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Bachelor Thesis IEM

Improving Master Data Governance Processes Within Supply Chain Management

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Management Summary

The subject of this research is the improvement of master data governance within the supply chain of Company X, a pharmaceutical company. Effective master data governance is crucial for ensuring data quality, consistency, and accuracy, which are vital for decision-making and maintaining regulatory compliance.

Problem

This research focuses on the processes of master data governance because Company X faces challenges with its master data management, including data inconsistencies, manual data entry processes, and inadequate utilization of their enterprise resource planning (ERP) system, SAP S/4HANA. These issues lead to operational inefficiencies and potential delays in the supply chain. The following research question is addressed in this thesis:

''*How can the master data governance processes be improved to enhance supply chain management efficiency?*''

Method

Four activities of the Design Science Research Methodology are used in this research to reach a solution for the core problem. The research involved a detailed analysis of current master data governance practices at Company X, including interviews with the master data specialists, as well as data analysis from the SAP S/4HANA ERP system and the cloud-based content management platform, Box. A SWOT analysis was performed for each major process to identify strengths, weaknesses, opportunities, and threats. After this, literature review was conducted to gain knowledge on different master data management tools, best practices for coordination between stakeholders and real-life case studies on successfully implemented master data governance processes within different industries.

Results

Data inconsistencies and errors were found in the material master maintenance, with a considerable percentage of materials having incorrect or missing information. Although there were relatively fewer errors in the purchase info record maintenance, the missing price data could cause delays and financial penalties. The source list maintenance analysis showed that some percent was outdated and some of the source lists contained inconsistent valid to dates. The high inconsistency and missing data in the customer master maintenance have a chance of frequent order and shipment delays. On top of that, standardization documents are lacking. The bill of materials and master recipes have manual updates of data that need to be highly accurate, making the process time consuming and error prone. The quality inspection maintenance data tables were often empty, making quality control and maintenance difficult. Lastly, technical limitations and communication gaps with suppliers and customers are key challenges in collaboration between stakeholders.

Key findings

After the data analysis in the ERP system and the interview results, some key findings were established. Data quality issues were common across various tables in the ERP system, leading to operational inefficiencies. Furthermore, reliance on manual data entry and updates increased the risk of errors. Moreover, the absence of standardized documentation for customer data contributed to inconsistencies of the master data. Also, suppliers and customers often faced technical difficulties in integrating with the system of Company X. Lastly, many functionalities of the SAP S/4 HANA system were not being fully utilized.

Conclusion and evaluation

To address these challenges, this thesis research recommends automating data entry and updates, standardizing documentation processes, enhancing technical capabilities and integration with suppliers and customers, and improving utilization of ERP system functionalities. By implementing these improvements, Company X can enhance its master data governance processes, leading to better data quality, operational efficiency, and overall supply chain management. Regular training, audits, and the adoption of new technologies are essential steps towards achieving these goals.

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List of Abbreviations

BDP = Bulk Drug Product
BOM = Bill of Materials
B2B = Business-to-Business
DP = Drug Product
DS = Drug Substance
ECR = Engineering Change Request
EDI = Electronic Data Exchange
ERP = Enterprise Resource Planning
KPI = Key Performance Indicator
MDG = Mater Data Governance
MDM = Master Data Management
MD3M = Master Data Management Maturity Model
OTC = Order to Cash
PTM = Procure to Make
PTP = Procure to Pay
QAL = Quality Approved List
SCM = Supply Chain Management
SRQ = Sub Research Question
SWOT = Strengths, Weaknesses, Opportunities and Threats
3PL = Third-Party Logistics Company

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1 Introduction

1.1 Company and Department Description

Company X is a leading biopharmaceutical company focusing on genetically defined diseases. The company has a small number of successful products commercialized in the market over the last couple of years. However, it is still a growing company because it still has products in development. Since it is a worldwide pharmaceutical company, the supply chain is overly complex and so is the master data of it. The supply chain of the company is essential for the production and distribution of its innovative medicines. The chain contains various stages starting from sourcing the raw materials for drug development to sourcing pack and label components to eventually manufacture and distribute finished products. This procedure involves good coordination with suppliers and manufacturers who need to ensure the materials' quality and that the delivery to the pharmacies is efficient and on time. Quality control measures are implemented throughout the production process to ensure the completeness of the drug products. When the manufacturing process of the drugs is completed, the products are distributed to healthcare providers and patients through a network of distribution plants and pharmacies in many countries, but mainly in the U.S., where the manufacturing is happening. Overall, Company X's supply chain has an important role in supporting its aim to develop and deliver innovative treatments for genetic diseases that improve the lives of patients worldwide. The purpose of master data governance (MDG) is to improve the quality, consistency, and relevance of data across the whole organization (Bonnet, 2013) and thus is highly important in pharmaceutical organizations because it ensures that all critical information related to their drugs, customers, clinical trials, suppliers, and manufacturing processes is accurate and consistent. This accuracy is highly important for decision-making, maintenance of product quality and safety, and ensuring compliance with strict GxP (Good Practices) regulations within the company. On top of that, the improvement of this MDG will result in an efficient and streamlined supply chain process.

The process of the master data in the supply chain department where this research focuses on is the material master and customer master. These are modules in SAP that the company uses from the Enterprise Resource Planning (ERP) system. The ERP system is called SAP S/4 Hana in this company and this system is a comprehensive, packaged software solution designed to integrate all aspects of the processes and functions into a unified system (Klaus et al., 2000). This is because these parts of the supply chain are managed by the master data team of the supply chain and the whole supply chain process would be too broad to apply the research to. The first part focusses on the creation, change and deletion of materials. The process flow of this part can be obtained in Appendix A. These materials could be raw materials, semi-finished materials (Drug Product (DP), Drug Substance (DS), Bulk Drug Product (BDP)), pack and label components, finished products, and products such as general supplies, packaging supplies and spare parts, and have all different codes which are mentioned later on. The second part contains the customer information, which is important to establish the ship-to, bill-to, and sold-to customer information in the system.

There are seven different types of materials which all support the production of the four products on the market. The most important material types are raw materials (ROH), semi-finished products (HALB), pack and label components (ZPKG) and finished goods (FG). The remaining components are exhibited in Section 2.1. There are plants worldwide in which these materials are stored, manufactured, or consumed, that is discussed later on in the report. If

materials come from an external supplier is supplying the materials, a purchase info record (PIR) with information of the price, lead time and vendor is needed. When a PIR is created, a source list with information where the materials come from is also needed. When a material needs other materials to be manufactured, the bill of materials (BOM) and master recipe are created in the system as well. This is the case with semi-finished products and finished goods. The BOM and master recipe are connected by an ECR (Engineering Change Request) number which triggers the system to send out a notification to create them. The last part in the scope of material master data is the quality inspection plan, which is highly important since it is a pharmaceutical company. These are created in the system to make sure there is quality inspection for mainly ROH, HALB and FG products in the plants where they are maintained. Another part in the scope of this research are the many different vendors that supply the different products to the company's plants and the many different global customers in the system which are hospitals and pharmacies.

1.2 Problem Identification

Since Company X is expanding, various aspects within the supply chain are changing. This includes the management and the governance of the master data. About two years ago, the system changed from an older version of SAP to a newer version named SAP S/4HANA. This change in the system was needed because the older system is limited in the sense that the application ana database run on separate systems and is disk-based (ZaranTech, 2023) and because the company is growing, a more automated system was necessary. The new system allows faster analytics, data access and processing, which results in better performance. However, even though SAP S/4HANA is a better and more efficient system, it is not optimally used in the company. There are faults in the data because the governance is not optimal. These faults are for example duplicate data, missing data, data that does not match with the quality approved lists, work instructions or standard operating procedure documents, and data that is outdated but not deleted. There are several causes for this inefficiency, which are mentioned in the problem cluster in Section 1.2.1.

1.2.1 Problem Cluster

A problem cluster is a convenient tool to establish whether and how problems are connected (Heerkens & van Winden, 2017, p. 22). Figure 1 illustrates the connections between the problems through cause-and-effect arrows. By identifying these connections, we can identify which problem to address first. This selected problem becomes the 'core problem'. This problem is the insufficient implementation of master data governance (MDG) practices in the supply chain management (SCM) of the company and there are some causes to this problem as seen in Figure 1. The first influence is the lack of a comprehensive ERP tool and the ineffective usage of the existing master data management (MDM) tool. These problems lead to incomplete or outdated data and data inaccuracy, inconsistency, and errors. The result of these different data insufficiencies is that there is difficulty in data analysis and reporting. Another cause of the core problem is the complexity of the supply chain data ecosystem. As already mentioned, the supply chain is overly complex and so is the master data of it. This leads to limited data integration and interoperability within the various parts of the supply chain. This again, leads to difficulties in data analysis and reporting, but also to operational inefficiencies and increased costs. The fact that the company is growing in a high pace is also a cause of the core problem. This causes difficulty in implementing data analytics and insights. The last problem causing the core problem is the resistance to change and the resistance of implementation of best practices. This is because of the lack of awareness and understanding of the ERP system from stakeholders and specialists.

1.2.2 Core Problem and Action Problem

The chosen core problem in this research is **''Insufficient implementation of master data governance practices in Supply Chain Management''** because this problem can only be influenced and does not have a direct cause itself (Heerkens & van Winden, 2017, p. 22). This core problem is selected because it describes most of the other problems in the company together in one problem. Through observation and interviews with a part of the master data team employees, it was concluded that the insufficiencies in the master data occurred several times. Because the supply chain is large and complex, there are many stakeholders and specialists involved in the planning, manufacturing and production process and they are all coming back to the master data team when they encounter issues. Most of the time, these issues occur because the master data is not streamlined and organized within the organization.
The chosen action problem in this research is **''Overcoming insufficiencies in Master Data Management within the Supply Chain''**. An action problem arises when there is a noticeable difference between what is considered standard or expected (norm) and the actual situation (reality), as perceived by the individual facing the issue (Heerkens & van Winden, 2017, p. 22). The norm and reality are not clearly seen in this action problem but could be defined by describing ''insufficiencies'' differently. By insufficiencies, the data inaccuracy, inconsistency, errors and incomplete or outdated data is meant. These factors are the reality in this action problem. The norm in this case, would be overcoming those insufficiencies by getting as close to 100% of no errors, incomplete or outdated data and standardizing it with the existing documents.

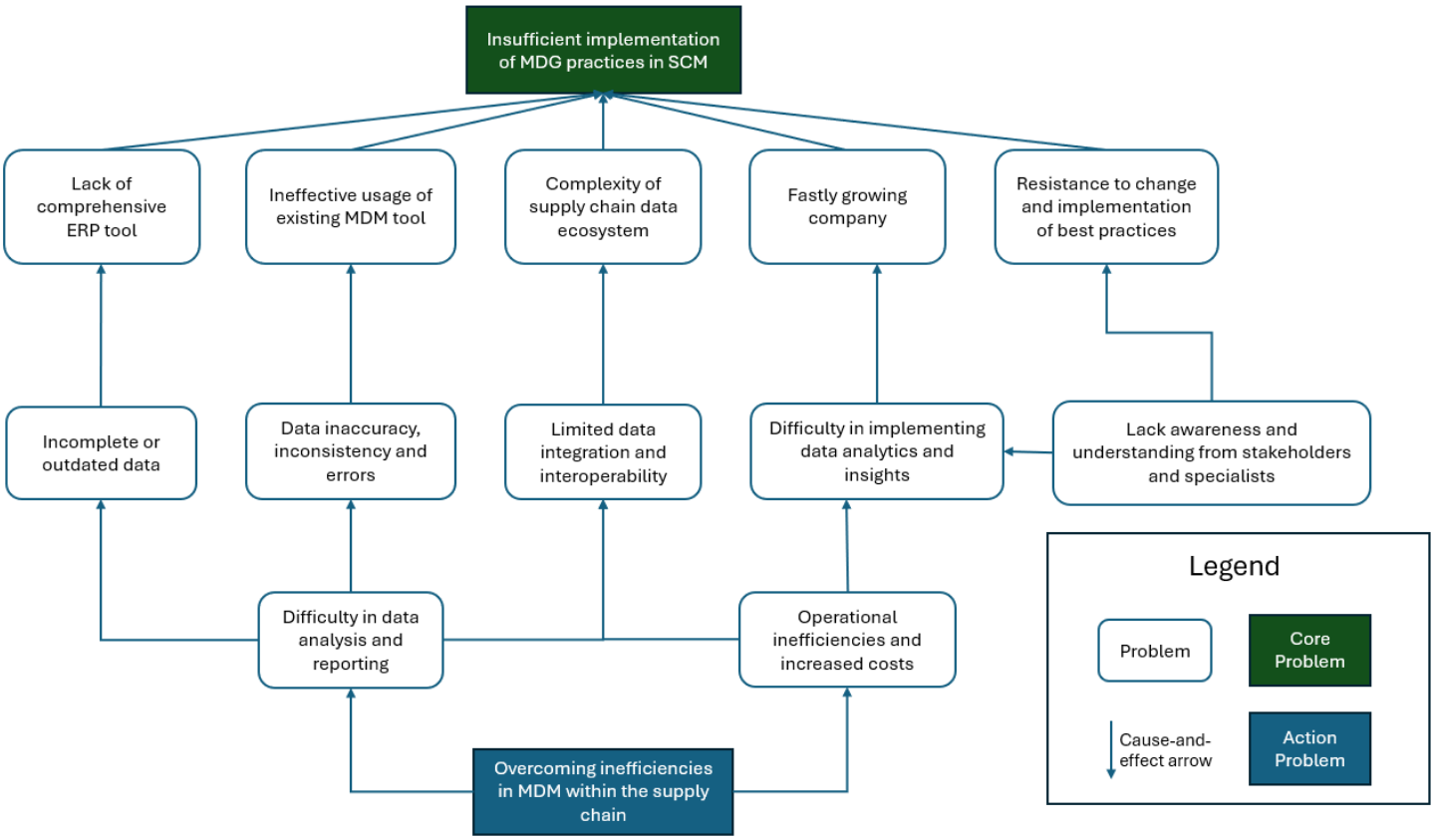

Figure 1. Problem Cluster

1.2.3 Measurability of Action Problem

The action problem needs to be operationalized to be able to transform it into variables to eventually make it measurable through these variables (Cooper & Schindler, 2013, p. 201). Thus, the norm and reality of this problem should be expressed in concrete and measurable variables (Heerkens & van Winden, 2017, p. 50). These variables can be measured by indicators. The method used to quantify the variables is concretising variables (Heerkens & van Winden, 2017, p. 51). This method enables the indicators to feature some parts of the variable that may or may not exactly cover the variable. The indicators that quantify those variables are as follows: 'the percentage of biased and outdated records', 'the percentage of missing or incomplete data fields', and 'the number of discrepancies or conflicts in information'. The real value is not known yet. The norm value is as close to 100% as possible.

1.3 Problem-Solving Approach

Four activities of The Design Science Research Methodology (DRSM) are chosen to be applied to this research due to several reasons. Firstly, the DSRM approach is essentially focused on solving problems and advancing scientific knowledge by developing innovative solutions and generating design knowledge (Brocke et al., 2020). Also, the goal is to improve technology in information systems by creating solutions that address real-world problems and contribute to improving the surrounding environment. This problem-solving approach fits best in this research because it is highly important to gain knowledge about the design of MDG tools and the ERP system, which are information systems. Not all activities are applied in this study because there is no artifact created that is applied in the company. The four relevant activities of this DSRM are as follows:

Activity 1. Problem identification and motivation: This first step is very similar to the first step in the Managerial Problem-Solving Method (MPSM) as it is about defining the problem through, in this case, a problem cluster. In this step, the research problem is defined, and the value of the solution is justified. With this justification, the motivation to seek solutions for the identified problem increases.

Activity 2. Define the objectives for a solution: The objectives of a solution can be deducted from understanding the problem statement and knowing what is achievable and viable. These objectives can be quantitative or qualitative in nature. In this research, the objectives are mostly qualitative because we want to indicate ways in which a desirable solution is better than the current one and also outline how an innovation is anticipated to address previously unexplored challenges.

Activity 4. Demonstration: In this step, the application of the deliverables in addressing one or more occurrences of the problem is demonstrated, involving its use in the improvement of MDG in SCM. The ''product'' which is the deliverables is used to help solve the problem.

Activity 6. Communication: In the last step, the research and product are going to be communicated with the company. On top of that, there is going to be a colloquium where I will exhibit my research through a presentation for my teachers and the supervisor of the company.

1.4 Research Questions

To be able to solve the core problem, there are some questions that need to be answered. There is one main research question that helps solve the core problem and the sub research questions that divide the main and more complex research question into smaller parts to make it more manageable and easier to solve (Heerkens & van Winden, 2017, p. 122). The goal of this research is to improve the MDG process, so the main research question is formulated as following:

"How can the master data governance processes be improved to enhance supply chain management efficiency?"

The first part of this research question is a knowledge problem because it contains a description of the research population, variables, and relationships (Heerkens & van Winden, 2017, p. 23). This part of the question is investigated in the results part of this report (Chapter 4) and contributes to activity 4 of the DSRM since it demonstrates the product, which is the implementation plan, that is used to help solve the problem. With this question, we seek to understand the relationship between improving MDG processes and enhancing supply chain management efficiency. We investigate how changes or improvements in MDG processes affect supply chain management efficiency and what specific improvements can be observed through detailed case study analysis. The research population is the supply chain part that utilizes the MDG processes. The independent variable here is the MDG process and the dependent variable is supply chain management efficiency.

The sub research questions (SRQ) are formulated as following:

SRQ1: How is master data currently managed, stored, and maintained within the supply chain?

SRQ2: What are the main challenges or pain points associated with current master data governance processes and coordination?

These sub research questions are answered through observation within the company's system, interviews with supply chain and IT professionals, specialists and other relevant stakeholders of Company X and by means of a data analysis on the ERP system in a descriptive way. The master data regarding the processes described in Section 1.1 is thoroughly observed within the system and analysed how it is managed, stored, and maintained within their ERP system. This helps to get a clearer picture of what the current practices are regarding the governance of the master data. The answer to these questions contributes to the problem identification and defining the objectives for a solution, so to activity 1 and 2 of the DSRM.

SRQ3: What are the features and developments of current MDM tools in the market?

