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**Change requirements on product data structures in
S/4HANA implementation**

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ABSTRACT:

Enterprise resource planning (ERP) renewal projects are common in today's organizations. As renovating and updating ERP systems typically involves many of the organization's resources, companies strive to ensure that large projects meet the planned goals and schedule. This study focuses on the renewal project of the SAP system, where several parts of the organization move to use a newer version of the ERP system. The basis for the research utilized the Design Science Research (DSR) approach for information systems, which focuses especially on developing systems and improving functions by producing additional information on open problems or questions. The research is limited to SAP's Material Management module, especially its product configuration and batch management-related features, as the future identified changes are particularly related to these areas. The research primarily focuses on product data structure changes that directly impact system data configuration and daily work in the system in terms of product management organization. The research utilized a multi-method approach, combining quantitative and qualitative research to gain a deeper understanding of the research questions. In the first phase of the research, previous academic research related to the key questions, the technical documentation of the SAP system, and other literature were used to map the system's requirements and well-proven operating methods. In the next step, the organization's current product information and structures were evaluated quantitatively in the data analysis phase. Additionally, the business context, observations, and requirements were clarified with the help of short interviews to ensure the best result. The research results combine the structural change requirements in terms of identified change areas considering both the technical requirements of the new system version and the business needs. As the product structure contains key information important to the company's business, the results section is partially anonymized.

Keywords: ERP, Configurable products, material variants, product management, batch management

VAASAN YLIOPISTO**Tekniikan ja innovaatiojohtamisen yksikkö**

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TIIVISTELMÄ:

Toiminnanohjausjärjestelmien (ERP) uudistusprojektit ovat yleisiä nykypäivän organisaatioissa. ERP-järjestelmien uudistaminen ja päivittäminen sitoo tyypillisesti paljon organisaation resursseja. Yritykset pyrkivät varmistamaan, että kyseiset suuret hankkeet onnistuvat suunnitelluissa tavoitteissa ja aikataulussa. Tämä tutkimus keskittyy SAP-järjestelmän uudistusprojektiin, jossa useampi organisaation osa siirtyy käyttämään järjestelmän uudempaa versiota.

Tutkimuksen perustana käytettiin tietojärjestelmien suunnittelutieteellistä tutkimusta (DSR), joka keskittyy erityisesti järjestelmien kehitykseen ja toimintojen parantamiseen tuottamalla lisätietoja avoimena oleviin ongelmiin tai kysymyksiin. Työn tavoitteena on erityisesti kartoittaa organisaation tuotehallintaan kohdistuvia muutoksia. Tutkimus rajoittuu SAP:n Material Management-moduuliin, ja erityisesti sen tuotteen konfigurointi, ja sekä erähallintaan liittyviin ominaisuuksiin, sillä tulevat tunnistetut muutokset liittyvät erityisesti näihin alueisiin. Tutkimus keskittyy ensisijaisesti tietorakennemuutoksiin, joilla on suora vaikutus järjestelmän konfigurointiin, sekä päivittäiseen työskentelyyn järjestelmässä tuotehallinnan osalta. Tutkimuksessa hyödynnettiin monimenetelmällistä lähestymistapaa, jossa määrällistä ja laadullista tutkimusta yhdistettiin kokonaisvaltaisemman ratkaisun kartoittamiseksi.

Tutkimuksen ensimmäisessä vaiheessa avainkysymyksiin liittyvää aikaisempaa akateemista tutkimusta, kirjallisuutta, sekä SAP-järjestelmän teknistä dokumentointia hyödynnettiin järjestelmän vaatimusten ja hyväksi todettujen toimintatapojen kartoittamiseksi. Seuraavassa vaiheessa organisaation nykyisiä tuotetietoja, sekä rakenteita arvioitiin määrällisesti data-analyysivaiheessa. Tämän lisäksi liiketoimintakontekstia, havaintoja ja vaatimuksia tarkennettiin

lyhyiden haastattelujen avulla parhaan lopputuloksen varmistamiseksi. Tutkimustulokset yhdistävät järjestelmän käyttöönottoon liittyvät järjestelmän rakennemuutokset yhdessä tarvittavien liiketoiminnantuoterakenteiden kanssa.

