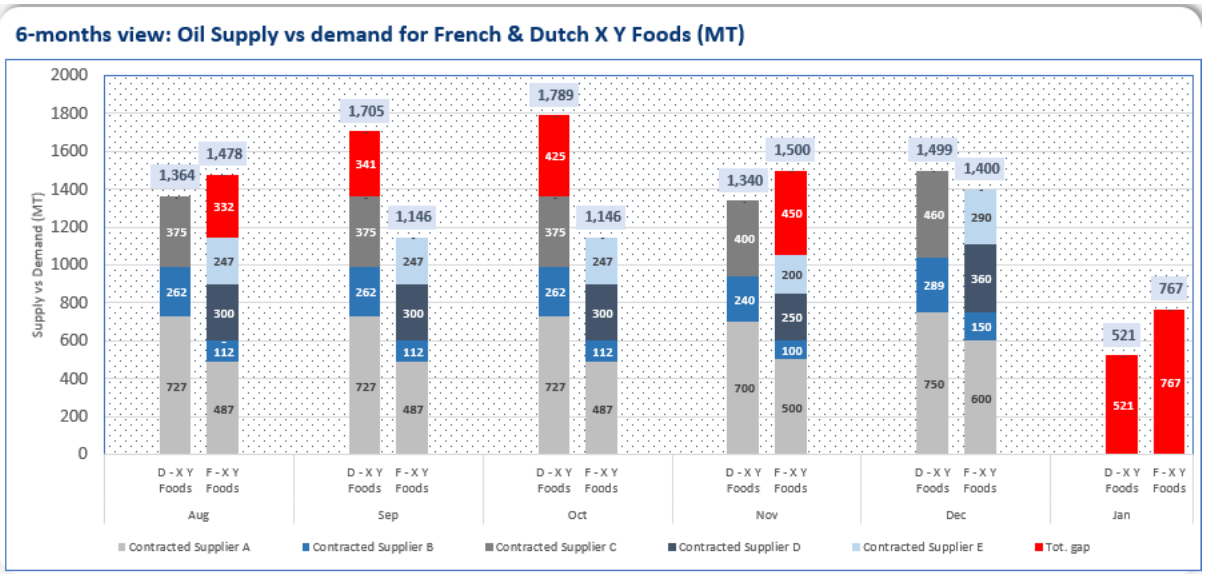

Figure 7: Supply versus Demand for French & Dutch X Y Foods

Figure 7 shows the visual representation of combining the supply and demand of oil. The insight provided shows the supply of oil per factory per month. What can be seen is how much of the oil is sourced from which supplier. Combining supply and demand in one graph shows the gap, which is depicted in red. This representation provides an in-depth analysis of where X Y Foods stand in terms of the ability to meet the demand requirement of the production facility. There is currently a gap for every month except December. With further alterations to the dashboard and the additional specifications that will be modelled, Figure 7 will be assessed again in the results section to showcase whether the final solution has given X Y Foods a better visual representation and whether the new proposed specifications minimise the gap.

4.4.2 Spot Volume

We define *spot volume* as the volume sourced during the month to meet the demand in case the contracted volumes fail to do so. The red bars in Figure 7 show the instances where a gap is expected based on the oil supply. The spot volume is a decision-making metric that decides the amount of oil that needs to be sourced so the factories can meet the demand requirement. This decision-making tool is part of Specification 9, which recommends how much oil needs to be sourced to the buyers. In this chapter, we model this tool, and in Chapter 5, we discuss the impact of this metric on X Y Foods.

Spot Volumes							
Factory	Month	Supplier	Gap (MT)	Confirmed vol. (MT	Quality approval	Spot	Further actions
French X Y Foods	August					-	
Dutch X Y Foods	October					-	
French X Y Foods	November					-	
Dutch X Y Foods	January					-	
French X Y Foods	January					-	
						-	
						-	

Figure 8: Decision-making tool

Figure 8 shows the decision-making tool modelled to be part of the interactive tool; it gathers the gap identified from the graph and inserts it in column "Gap (MT)" based on the respective factory and month. Column "Confirmed vol. (MT)" is the amount of oil recommended to be sourced based on the gap. For the spot volume to be delivered and used, it has to go through some quality approval for food safety and quality reasons (FSQ). After this is confirmed, the oil sourced via the spot volume is available for production use. This is then reflected in the dashboard, so the gap is minimised.

Before we can make decisions regarding the sourcing strategy, essential information should be given concerning the logistics side of delivery, such as the truck size (capacity), Lead time, and the distance of the suppliers from the factory.

Supplier	***Truck capacity in (MT)***	***LT in (days) for Dutch***	***LT in (days) for French***	***Min Lot size (MT)***	***Distance from French X Y Foods in (Km)***	***Distance from Dutch X Y Foods in (KM)***
Supplier A	45.5	5	7	25	154	160
Supplier B	45.5	7	7	25	260	133
Supplier C	25	7	-	24.5	-	141
Supplier D	25	-	4	24.5	266	-
Supplier E	45.5	-	3	25	300	-

Table 6: Sourcing Logistics

With all this information, we can make decisions based on the amounts of oil to order and from which suppliers to prevent a stock-out situation for a given month.

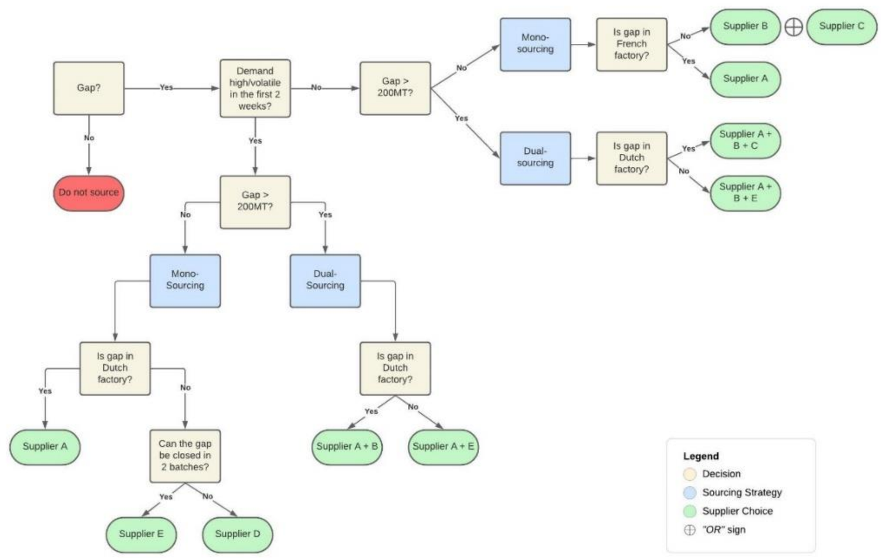

Figure 9: Decision-making tree

Figure 9 depicts a decision tree that helps the X Y Foods actors visualise which supplier to order from based on the gap. The first decision that is essential to determine whether spot volumes should be ordered concerns if there is a gap in month i. Next, if there is a high demand in the first two weeks of the month, the suppliers with the lowest lead time have priority; this is the case to ensure oil arrives on time and prevent a stock-out scenario. We decide if the gap is high in the first two weeks by looking at Figure 4, which depicts the weekly demand. We define a monthly demand as high if the demand in the first two weeks is over 70% of the total contractual volumes supplied for that month.

Additionally, a volatile demand is observed if a carry-over volume from the previous month covers the demand in month i. After which, the size of the gap is considered. A dual-sourcing strategy is carried out if the gap is over 200 MT. A dual-sourcing strategy allows for better scalability and flexibility when sourcing large quantities of oil. Sourcing over 200 MT of oil on short notice is considered challenging given the capacity limitations of the suppliers; procuring oil from multiple suppliers is a more reliable strategy to ensure multiple suppliers can be utilised to meet large quantities and further maintain the relationship between the supplier and X Y Foods. The next metric considered to recommend which supplier should be utilised is the truck capacity and the distance between the facility and the supplier. If the gap can be covered in two batches (from one supplier), the truck capacity is more relevant to the distance as fewer deliveries are made, leading to a more efficient supply chain. However, if the same number of batches can minimise the gap, then looking at the distance between the facility and the supplier becomes relevant. It is important to note that distance does not impact X Y Foods' costs, as this indirect cost is the supplier's responsibility, not X Y Foods's. However, the environmental cost is accounted for by X Y Foods. Having a longer route impacts the carbon footprint of the factory. Based on the mentioned metrics, we depict the optimal supplier(s) X Y Foods should source from based on the mentioned conditions.