SRQ4: What collaboration is required between different stakeholders (e.g., suppliers, manufacturers, distributors) to improve MDG?

SRQ5: What are some real-world examples of companies or organizations that have successfully improved MDG in their supply chains?

These sub research questions are answered through literature review, case studies, and expert reviews and recommendations. This involves gathering information about the different MDM

tools in the market and their features, best practices on collaborations between stakeholders within organizations to improve MDG processes and case studies on already implemented MDM solutions within different industries. A part of this chapter includes an applied systematic literature review to gather the necessary information. These knowledge problems contribute to activity 3 of the DSRM because they help the design and development of the deliverables. It is the input for the suggested solution approach.

SRQ6: What KPIs are used to measure the effectiveness of MDG in the supply chain?
This sub research question is answered through literature review to identify commonly used Key Performance Indicators (KPIs) for measuring MDG effectiveness in the supply chain. A comprehensive list of potential KPIs is made. Furthermore, examining KPIs used in case studies will provide valuable insights into the practical application and their impact on supply chain performance. This knowledge problem contributes to activity 5 of the DSRM because it evaluates the solution by assessing the effectiveness of the product in addressing the problem.

1.4.1 Research Design

The type of research is mainly descriptive, and the strategy is mostly qualitative, which means that the focus lies in the description of facts associated with the subject population and understanding how and why things happen as they do (Cooper & Schindler, 2013, pp. 134 & 144). The data collection methods are mainly interviews, observation, analysis, and literature review. The interviews are conducted with five participants who are actively working with the master data in Company X. Like the organization, these participants are also anonymized. Table 1 exhibits more information about the participants. Three participants were asked to fill in the questions as a questionnaire because of the work time difference. Only five participants could contribute to the interviews since Company X is a relatively small company with few employees responsible for the different work fields in the organization. The research design of this report is described in Table 2. The table also contains the research population, subjects, data processing method and the tasks related to the sub research questions.

Table 1. Interview participants information

Participants	Work field	Method of Questionning	Based
Participant 1	Responsible for OTC side and IT	Interview	Amsterdam
Participant 2	Responsible for material and customer master data	Interview	Amsterdam
Participant 3	Responsible for PTP side and system development	Questionnaire	United States
Participant 4	Responsible for PTP business side and system development	Questionnaire	United States
Participant 5	Responsible for PTM business side and system development	Questionnaire	United States

1.4.2 Research Scope

As already described in Section 1.1, this research focuses on the master data department within the supply chain of Company X. Within this master data in the supply chain, the focus is on the data related to materials and customer creation, change, and deletion. The other modules in the ERP system regarding supply chain is not included in the research because they are not included within the responsibilities of the master data specialists. However, there is one role in the master data, vendor master, that is the responsibility of the finance team. The person responsible for this is taking part in the interviews to also get a brief understanding of the current state of this module. This is the only analysis regarding the vendor master. The research scope involves the development of the solution but not the actual implementation because there is a time limit of 10 weeks.

Table 2. Research Design

Knowledge Question	Type of Research	Research Population	Subjects	Research Strategy	Data Collection Method	Data Processing Method	Tasks related to SRQ
SRQ1: How is master data currently managed, stored, and maintained within the supply chain?	Descriptive	Company	Supply Chain master data team of specialists	Qualitative research	Short Interviews and System/Document Analysis (cross-sectional)	Qualitative analysis of responses, categorization of management practices.	Direct observation of the master data process, conduct interviews to understand the current situation better.
SRQ2: What are the main challenges or pain points associated with current master data governance processes and coordination?	Descriptive	Company	Supply Chain master data team of specialists, ERP tool	Qualitative research	Short interviews and Observation (cross-sectional)	Qualitative analysis of responses, identification of common pain points.	Direct observation of the master data process, conduct interviews to identify more pain points, create SWOT analysis and overview.
SRQ3: What are the features and developments of current MDM tools in the market?	Descriptive	Literature	MDM tools	Qualitative and quantitative research	Literature study for multiple sectors (cross-sectional)	Comparative analysis of features, functionalities, and user feedback and a scoring matrix.	Conduct an SLR, execute a comparative analysis with evaluation criteria to see if there is a potential tool that fits company's needs, use scoring matrix.
SRQ4: What collaboration is required between different stakeholders (e.g., suppliers, manufacturers, distributors) to improve MDG?	Descriptive	Literature	Stakeholders	Qualitative research	Literature review, case studies (cross-sectional)	Qualitative analysis of collaborative practices and relationship dynamics.	Conduct literature review and interviews with MDM team.
SRQ5: What are some real-world examples of companies or organizations that have successfully improved MDG in their supply chains?	Descriptive	Literature	Other companies and organizations (that have successfully improved MDG in their supply chain)	Qualitative research	Case study analysis (cross-sectional)	Qualitative analysis of case study findings, identification of successful strategies and outcomes.	Conduct a case-study analysis on industry sectors that have successfully implemented MDG.
SRQ6: What KPIs are used to measure the effectiveness of MDG in the supply chain?	Descriptive	Company and Literature	Effective KPIs, Supply Chain master data team of specialists	Qualitative and quantitative research	Literature review, interview result analysis, and Observation (cross-sectional)	Analysis of identified KPIs, categorization based on relevance and applicability.	Analyse and observe which KPIs are the most effective with the help of literature review, and make a list, conduct additional literature review.

1.4.3 Reliability and Validity

Validity in research means whether the results are true or not and whether a measure accomplishes its claims (Cooper & Schindler, 2013, p. 201). Since the goal in this research is to improve MDG activities in supply chain with the accuracy of the master data as indicator, it is important that the KPIs really measure the accuracy of the master data. There is internal validity, which means how much researchers can claim that changes in the dependent variable (the outcome) happened because of what manipulations are done to the variable (Cahit, 2015). For this reason, we carefully choose the dependent variable and the independent variable with the measurable indicators that influence it. There is also external validity. This happens when a cause-and-effect connection that has been observed can apply to different persons, settings, and times (Cooper & Schindler, 2013, p. 657). In simpler terms, the results of the research of your (smaller) group should be judged to apply to some other larger population. If the study lacks good external validity, its results are not considered credible. Since there are numerous other companies working with MDG in the supply chain department, this research could also be applied to other research populations or be used as a guideline.
Reliability in research means that the measurements are precise, accurate and supply consistent results (Cooper & Schindler, 2013, pp. 260-261). It makes sure that repeated measurements yield similar outcomes and are free from random errors. As already stated before, the most used data collection methods in this research are interviews, observations, and literature research. To make sure that the results are reliable, I evaluate the equivalence of the observations from other data collectors in the company. Additionally, I make sure that the interviews are as structured as possible and have a clear methodological description to make sure that it is precise and accurate and can be carried out by other researchers.

1.4.4 Limitations

There are some limitations in this research that are important to mention because they have an influence on the design, the data and the results of this project. First, it is relevant to mention that the results could be less valid and reliable because data of other organizations regarding the implementation of improved MDG processes would be private and not available or accessible for research. Since there are three knowledge questions that require literature research, it could have an impact on the results. Secondly, an important person in the company whose expertise was highly important regarding this research is no longer working with the company. Another important person with great expertise in the scope of the research that was guiding, is taking a longer leave. The reason why this could be a limit is because it is a company with a relatively small number of employees, so the departments do not have a high number of employees with the same responsibilities.

1.5 Deliverables

With the help of the research that is conducted to find a solution to the problem, the results are exhibited as the following deliverables:

1. An overview of the current practices, challenges, and opportunities for improvement, together with the development of the KPIs to measure the outcomes. Observations are made to analyse the current situation in the company and challenges and opportunities are identified through a SWOT (strengths, weaknesses, opportunities, and threats) analysis.
2. An analysis of different MDM tools available in the market. A list is made with the features, functionalities, the market leaders, and their performance metrics with the help of literature review. A scoring matrix is used to find what the best tools in the market are based on the needs of Company X.
3. A proposal of specific improvements and recommendations for the improvement of MDG processes.
4. An implementation plan outlining the steps, timelines, and resources required to carry out the solution proposal.

1.6 Outline

Table 2 exhibits the structure of the report with the chapters linked to the research questions of this research.

Table 3. Structure of the Report

Chapter	**Research questions**
1. Introduction	**-**
2. Current situation of the master data	*1. How is master data currently managed, stored, and maintained within the supply chain?*
	2. What are the main challenges or pain points associated with current master data governance processes and coordination?
3. Literature review on master data management	*3. What are the features and developments of current MDM tools in the market?* *4. What collaboration is required between different stakeholders (e.g., suppliers, manufacturers, distributors) to improve MDG?* *5.What are some real-world examples of companies or organizations that have successfully improved MDG in their supply chains?*
4. Results and implementation approach	**Main research question:** *How can the master data governance processes be improved to enhance supply chain management efficiency?*
5. KPIs and measurement of solution	*6. What KPIs are used to measure the effectiveness of MDG in the supply chain?*
6. Conclusion and recommendation	**All (sub) research questions**

2 Current Situation of the Master Data

In this chapter, the aim is to gain knowledge about the current situation regarding the master data and finding the root causes of the core problem by answering the first two sub research questions:

How is master data currently managed, stored, and maintained within the supply chain?

What are the main challenges or pain points associated with current master data governance processes and coordination?

The knowledge and facts about the current situation are gained through interviews and a questionnaire with the master data team of Company X by considering their perspective, through data analysis on MDG processes in the SAP S/4 HANA ERP system (see Figure 2) and a data management application named ‘’Box’’ that is used in this company. The questions of the conducted interviews can be found in Appendix B. A SWOT analysis is performed for each process to help give an overview of the different strengths, weaknesses, opportunities, and threats regarding the current situation. The opportunities found in the SWOT analyses help with eventually arriving at a solution.

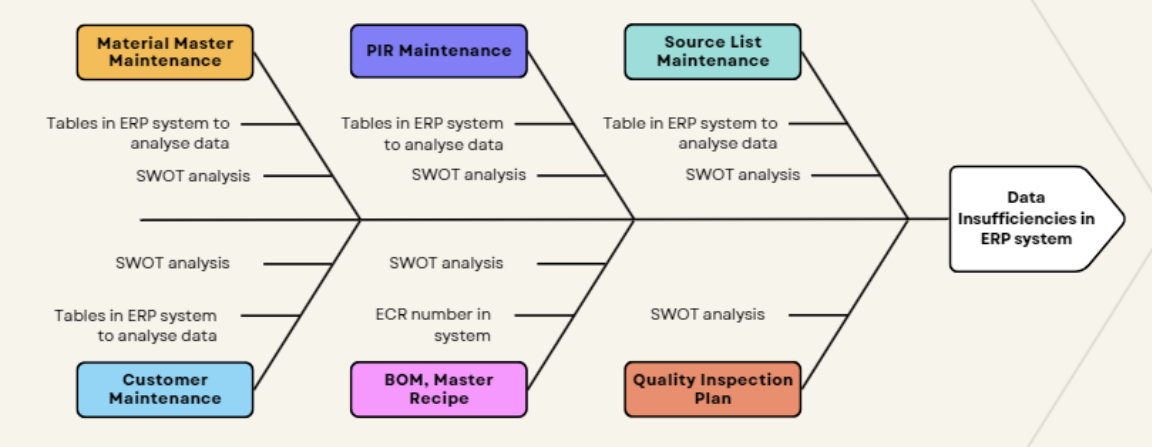

Figure 2. Ishikawa diagram on entry points analysed in ERP system

2.1 Material Master Maintenance

The first module that is analysed to extract the insufficient data is the material master. Within the ERP system, there are entry points that serve as navigation within the ERP system to access the transactions, functionalities and necessary information about all master data (Ben-Yosef, 2024). Within the system, there are different tables that provide all the fields maintained for different entry points. These tables are used to extract material master data and analyse it in Excel. Regarding the material master maintenance, there are two relevant tables withdrawn from the system for analysis. While analysing this set of data, the quality approved list (QAL) that describes what information is mandatory in the fields when entering characteristics of materials in the system is considered as the standard. This QAL is specifically used in Company X to indicate a guideline for the key fields in the material master. In this process, the outdated, double, and missing data is examined, and it is compared with the information on the QAL to see what data is incorrect in the system. The rest of the material master related data is also analysed with the help of the related tables in the next sections. The process flow of the material maintenance can be found in Appendix A.

The relevant tables for the material master maintenance analysis are called ‘MARA’ and ‘MARC’ within the ERP system. In the ‘MARA’ table, all the characteristics of the materials that are created in the system are shown, however not the characteristics of the plants that the materials are stored in. Better said, the information is on material level, which is called client level, and not on the plant level. The number codes of the materials indicate what the material type is (See Table 4), and they all have different standards that need to be met when creating them. There are 1,391 materials in total existing in the system. Some of them, approximately 16%, have a deletion flag checked, which means that the material is obsolete and no longer being used. When a material is considered obsolete, the stock in the system should be set to 0, the status should be changed to ’A5-Obsolete’, and some MRP settings should be changed accordingly. The stock levels and MRP settings are visible in the other relevant table called ’MARC’, which contains information about the plants that the materials are stored and consumed in. Active materials should all have status A3. Table 5 shows the meaning of the status codes.

Table 4. Material Codes per Type

Material Code	Material Type
10000000-19999999	Spare Parts (ERSA)
20000000-49999999	Semi-finished products (HALB - DP, DS, BDP)
50000000-59999999	Finished products (FG)
60000000-69999999	Raw Materials (ROH)
70000000-79999999	Pack & Label Components (ZPKG)
90000000-94999999	General Supplies (UNWB)
95000000-99999999	Packaging Components (VERP)

Table 5. Statuses with descriptions in ERP system

Status code in ERP System	Description of code
A1	New Item, Pending Approval
A2	Data Set-Up Complete
A3	Approved
A4	Discontinued
A5	Obsolete, Do Not Use Material

The most important findings in the tables of the insufficiencies in the material master are presented in pie charts. By most important findings, it is meant that only when four or more material codes contain a specific insufficiency within one of the fields are presented in the pie charts as incorrect data. As can be seen in Figure 3, there is a part of the materials that do not have a deletion flag (DF) checked but have a status A1 or A5, which should not be the case. However, there are also materials with a deletion flag checked but have status A1 or A3 which is clearly not aligned. The rest of the analysed data that is insufficient in the ‘MARA’ table is missing data. In total, there are 401 materials containing incorrect data, according to the QAL standards. However, since one material can contain more than one data error, it is not sure what the percentage of insufficient data is. Only the percentage of each field with incorrect data can be calculated. There are 224 materials with a deletion flag checked, and 62 of them have an incorrect status which is nearly 28%. Another key finding is that 16.5% of the materials have no transportation group filled in the system, which is mentioned as mandatory in the QAL. Lastly, 4% of the materials miss information in the catalog profile field, which is also indicated as mandatory in the QAL. The specialists stated that there was some data loss when a newer version of the ERP system was implemented, which could explain the data insufficiencies. They stated that the reason for this is because supporting documents mapping all different processes are missing.

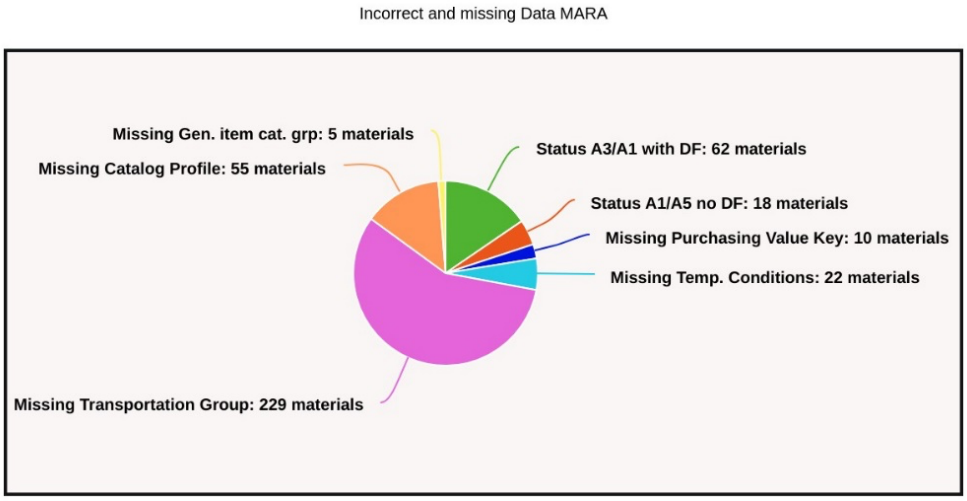

Figure 3. Incorrect and missing data from MARA table

As already mentioned, the 'MARC' table contains information about the materials on plant level, so the table shows all information of the plants of Company X in which the materials are stored and consumed. Since there are relatively more lines and fields with characteristics of the materials in this table because one material can be stored and produced in multiple plants of Company X, there are also more errors measured.
There are relatively many insufficiencies in the master data of the plant information. The pie chart and explanation of it can be seen in Appendix C. In total, there are 2,591 lines of data and 5,491 insufficiencies analysed, which is almost double of how many materials exist in the ERP system, 1,391. Most of the insufficiencies are wrongly filled in the system or missing data that should be filled in with a standard value according to the QAL. A relatively large number of materials have status A5 or no status at all and no deletion flag checked, which should not be the case. Also, some materials still have status A1 or A2 while they show as being active in the system.
In Figure 4, the inconsistency of the ABC indicator field is shown. This field is filled out for one part of the materials but left out for most of the materials. It is not mentioned as a mandatory field in the QAL and also not in the material request form, so it is unclear when or what indicator needs to be filled in for which material. The specialists indicated that there are people in the organization that do not know how to work with the functionalities in the ERP system. This can also cause inconsistencies of the master data. Figure 5 shows the descriptions of the indicators.