Tuoterakenteen sisältäessä yrityksen liiketoiminnalle tärkeitä avaintietoja, on tässä työssä tuotu esiin vain tuloksien julkinen osuus osin anonymisoituna.

Keywords: ERP, konfiguroitavat tuotteet, materiaalivariantit, tuotehallinta, erähallinta

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ABBREVIATIONS

ERP	Enterprise Resource Planning (System)
SAP ECC	Previous version of SAP ERP
SCM	Supply Chain Management
BOM	Bill Of Materials
MTO	Make-to-Order
MTS	Make-to-Stock
ETO	Engineering-To-Order

MM	SAP Material Management Module
MD	Master Data
MDM	Master Data Management
VC	Variant Configuration
CMMR	Configurable Material Master Record
S/4HANA	Latest version of the SAP ERP system
LO-VC	Material Variant Configuration
SO	Sales Order
CM	Configurable Material
LIFO	Last-In-First-Out
FIFO	First-In-First-Out
POS	Point-Of-Sale
PP/PP-PI	Production Planning for Process Industries
IM	Inventory Management
SD	Sales and Distribution
WM	Warehouse Management
1-N	One to Many
GMP	Good Manufacturing Practice

1 Introduction

The main purpose of this thesis is to highlight, prepare, and document the change requirements coming to the product data structures in an upcoming Enterprise Resource Planning system implementation from the case company's Product Management organization point of view. In addition, the cross-process impacts of data changes and requirements coming as input from other processes to product data are considered and reviewed. Enterprise resource planning (ERP) system implementation projects aim to achieve cost savings, process improvements, and increased efficiency in operations. (Goeun, 2013) On the other hand, implementation projects often involve resources in and outside of the organizations, which makes the preparation work play a key role in the successful on-time delivery of the new system. Previous academic studies show that providing information, training, and preparing the users and the organization for the upcoming changes is vital in order to achieve the benefits of implementing an ERP system. (Ram, et al., 2013)

This research is made as a case study for a specific case company, but the questions the organizations must be able to answer before implementing the new ERP system are partly common in their nature. In the world of ERP system implementations, the current trend is to rely on the out-of-the-box features and capabilities of the technology provider as much as possible. This approach helps organizations to achieve their objectives more efficiently and effectively. However, it is vital to note that when researching business requirements, each company's unique needs must be considered, as they may differ significantly from those of other corporate entities. (Aires & Abrantes, 2022) Therefore, it is essential to thoroughly analyze the company's specific needs to ensure that the ERP system can adequately meet them. (Espeter, 2022)

Understanding relevant product data and required structure changes will decrease time in later project phases, including testing and data migration. Many previous ERP-related research studies have focused on post-implementation impacts and findings after implementing the system rather than pre-design phases, which typically include some

level of uncertainty due to the new system and often large project organization. In order to successfully implement manufacturing engineering and supply chain processes into a new ERP environment, global manufacturing companies must carefully evaluate the manufacturing process and resources best suited for each manufacturing site. Carefully planned product data management (PDM) integration is crucial for ERP system implementation in a global manufacturing environment. (Lee & Leem, 2011)

Information and knowledge sharing has become increasingly relevant to ensuring that knowledge can be easily communicated and exchanged between organizational stakeholders. The barriers and enablers need to be well understood, as projects often face challenges regarding knowledge sharing. Previous academic studies show that a common problem during ERP implementations is the knowledge gap between the system end users, project core team members, external partners, vendors, and management. (Li et al., 2017) Despite the significant differences in organizational requirements, context, content, and business requirements, organizations often face similar challenges throughout the project. (Mahmood et al., 2023) (Aires & Abrantes, 2022) (Finney & Corbett, 2007)