4.4.3 Carry-over Volume

As mentioned in Chapter 2.3, one of the limitations of the current weekly routine is that it does not consider carry-over volume from the previous month (if any). Hence, a formula will be constructed to assess whether there has been a surplus of supply in the month that can be used to fulfil the demand in the month. Modelling carry-over volume addresses specification three, as found in Table 3.

To be able to identify whether a carry-over volume is available for a given month, the following formula is used:

$$CV_i = \max \{ C_{i-1} + S_{i-1} - D_{i-1} , 0\}$$

$$where\ (i\ \in \{1, \dots ,6\}).$$

C_i : $contracted\ volume\ during\ month\ i$

S_i : $Spot\ volume\ during\ month\ i$

D_i: $Demand\ of\ oils\ during\ month\ i$

CV_i: $Carry\ on\ volume\ during\ month\ i$

4.4.4 Oil consumption

The oil consumption is a specification that aims to project the weekly oil consumption. This visibility allows X Y Foods actors to oversee what is being consumed per week, per factory, and per supplier, achieving the highest levels of visibility. This view allows the coordinators to track what the factories are consuming. Additionally, it oversees how much of the contracts are being consumed. This view is currently not present in the weekly routine. Not only does this specification offer insight but it can also be used extensively to track the current situation.

Primary data extraction is conducted to model this specification. After validation with the coordinators, the best way to replicate the reality of the situation in terms of the consumed oil per week, per factory, and per supplier is by extracting the open Purchase orders (PO) and delivered volumes and summing them. Open POs are the orders placed by the material schedulers weekly used to fulfil the demand requirements that are communicated; once those purchase orders are placed, they are automatically used from the contract account of the respective supplier. *Delivered volumes* are the volumes that the respective factory received. For this reason, this summing of those metrics allows X Y Foods to analyse and visualise the weekly consumption per plant, supplier, and factory.

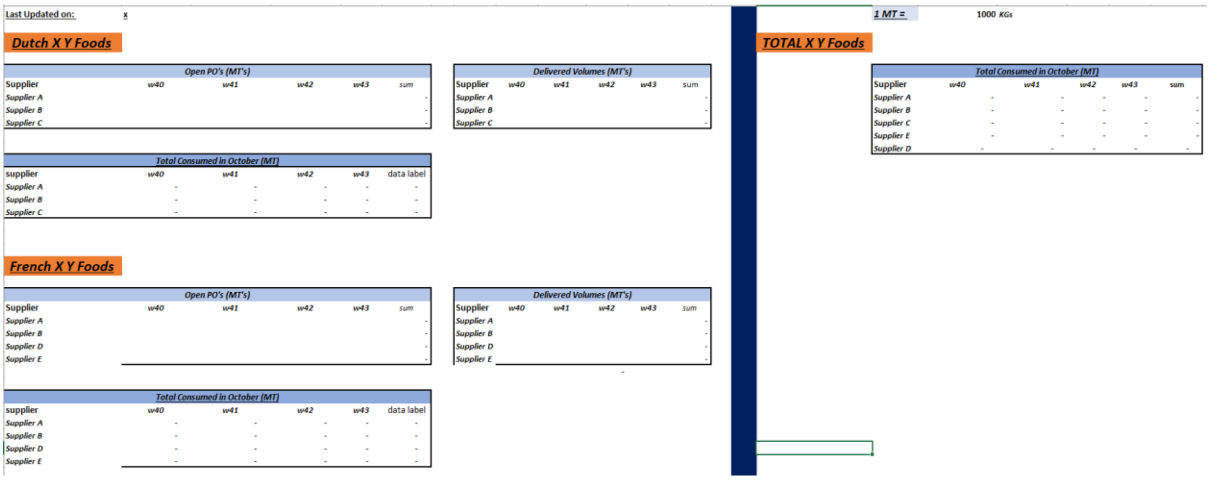

Figure 10: Weekly consumption detailed view

Figure 10 shows how the weekly consumption view is developed; this provides a view of the weekly amount of oil consumed per factory per supplier. The table on the right of the figure showcases the volumes of oil consumed per supplier regardless of the plant. This view provides buyers insight into the total amount of oil consumed per supplier. In the results section, this figure will be populated and reflected visually in the dashboard. The data extraction method can be found in Appendix C.

4.4.5 Action Point Tracker

The action point tracker is part of specification 8 in Table 3. This tracker allows monitoring tasks in procuring, managing, and tracking the oil portfolio. This will be created using a table that includes the responsible actors, the task to be completed, and the due date. The importance of having an action point tracker is as follows.

Task accountability: established through an Action Point Tracker, which effectively refers to ownership and responsibility for individual action items or tasks. This practice aids in preventing missing or ignoring tasks while also establishing responsibility for the timely completion of assigned actions by individuals or teams.

Task visibility: provides a central location for tracking and monitoring all relevant tasks for the procurement and management of oil. This, therefore, reduces ambiguity and miscommunication (one of the problems in the current weekly routine).

Improved communication: promotes better communication within the team, as task-related information is readily available, as well as the respective deadlines and the responsible personnel.

4.4.6 Other Specifications

This section of modelling the dashboard will address the importance of all other specifications in Table 3. Modelling the specifications found below can be done quickly manually, and hence, no specified section is needed to address those specifications:

Filter data based on category and region

Filtering data based on a given category is essential for relevance. Filtering allows the user to visualise data that is only relevant to them. For example, when visualising oil consumption at respective plants, it is relevant to filter the data based on the factory and supplier since the respective factory coordinator can have visibility of his concerned factory. The buyer can have insight into how much oil the factory has consumed from a particular supplier, which helps decide how much oil is needed to be procured and from what supplier. This specification is implemented indirectly in the dashboard by ensuring all other specifications give insight based on a specified category and region.

Represents up-to-date data

The current weekly routine takes place every Thursday. This is because the material schedulers place orders every Wednesday, so having the weekly routine every Thursday ensures that the most recent data is presented. Hence, the dashboard will be updated before the weekly routine meeting on Thursday.

Cover Page

A cover page showcasing the dashboard's functionalities and a how-to-use section are vital since the dashboard is a new solution needing user adoption. Clear instructions on using the dashboard can facilitate user adoption and promote its effective use within X Y Foods. Additionally, the use of a cover page promotes clarity and guidance. It gives users a clear understanding of the dashboard's objective and how to navigate and interact effectively.

4.5 Conclusion

This chapter started with the motivation for the choice of the statistical study that will be used to validate whether the demand requirement assumption is justifiable or not. After this, data analysis was conducted to verify whether it was reasonable to make this assumption. It was concluded that the demand requirement assumption only holds for French X Y Foods. This chapter then delved into which demand data set will be used, combining both for reasons stated in the respective section. The specification requirements for modelling the dashboard were set as follows. The last section of this chapter showed the specifications built, explaining what, how, and why those specifications were chosen and built. It was concluded that the dashboard is built by taking into account all the needs of the different actors within the supply chain, and hence, a solution was built based on a given time period, per factory, and per supplier, which, as a result, gives X Y Foods better visibility. Chapter 5 of this report revolves around the results obtained after the dashboard was built and implemented, which looks at the results achieved after implementing the identified specifications. Additionally, it explains the rationale behind choosing suppliers to procure from to avoid a stock-out situation as part of the decision-making tool.

5. Results

This chapter dives into the results of the implemented dashboard. The final dashboard solution is described and discussed at length. The key learnings of the dashboard and the decisions that need to be taken to prevent a stockout situation are also described. Finally, the section evaluates how the newly created specifications impact the supply versus demand gap expected at a given month. Section 5.1 of this chapter discusses the impact of the implemented carry-over volume model on the gap between supply and demand for a given month. Followed by a weekly consumption view that gives insights to the buyers addressed in Section 5.2. Section 5.3 The decisions are taken to prevent a stockout situation based on the observed gaps. Section 5.4 shows the final view of the interactive dashboard. This chapter ends with a conclusion, which is assessed in section 5.5. This chapter is part of the seventh and final stage of the MPSM methodology – evaluating the solution and hence addresses the final research question:

4. What recommendations could be made from the dashboard?

5.1 Carry-over volume results

Before the decisions X Y Foods can make from the implemented dashboard can be addressed, we discuss the insights the specifications built and what they potentially offer. After implementing the carry-over volume model, it was found that there is a surplus of oil supply for the given months based on the supply and demand of oil for each month between the Dutch and French X Y Foods factories.