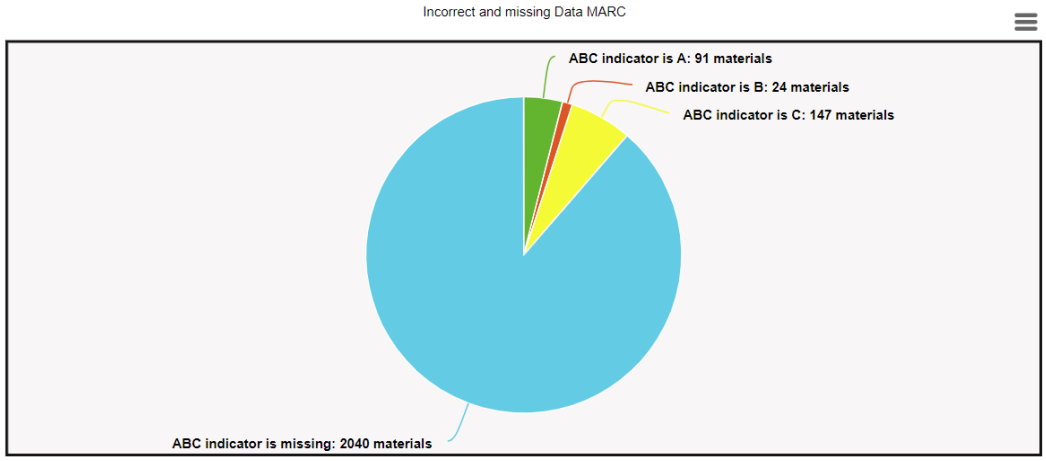

Figure 4. Inconsistent and missing data from MARC table

A...	Description
A	Significant Material
B	Material - Medium Significance
C	Material - Low Significance

Figure 5. ABC indicator descriptions in ERP system

For the maintenance requests of the materials, there is a form that needs to be filled in electronically by the people who request it. This form is filled in by the responsible stakeholders and specialists in a documenting system. Next to the QAL, this form also contains information about the material (see Appendix D). This information is mandatory to fill in because it is requested by the stakeholders that plan the flow of the material maintenance. This results in the information on the form being consistently filled in the system when creating, extending or changing materials, PIRs and source lists. The specialists stated that the form does not contain all the mandatory key fields in the ERP system which means that sometimes the stakeholders can miss some fields or do not know what information exactly needs to be filled in. Figure 6 shows all the SWOT components analysed in this section.

Figure 6. SWOT analysis of material master maintenance

2.2 PIR Maintenance

Apart from the tables for the materials, there are also two tables for the PIRs that are used to analyse the master data. The first table is called 'EINA' and exhibits the PIR number and the connected material number or material group number. It contains information about the material rather than the purchasing data which is exhibited in the second table called 'EINE'. This purchasing data includes for example the plant numbers, lead times, the prices, and the order quantities. Since there are not as many fields in the entry point for the maintenance of PIRs as there are in the entry point of the maintenance for the materials, the incorrect data is also a lot less. Also, most of the fields in this module are mandatory so one cannot create a PIR

without filling in these fields. Both tables are combined for their results on the pie chart in Figure 7, which shows the percentage of insufficient data out of the total of the associated table.

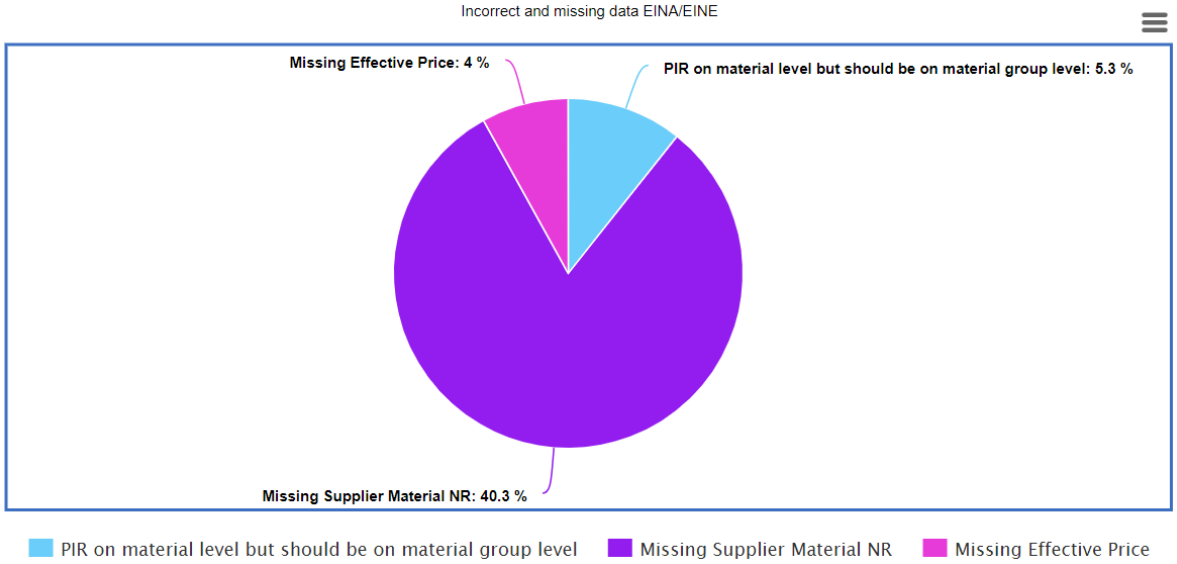

Figure 7. Incorrect and missing data EINA/EINE tables

The specialists indicated that when the price is missing there are delays in different processes such as approvals and deliveries which affects customer satisfaction and financial losses because the company gets penalties for late payments. Figure 8 exhibits the SWOT components that are analysed in this section.

Figure 8. SWOT analysis for PIR maintenance

2.3 Source list Maintenance

Furthermore, there is a table 'EORD' that exhibits information about the source list master data. Since the source list has even fewer fields than the PIR, the only error that could be obtained was the outdated data. The rest of the information is mandatory and must be inserted in the entry point sufficiently because otherwise materials is not able to be externally supplied, which can lead to delays in different processes as is also stated by the specialists. In Figure 9,

the numbers and percentages of source lists with a validity date in the past can be obtained with the different dates. It can be noticed that 11.7% of the source lists are outdated and still present in the system. Since these source lists are not active anymore, they should be removed from the system. The validity to dates of 2024 in the past and 2023 are obtained as outdated and the validity to dates of 2099, 2999, and 9999 are dates that are valid to 'forever'. These dates are set this way so that the material master specialists do not have to constantly check if the validity to date needs to be extended because the source lists are still valid. However, these dates are rather inconsistent because there are three valid to dates in the future that indicate the same meaning but are inserted in the system with different dates. Figure 10 exhibits the SWOT components analysed in this section.

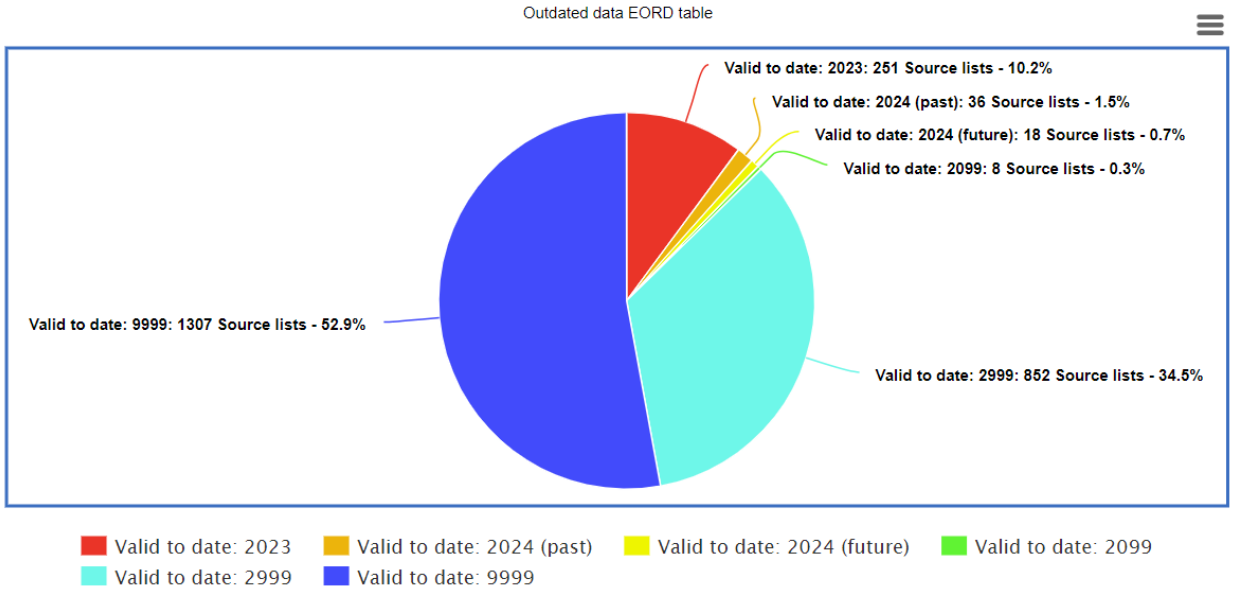

Figure 9. Valid to dates of source lists from table EORD

Figure 10. SWOT analysis of source list maintenance

2.4 Customer Master Maintenance

For the customer master entry point, there are two tables 'KNVV' and 'KNA1'. The first one shows the sales area data of the customers in the system and the second one shows the business partner's information like name, address, telephone number, email, etc. The sales area of the customers is highly inconsistent, however there is no document within the company that describes what is mandatory to fill in and what to fill in for which customers, so the incorrect data cannot be checked compared to a standard. Specialists mention that because of this inconsistent and missing data, employees of Company X need to get in touch with their customers or vendors to confirm their information and this causes delays in supply chain processes. On top of that, when the delivery information is incorrect in the system, it has a negative impact on the delivery process of the products, which is very critical in a lifesaving pharmaceutical industry. The only data that can be analysed is the customers that are blocked, so the customers that are obsolete and have a deletion flag in the system, in the sales area. However, these customers should still be kept in the system for visibility when necessary. Since there is no document available like the QAL for the material master data, it is hard to analyse missing or insufficient data. There is no coherence of the data. When customers are created in the system, the business team that requested this sends an email out with a form with information about the customer that should be filled out by the customers and the regarding customer operations team within Company X. The regarding process flow can be found in Appendix E. Since this information is mandatory, the second table can be used to analyse whether all this information is consistent within the system.

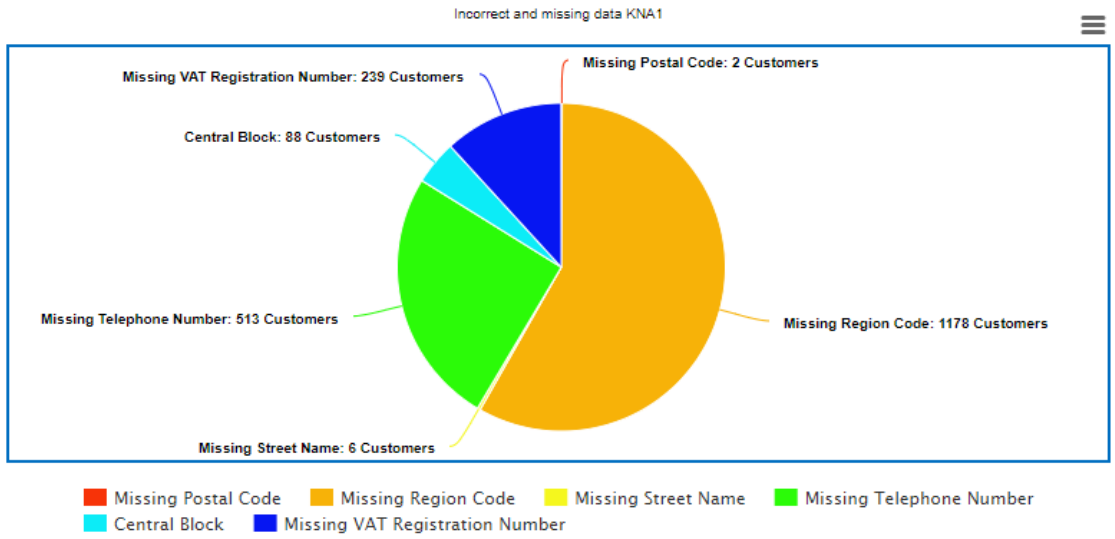

Figure 11. Incorrect and missing data from KNA1 table

Within the KNA1 table, there are many inconsistencies such as missing data that should be mentioned on the customer form as mandatory fields. For the inconsistent data that is not exhibited in the pie chart in Figure 11, it cannot be said whether this should be the way it is managed in the system or not because again, there is no standardized document where it can be seen what needs to be filled in where and for which customers. This is also confirmed by the specialists within the company. Figure 12 exhibits the SWOT components analysed in this section.

Figure 12. SWOT analysis of customer master maintenance

2.5 BOM, Master Recipe and Quality Inspection maintenance

The entry points for the BOMs and the master recipes have tables in the ERP system as well, however, the data must be correctly entered in the system because otherwise it has an effect on the business team and their responsibilities, and they connect the master data team for the occurring errors. So, there are no insufficiencies that can be analysed or measured here.
Nevertheless, there is an ECR number created in the system which triggers the BOM and master recipe updates in the system, which cannot be found in any table in the ERP system. Even though there is a list created with the ECR numbers and related BOM's and master recipes and shared in the application Box (discussed in Section 2.6), this list needs continuous manual updates which is time consuming and prone to error. Different specialists indicated that it would work to have an official list in the erp system that shows these various ECR numbers linked with the BOM and master recipe updates. This way, the data will be automatically updated and will not need continuous maintenance from the master data team, which would also be vulnerable for human error.
The last entry point of the material master data is the inspection group maintenance. When looking in the system for the tables for this module, there are two tables in which data is expected, but both are empty. So, the data of the inspection groups cannot be analysed. This makes the quality inspection maintenance harder since the data cannot be monitored through the tables in the ERP system like the other entry points. The specialists state that there are incorrect quality release updates in the material master sometimes that hinder the batches from being supplied to the customers since it will not be released. There are more tables that are related to material and customer maintenance data that are empty within the system, which indicates that the ERP system is not being used optimally. The specialists also state that the ERP system is not optimally being used and that there are many functionalities of the system

that still need to be developed for usage. Figure 13 exhibits the SWOT components analysed in this section.

Figure 13. SWOT analysis of the BOMs, master recipes and quality inspection plan maintenance

2.6 Analysis in Data Management Application

Company X uses a cloud-based content management platform called Box. In this application, people from the whole company can edit and access documents. For the master data, there is a folder called ‘’Master Data Governance’’ with files that support the MDG (See Appendix F). When looking at the ‘’Customer Master Data’’ folder, there are no files to be found. So, the customer data was planned to be managed in Box, however nothing is initiated yet. In the ‘’Data Update’’ file there are some files that need to be updated. In the ‘’Completed tasks’’ folder, there are six files that contain completed data clean up documents. This data clean-up is a great opportunity to help data governance, however it needs to be made true for all the insufficient fields in the material and customer master data. On top of that, the files that still need data clean up were updated in October and November 2023, which means that there has been no progress made on these files since. The ‘’Overview Quality Inspection Plan Group’’ file contains all the inspection groups that are created in the system to keep track of the group numbers they are assigned to. Lastly, the last file “ECR Overview’’ is a file with information about all master recipes and BOM’s with their related ECR number and other relevant information. This file is not organized and still misses information since it has not been updated for a long time and since the last update, new master recipes and BOM’s have been created. Figure 14 exhibits the SWOT components analysed in this section.

Figure 14. SWOT analysis of Box files maintenance

2.7 Collaboration of Stakeholders

To gain a better understanding of the collaboration processes between the stakeholders, customers, and external parties, interviews are conducted with specialists working with the master data in Company X. The participants are anonymous again, similar to the first part of the interviews to protect their privacy. These results help in the research of finding methods to improve MDG within the supply chain department. The questions are provided in Appendix A, part 2.

The first question indicated the current process of collaboration. It is determined that the main method of communication between stakeholders is through electronic data interchange (EDI). There are EDI industry standards, and the third-party logistic companies (3PLs) are integrated via EDI. The customer master data is in some cases linked from the system of the 3PLs and some of them are created manually. The 3PL's are facilitating and providing EDI invoices to the customers and to the suppliers. They are also integrated with government agencies on the incoming and outgoing invoices, for example for Spain and Italy.

The second question is about the challenges of the collaboration processes. There are quite a few challenges mentioned by the participants. Firstly, there is a limitation in the technical capability of suppliers, which is mentioned as a major issue. Integration becomes difficult if the suppliers and manufacturers are not technically capable. The same issues apply to the business-to-business (B2B) customers and hospital customers. Additionally, there are some issues regarding the communication of customer information. For some countries, the customers are created manually within the system and the information is shared via email. The customer form (see Appendix E) contains fields with mandatory information that needs to be provided by the customers and some of it by the finance team. The stakeholder responsible stated that a lot of the time, there's information missing on the form which causes errors in the system. The customer operations team contacts the master data team, indicating that there are

errors in the orders and shipments because of incorrect or missing information in the ERP system. Lastly, there seem to be issues in the collaboration process of the material master maintenance form (see Appendix D). This form has standard fields that provide information for the master data team to update in the ERP system. Many times, there are communications happening via email excluding the master data team, which causes changes in information that is not communicated with the master data team. This causes wrong information in the system and makes it difficult to identify any potential errors in the material set up. It also delays the approval process and makes it difficult to identify at a later point as to why a part was set up differently than what was initially requested.

The last few questions are all related to what the participants think would be a successful implementation to enhance the collaboration with the different parties mentioned in Company X. Some examples of successful collaboration efforts in the organization are data sharing platforms, like EDI with vendors and customers, and MDM-synchronizing required master's with suppliers and customers. Some mentioned tools that would be effective in facilitating collaborations are MDM for customer, material, purchase related and pricing masters, EDI for integration with suppliers and customers, vendor invoice management (VIM) for vendor invoice processing and Ariba for supplier management. The mentioned strategies are proper change management, proper documentation processes, stakeholder engagements and regular meetings with suppliers and customers to keep everything up to date. The participants mentioned that the improvement should be an automated process of receiving information from external partners (i.e. a portal or EDI) and an automation within the ERP system for the master data maintenance and approval processes. Additionally, exploring the latest technologies around MDG, regular audits and training programs are mentioned as possible improvement points to enhance collaboration. In Chapter 3, there is more of the exploring of the latest technologies around MDG through literature review and case studies. Figure 15 exhibits the SWOT components analysed in this section.

Figure 15. SWOT analysis of current stakeholder collaboration

2.8 Conclusion

This chapter has provided a comprehensive analysis of the current state of MDG within the supply chain of Company X. Through a detailed examination of the material master, PIR, source list, customer master, BOMs, master recipes and quality inspection maintenance, several critical insights are revealed. The first two sub research questions have been answered through interviews and analysis in the ERP system SAP S/4 HANA and SWOT analyses.

How is master data currently managed, stored, and maintained within the supply chain?

Master data at Company X is managed and stored primarily within the SAP S/4HANA ERP system, complemented by the cloud-based content management platform, Box. The material master and customer master data are maintained through specific tables such as MARA, MARC, EINA, EINE, EORD, KNVV, and KNA1. However, the current processes show manual updates, leading to various errors and inconsistencies. The key practices involve the use of a QAL for standardization, but adherence is inconsistent, leading to data quality issues.

What are the main challenges or pain points associated with current master data governance processes and coordination?

The primary challenges identified include data inconsistencies and errors, manual processes, lack of standardization, technical limitations and integration issues and inadequate utilization of ERP capabilities. Addressing these challenges requires a united effort to enhance data governance practices, improve process automation, and ensure comprehensive training and support for all stakeholders involved in MDM.

3 Literature Review on Master Data

In this chapter, a literature review is conducted to gain knowledge about MDM, MDG, data quality, coordination, the MDM tools in the market and their features and case studies of real-life implementations in different industries by answering the following sub research questions:

What are the features and developments of current MDM tools in the market?

What collaboration is required between different stakeholders (e.g., suppliers, manufacturers, distributors) to improve MDG?

What are some real-world examples of companies or organizations that have successfully improved MDG in their supply chains?

Figure 16 shows the diagram with an overview of the different parts of this chapter.

Figure 16. Overview of literature review topics

3.1 MDM and MDG Processes

MDM establishes a single, authoritative source of truth for critical data elements across the enterprise (Thomson & Anderson, 2024). It breaks down data silos, enhances data quality, and facilitates seamless data integration. Additionally, it empowers organizations to make data-driven decisions, drive operational efficiency, and enable strategic initiatives. On top of that, it plays a pivotal role in accelerating time-to-market, optimizing supply chain operations, and enhancing customer engagement. Lastly, it catalyzes enterprise transformation by unlocking the complete capabilities of data assets and urging continuous advancement in the digital age.

Some key principles of MDM involve data governance, data quality management, and data integration. Furthermore, it ensures that the master data is coherence and integer, which underpins critical business operations and decision-making processes. Organizations leverage MDM to adapt to market shifts, launch new products/services, and optimize business processes. MDM serves as an important facilitator for organizations that want to control the ability of their data assets and derive actionable insights.

Master data governance is an important part of data governance that focuses on managing and ensuring the quality, consistency, accuracy, and reliability of an organization's most important data assets, known as master data (Abraham et al., 2019). Master data typically includes core business entities such as customers, products, employees, and suppliers, which are shared across multiple systems and business processes.
Improving master data governance involves implementing strategies, processes, and technologies to enhance the management and quality of master data throughout its lifecycle. Some key aspects and best practices for improving MDG are data quality management, data governance framework, data stewardship, data standards and metadata management, data integration and MDM, data governance tools, data security and compliance and data governance training and awareness. By implementing these strategies and best practices, Cheng and Kim & Cho also describe that organizations can enhance the quality, consistency, and reliability of master data, causing the improvement of making decisions (Dahlberg & Nokkala, 2015), operational efficiency, and regulatory compliance. MDG plays an important role in ensuring that organizations extract maximum value from their data assets while minimizing the hazards of poor data quality and management.

3.2 Data Quality

Data quality is an important aspect of data management that mentiones the accuracy, completeness, consistency, timeliness, and reliability of data (Abraham et al., 2019). If the data quality is deficient, it can lead to inadequate insights, improper decision-making, compliance issues, and operational inefficiencies (Nulhusna et al., 2022). Improving data quality involves implementing strategies, processes, and technologies to enhance the overall quality of data of companies. Some key aspects and best practises to improve data quality listed by Abraham are:

- **Data Profiling**: Conduct data profiling to analyse the structure, content, and quality of data. Identify deviations in data, duplicates, values that are incomplete, and inconsistencies impacting data quality.
- **Data Cleansing**: Implement data cleansing techniques to correct errors, remove duplicates, standardize formats, and enrich data. This process involves deduplication, normalization, validation, and enrichment of data.
- **Data Standardization**: Establish data standards, naming conventions, and data quality rules to ensure consistency and uniformity across datasets. Standardizing data formats and values improves data quality and interoperability.
- **Data Validation**: Implement verification processes to confirm that data conforms to established quality standards and business guidelines. Validate data against defined constraints, formats, and reference data to maintain data integrity.
- **Data Governance**: Create a data governance structure that outlines roles, responsibilities, policies, and procedures for maintaining data quality. Designate data stewards to manage data quality initiatives and ensure adherence to data quality standards.

- **Data Quality Metrics**: Establish data quality metrics and key performance indicators (KPIs) to evaluate and monitor data quality levels. Monitor metrics like completeness, accuracy, consistency, and timeliness to gauge improvements in data quality.
- **Data Quality Tools**: Use data quality tools and software to automate data quality checks, profiling, cleansing, and monitoring. The data quality tools identify data issues, provide data quality reports, and facilitate data quality improvement processes.
- **Data Quality Training**: Provide data quality training and awareness programs to educate employees on data quality best practices, data governance principles, and the importance of maintaining high-quality data.
- **Data Quality Monitoring**: Set up ongoing data quality monitoring procedures to regularly evaluate and oversee data quality. Utilize data quality dashboards, alerts, and reports to track trends and identify issues.
- **Data Quality Improvement Projects**: Launch data quality improvement initiatives to tackle specific data quality problems, refine data quality processes, and foster a culture of data quality within the organization.

By adopting these strategies and best practices, organizations can improve data quality, expand the reliability of data-driven decisions, enhance operational efficiency, and ensure compliance with regulations (Ibrahim et al., 2021). Improving data quality is a continuous effort that demands dedication, teamwork, and continuous oversight to sustain high-quality data throughout the company.

3.3 Coordination of Stakeholders

As also concluded from the interview results, the collaboration between different stakeholders and specialists, such as suppliers, manufacturers, and distributors in a company is essential to improve MDM and MDG (Loshin, 2009). This collaboration involves establishing processes and procedures for collaboration to manage the coordination of participants. It also requires a shift from a confrontational approach to collaborative approach, where stakeholders clearly explain their needs and concepts.
Additionally, it is important to align metadata and data exchange interfaces, so they fit well within the overall business framework. It also requires stakeholder interviews to understand and prioritize data requirements, as well as to collect and synthesize these requirements into an enterprise view. The interviews with stakeholders of Company X were conducted in Chapter 2 and the results help with understanding the requirements of the collaboration between stakeholders. This collaboration is crucial for establishing a general group of procedures to reach a generic agreement and supply a list with metadata that defines and explains master data objects and is essential for ensuring the success of MDM and ensuring that all stakeholders and specialists agree on the definition and use of master data objects. The general agreement on the definitions and usage of data objects is to ensure consistency and accuracy in the master data. So, all stakeholders need to collaborate to ensure that the data is aligned with the quality requirements of the functions of the customer by establishing data quality standards, rules, and processes that are adhered to by all parties involved in the supply chain data. Moreover, setting up data governance requires the involvement of senior management to develop an effective oversight structure for data governance, custody, and stewardship. This ensures that the information needs of all stakeholders are fulfilled and that there are procedures in place to resolve rivalry of data within the organization. On top of that, evaluating if it's possible to move towards a master data environment involves collaboration among stakeholders to determine whether the business application client requirements fit with using a main storage space, and if the available data sources can be combined effectively to create the correct master

data set. Lastly, collaboration is needed to establish the objectives and goals for MDG. Different stakeholders could have different ideas for the maintenance of master data and it's important to work with them to align and establish the requirements and objectives.
To ensure buy-in and participation from key stakeholders for MDM implementation, some actions can be undertaken. The first one is to identify the team members who will benefit from MDM within the company. Then, the value and justification of MDM needs to be defined. Furthermore, the objectives and goals of the MDM implementation need to be documented by working with the stakeholders. After this, coordination with stakeholders and process owners is necessary to outline the implementation's functional abilities to perform. Another action is providing a detailed summary of the implementation impacts to establish compliance while the last data needs are defined. Also, the value of MDM needs to be communicated to senior management to gain their support and authorization. Additionally, a plan for enterprise data integration that aligns with stakeholders' expectations needs to be developed. Then, with the help of these expectations and needs of the stakeholders, a migration plan needs to be created for the concerned applications. Lastly, a collaboration with stakeholders is necessary to make sure that all the expectations are uniform.
Furthermore, stakeholder collaboration is crucial for ERP implementation in a company for successful deployment and utilization of ERP systems to maximize its benefits (Wu & Cao, 2009). ERP implementations contain different stakeholders such as the company's internal teams, ERP consultants, and software vendors. Effective collaboration among these parties is essential for a successful implementation. Additionally, by fostering collaboration, organizations can share knowledge, best practices, and experiences, leading to better decision-making and problem-solving during the implementation process. It will also help in overcoming challenges, sharing solutions, and ensuring that the ERP system is in line with the company's requirements and goals (Smolander et al., 2016).
However, there are also some challenges in collaboration. Challenges in collaboration for ERP implementations can arise from issues such as compatibility, connectivity, and security concerns across different organizations with diverse IT infrastructures. Overcoming communication barriers and minimizing communications overhead are also key challenges that organizations face when striving for effective collaboration among stakeholders.
To improve the collaboration between parties, it is important to consider knowledge repository systems. An example of this system is Epics, and it plays an important role in the support of the collaboration for ERP implementations by capturing and sharing implementation knowledge within and beyond organizational boundaries. These systems enable users to explore and search knowledge cases from different perspectives, enhancing knowledge sharing and decision-making within the ERP system.

Another facilitation in collaboration is Web 2.0 technologies. While large-scale bottom-up community efforts supporting ERP implementations are not common, emerging Web 2.0 technologies help the progress of collaboration within organizations. Tools such as wikis, social tagging systems, and recommender systems can support collaborative documentation, knowledge contribution, and design recommendations in ERP systems.

The deployment of collaboration tools at ERP software vendors or within organizations undergoing ERP implementations, can enhance collaboration and knowledge sharing. Progressive efforts involving collaboration between software vendors, research teams, and ERP implementation partners can lead to successful deployment of collaboration tools for ERP systems (Dittrich et al., 2009).

3.4 MDM Tools in the Market

Data governance is important in organizations, particularly for companies with various divisions and applications that lack integration face challenges (Dewi et al., 2019). Based on this source, there are some key challenges in managing data from multiple sources. The key challenges are the duplication of data for various products, difficulty in generating consolidated reports and the need for good data governance and MDM to regulate how data is stored, controlled, and maintained with high quality. These issues are addressed by implementing an MDM system. The features of this proposed system are as follows:

- Application Databases: The original databases where the data for different applications is stored.
- Data Sourcing: This involves ETL (Extract, Transform, Load) processes to pull data from the original application databases, clean it up and prepare it for the MDM system.
- MDM Services: These are the key functions and processes that the MDM system performs to manage and maintain the data.
- Master Data Repositories: The are special databases where the cleaned and standardized master data is stored.
- Data Distribution: This process records data transactions and shares the updated data with other applications that need it.
- Data References: This is the process of aligning and merging data from various applications with the master data to keep everything consistent and up to date.
- MDM Presentation Services: A web-based interface that allows users to access and interact with the MDM system.
- Centralized MDM system: This system ensures that all the data remains consistent and of high quality across the organization.
- It uses an open-source platform, Pentaho Data Integration, and Docker for virtualization.

Another solution is a master data monitoring application, called the pureshare method (Naufal et al., 2020). Several key challenges with data management are faced here, which includes data duplication, lack of control on data reference and lack of monitoring and securing master data. This leads to inconsistencies and inefficiencies in their data sources, difficulties with ensuring accuracy and consistency of the data used across different applications and data integrity issues. These challenges highlight the need for a comprehensive MDM system to address these three issues. The proposed solution uses a mixture of top-down design and bottom-up implementation procedures. This ensures that this dashboard design aligns with the business objectives while also meeting the technology requirements. Additionally, it focusses on ensuring compatibility between the business objectives of the organization and the technological aspects of dashboard development. Also, it follows a structured approach, including planning and review, system and data review, prototype design and improvement, and release which ensures that the dashboard development process is well-organized and efficient. It is web-based, allowing it to be used in various places. It provides real-time monitoring processes to ensure compliance with the company's business policy. Additionally, it has the ability to create various types of visualization, including presenting data in the form of tables and graphics. Furthermore, it includes conformance to business rules that define master data for the organization, full capabilities for designing the visualization of master data, user-friendliness, reporting in table format, platform availability in PHP/Java, and cost ownership as open source. Lastly, the application is designed to check and maintain master data quality, with features such as the ability to control data that is unfit with master data, a dashboard page with various functionalities, and the capability to monitor, add, and update data on the system.

Furthermore, there is a source that mentions additional problems regarding the MDM (Riesener et al., 2022). These are data inconsistencies, time-consuming processes, error-prone operations, limited scalability, lack of data governance and difficulty in data analysis. The solution mentioned in this source is addressing these challenges through the adoption of AI tools and automation in MDM, which ensures that companies can enhance data quality, streamline processes and improve the overall efficiency of managing complex data sets. These AI tools like natural learning processing (NLP) and machine learning (ML) aid in automating the MDM process in the following ways:

- NLP algorithms such as named entity recognition (NER) can extract relevant information from unstructured data sources and standardize it for further processing.
- AI can analyse language patterns, identify inconsistencies, and correct errors in large datasets, thereby enhancing data quality.
- ML algorithms can be trained to identify duplicate entries in master data sets by analyzing similarities between components, which leads to improved data consistency.
- AI techniques can integrate data from diverse sources with various formats, languages, and naming conventions, ensuring data consistency and accuracy.
- By automating data management tasks, AI can help companies establish and maintain effective data governance practices, reducing the risk of faulty data resulting from system interface issues.
- AI-powered solutions can scale to handle large datasets and repetitive tasks, reducing the manual effort required for data maintenance and management.

Another solution is the Unidata Platform Architecture (Kuznetsov et al., 2022). This architecture is designed to be modular and open-source, allowing for flexibility and extension-ability. It aims to address the limitations of traditional MDM toolkits by offering a component-based architecture and adaptability to various software ecosystems. It consists of four main components: Platform Core, Storages, MDM and Extra MDM. Each of the components serve specific functions within the system. The Platform Core includes basic modules for core services like system boot, job batches, and data types. The Storages focus on data stores abstraction and simplification, ensuring compatibility with the platform. The MDM component handles basic MDM functionality such as metadata management, duplicate detection, and business process implementation. The extra MDM offers advanced MDM features beyond the basic functionality provided by the MDM component.
The last paper that is reviewed describes multiple products and compares them. It also gives different architectural solutions and compares them to each other (Kokemüller & Weisbecker, 2009). Several solutions and technologies are discussed in the context of MDM. The following solutions proposed are:

- Reference Reconciliation Mechanisms: Systems include mechanisms for reference reconciliation, with some providing basic algorithms for this purpose. Three systems (Stibo, Sun, Tibco) can assess references between objects for reconciliation, and Sun offers a trainable algorithm for this task.
- Data Quality (DQ) Algorithms: Some systems need entities to successfully pass DQ algorithms before they can be added to the database of the system. Every newly produced entity is checked by the system for its data quality.
- Workflow Configuration: Systems offer constructable workflows for determining the next steps for potential matches.

- Peer-To-Peer (P2P) Technologies: The trend towards greater autonomy in integrated enterprises through P2P technologies is noticed.
- RFID Technology: The use of RFID technology to optimize supply chains is emphasized. Particularly regarding the cost-benefit imbalance for small or medium-sized suppliers. This technology is utilized in their management group to help SMEs reduce the investments required to take advantage from this technology.
- Architecture VIANA: This architecture possesses several key qualities that make it a notable solution in the realm of MDM.
    - Peer-Based Integration: VIANA is designed around a P2P integration model, where all participants are equal in the network structure. This represents an organizational model where independent enterprises share information fairly and are accountable for integrating with partners.
    - Support for Different Integration Scenarios: VIANA supports various integration scenarios, including integration using a central service provider, integration without a central service provider (common in SCM), and intra-organizational integration. This flexibility allows for different approaches to data integration based on the specific needs of the participating entities.
    - Focus on Data Quality and Information Homogeneity: The architecture focuses on the concrete integration of master data and operational data, focusing on enhancing data quality. The goal is to enhance data quality and gain consistent information across enterprises.
    - Benefit for All Participating Partners: VIANA is designed to ensure that all participating partners benefit from the integration architecture. It supports scenarios that create a Win-Win situation for all involved parties, emphasizing mutual advantages and collaboration.
    - Efficient Communication and Integration: Communication and integration within VIANA are established by peers, allowing for efficient data exchange and collaboration among the networked participants. This peer-based approach enhances flexibility and autonomy in data integration processes.

These solutions and technologies represent a mix of data reconciliation, data quality, workflow management, and emerging technologies like P2P and RFID that are shaping the landscape of MDM. The tool that is described in this paper is the VIANA architecture, so this tool is going to be used to compare with the other tools in the next section.
Overall, these five sources give a good exhibition of the important features and developments of different MDM tools. These features are compared with each other in a scoring matrix in Chapter 4 to eventually find a potential MDM tool in the market to recommend to Company X.

3.5 Maturity Level

Maturity models are a measurement of an organization's ability for continuous improvement in a specific area, in this case the area is MDM (Pratama et al., 2018). The purpose of maturity models is to assess an organization's maturity level in a particular domain, providing a roadmap for improvement and optimization. Maturity models help organizations understand their current state in a specific domain and provide a structured approach to progress towards higher maturity levels. By following the guidelines of maturity models, organizations can optimize processes, enhance data quality, improve decision-making, and achieve better outcomes in their respective fields. Oracle, Dataflux, Kumar and MD3M are examples of maturity models used in MDM.

Oracle's model focuses on profiling data sources, defining a data strategy, consolidation planning, data maintenance, and utilization, with four maturity levels: marginal, stable, best practice, and

transformational (Rahman et al., 2019). It includes elements such as assessment of master data quality and master data ownership. Provides a comprehensive framework for managing master data within organizations. This model offers a structured approach to managing master data and provides a clear understanding of data quality and ownership. Yet, it may lack detailed focus in certain areas compared to other models and it could be improved by incorporating more granular features.