Month	**Surplus in supply?**	**Amount of surplus (in MT)**
August	*No*	-
September	*Yes*	421
October	*Yes*	359
November	*No*	-
December	*Yes*	758
January	*TBC*	-

Table 7: surplus in supply versus demand for French X Y Foods

Month	**Surplus in supply?**	**Amount of surplus (in MT)**
August	*Yes*	378
September	*No*	-
October	*No*	-
November	*Yes*	250
December	*Yes*	389
January	*TBC*	-

Table 8: Surplus in supply versus demand for Dutch X Y Foods

Tables 7 and 8 show that a surplus in supply exists for both factories. Namely, French X Y Foods had a surplus in supply in September and October of 421 and 359 MT, respectively. Additionally, it can be seen that there is an expected surplus of 758 MT in December based on the current expected demand requirements for the French factory. As for the Dutch factory, there was a surplus of 378 MT in August. Moreover, there is an expected surplus of 250 and 389 MT, respectively, in November and December.

The identified surplus for the given months at the given factories can be used to fulfil the demand of month $i + 1$ and hence used as a carry-over volume.

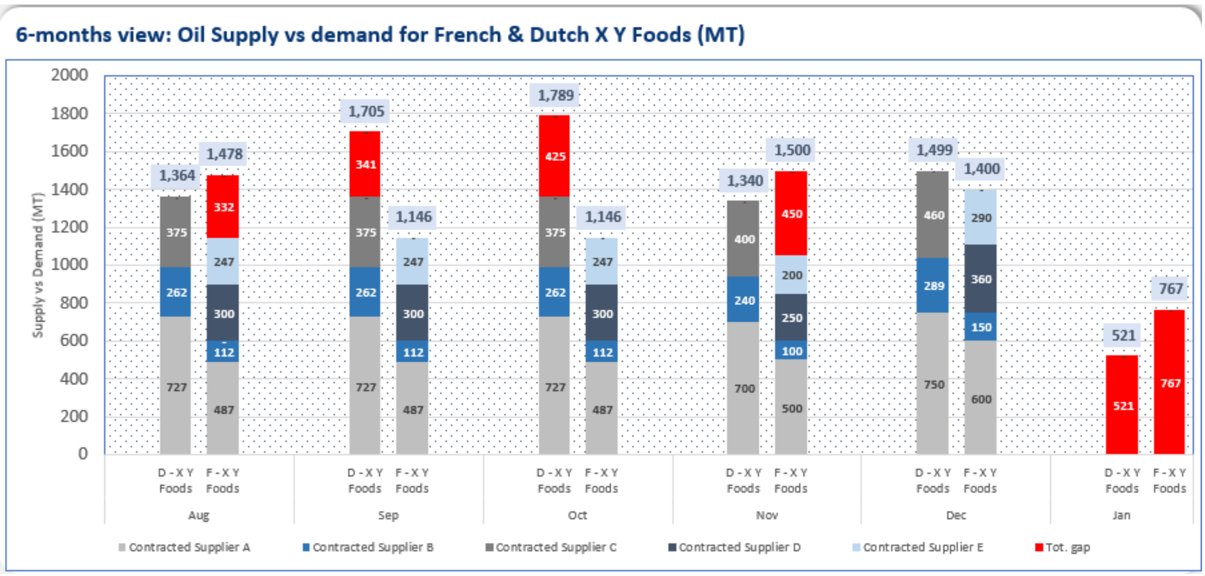

Figure 11: Gap before carry-over volume implementation

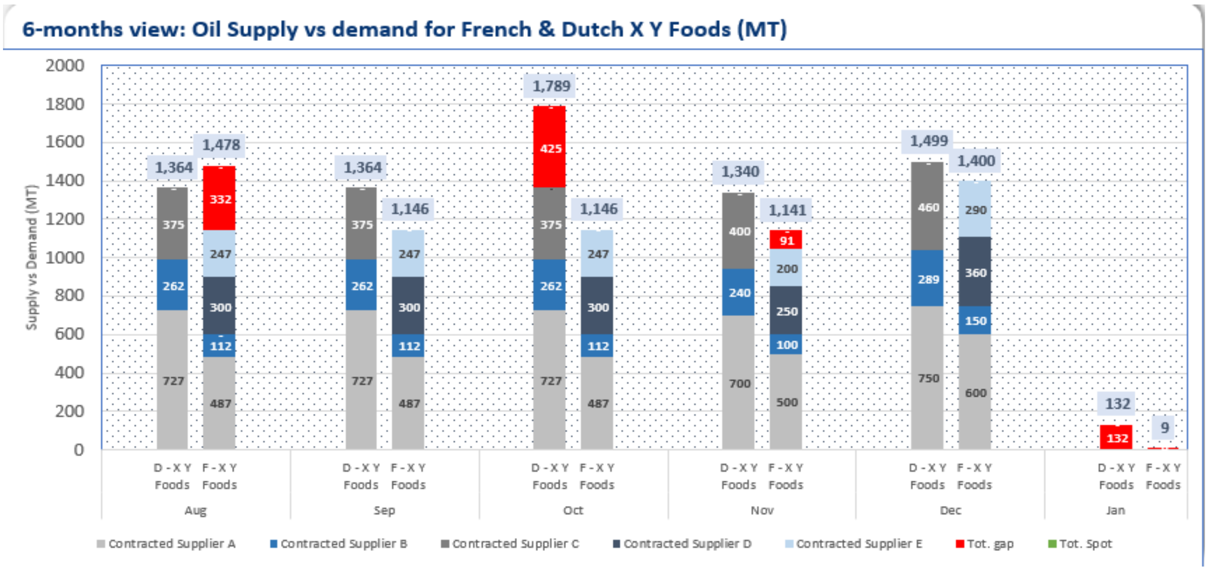

Figure 12: Gap after carry-over volume implementation

Figure 11 shows the identified gap before the carry-over volume implementation. The results of the carry-over volume implementation can be seen in Figure 12. The carry-over volume implementation results are profound. Most identified gaps are either gone or reduced. A detailed view of the results in terms of gaps is shown in Table 9.

month	***Factory***	***Gap before carry-over volume implementation in (MT)***	***Gap after carry-over implementation in (MT)***
August	*French X Y Foods*	332	332
September	*Dutch X Y Foods*	341	0
October	*Dutch X Y Foods*	425	425
November	*French X Y Foods*	450	91
January	*Dutch X Y Foods*	521	132
January	*French X Y Foods*	767	9

Table 9: Carry-over volume implementation results

August

The gap seen in August was kept the same even after the carry-over volume implementation. The reason for this is that the data set analysed starts in August. The analysed data set does not have the supply and demand for July; hence, we cannot see whether a surplus in July could be taken into August to minimise the gap of 332 MT for French X Y Foods.

September

What can be seen in September is that the gap that was present before the carry-over volume implementation is no longer present. This is because, during August, Dutch X Y Foods procured more oil than needed to meet the demand set by the production facilities. Hence, this extra supply can cover the gap in September. The carry-over volume implementation has not only shown visibility in this regard. However, it can also reduce potential gaps by replicating the situation's reality by looking at it holistically.

October

The 425 MT gap in October has remained the same after the implementation. This is because there was a surplus supply for the Dutch factory in September. This shows that the carry-over volume does not necessarily "create" extra oil but analyses the supply versus demand of every given month and connects them. An absent approach previously was the weekly routine, which looked at each not separately and without interconnectedness.

November

The gap for November has been reduced by 79.7%. The gap has been shortened to only 91MT for the French factory. The reason for this is the surplus in supply identified in October. The surplus of 359MT helped minimise the gap to 91MT.

January

Before the implementation of the carry-over volume, the visualised gap for the French and Dutch factories was 767 and 521 MT, respectively. It is important to note that that "gap" is present because the buyers did not book the contractual volumes for January. Hence, this gap is seen as there is currently no supply in the system to meet the forecasted demand in January; however, because of the surplus seen by both factories in December, the visualised gap is only 132 and 9 Mt for the French and Dutch factories, respectively. Looked at the supply data X Y Foods book on average 1,000 MT for each of its factories. Because of the carry-over volume implementation, X Y Foods will now only need a total of roughly 141 MT to meet the demand of both factories, given that the demand remains constant.

5.2 Weekly oil consumption visibility

The weekly oil visibility consumption is the following specification to be addressed within the implemented dashboard. Having this level of visibility and filter on the oil consumption in terms of what is consumed per week, per factory, and supplier has several competitive advantages. Regarding resource allocation, weekly consumption data provides the basis for an informed decision-making protocol. It helps optimise the allocation of oil and allows X Y Foods actors to track whether the factory can consume the sourced oil of that given month. This insight, therefore, allows X Y Foods to become more agile and allows the company to track the oil portfolio in more detail and accurately, which helps it respond faster to fluctuating demands. The modelled weekly view for both French and Dutch X Y Foods is seen in the figure below.

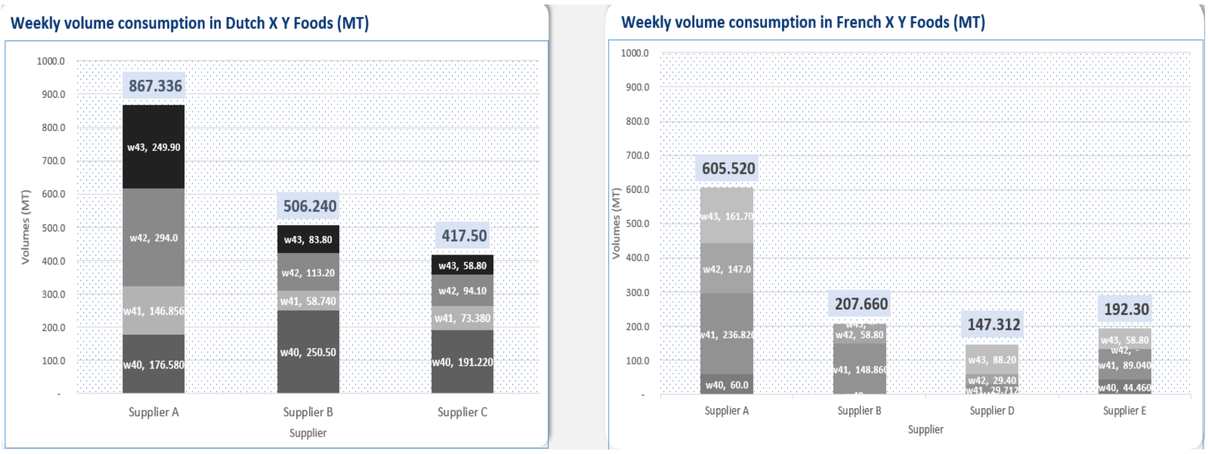

Figure 13: Weekly oil consumption

Figure 13 shows the weekly oil consumption for October. Hence, weeks 40 to 43 are addressed. The given consumption is based on the delivered volumes entering the respective plants and the POs placed for a given week. Additionally, a more detailed view is developed and can be seen in Appendix C. Moreover, this implemented model can help oversee the consumed percentages of the contracted volumes, a view and insight not currently available in the weekly routine.

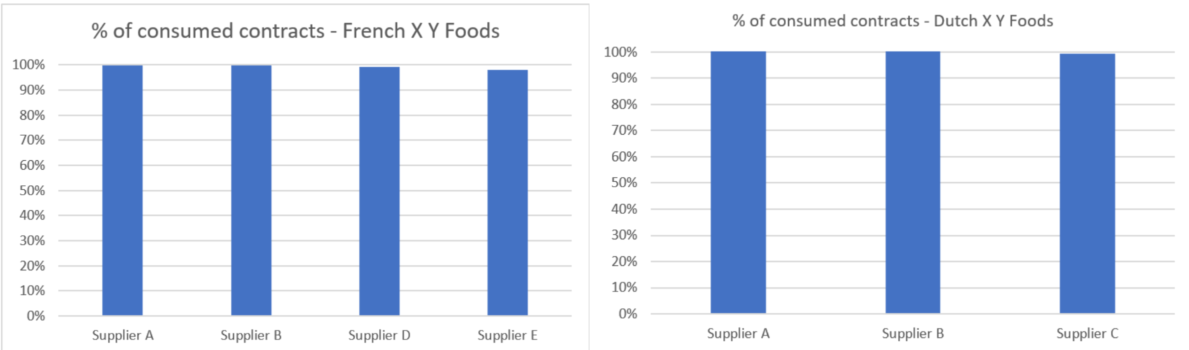

Figure 14: Percentage of used contracts for French & Dutch X Y Foods

This additional view gives the buyers insight into how much X Y Foods has used its contractual agreements with the respective suppliers over October. It can be seen that for both Dutch and French X Y Foods, the contracts with the suppliers have primarily all been used, with the least being 98%. For the Dutch factory, this makes sense since all the supply was needed to fulfil the exceeding demand in October. However, this should be different for the French factory. In an optimal scenario, it is best if each month only consumes the supply needed to fulfil the demand. For example, if the demand for a given month is 100 MT, consuming only 100 MT of the contractual agreements is best. However, this is currently not the case, and hence, for October, there has been a surplus of nearly 360 MT in the French factory, to be precise. However, this surplus can be used to fulfil the demand for the next month. Overbooking oil has severe implications in terms of inventory management and costs. The storage of this volume for a more extended period increases holding costs and warehouse expenses. Therefore, a healthy percentage of consumed contracts for October would be 68%. A percentage of 68% means that French X Y Foods has consumed enough of its contracts to meet the demand of 787 MT for October. Any percentage higher than that would mean that X Y Foods has ordered more than it needs to fulfil the demand during October.

5.3 Decision-making tool to avoid a stockout situation

This section aims to give recommendations based on the decisions X Y Foods can take to meet the demand of its factories, where a gap is seen in month i. Given that the new proposed dashboard has significantly reduced the observed gap, gaps still need to be addressed, as shown in Figure 12.

Month	***Factory***	***Observed Gap in (MT)***
August	*French X Y Foods*	332
October	*Dutch X Y Foods*	425
November	*French X Y Foods*	91
January	*Dutch X Y Foods*	132
January	*French X Y Foods*	9

Table 10: Gap between supply and demand

A decision must be taken to cover the observed gap in the given months and factories in Table 9. As discussed, the dashboard has a section called spot volumes that aids with the decision-making process and gives recommendations on the amount of oil that needs to be ordered to prevent a stockout situation. Insight on which supplier to order from will also be presented based on the decision tree depicted in Figure 9.

5.3.1 Sourcing Decisions for French X Y Foods

For August, the French factory has an observed gap of 332 MT, so a dual-sourcing strategy will be used. The lead time in this scenario is irrelevant since all suppliers have a lead time of a maximum of one week, and the expected shortage of supply is expected to happen towards the end of the third week of August (week 33); hence, the demand is not high in the first two weeks. Based on this discussion, the given recommendation is to procure oil from suppliers A, B, and E in week 32. The choice of week 32 goes back to minimising the holding cost as much as possible while still meeting the demand at the right time. We source four whole batches totalling 182 MT from supplier A, 90 MT from supplier B done over two whole batches, and two batches totalling 59 MT from supplier E.

There is an observed gap of 91 MT in November after the carry-over volume implementation. Given that the demand for November is relatively high in the first two weeks, it is essential to ensure that oil sourcing is done in the first week of November to meet the high-demand requirements. It is optimal to choose a supplier with the least lead time in that case since the demand for November in French X Y Foods is met by the contracted volumes as well as the carry-over volume of 421 MT from October, given the high volatility of the demand requirements data it is best to choose a supplier with the lowest lead time to ensure the demand is met in times of fluctuating data. Looking at the decision tree in Figure 10, the recommendation for November is to procure 91 MT of oil from supplier E, which will be done throughout two total deliveries of 45.5 MT per delivery.