Dataflux model includes a structured approach with five maturity levels: initial, reactive, managed, proactive, and strategic performance (Vásquez et al., 2018). The key focus areas are governance, management, and integration of master data. This model emphasizes performance and strategic aspects of data management. However, it could benefit from more detailed focus areas to enhance assessment and it may require additional customization to align with specific organizational needs.

Kumar's model consists of six maturity levels: ignorant, initial, isolated, organized, unified, and optimized, lacking specific focus areas but providing insight and experience in mastering data management and into different stages of maturity (Ko et al., 2021). This model offers a highly straightforward approach to understanding the maturity levels and helps organizations with assessing their progress in MDM. Nevertheless, it lacks detailed focus areas for a more comprehensive assessment, and it might not provide as nuanced insights as the other models.

The MD3M model focusses on five key topics: data model, data quality, usage and ownership, data protection and data maintenance (Spruit & Pietzka, 2015). It provides a detailed assessment of master data maturity levels within organizations. Additionally, it emphasizes the importance of implementing capabilities in all key topics to achieve higher maturity levels. This model provides a benchmarking tool for organizations to compare their levels. Nonetheless, it requires comprehensive implementation across all key topics for optimal results and it may be complex for organizations with limited resources.

3.6 Real-life Implementations in Different Industries

Case study 1: Healthcare Domain

MDM in the healthcare domain involves consolidating data from various source systems to create a unified, accurate, and complete view of patient and provider information (Tak, 2015). Approaches such as master patient index (MPI) are utilized to ensure accurate matching of patient and provider data. Also, revalidation processes are implemented to update information and maintain data accuracy. These processes help in improving data governance processes, enhancing the quality of care, reducing risks in clinical activities, streamlining administrative tasks, and increasing revenue. This centralized data has facilitated a more accurate diagnosis, a reduce in costs and an optimized healthcare resource utilization.

Data duplication issues can arise when disparate systems store conflicting information. With the implemented MDM, data divergence is addressed by consolidating all the data related to a specific patient into a unified master data record. This consolidation ensures consistency and accuracy in patient information across different systems.

Master data quality can deteriorate over time, impacting the reliability of healthcare data. With the implemented MDM, pre-cleansing and standardization functions to enhance and maintain data quality is incorporated. Additionally, by leveraging relationships data in various domains like patient and provider information, MDM ensures data accuracy and integrity.

This implementation of MDM in healthcare streamlines data management processes and governance. It centralizes patient and provider data through MDM which enhances business operations, efficiency and the quality of the provided care. Mastering data through MDM helps in overcoming challenges related to data inconsistencies, duplication, and data quality degradation.

Case study 2: Academic and student service management (AKMA) University

AKMA University faced challenges with data synchronization, integration, and accessibility, prompting the need for a more efficient system (Ana, 2023). The research conducted by the University team focused on the success of the higher education governance system in the information and digitalization era. The new solution implemented at AKMA University is called a "Digital-Based Database Governance Development Management with Master Data Management" system.

The implementation involved preparing vision, mission, and strategic plans with stakeholders, following GUG principles to reduce management errors. The solution aimed to improve higher education academic services by enhancing data and information management through a Terminal Information System and Academic Information System. The system impacted various stakeholders, with lecturers and students acknowledging its positive effects on academic services and management complexity solutions. This system can help overcome data duplication issues, ensure data accuracy, and facilitate integrated data management processes at the university.

Database governance and digitization played a crucial role in enhancing MDM, with a regression equation indicating a high impact on improving data governance and digitization at AKMA University. The new solution contributed to enhancing MDM at AKMA University by 93% through database governance and 52.8% through digitization. The regression equation reveals that database governance and digitization account for 87.5% of the changes in MDM. The success of the system was evident in its positive effects on MDM, demonstrating the importance of digital-based governance in higher education institutions.

Case study 3: Manufacturing Industry

MDG and MDM are successfully implemented through the establishment of a MDM system, data integration with other systems, extraction of shared and stable business data to create a unified master data resource base, and unified management of master data entry, audit, release, and synchronization with business systems in a manufacturing industry (Yali et al., 2023). This implementation allows for the sharing and utilization of master data across various systems, supporting data exchange for business collaboration and integration with new systems in the future.

There are a lot of benefits of the successful implementation of MDM and MDG. MDM facilitates data transmission among different departments within an enterprise, enabling data interoperability, information transmission, and functional linkage. It ensures data uniqueness and lays the groundwork for the standardization of data import, exchange, statistics, and analysis. Additionally, by promoting the construction of master data services and managing master data through a unified interface, organizations can standardize core data, promote data sharing and interaction between systems, and enhance the efficiency of data flow within the enterprise. Furthermore, through centralized data management, organizations can ensure data consistency, accuracy, and completeness, leading to better decision-making and operational efficiency. On top of that, MDG helps organizations in creating data governance policies, procedures, and controls to maintain data quality, security, and compliance with regulations. Also, by streamlining MDM processes, organizations can reduce data redundancy, errors, and inconsistencies, leading to improved operational efficiency and productivity.

3.7 Conclusion

In this chapter, a comprehensive literature review is conducted to gain an in-depth understanding of MDM, MDG, data quality, coordination among stakeholders, current MDM tools, and real-world case studies of MDM implementations. The review was structured around the following sub-research questions:

1. **What are the features and developments of current MDM tools in the market?**
    - The current MDM tools in the market, such as the MDM system and the Unidata Platform Architecture, offer advanced features including data sourcing, MDM services, master data repositories, data distribution, and MDM presentation services. These tools focus on enhancing data quality, integrating data from diverse sources, and providing user-friendly interfaces for better data management. Emerging technologies like AI, NLP, and ML are being integrated into MDM tools to automate processes, improve data consistency, and ensure scalability.
2. **What collaboration is required between different stakeholders (e.g., suppliers, manufacturers, distributors) to improve MDG?**
    - Effective MDG requires robust collaboration among various stakeholders, including suppliers, manufacturers, and distributors. This involves establishing clear communication channels, aligning metadata and data exchange interfaces, and engaging senior management for data governance oversight. Stakeholders must work together to create standardized processes, set data quality expectations, and maintain a unified approach to data management. Knowledge repository systems and Web 2.0 technologies are instrumental in fostering collaboration and ensuring successful MDM and MDG implementation.
3. **What are some real-world examples of companies or organizations that have successfully improved MDG in their supply chains?**
    - The review highlighted several real-world examples:
        - **Healthcare Domain**: Implementation of MDM led to a unified patient and provider information system, improving data governance, reducing risks, and enhancing the quality of care.
        - **AKMA University**: A digital-based database governance system improved academic services by enhancing data management and reducing management errors, highly impacting stakeholders.
        - **Manufacturing Industry**: Establishing a MDM system facilitated data sharing and integration, leading to improved operational efficiency, data accuracy, and compliance with regulations.

In summary, the literature review confirms that MDM and MDG are critical for ensuring data quality, consistency, and reliability across organizations. The collaboration between stakeholders is essential to achieve successful MDM implementation. Real-world case studies demonstrate the tangible benefits of robust MDM systems, such as improved decision-making, operational efficiency, and strategic business growth. The sub-research questions have been thoroughly addressed, providing valuable insights into the features of the MDM tools, collaboration requirements, and successful implementations of MDM and MDG in various industries.

4 Results and Implementation Approach

This chapter describes the solution approach with the help of finding the current maturity level of Company X and finding a suitable MDM tool with the help of a scoring matrix based on the needs of Company X and literature review. After establishing these results, an implementation plan is created with the solution recommendations for the company. The first part of the main research question is answered here:

How can the master data governance processes be improved to enhance supply chain management efficiency?

4.1 MD3M Approach

Based on the literature review on the different master data maturity models, the Master Data Management Maturity Model (MD3M) is chosen to apply to the current MDM situation in Company X because this model contains the most important key topics that apply to the situation at the company. Additionally, it provides a benchmarking tool for Company X to compare its level. So, apart from the interviews and SWOT analysis results, the MD3M method is another way to identify what Company X needs. The focus areas of the key components of this maturity model are obtained in Figure 17.

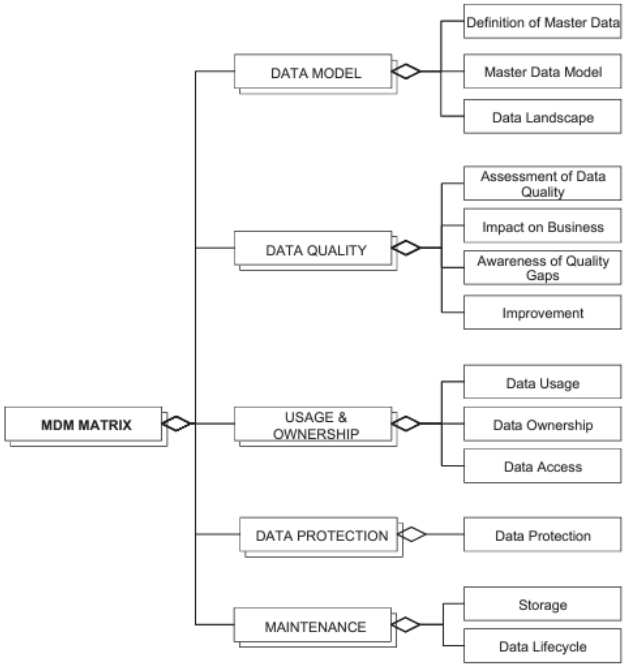

Figure 17. MDM Maturity Matrix (Spruit & Pietzka, 2015)

By identifying the specific focus areas and capabilities, the existing practices can be compared with the defined maturity levels in the model (Spruit & Pietzka, 2015). The model enables identifying areas where the MDM practices can be improved by comparing the company's initiatives with best practices. Furthermore, the MD3M model allows taking both reactive and proactive approaches to improvement because the company can react to existing issues by correcting errors in data and also take proactive measures such as changing data entry processes to prevent future mistakes. The maturity levels of the MD3M include the initial, repeatable, defined process, managed and measurable, and optimized stages. The descriptions of the different maturity levels are exhibited in Figure 18. These descriptions give an indication on the maturity level that the organization is currently in and what still needs to be improved.

Level	Description
1: Initial	A first awareness for issues regarding the topic of MDM has been raised on an operational level. Initial steps are initialized
2: Repeatable	Measures from individuals are conducted to solve individual problems. No connection to other units or projects. Still operational
3:Defined process	First collaborations take place on a tactical level. Awareness was created for the existence of other initiatives
4: Managed and measurable	Best practices are in place for handling of MDM. There are defined processes on a tactical level
5: Optimized	Optimized handling of MDM. The organization's efficiency has been improved. Tactical approach on the topic

Figure 18. Description of the derived MD3M maturity levels (Spruit & Pietzka, 2015)

After understanding the model and familiarizing with its components, the current state is assessed by evaluating Company X's current MDM practices against the maturity model. The strengths and weaknesses that are identified with the interview results and SWOT analysis is used here. After this, the improvement areas need to be identified. This would mainly involve addressing gaps in understanding, improving cooperation between stakeholders, establishing standard data formats, and constructing an enterprise-wide master data model. Lastly, after the identification of improvement areas, the final improvement plan is developed. This plan is used to enhance MDM capabilities within Company X and includes specific actions, timelines, and responsible parties for implementing improvements.
There is a questionnaire that is developed and provided by Spruit and Pietzka (Spruit & Pietzka, 2014), that needs to be filled in to help assess the maturity level of the company. This was filled in by the participants of the interviews and the results are exhibited in Table 6 and 7.

Table 6. MD3M regarding master data in Company X

	Initial	Repeatable	Defined process	Managed and measurable	Optimized
Data model					
Definition of master data	Implemented	Implemented	Implemented	Implemented	Missing
Master data model	Implemented	Implemented	Implemented	Missing	Missing
Data landscape	Implemented	Missing	Missing	Missing	Missing
Data quality					
Assessment of data quality	Implemented	Implemented	Implemented	Implemented	Implemented
Impact on business	Implemented	Implemented	Missing	Implemented	Missing
Reasons/sources for poor quality	Implemented	Missing	Missing	Implemented	Missing
Improvement	Missing	Implemented	Missing	Missing	Implemented
Usage and ownership					
Data usage	Implemented	Implemented	Implemented	Missing	Missing
Data ownership	Implemented	Missing	Implemented	Implemented	Implemented
Data access	Implemented	Implemented	Implemented	Implemented	Missing
Data protection					
Data security	Implemented	Implemented	Implemented	Implemented	Implemented
Maintenance					
Storage	Implemented	Implemented	Missing	Implemented	Missing
Data lifecycle	Implemented	Implemented	Implemented	Missing	Implemented

Table 7. Results of MD3M

Maturity per level	Total	Implemented	Missing
1	13 (100%)	12 (92.3%)	1 (7.7%)
2	13 (100%)	10 (76.9%)	3 (23.1%)
3	13 (100%)	8 (61.5%)	5 (38.5%)
4	13 (100%)	8 (61.5%)	5 (38.5%)
5	13 (100%)	5 (23.1%)	8 (76.9%)

Although the results show that 43 out of 65 (see Table 7) aspects are already implemented in Company X, there are still some important business functions missing. The first component of the data model function is only missing the optimized level, which means that the company needs to establish standard formats in order to reach the full maturity level here. The second component has the last two levels missing. This indicates that a clear plan with the intervals and the responsibilities involving data maintenance needs to be established and needs to be

communicated with the relevant roles in order to reach the final level of maturity here. The last component of the data model function has only the first level implemented. This means that the company needs to work on the data landscape and needs to aim to have a consistent inventory of all data sources and the associated systems they are used by. Additionally, the redundancies need to be solved and the data logic should be scalable. The second business function is data quality and contains four components, where the first one is completely implemented, so the maturity level here is five. The second component needs two more implemented levels to have the maximum maturity level. To get to this level, the company needs to make sure that it can explain how insufficient master data has an effect on the business in both financial and non-financial ways and can categorize these impacts using financial terms. The third component has three levels missing. To reach the fifth maturity level here, there needs to be awareness of the various reasons for poor data and where they exist within the company. The last component of the data quality function also has three levels missing. Here, the company needs to make sure to regularly assess the quality of the data along the benchmarking system to secure the defined quality within the master data. The usage and ownership function has relatively more levels at the implemented state than the previous functions. In order to get to complete maturity, the employees need to use the possibilities they have and not be reluctant to use certain systems to get data from. Furthermore, the owners of the data elements need to define the usage, purpose and content of the data. Lastly, all employees need to know which sources they have access to and what can be found here for their purposes. The next business function is data protection, and it is already in the maturity state, so no improvements need to be made here. The last business function is maintenance and misses three levels in total. Here, there is need of automatic tools that can regularly check for redundancies and duplicates. Also, the data needs to be stored in innovative ways with different possibilities of forecasting and analysis. Finally, for every data object, one source of truth needs to be established. To conclude, even though most components need improvement to get to the maximum maturity level, the total percentage of implemented capabilities versus missing capabilities is 66,2% (43 out of 65 defined capabilities). The results in Table 7 illustrate a general trend where capabilities become less implemented as maturity levels increase.

4.2 Comparison and Scoring Matrix MDM Tools

Based on the results of Company X's needs that are established through interviews and SWOT analyses, a scoring matrix (see Table 8) is created for the purpose of comparing the different solutions of MDM found through literature review. The found solutions are the following: MDM System, Pureshare Method, AI-Powered MDM, Unidata Platform and VIANA Architecture. The success criteria contain 26 components which are important features of the tools gained through literature review. The weighting criteria is based on their importance to Company X. The assigned scores are based on the capabilities and features of the MDM solutions, starting from 1, which is poor, until 10, which is excellent.

To make the calculations easier and flexible for any changes in the assigned scores or weighted criteria, it was decided to use a VBA code. This code can be seen in Appendix G. Each weight score (0-1) is multiplied with the scores of all success criteria per solution (0-10) and added to get to the final score of that solution. Looking at the scores, the highest is 150,35 for the Unidata Platform solution. Its most outstanding features are data accuracy, completeness and consistency, duplicate detection and elimination, ETL capabilities, cross-platform compatibility, scalability, automation, open-source availability and modularity and extensibility. Most of these features are most important to the company and that's why it has the highest score. The only feature that is a bit on the lower side is the NLP and ML integration ability. However, the second best scored MDM solution, AI-Powered MDM, has an outstanding score for this quality. It also has a high score for automation and data accuracy,

completeness and consistency. On top of that, the score, 145,67, is relatively close to the Unidata Platform solution. This makes the second-best solution also a good candidate for Company X to consider implying.

Table 8. Scoring Matrix of MDM Tools

Criteria	MDM System	Pureshare Method	AI-Powered MDM	Unidata Platform	VIANA Architecture	Weight
Data Accuracy, Completeness, Consistency	8	8	10	9	7	0,95
Duplicate Detection and Elimination	8	9	9	9	6	0,9
Error Correction	6	7	9	8	5	0,9
Policy Compliance	7	6	7	7	4	0,75
Data Stewardship	8	7	7	8	5	0,85
Audit Trails	6	6	7	8	5	0,3
Access Control	7	5	6	8	6	0,75
ETL Capabilities	10	5	8	9	7	0,75
Real-time Integration	6	7	8	8	7	0,6
Cross-Platform Compatibility	9	5	8	9	8	0,4
Reference Data Management	8	8	9	8	6	0,7
Scalability	6	6	9	9	8	0,7
Performance	7	7	9	8	7	0,75
Automation	7	5	10	9	6	0,99
NLP and ML Integration	3	3	10	6	4	0,9
User-Friendliness	7	8	6	7	5	0,85
Visualization Capabilities	7	8	6	7	4	0,6
Web-based Access	7	7	6	7	5	0,87
Reporting Features	7	8	6	7	5	0,75
Cost Efficiency	9	9	8	8	5	0,95
Open Source Availability	9	10	5	9	4	0,4
Modularity and Extensibility	6	6	7	9	8	0,7
Workflow Management	7	5	7	8	6	0,8
Peer-to-Peer Integration	6	4	5	7	10	0,55
Real-time Monitoring	7	9	7	7	7	0,55
Dashboards and Alerts	6	9	6	7	5	0,8
Total	134,07	129,44	145,67	150,35	111,89	

The remaining three alternatives have a relatively low score on the important features for Company X. For example, the automation feature, which is explicitly mentioned during the interviews as much needed, has a score of 7 for the MDM System, a 5 for the Pureshare Method, and a 6 for the VIANA Architecture. The other important features mentioned by the research participants such as data accuracy, completeness and consistency, error correction, and web-based access score for most of the time are also lower on these remaining three solutions.