To conclude the sourcing recommendations for French X Y Foods, January has a gap of 9 MT. This gap is currently observed due to the absence of contractual agreements for January. Therefore, we will deviate from the decision tree depicted in Figure 9. X Y Foods will not need to reach a contractual agreement with its suppliers to fulfil the demand for the French factory. Additionally, it is not wise to order spot volumes since the minimum order quantity (MOQ) is 25 MT. Hence, the recommendation for January is to sign contractual agreements with each of the suppliers supplying the French factory based on the demand requirements for February. With that, add 10 MT of the contracted volumes for February to meet the demand for January. Finally, ensure that one batch of the MOQ (25 MT) is delivered in the first week of January.

5.3.2 Sourcing Decisions for Dutch X Y Foods

For October, the Dutch factory is facing a shortage of 425 MT. It is challenging to source such an amount of oil on short notice from one supplier; hence, we opt for a dual-sourcing strategy. Given the high demand in the first two weeks, 425 MT will be split amongst all three Dutch X Y Foods suppliers. Suppliers A, B, and C. Four full deliveries from supplier A totalling 182 MT will be ordered, as well as three full deliveries totalling 75 MT from supplier C. Finally, the rest of the gap will be filled by ordering three whole batches and a fourth batch of 31.5 MT totalling 168 MT from supplier B. The sum of this sourcing strategy is 421 MT, which aims to cover the gap for October.

The situation for January is similar to that of French X Y Foods, the differences being in the size of the gap of 132 MT; hence, using the strategy of using the contracts of February to cover the gap for January is not sufficient. To cover the gap of 132 MT, we will source oil from supplier A, with three batches totalling 132 MT.

5.3.3 Sourcing decisions reflected in the dashboard

This section shows how the sourcing strategy explained in the previous section will be reflected in the dashboard.

Spot Volumes							
Factory	Month	Supplier	Gap (MT)	Confirmed vol. (MT	Quality approval	Spot	Further actions
French X Y Foods	August	Supplier A	332	182	yes	182	NA
French X Y Foods	August	Supplier B	332	90	yes	90	NA
French X Y Foods	August	Supplier E	332	60	yes	60	NA
Dutch X Y Foods	October	Supplier A	425	182	yes	182	NA
Dutch X Y Foods	October	Supplier B	425	168	yes	168	NA
Dutch X Y Foods	October	Supplier C	425	75	yes	75	NA
French X Y Foods	November	Supplier E	91	91	yes	91	NA
Dutch X Y Foods	January	Supplier A	132	132	yes	132	only spot is needed to cover gap
French X Y Foods	January		9			-	align 10 MT from feb. contracted voulmes

Figure 15: Decisions taken to cover the gap

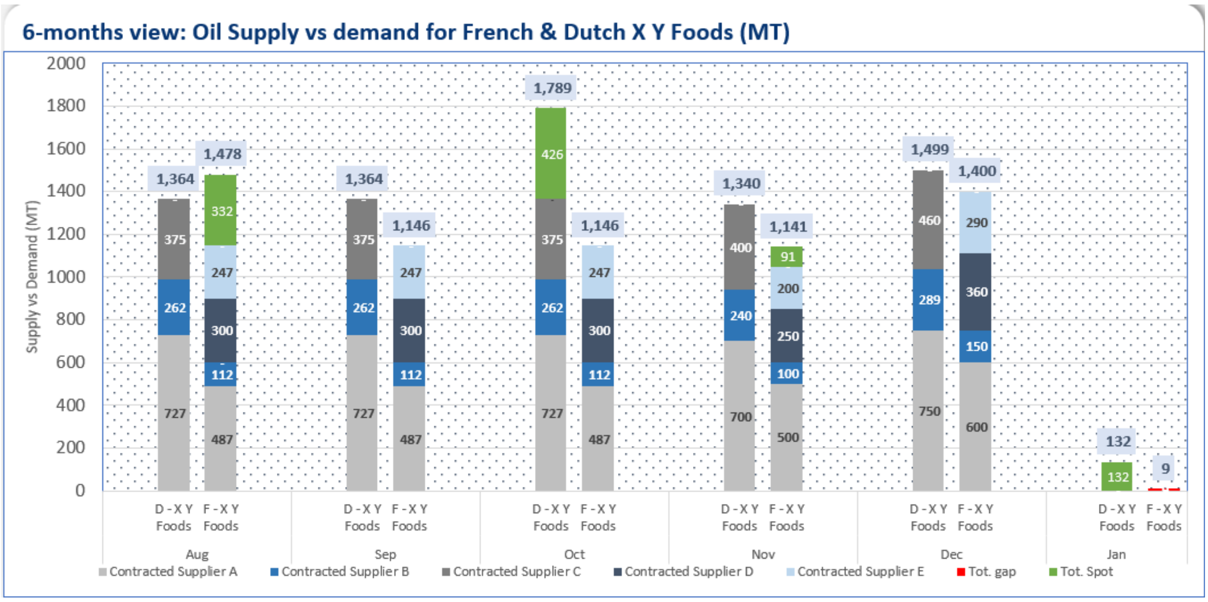

Figure 16: Final supply versus demand view

With those recommendations in place and as the current demand requirements hold, X Y Foods will prevent a stockout situation for all six months and for both factories. The 9 MT gap seen for French X Y Foods for January will eventually be covered once the contractual agreements for February are in place as per the given recommendation. It is important to note that those gaps are covered only by acquiring quality approval from the FSQ team.

5.4 Final Dashboard View

The final interactive dashboard view is depicted in Figure 17. This dashboard aims to help visualise the supply and demand of the raw material oil. Additional insight, such as an expected gap, actions to cover the gap, each factory's weekly oil consumption, and an action point tracker, can all be seen in Figure 17.

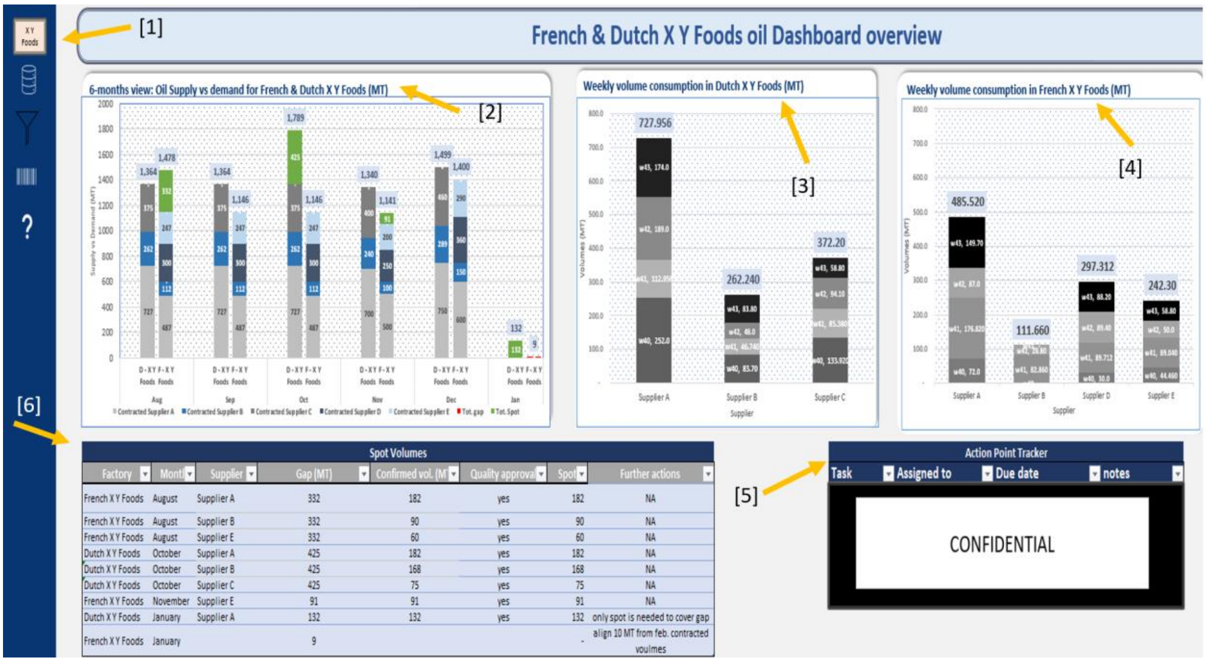

Figure 17: Interactive Dashboard

[1] is a section that helps the user navigate through the different detailed sheets of the Excel file. The first button navigates to the main screen (dashboard view), and the second button navigates to the sheet that contains the monthly view insight. This includes the contracted monthly volumes, gaps, and carry-over volumes. Next, the third button gives a detailed view of the weekly oil consumption; the fourth button gives a view of all the necessary contact details of the suppliers, coordinators and all necessary actors involved in the oil portfolio, both internally and externally. Finally, the last button links to the cover page of the dashboard. Those detailed sheets can be viewed in Appendices B-E [2], which show a supply versus—demand figure. Per bar, this includes the supply of oil from the different suppliers. A red bar (if present) shows a gap between the supply and demand. A green bar shows that a decision has been taken (based on the dashboard's recommendation) to cover the gap. This view gives insight into each of the six months for both factories. [3] shows what is being consumed per week, per factory, per supplier for Dutch X Y Foods; the same is shown for [4] but for the latter factory. [5] is an action point tracker that shows what task needs to be taken to either manage, track, or source the raw material oil and the person responsible for the task. Finally, [6] shows the recommendation section based on the observed gaps in Figure 12. We assume that all recommendations have been granted quality approval to show the reader how this is reflected on the dashboard.

5.5 Conclusion

This chapter reflected and analysed the results of creating the dashboard; the dashboard's detailed specifications have been addressed. Additionally, the results of the implemented dashboard have been addressed at length. Finally, decisions were made regarding the number of oil that needed to be sourced to prevent a stockout. Chapter 6 of this report concludes the thesis by summarising the main findings, giving recommendations to X Y Foods, and finally, describing the limitations and future research opportunities associated with this thesis.

6. Conclusion and Recommendations

The motivation behind this research is to allow X Y Foods to visualise the supply versus demand of their essential raw material for producing product x, oil, in a holistic manner and, hence, solve their core problem of not having clear and concise visibility of their supply versus demand of oil. The main research question is, *"How can X Y Foods visualise the supply versus demand of oil and make procurement decisions to avoid a stock-out situation in its production facilities?"* This enables the formulation of research that tackles this supply chain issue.

The following findings, recommendations, and limitations were present during this research and are addressed in the sections below. Section 6.1 highlights the conclusions drawn following the research and the recommendations addressed in Section 6.2. This study's limitations and future research opportunities are discussed in Section 6.3, respectively.

6.1 Main Findings

To have a holistic understanding of the supply and demand of oil at X Y Foods, an interactive dashboard was created that provides X Y Foods information about the supply and demand of oil on a weekly and monthly basis, the consumption of oil for both factories, namely, French and Dutch X Y Foods, the percentages of the consumed contracts per supplier. Those specifications were all constructed such that a view per supplier, per factory, per period aided the highest levels of visibility possible for this scenario.

This interactive dashboard was not only created to replicate the reality of the situation but also to serve as a decision-making tool and, hence, give recommendations regarding the amount of oil to be sourced for each given period where a gap is expected. Further elaboration on which supplier to source from based on an identified sourcing strategy was also present. The main findings of the research are explained below:

1. Product x is produced at French and Dutch X Y Foods. The essential raw material needed for production is oil from five different suppliers. Suppliers A and B supply oil to both factories, whereas supplier C supplies oil to the Dutch facility only, and suppliers D and E supply oil to the French facility.
2. The demand requirement assumption turns out to be faulty for Dutch X Y Foods. Hence, there is a mismatch between the demand for oil-extracted SAP and the factory-communicated demand. We testify whether the demand requirement assumption holds by comparing the MAPE against 15%, which is the threshold of an accurate data set, due to the nature of calculating the oil demand, which is outside the scope of this research.
3. MSE and MAPE were the metrics used to testify to the demand requirement assumption. It is concluded that French X Y Foods has a better data quality overall than the Dutch facility. The reason for this is the lower value obtained from the demand requirement of the French facility (11.1%) in contrast to 15.4% at the Dutch factory, which implies that, on average, the SAP data is closer to the factory requirement data for the French factory than for the Dutch one.
4. For supply security reasons, it has been decided that the chosen data set will be a mixture of SAP and factory-communicated data. The higher demand per week i will be chosen to ensure enough oil is procured during mismatched demand data.
5. The carry-over volume specification showed the negative implication of treating each month separately. The gap of a given month was minimised immediately by using the preceding month's surplus to cover the current month's demand.
6. The weekly oil consumption visibility gives detailed insight to the buyer regarding whether each factory is consuming its contractual volume with its suppliers.

7. There are five instances where there is an expected gap in both factories. This gap is covered with the *spot volume* specification volume created. Which is the volume sourced during the month to meet the demand in the contracted volumes, but it fails to do so.
8. The interactive dashboard provides a breakdown on a weekly and monthly basis regarding the amount of oil on hand, the demand needed to fulfil the production of product x, and the potential gaps between supply and demand (if any). A further breakdown is available per factory, per supplier, and period. Finally, a recommendation section is present regarding the amount of oil to source to cover the gap, which is motivated by the sourcing strategy identified in Section 4.4.2.

6.2 Recommendations

1. The first recommendation concerns the amount of oil that needs to be sourced to avoid a stock-out situation. There are five instances where a gap is expected. The following recommendations are given to close the given gap:

- Procure 182 MT from supplier A, 90 MT from supplier B, and 60 MT from supplier E for French X Y Foods for August.
- Procure 182 MT from supplier A, 75 MT from supplier C, and 168 MT from supplier B, which covers the gap of 421 MT for Dutch X Y Foods for October.
- Procure 91 MT from supplier E to cover the gap for French X Y Foods for November.
- Sign a contractual agreement for February for French X Y Foods and add 10 MT of the contracted volumes for February to meet the demand of January. Finally, ensure that one batch of the MOQ (25 MT) is delivered in the first week of January.
- Procure 132 MT from supplier A for Dutch X Y Foods for January.

2. The second recommendation is to eliminate the demand requirement assumption, as there is a mismatch between the factory-communicated data and SAP. Hence, a root cause analysis should identify why those discrepancies occur. Additionally, it is essential to solve this issue as the proposed strategy in this thesis concerns making recommendations based on the higher demand between both datasets, which solves the problem in the short term. However, using this strategy in the long run has severe implications for the business's inventory and cost levels. Excess inventory or stock-out risk is reduced when sourcing decisions are made based on accurate demand forecasts.

3. Use an efficient sourcing strategy that optimises the factories' inventory levels. The dashboard allows for such a strategy as it gives detailed visibility over the supply chain and allows for long-term planning via the 6-month view. This strategy includes fulfilling the demand through contractual agreements. Spot volume should only be used in case of emergencies. Closing the gap through contractual agreements maintains a good relationship with the suppliers and ensures price stability, including stable pricing and shielding through market fluctuations. This is important for oil since this is a raw material ordered from a volatile market with potential cost spikes. Another reason for closing the gap through contractual agreements is supply assurance. Long-term contracts secure a consistent supply. However, sourcing in a short period may result in uncertainties and challenges in securing the desired quantities.

6.3 limitations and future research

My role as a researcher and intern at the company is operational; for that reason, the current proposed solution addresses the problem from an operational point of view. However, the interactive dashboard addresses the core problem: the lack of supply versus demand visibility. My research has identified a limitation in how the company gathers its data—the proposed solution aimed to make sourcing recommendations based on known data quality. However, noticeable discrepancies between SAP and the factory communicated data limit this thesis and presented a future research opportunity.

The second limitation of this research study is choosing the data points with higher demand, which has a trade-off of increased costs. The reason behind this choice is to ensure that enough oil is procured to minimise the chance of a stock-out situation, given the purpose of this research.

Future research opportunities should include understanding why those discrepancies occur and solving those discrepancies so X Y Foods can make procurement decisions based on an accurate data set, which, of course, has a strategic and not an operational stance.

Due to its promise and improved visibility, the dashboard should be implemented, and future research should arise to compare how X Y Foods operates with better visibility and more insight regarding the supply versus demand of oil.