4.3 Implementation Plan

The current solutions that are found in this research are shown in an implementation plan. These implementation methods are shown in Table 9. These solutions are gathered through analyzing the current situation and the conducted SWOT analyses with the opportunities for improvement, through interview results from the specialists in Company X, through literature review, through assessing the maturity level of Company X and finally through getting to an MDM tool that will help the company to improve the MDG processes.

Table 9. Implementation plan for improving MDG processes

Method	Description	Elaboration
1	**Standardize data entry processes**	Create a QAL for the customer master with mandatory key fields, extend the material and customer master request form with more mandatory key fields, develop clear and complete master data intake forms to make key fields mandatory and prevent incomplete or missing data.
2	**Monitoring and updating master data files**	Periodically monitoring and updating the master data files in Box application to ensure timely data, create and maintain data clean up files for all key fields in material master.
3	**Regular audits and training programs**	Training programs regarding the MDM/MDG processes and training programs regarding the functionalities of the ERP system need to be offered to avoid human errors in master data.
4	**Mapping data structures and processes**	All the different data structures and processes need to be mapped to properly transfer data from one system to another system and prevent data loss in this process.
5	**Implementation of MDM tool**	Consider implementing the Unidata platform tool that is suitable for the needs of Company X which can automate approval processes and updates and improve the quality of the master data.
6	**Implementation of data sharing platforms**	Implement web-based automated management tools and data-sharing platforms such as MDM for customer, material, purchase related and pricing masters, EDI for integration with suppliers and customers, VIM for vendor invoice processing and Ariba for supplier management.
7	**Enhance stakeholder engagement**	Foster collaboration among stakeholders through regular meetings and proper documentation processes, engage senior management in the data governance framework to ensure alignment and support for MDG initiatives.

4.4 Conclusion

This chapter accurately outlines the solution approach for enhancing MDG processes at Company X by determining its current maturity level and selecting a suitable MDM tool based on a scoring matrix. The findings from the current situation analysis and literature review, along with a structured implementation plan address the primary research question:

"How can the master data governance processes be improved to enhance supply chain management efficiency?"

One of the key findings in this chapter is the MD3M approach that is selected to evaluate Company X's current MDM practices. This model provides a comprehensive framework for identifying strengths and weaknesses in the company's data management processes. The identified gaps for Company X are the lack of crucial business functional at higher maturity levels, particularly in the areas such as data model standardization, data maintenance, and data quality awareness. Addressing these gaps is essential for reaching full maturity in MDM.
Another key finding is the best suitable MDM tool for Company X that is found by comparison of tools in a scoring matrix. This scoring matrix was developed based on the needs of Company X, derived from interviews and SWOT analyses. The evaluation criteria included 26 components and their weights were based on their importance. The highest-scoring solution is the Unidata Platform due to its important features.
The last key finding is the comprehensive implementation plan containing a structured approach. This plan exhibits the specific actions, timelines and responsibilities to enhance MDG and MDM capabilities and improve SCM efficiency at Company X.

5 KPIs and Measurement of Solution

In this chapter, the following sub research question is answered through literature review, case studies, and analysis on the important KPIs within Company X.

What KPIs are used to measure the effectiveness of MDG in the supply chain?

The commonly used KPIs are identified in this chapter to enable Company X to measure the effectiveness of MDG processes. A comprehensive list of potential KPIs is made available. The KPIs that can be used to measure the continuous improvement of MDG processes are investigated.

5.1 KPIs and their importance in Master Data

KPIs are tools that help maintain high performance levels, aid in setting and achieving higher goals, and provide real-time monitoring of relevant metrics within an enterprise (Kaganski et al., 2017). In this research, the KPIs are essential to evaluate the performance and effectiveness of MDM initiatives (Dewi et al., 2019). They help measure the success of data governance practices and the quality of master data within the organization. Monitoring KPIs allows Company X to track and measure their progress in data management, pinpoint areas needing improvement, and make informed decisions grounded in data-driven insights. It also leads to enhanced data quality, streamlined processes, and improved decision-making capabilities. With the help of the KPIs, Company X can continuously measure their progress to eventually reach the final level of maturity of the key components regarding the master data.
KPIs can be measured using various methods and tools (Kaganski et al., 2017). The approach that can be used in this case is algorithmic analysis. The use of algorithms to analyze interview responses and expert decisions can help in the selection of appropriate KPIs for a particular company. This approach involves data analysis algorithms to identify and select the most relevant KPIs based on the company's specific needs.
The interviews conducted to aid the results of the previous chapters are used to define the KPIs that measure the effectiveness of MDG processes. The referred key factors that contribute to the quality of the master data mentioned by the specialists are accuracy, timeliness, completeness and consistency of the master data. These data quality metrics are used as the KPIs that are relevant for MDG.

5.2 KPIs in MDG processes

Accuracy
Data accuracy rate: Measures the percentage of master data records that are free from errors or inaccuracies (see Section 2). The accuracy of master data can be measured through data governance, data quality management, and data integration processes (Thomson & Anderson, 2024). Data accuracy indicates whether the values stored for an object are correct and precise Olson, 2003). It involves ensuring that the data values are the right values and are displayed consistently and clearly. Accuracy is crucial to prevent errors and ensure that data is reliable for decision-making. Establishing a unified source of master data is necessary to ensure accuracy.

Timeliness
Timeliness of data updates: Measures the speed at which changes or updates to master data are processed and reflected in relevant systems. Timeliness of data refers to the data being available when needed and up to date. Timely data is essential for making informed decisions based on

the most current information available (Olson, 2003). Outdated data causes imprecise analysis and decision-making. It can be measured by the on-time completion percentage, so whether an assignment or task is completed by a given deadline or not. Timeliness can also be measured by monitoring the delays in data updates.

Completeness

Data completeness rate: Assesses the percentage of required data fields that are populated and complete within master data records (see Chapter 2). It refers to having all the necessary information required for a specific purpose (Olson, 2003). Incomplete data can create misunderstandings and hinder effective decision-making. For example, missing information in a database can result in inaccurate analysis and reporting. To reach complete data in the system, the data completion rates for all required fields should be monitored and the coverage of essential data elements in the master data should be assessed.

Consistency

Data consistency rate: Involves ensuring that data values are uniform and follow the same format or standards throughout the dataset (Olson, 2003). Consistent data allows for accurate comparisons and aggregations. Inconsistencies in data can lead to misinterpretations and errors in analysis. In order to keep the master data consistent, the uniformity of data formats and conventions need to be evaluated and data integration processes need to be monitored to ensure consistency in information. These KPIs can be measured as a percentage by the following equations:

$$\frac{Number\ of\ accurate\ data\ entries}{Total\ number\ of\ data\ entries\ in\ dataset} * 100\%$$

Accurate data entries are in this case the data entries that correctly reflect the real-world values they represent with no errors or disrepancies.

$$\frac{Number\ of\ completed\ tasks\ within\ deadline}{Total\ number\ of\ tasks\ with\ a\ specified\ deadline} * 100\%$$

The completed tasks are in this case the tasks that have been finished and all required work has been done. Within deadline means the tasks that are completed on or before their assigned deadline.

$$\frac{Number\ of\ complete\ data\ entries}{Total\ number\ of\ data\ entries\ in\ dataset} * 100\%$$

Complete data entries are in this case data entries that contain all required fields and information, with no missing parts.

$$\frac{Number\ of\ consistent\ data\ entries}{Total\ number\ of\ data\ entries\ in\ dataset} * 100\%$$

Consistent data entries are in this case data entries that are uniform and follow the same standards, rules and formats across the dataset, without contradictions or variations.

It is important to note here that the percentage of accurate, complete and consistent data entries can only be measured by material or customer type or by field in the ERP system since one material and customer can contain multiple inaccurate, incomplete or inconsistent master data, as discussed in Chapter 2. Another two key factors that can be seen as KPIs are maturity and policy adherence. These KPIs are already discussed in the previous parts of this report.

Maturity
Data governance maturity level: Evaluates the maturity level of the organization's MDG practices based on defined maturity models (see Chapter 4). It provides insights into the organization's progress in maturing its data governance capabilities over time. There are several methods to measure the maturity of an organization, however in this research, the MD3M method was chosen. To measure this KPI, the maturity matrix and questionnaire is used (Spruit & Pietzka, 2015). This method can be used again to measure the maturity level of the MDG practices in Company X when the improvement methods are implemented. This way, it ensures continuous improvement because it helps identify the areas that need enhancement.

Policy Adherence
Information policies: Evaluates the degree to which MDM practices align with the established data governance policies and standards (see Chapter 2). It reflects the effectiveness of governance frameworks in ensuring data integrity and compliance. Information policies need to be recorded. Shared and implemented throughout the organization (Loshin, 2009). They should cover aspects such as data security, privacy, access controls, data retention, data quality standards, and compliance requirements. Regular reviews and updates of information policies are essential to adapt to changing business needs and regulatory environments. One way to measure this KPI would be to get the percentage of data activities that comply with established policies.

5.3 Conclusion

In this chapter, the KPIs that are essential for measuring the effectiveness of MDG processes within the supply chain are examined. By addressing the sub research question **"What KPIs are used to measure the effectiveness of MDG in the supply chain?"**, an overview of the relevant KPIs is provided.
The KPIs that are analyzed because of their relevance according to specialists in Company X are accuracy, timeliness, completeness and consistency. They can be quantified using formulas that calculate the percentage of accurate, timely, complete and consistent data entries. These measurements provide a clear view of the data quality and governance practices within the organization since these KPIs can be used by the company to continuously monitor and measure and thereby improve their performance regarding MDG processes in the supply chain. On top of that, by measuring the performance of the data through the KPIs, the company can aim to reach the final level of maturity. The additional KPIs that are already implemented in this research are maturity and policy adherence. In conclusion, the identified KPIs offer a clear path for continuous improvement, ensuring that the company can leverage its data assets effectively and achieve its goals regarding supply chain efficiency.

6 Conclusion and Recommendation

This chapter summarizes the key findings of the research on improving master data governance (MDG) processes to enhance supply chain management efficiency. The study focused on Company X, examining how it currently manages, stores, and maintains its master data. Through interviews, system analysis, and SWOT analysis, the research identified multiple challenges and areas for improvement. The study also reviewed existing MDG tools, collaboration among stakeholders, and successful examples from other industries. By linking these insights with the situation at Company X, the research proposes a solution to improve MDG processes. This solution aims to reduce data errors, streamline processes, and enhance overall supply chain efficiency not only in Company X but also in other organizations. The chapter ends with suggestions for further research to address the limitations identified in the study.

6.1 Summary and key findings of research

This research aimed to address the main question: "How can the master data governance processes be improved to enhance supply chain management efficiency?". This research question is eventually answered through sub research questions. The study was conducted within the context of Company X, focusing on its master data governance (MDG) processes. The first two sub research questions were answered by analyzing the current situation in Company X, through interviews, analysis in the ERP system SAP S/4 HANA and SWOT analyses to identify the opportunities that helped finding solutions. Through a detailed examination of the material master, PIR, source list, customer master, BOMs, master recipes and quality inspection maintenance, several critical insights were revealed.

How is master data currently managed, stored, and maintained within the supply chain?

Master data at Company X is managed and stored primarily within the SAP S/4HANA ERP system, complemented by the cloud-based content management platform, Box. The material master and customer master data are maintained through specific tables such as MARA, MARC, EINA, EINE, EORD, KNVV, and KNA1. However, the current processes show manual updates, leading to various errors and inconsistencies. The key practices involve the use of a QAL for standardization, but adherence is inconsistent, leading to data quality issues.

What are the main challenges or pain points associated with current master data governance processes and coordination?

The primary challenges identified include data inconsistencies and errors, manual processes, lack of standardization, technical limitations and integration issues and inadequate utilization of ERP capabilities. Addressing these challenges requires a united effort to enhance data governance practices, improve process automation, and ensure comprehensive training and support for all stakeholders involved in MDM.

The following three sub research questions were answered through literature review and case studies to gain an in-depth understanding of MDM, MDG, data quality, coordination among stakeholders, current MDM tools, and real-world implementation examples in different industries.

What are the features and developments of current MDM tools in the market?

The current MDM tools in the market, such as the MDM system and the Unidata Platform Architecture, offer advanced features including data sourcing, MDM services, master data repositories, data distribution, and MDM presentation services. These tools focus on enhancing data quality, integrating data from diverse sources, and providing user-friendly interfaces for better data management. Emerging technologies like AI, NLP, and ML are being integrated into MDM tools to automate processes, improve data consistency, and ensure scalability.

What collaboration is required between different stakeholders (e.g., suppliers, manufacturers, distributors) to improve MDG?

Effective MDG requires robust collaboration among various stakeholders, including suppliers, manufacturers, and distributors. This involves establishing clear communication channels, aligning metadata and data exchange interfaces, and engaging senior management for data governance oversight. Stakeholders must work together to create standardized processes, set data quality expectations, and maintain a unified approach to data management. Knowledge repository systems and Web 2.0 technologies are instrumental in fostering collaboration and ensuring successful MDM and MDG implementation.

What are some real-world examples of companies or organizations that have successfully improved MDG in their supply chains?

The first industry that has successfully implemented MDG processes within their organization is the healtcare domain. Their implementation of MDM led to a unified patient and provider information system, improving data governance, reducing risks, and enhancing the quality of care. The second industry is the AKMA Univeristy and they implemented a digital-based database governance system improved academic services by enhancing data management and reducing management errors, highly impacting stakeholders. The last example is the manufacturing industry. Establishing an MDM system in this industry facilitated data sharing and integration, leading to improved operational efficiency, data accuracy, and compliance with regulations.

The following question is a knowledge question which is the first part of the main research question in this study. It was answered by linking the current situation in Company X with the literature review and case studies to eventually get to a solution to improve MDG processes at the company. First, the current maturity level of Company X was determined and then a suitable MDM tool was chosen for the company based on a scoring matrix.

How can the master data governance processes be improved to enhance supply chain management efficiency?

The selected maturity model was the MD3M approach. The strengths and weaknesses were identified, which helped in finding a suitable MDM tool for Company X and eventually creating a structured implementation plan outlining the steps, timelines, and resources required to carry out the solution proposal. The solutions in this implementation plan contribute to the enhancement of supply chain management efficiency because with these steps, data errors will be close to entirely eliminated and processes will be streamlined which causes less delays and financial losses, and a higher customer satisfaction. The efficiency can be quantified by the KPIs given in Chapter 5 when the solutions are implemented within the MDG processes. The

MDM tool that is found by the comparison of tools in a scoring matrix is the Unidata Platform tool. The best features of this tool were important to the needs of Company X, thus this was the highest scoring MDM solution. This maturity model can be applied to the needs of other organizations to find an MDM solution. The implementation plan can be utilized for the improvement of MDG processes in different industries.

The last sub research question is answered through analysis on KPIs that are essential for measuring the effectiveness of MDG processes within Company X's supply chain.

What KPIs are used to measure the effectiveness of MDG in the supply chain?

An overview of the relevant KPIs is provided. These relevant KPIs are established through their relevance according to specialists in Company X. The regarding KPIs are accuracy, timeliness, completeness and consistency of the master data. They can be quantified using formulas that calculate the percentage of accurate, timely, complete and consistent data entries. With the help of these KPIs, Company X can continuously monitor their progress on the improvement of their MDG processes and in reaching the final level of maturity.

In conclusion, the research provides a detailed roadmap for enhancing MDG processes at Company X, emphasizing automation, standardization, technical improvement, and better utilization of ERP functionalities. By addressing these areas, Company X can achieve greater data quality, operational efficiency, and overall SCM effectiveness. This effectiveness of SCM can be recognized by observing the decrease in delays in order, approval, shipment and delivery processes and also the decrease in financial losses such as penalties for delayed processes. Another factor that shows improved effectiveness of SCM is the customer satisfaction rate.

6.2 Limitations of research and suggestions for further research

There are some limitations in this research apart from what is described in Section 1.4.4. the first one is the sample size. The research was limited to a small number of participants from Company X, which might not fully represent the broader challenges and perspectives within the organization. This is due to the fact that Company X is still relatively small and growing, so there are not many responsible specialists for the specific functions within the company. Furthermore, a limitation was the scope of data analysis. The data analysis was limited to specific tables within the ERP system, which could mean that some other critical data areas were overlooked. The last limitation would be the time constraint. The research was conducted over a limited period, which may have impacted the depth of analysis and comprehensiveness of the key findings.

There are some suggestions for further research which could help as recommendations for other researchers and Company X to broaden their research. The first one is broader stakeholder engagement. Future research should include a wider range of stakeholders across different departments to gain more comprehensive insights. Additionally, extended data analysis would be a suggestion to consider. This involves expanding the scope of data analysis to include more tables and data points within the ERP system. Lastly, conducting longitudinal studies to assess the long-term impact of implemented improvements on MDG processes would be a recommendation.

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Appendices

Appendix A: Material Master Process Flow

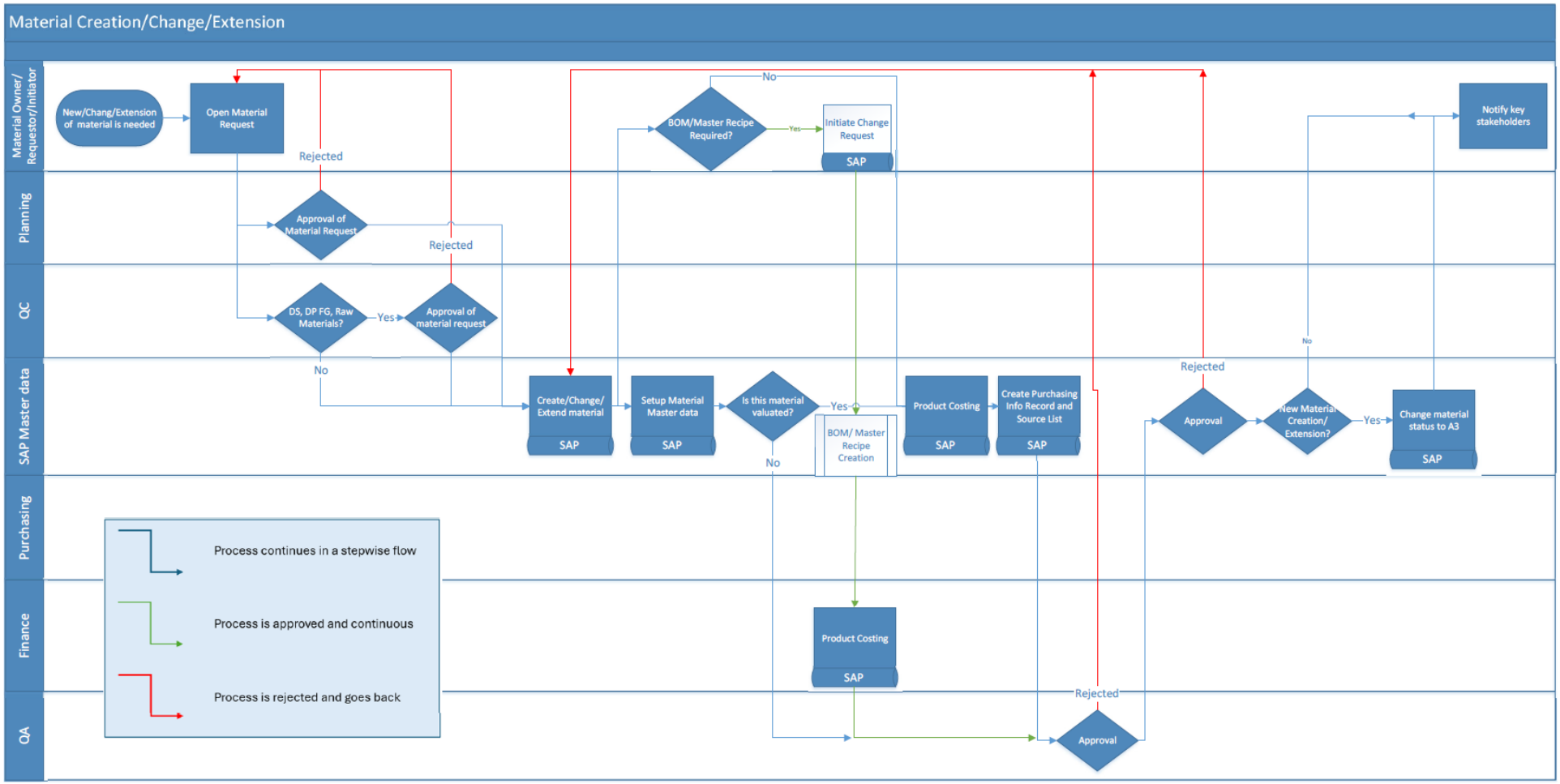

Figure 19. Material master process flow

Appendix B: Interview questions SRQ1 + SRQ2

Part 1

1. Can you describe your role in managing master data within the supply chain?
2. What are the common challenges you encounter when working with the master data that you are working with?
3. Have you faced any issues with the accuracy or completeness of the master data you are working with? If so, could you provide examples?
4. How do inconsistencies or errors in the master data you are working with impact supply chain processes from your experience?
5. Can you share some instances where inaccuracies in master data caused disruptions or delays in supply chain operations?
6. What are some key factors that contribute to the quality of the regarding master data in your opinion?
7. How do you currently manage the master data?
8. How do you communicate master data issues or discrepancies within your team or across departments?
9. Have you encountered any difficulties in aligning master data across different systems/platforms used within the company?
10. From your perspective, what improvements could be made to enhance master data governance processes in supply chain management?

Part 2

1. Can you describe the current collaboration processes between suppliers, manufacturers, and distributors regarding master data governance in the supply chain?
2. What are the key challenges you encounter when attempting to collaborate with external stakeholders (e.g., suppliers, manufacturers) on master data governance initiatives?
3. How do you currently communicate and share master data with external partners, and what improvements do you think could be made in this regard?
4. Have you experienced any difficulties in aligning master data standards or formats with your external partners? If so, how have you addressed these challenges?
5. Can you provide examples of successful collaboration efforts that have led to improvements in master data quality or governance within the supply chain?
6. What strategies or tools do you believe are effective in facilitating collaboration between stakeholders for master data governance purposes?
7. How do you ensure alignment between internal master data governance processes and those of your external partners?

Appendix C: Pie chart of ''MARC'' table results

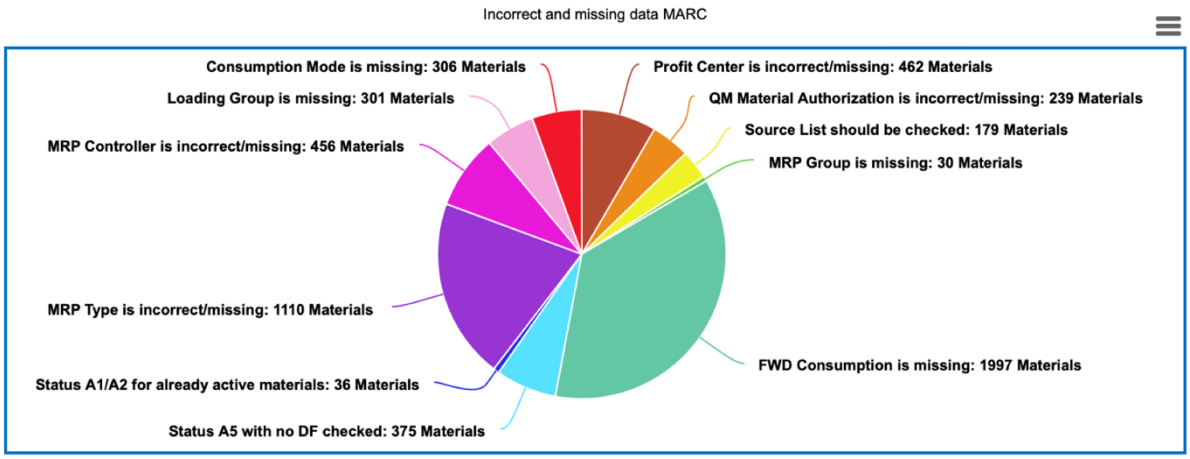

Figure 20. Inconsistent and missing data in MARC table

All the fields described in Figure 20 are information on plant level. The profit center indicates what the cost element is for the materials, and it depends on the material type and drug type what should be filled in as profit center. In the QAL, the profit center that needs to be filled in is given for the material and drug types. 462 materials show wrong information in the profit center field, which is nearly 18%. The QM material authorization indicates the type of authorization needed for the activities, which should be in this case 000022 and means that it requires a digital signature at usage decision. Approximately 9% of the materials have incorrect or missing information regarding this field. The source list should be always checked for externally procured materials and materials that are stored in a plant, coming from another plant. 179 materials do not have the source list field checked in the system while this is mandatory, which is 7% insufficiency. The MRP group indicates whether the material is internally or externally procured and is a mandatory field for every material in the system. For 30 materials, this field is empty, which is approximately 1%. The consumption mode indicates whether the consumption needs to be carried out as forward or backward consumption or both. This field is mandatory, and the forward (FWD) consumption is also mentioned as a mandatory field. However, 1997 materials are missing the FWD consumption field, and 306 materials are missing the consumption mode field. This is 77% and 12% insufficiency for the fields respectively. Furthermore, 14.5% of the materials have an A5 status on plant level with no deletion flag checked and 1.4% of the materials are active yet have an A1 or A2 status. Additionally, the MRP type indicates the MRP procedure that is used for the planning of materials. Nearly, 43% of the materials have this information incorrect or missing in the system. The MRP controller indicates the requirement for the planning and availability of the material and is incorrectly filled in or missing for 17.5% of the materials. Lastly, the loading group field determines which group will load the material for the transportation of it and is missing for nearly 12% of the materials.

Appendix D: Form for maintenance of material master

Fill Out Below Information (By Initiator)	
BUSINESS SCENARIO	☐ Clinical use ☐ Commercial use
REQUEST TYPE	☐ New SAP Material Number Request (Fill out Section I.I) ☐ Extend SAP Material Number to Other Location (Fill out Section I.II) ☐ Change SAP Material Number Request (Fill out Section II) ☐ Change SAP Planning material from non-GMP to GMP (Fill out Section II) ☐ Multiple[1] SAP Material Create/Change/Extend Request [1]Note: Provide information in attachment; check metadata Attachment section of FRM-00506 for template.
REQUESTED MATERIAL TYPE	☐ FERT - Finished Goods (FG) ☐ HALB - Semi-Finished Goods (DS, DP, BDP, intermediates) ☐ ROH - Raw Materials ☐ ZPKG - Packaging Components ☐ VERP - Shipping Systems ☐ ERSA - Spare Parts ☐ UNBW - General Supply
[redacted]	

Section I.I: New SAP Material Number Request ☐ N/A - Go to Section I.II		
MATERIAL INFORMATION		
Material Description: Note: Follow QAL-0046, maximum of 40 characters.	Click or tap here to enter text.	
Base Unit of Measure of the material (e.g., vials, grams, etc.):	Click or tap here to enter text.	
Plant Location(s) – Name and ID:	Click or tap here to enter text.	
Is Bill of Material (BOM) applicable for this material? If 'Yes', update BOM/MR info in Section III, stage 3; follow SOP-00543)	☐ Yes ☐ N/A Tekst	
Is Master Recipe applicable for this material? If 'Yes', update BOM/MR info in Section III, stage 3; follow SOP-00543)	☐ Yes ☐ N/A	
ADDITIONAL INFORMATION		
Storage Temperature:	☐ -15°C to -25°C ☐ 2°C to 8°C ☐ 15°C to 30°C ☐ Ambient ☐ 2°C to 25°C ☐ 2°C to 30°C ☐ Other: Click or tap here to enter text.	
Post to inspection flag: Applicable for 3PL plant(s)	☐ Yes ☐ No	
Is Quality Release Required? For multiple plants, provide Plant ID with each Inspection Type: Note: If "Yes", QA must complete "Quality Inspection Setup" in Section III, Stage 3	☐ Yes (Select the Inspection Type from below) ☐ 01-Goods Receipt Insp. For Purchase Order ☐ 04-Goods receipt inspection from production ☐ Other: Click or tap here to enter text. ☐ No	Plant ID Click or tap here to enter text. Click or tap here to enter text. Click or tap here to enter text. Click or tap here to enter text.
Does this material move to other Plant Location(s)? If 'Yes', please indicate which are supplying plant and receiving plant. [redacted]	☐ Yes Click or tap here to enter text.	
Other Information:	☐ No	
PURCHASING INFORMATION ☐ N/A [redacted]		
Who is supplying/manufacturing this material to/for [redacted]	[redacted]	
Average Goods Receipt processing time (in days):	Click or tap here to enter text.	

Figure 21. Material master maintenance form

Provide below information if External Supplier, CMO or Pack & Label Site is supplying the material: ☐ N/A Note: For batch pricing, below information is not required. Update the batch pricing in Master Recipe template per SOP-00543.	
SAP Vendor Name and Number:	Click or tap here to enter text.
Price per Order Unit:	Click or tap here to enter text.
Purchasing Unit of Measure:	Click or tap here to enter text.
Vendor Material Number (optional):	Click or tap here to enter text.
Catalog Number (optional):	Click or tap here to enter text.
Supplier Catalogue Number (optional):	Click or tap here to enter text.
Monthly usage (optional):	Click or tap here to enter text.
[redacted]	

Section I.II SAP Material Number Extension to Other Plant Location ☐ N/A - Go to Section II		
SAP Material Number:	Click or tap here to enter text.	
SAP Material Description:	Click or tap here to enter text.	
Note: For multiple material numbers, fill out the Provide information in attachment; check metadata Attachment section of FRM-00506 for template.		
Provide (all) Plant IDs where above material needs to be extended. Indicate supplying and receiving plant in the format [Supplying Plant]> [Receiving Plant] [redacted]	Click or tap here to enter text.	
Post to inspection flag: Note: applicable for 3PL plant(s)	☐ Yes ☐ No	
Is Quality Release Required? If multiple plants, provide Plant ID for each Inspection Type: Note: If "Yes", QA must complete "Quality Inspection Setup" in Section III, Stage 3	☐ Yes (Select the Inspection Type) ☐ 01-Goods Receipt Insp. For Purchase Order ☐ 04-Goods receipt inspection from production ☐ Other: Click or tap here to enter text. ☐ No Click or tap here to enter text.	Plant ID Click or tap here to enter text. Click or tap here to enter text. Click or tap here to enter text. Click or tap here to enter text.
Average Goods Receipt processing time (in days):	Click or tap here to enter text.	
	If External Supplier is providing the above material in requested plant location, provide below information: ☐ N/A	
	Receiving Plant ID:	Click or tap here to enter text.
	Purchasing Unit of Measure:	Click or tap here to enter text.
	Price per Order Unit:	Click or tap here to enter text.
	SAP Vendor Number:	Click or tap here to enter text.
	Catalog Number (optional):	Click or tap here to enter text.
	Supplier Catalogue Number (optional):	Click or tap here to enter text.
	Monthly usage (optional):	Click or tap here to enter text.
Additional Comment:	Click or tap here to enter text.	

Section II SAP Material Master Change Request ☐ N/A - Go to Section III	
SAP Material Number & Description for change request	
SAP Material Code:	Click or tap here to enter text.
SAP Material Description:	Click or tap here to enter text.
Plant ID:	☐N/A Click or tap here to enter text.
Fields to be changed	New value
Material Description:	☐N/A Click or tap here to enter text.
Post to inspection flag:	☐N/A Click or tap here to enter text.
Quality Inspection Setup:	☐N/A Click or tap here to enter text.
Temperature condition:	☐N/A Click or tap here to enter text.
Vendor Material Number in Purchase Info Record (PIR)	☐N/A Click or tap here to enter text.
Other: Specify field name.	☐N/A Click or tap here to enter text.
Justification for Change:	Provide justification and if available provide reference document number.

Figure 22. Material master maintenance form (part 2)

Section III SAP Material Master Execution List This section to be filled out by executors	
STAGE 1	
PLANNING REVIEW (PLANNING)	
Provide supply chain flow of the material	☐N/A Click or tap here to enter text or refer to attachment.
Material request was reviewed and approved by	Click or tap here to enter text.
QUALITY CERTIFICATE (QUALITY CONTROL) Note: Applicable for General Supply & Raw Material only	☐N/A
Type of certificate required	☐N/A Click or tap here to enter text.
STAGE 2	
SAP MATERIAL MASTER REVIEW (SAP MASTER DATA) Note: Update the Veeva Document "FRM-00506 SAP Material" [*Insert Material Number*] [*Request Type*] by inserting Material Number and adding the stage 2 execution date in format DDMMMYY.	
Applicable for Section I only: ☐N/A	
Assigned SAP Material Number:	Click or tap here to enter text.
SAP Description:	Click or tap here to enter text.
Plant Name & Plant ID:	Click or tap here to enter text.
Comment:	Click or tap here to enter text.
Applicable for Section II only: ☐N/A	
SAP Material field(s) changed according to section II details:	Click or tap here to enter text.
STAGE 3	
PURCHASE INFO RECORD (SAP MASTER DATA)	☐N/A
Purchase Info Record:	☐Created ☐Changed ☐N/A
Source List:	☐Created ☐Changed ☐N/A
Comment:	Click or tap here to enter text.
QUALITY INSPECTION SETUP (SAP MASTER DATA) Note: Required if "Quality Release Required?" = "Yes" in section I.II - Follow WI-00145	☐N/A
QM Inspection Type:	Appropriate Inspection Type(s) set up for each plant/material combination? ☐Yes ☐N/A
QM Inspection Plan:	Inspection Plan set up correctly for each plant/material combination? ☐Yes ☐N/A
BOM/MASTER RECIPE INFORMATION REVIEW (INITIATOR) Note: Do not complete task in stage 3 until ECR workflow is approved	☐N/A
Engineering Change Request (ECR) Number for BOM:	Click or tap here to enter text. ☐N/A
Engineering Change Request (ECR) Number for Master Recipe:	Click or tap here to enter text. ☐N/A
STAGE 4	
MRP INITIAL SETUP (PLANNING)	☐N/A
MRP Views:	☐Created ☐Changed ☐N/A
Production Version is reviewed: (Applicable only if Master Recipe is required)	☐Yes ☐N/A
PRODUCT COSTING (FINANCE)	☐N/A
Product costing is created for the requested material(s) in requested plants:	☐Yes ☐No ☐N/A
Profit Center is verified:	☐Yes ☐No
Valuation Class is verified:	☐Yes ☐No
Comment:	Click or tap here to enter text.
FINAL APPROVAL (IN VEEVA WORKFLOW)	
Required Approvers' Departments	
Quality Assurance	
SAP Business Analyst	
Note: Upon approval of this form, **Request Initiator** will notify all the applicable stakeholders indicated in SOP-00510.	

Figure 23. Material master maintenance form (part 3)

The first section indicates whether the request is for clinical or commercial use, what type of request it is and what material type is requested. Then, there are three sections, where one of them will be filled out according to what the request is (creation, extension or change). Eventually when the required information is filled out in the form, the form goes to the material master team to fulfill the request in the system and the different stages are completed in the ERP system. Stage 4 is for the planning and finance team and stage 5 is for the final approval where the regarding quality assurance person and SAP business analyst is responsible.