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Appendix

Appendix A: Consumption of oil data extraction

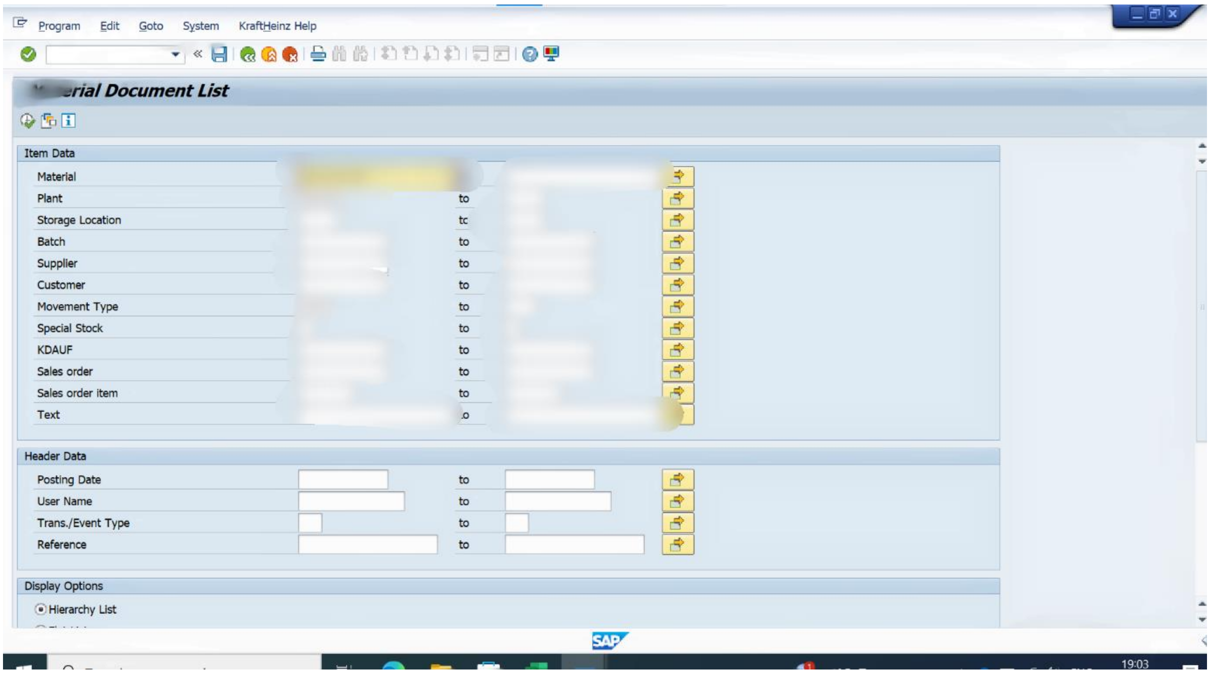

Figure 18: SAP extraction of delivered volumes

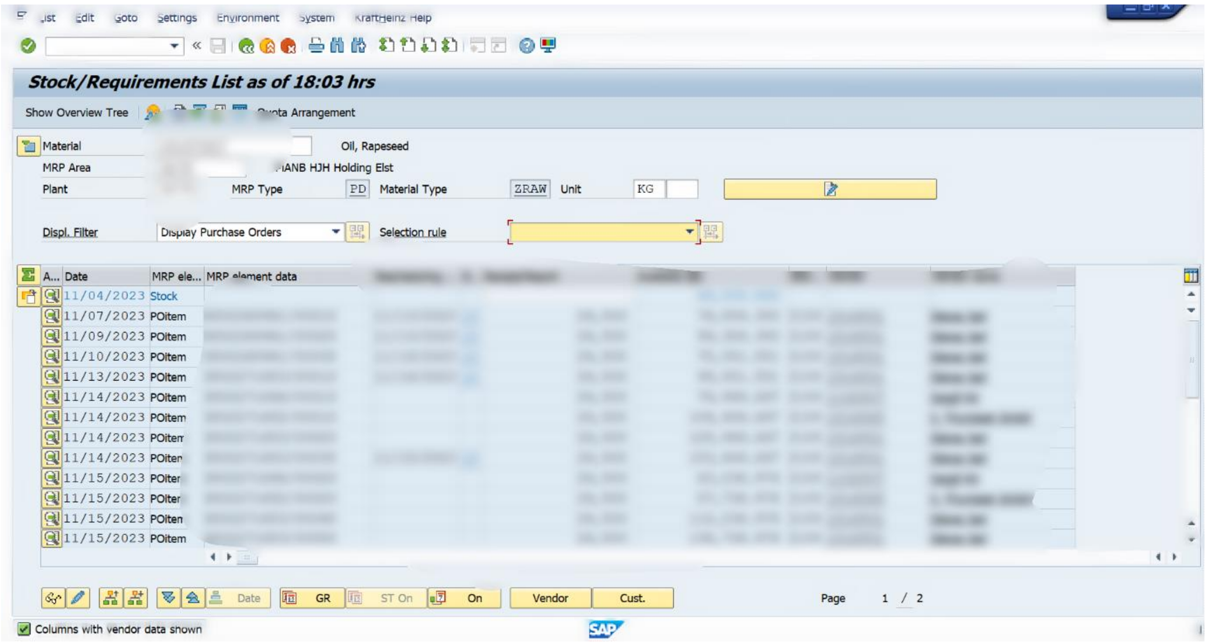

Figure 19: SAP extraction of purchase orders

Appendix B: Detailed Monthly Data

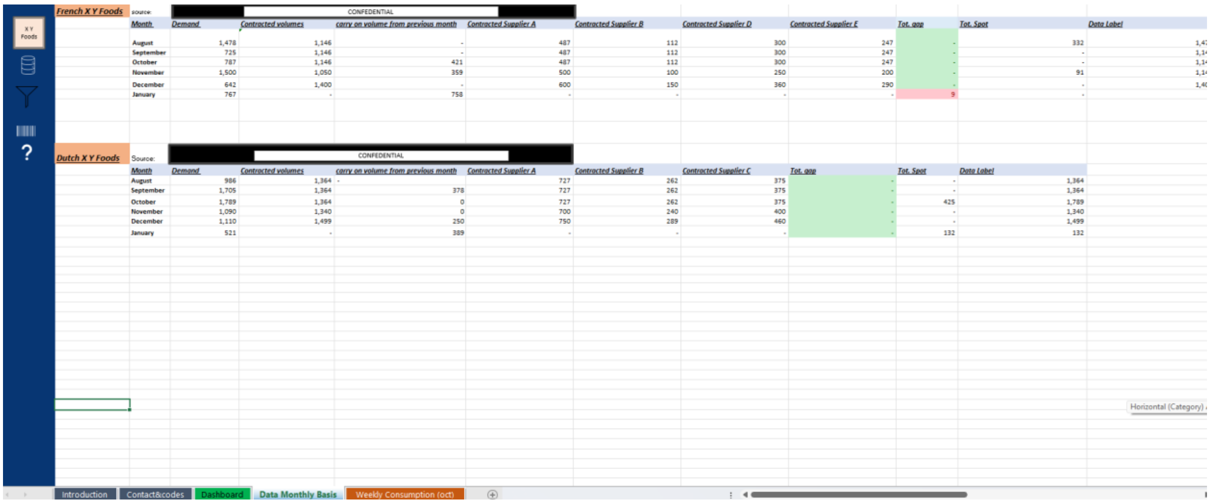

Figure 20: Monthly view

Appendix C: Detailed Weekly Consumption Data

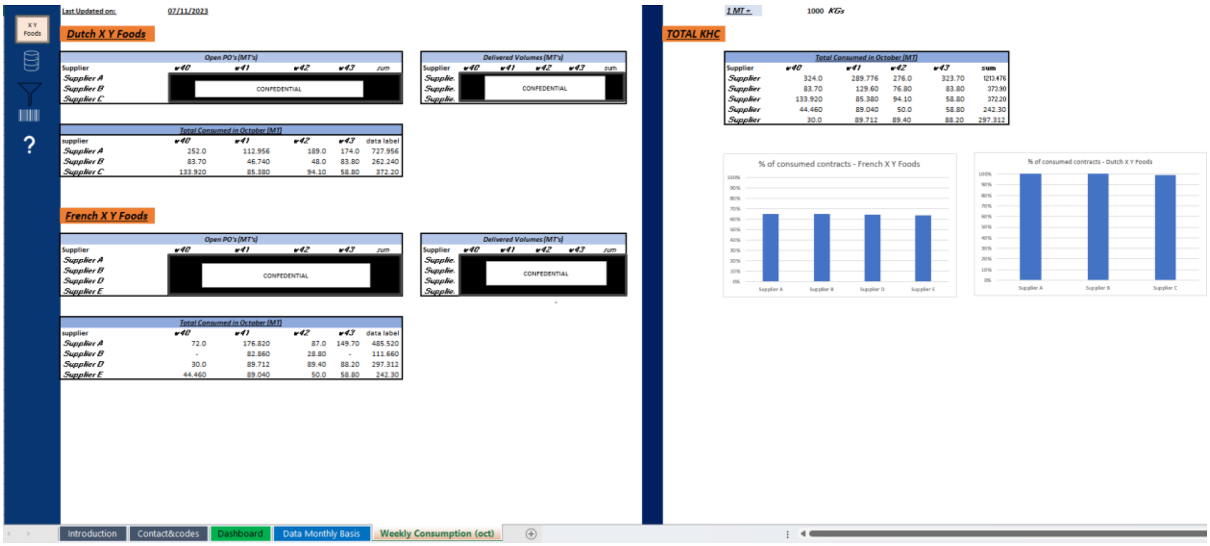

Figure 21: Weekly view

Appendix D: Dashboard Cover Page

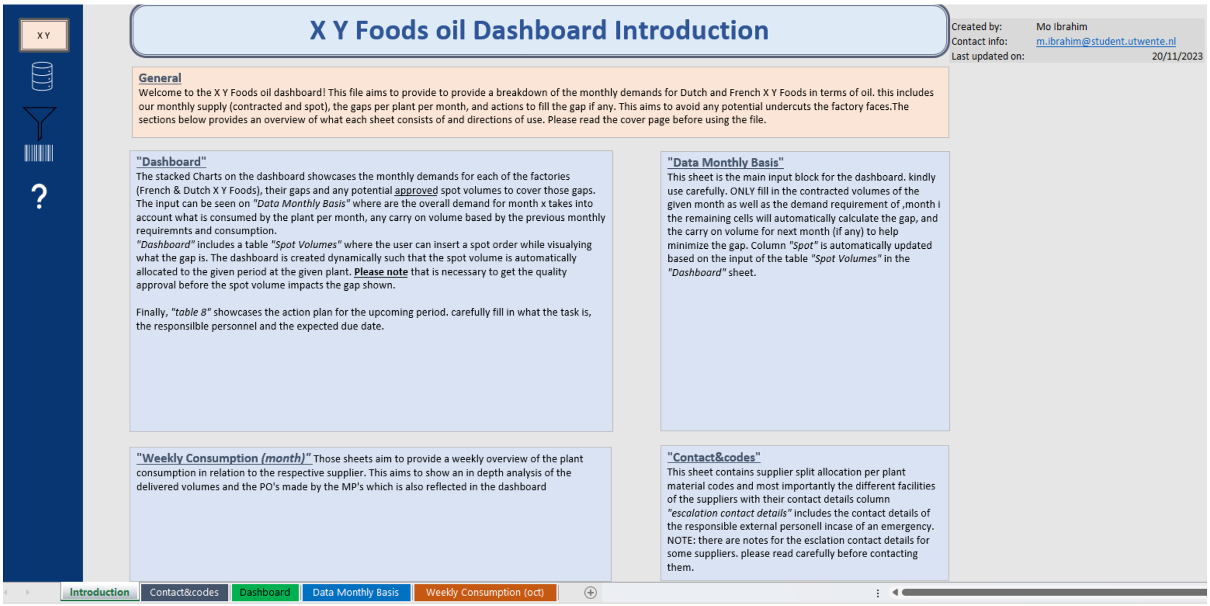

Figure 22: Cover Page

Appendix E: Contact & Codes

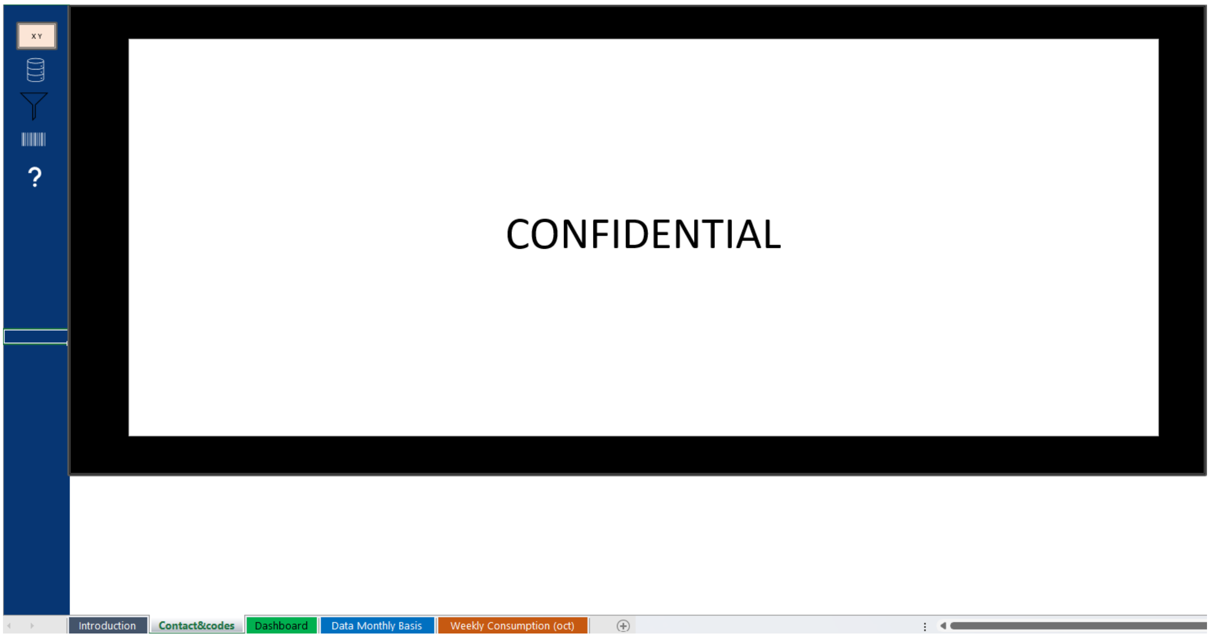

Figure 23: Contact & codes for suppliers and factories

Appendix F: Code to calculate MSE and MAPE

```
Function MeanSquaredError(rng1 As Range, rng2 As Range) As Double

Dim n As Long
Dim i As Long
Dim sumSquaredDiff As Double

n = rng1.Rows.Count     'is able to calculate MSE of any range size
sumSquaredDiff = 0

    If n <> rng2.Rows.Count Then
        MeanSquaredError = CVErr(xlErrValue)    ' returns an error if the ranges are of different sizes
        Exit Function

            End If

For i = 1 To n

sumSquaredDiff = sumSquaredDiff + (rng1.Cells(i, 1) - rng2.Cells(i, 1)) ^ 2     ' sums the sqaured errors

        Next i

MeanSquaredError = sumSquaredDiff / n    ' returns the mean of the squared error

End Function
```

```
Function MeanAbsoultePercentageError(rng1 As Range, rng2 As Range) As Double

Dim n As Long
Dim i As Long
Dim sumAPE As Double

n = rng1.Rows.Count     'is able to calculate MAPE of any range size
sumAPE = 0

    If n <> rng2.Rows.Count Then
        MeanAbsoultePercentageError = CVErr(xlErrValue)   ' reutrns an error if the ranges have different sizes
        Exit Function

            End If

For i = 1 To n
    If rng1.Cells(i, 1) <> 0 Then
      sumAPE = sumAPE + Abs((rng1.Cells(i, 1) - rng2.Cells(i, 1)) / rng1.Cells(i, 1))    ' sums the absolute percentage errors
          End If

Next i
MeanAbsoultePercentageError = (sumAPE / n) * 100    'returns the mean of the ABS

End Function
```

Figure 24: VBA code to calculate MSE and MAPE