Appendix E: Customer Maintenance

E.1 Process Flow

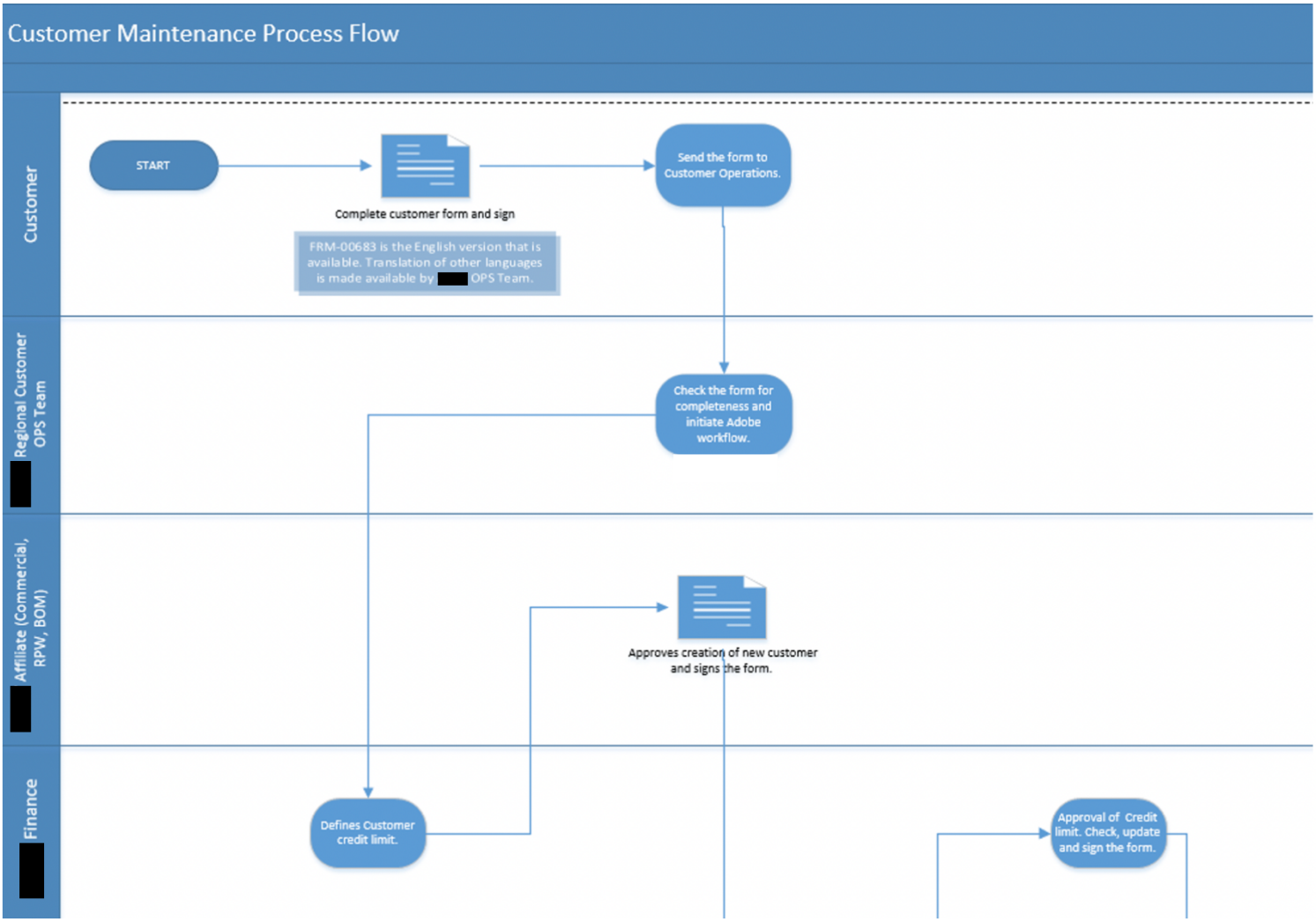

Figure 24. Customer maintenance process flow

When a customer needs to be created in the system, the process starts with the customer themselves. The customer completes the provided form with as much information as possible to fill in the ERP system and signs it. Then, the form is sent to the customer operations team of Company X. The form is checked by this team for completeness and the workflow is initiated. After the initiation of this workflow, the finance team defines the credit limit and the regarding affiliate of Company X approves the new customer creation and signs the form as well. Now, the creation of the customer in the system can start.

E.2 Customer Form

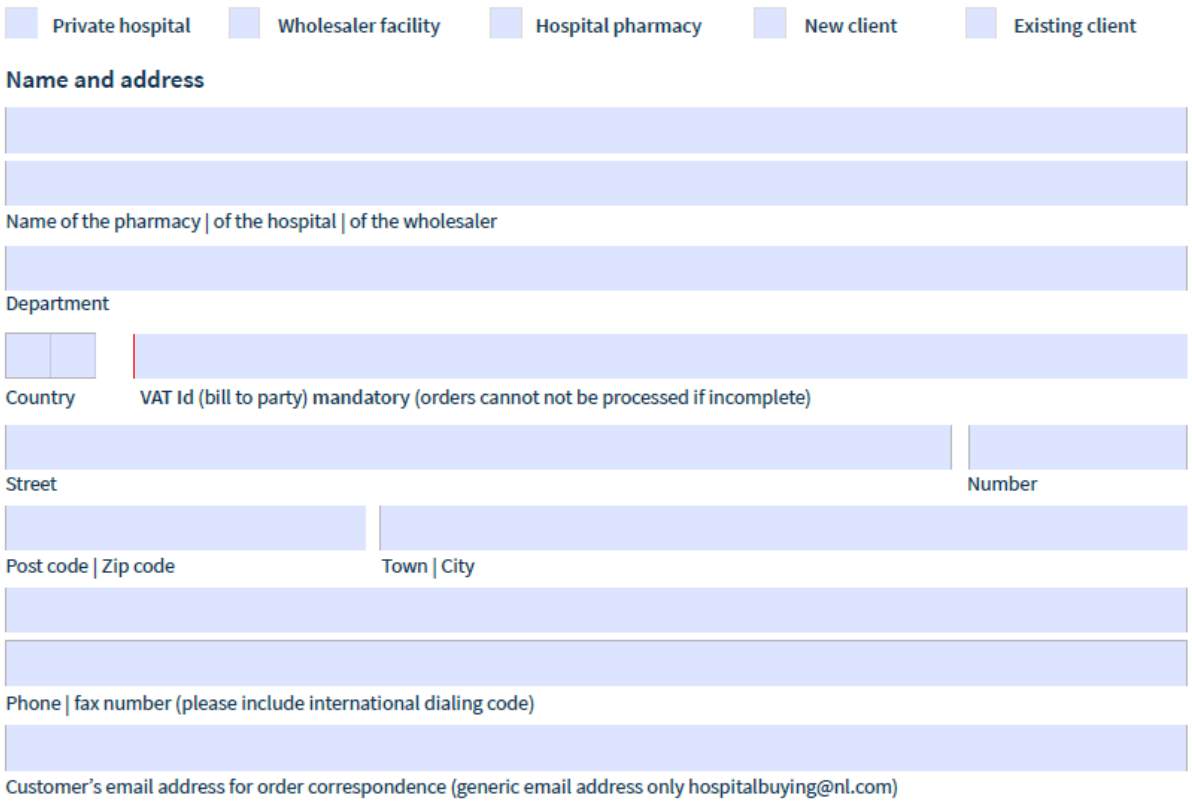

Figure 25. Customer form

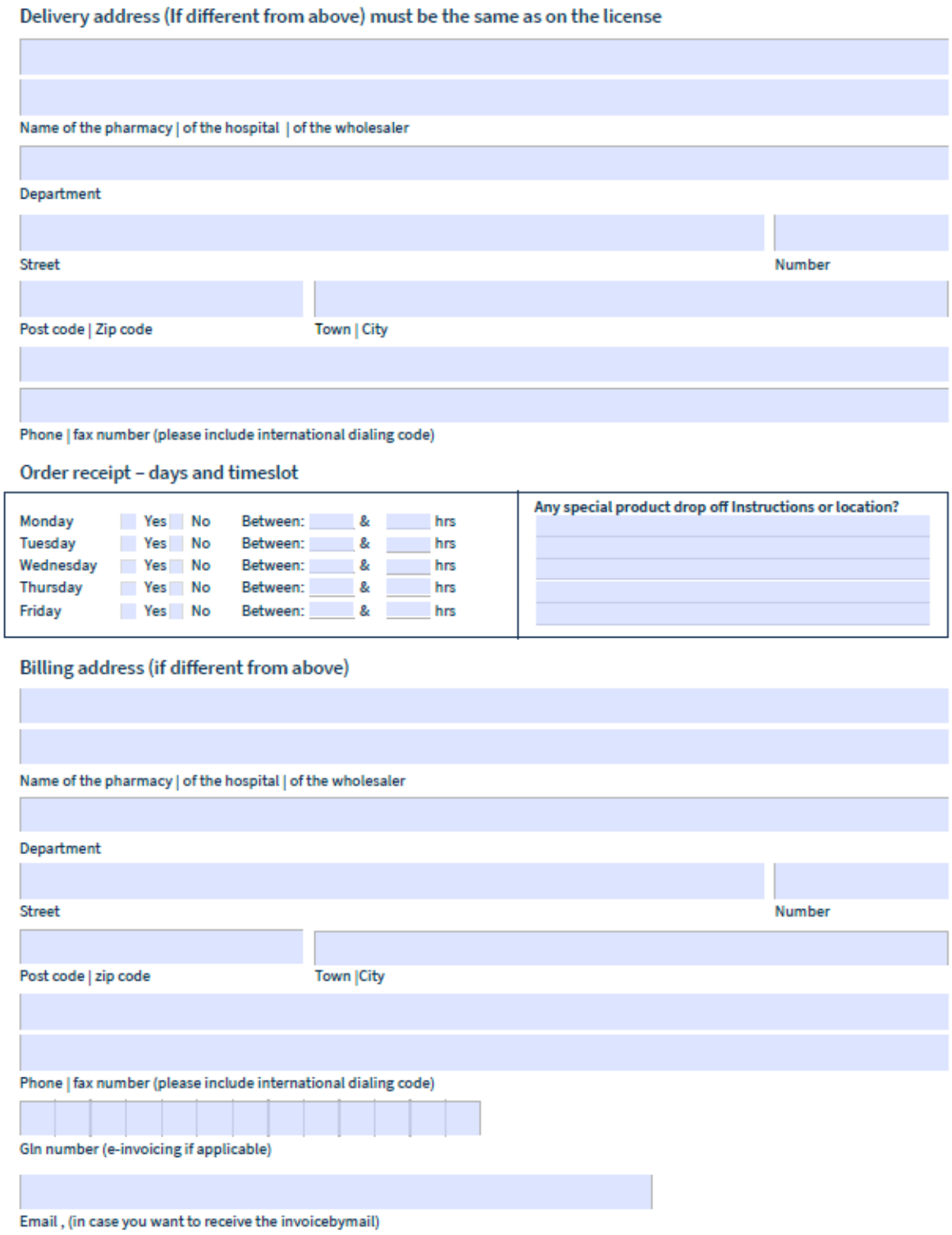

Figure 26. Customer form (part 2)

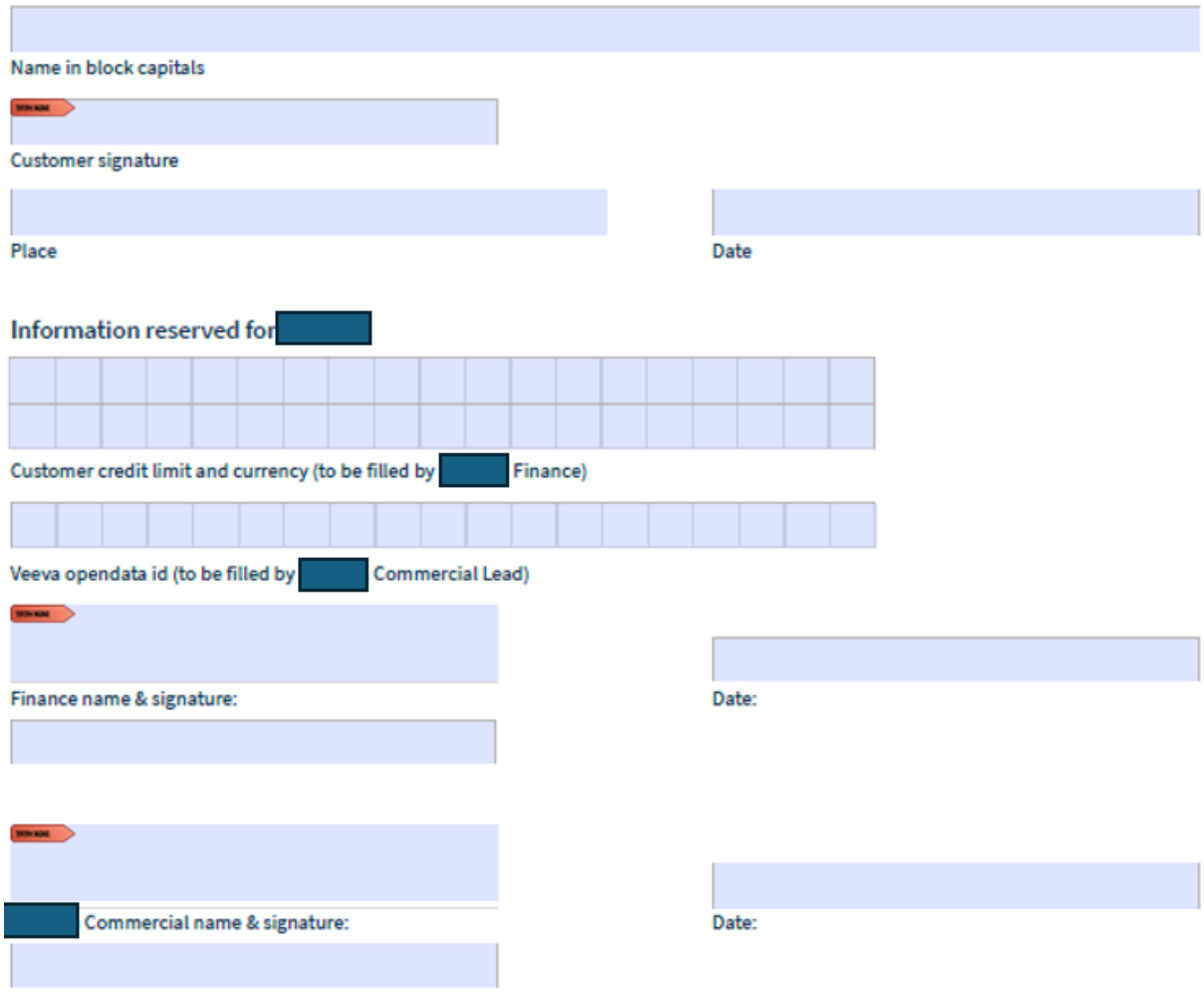

Figure 27. Customer form (part 3)

Appendix F: MDM and MDG files in management application Box

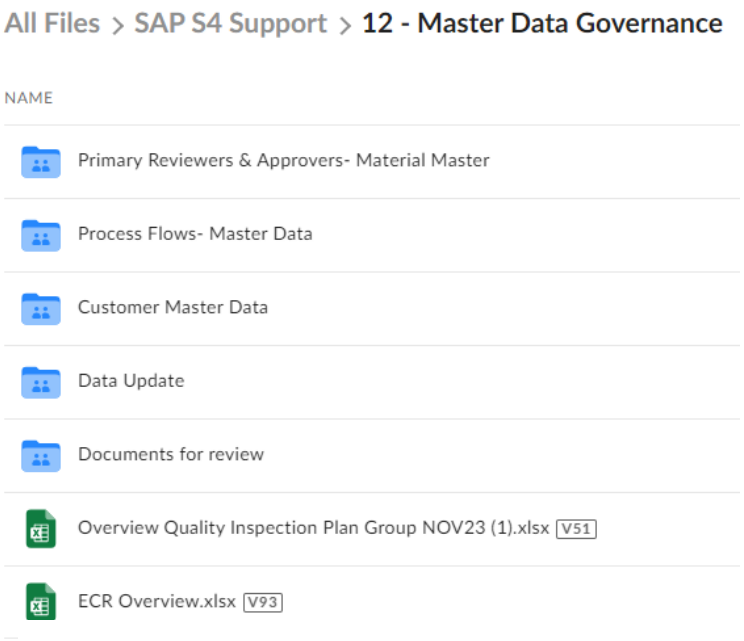

Figure 28. MDG file in Box

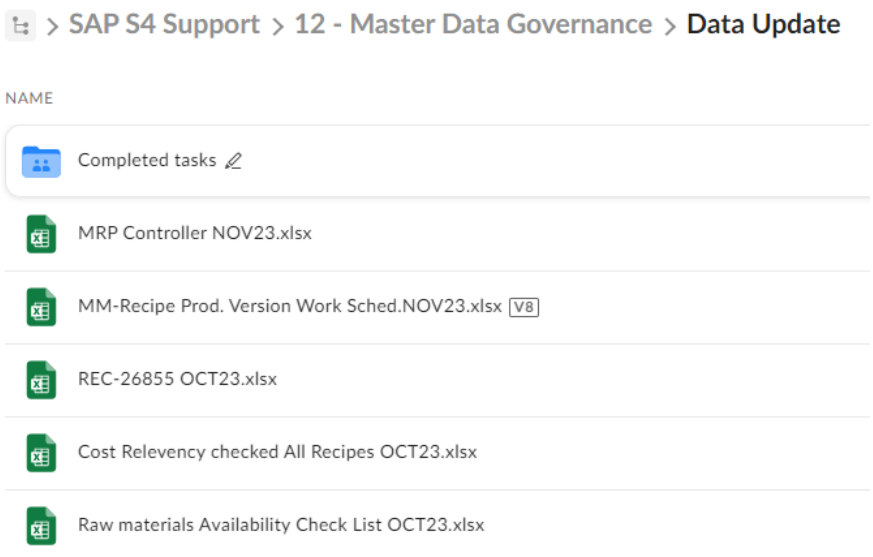

Figure 29. Data update file for MDG process files in Box

Appendix G: VBA code calculating the total scoring of the MDM solutions

```
Sub CalculatedWeightedScores()

Dim ws As Worksheet
Set ws = ThisWorkbook.Sheets("ScoringMatrix")

Dim scoreRange As Range
Dim weightRange As Range
Dim resultRange As Range

Set scoreRange = ws.Range("M5:Q30")
Set weightRange = ws.Range("R5:R30")
Set resultRange = ws.Range("M31:Q31")

Dim i As Integer
Dim j As Integer
Dim WeightedSum As Double

For j = 1 To scoreRange.Columns.Count
    WeightedSum = 0

    For i = 1 To scoreRange.Rows.Count
    WeightedSum = WeightedSum + scoreRange.Cells(i, j).Value * weightRange.Cells(i, 1).Value
    Next i

    resultRange.Cells(1, j).Value = WeightedSum

Next j


MsgBox "Calculation complete"


End Sub
```

Figure 30. VBA code calculating the scores of MDM tools