The primary objective of this research is to establish a framework that integrates the current knowledge of past organizational decisions and product data structure requirements while also considering the differences between the old and new ERP system technology before the system-building phase. This so-called exploration cycle ensures that all project participants clearly define and understand the company's requirements, further ensuring a solid foundation for the rest of the project. (Espeter, 2022) As data is identified as one of the most critical assets of organizations, the data structures serve as a fundamental foundation for a successful system implementation. (Premaratne et al., 2011) Furthermore, this research will provide an overview of the essential product (SAP) data structure changes that must be considered in the company context, focusing especially on areas where the change need has been identified in the earlier stages of the project (Material variants and Batch Management). As the major

goal of ERP is to improve business operations and decrease costs, the standardization of processes and data structures needs to be streamlined to allow an organization to centralize its administrative activities, improve its ability to deploy new system functionalities, and reduce future maintenance costs. Research shows that the challenges faced during ERP implementations are often not caused by the technology itself but rather by the complexity of changes caused within the organization. (Goeun, 2013)(Bingi et al., 1999) (Finney & Corbett, 2007)

1.1 Case company introduction

Metsä Tissue is one of the leading manufacturers of Tissue paper products in Europe and one of the leading manufacturers in the world of greaseproof paper products. Metsä Tissue has nine mills in five countries, producing high-hygiene products for consumers and professionals. It has six own brands, and it also manufactures products for European retailers. Metsä Tissue targets achieving fossil-free mills and own-produced products by 2030. In terms of product manufacturing, Metsä Tissue focuses heavily on ensuring the continuous improvement of its operations and compliance. Metsä Tissue follows the principles of Good Manufacturing Practice (GMP) when manufacturing all its products.

Paper production is achieved through a highly automated and enclosed mechanical process, ensuring strict safety, hygiene, and quality control standards are adhered to. (Metsä Tissue mills, 2024) Paper mills typically adhere to a well-established and refined process, which involves managing and processing materials through a series of stages, employing specialized equipment for each step. The equipment used in these processes operates relatively steadily and is responsible for executing a specific function in the manufacturing process. The typical high-level manufacturing flow for tissue paper production (Figure 1.) includes a supply of raw materials, including pulp and other needed components such as chemicals, water, and energy available for the manufacturing; the paper manufacturing then takes place at a paper machine. A base paper reel is received as output from the paper machine, which is then converted into

the final product depending on the required product characteristics. The final product is further packaged and palletized for later supply chain stages.

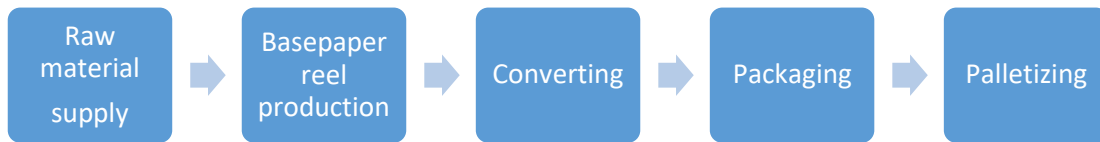


Figure 1. Simplified example of typical tissue product manufacturing phases.

1.2 Research questions

The research questions focus on improving the understanding of the impact caused by the system upgrade on the data structures and daily work.

1. "What relevant products from the current system will be used in the future ERP and batch management?"

This research question aims to thoroughly define the necessary product scope for implementing ERP.

2. "What are the implications of the newly introduced batch management functionality on the organization responsible for managing the products?"

The case company is already utilizing other traceability features of ERP and connected systems to manage traceability throughout the supply chain processes. However, with batch management, some information available is expected to be utilized more efficiently and automatically. The research aims to investigate typical batch management

best practices and characteristics used for products that can be used together with SAP's batch management functionality. Also, the impact on product data structures is reviewed.

3. "What are the required product data structure and/or data element changes to fulfill all cross-process area needs?"

To ensure that all the requirements across different processes are met, it is crucial to identify the mandatory changes that need to be made in the product data structure and elements. This includes analyzing the current data structure and identifying the elements that need to be modified, removed, or added to meet the requirements of related processes. Proper understanding of these requirements is essential for successful system implementation.

It is important to note that any additional analysis required during the system-building phase may cause delays and negatively impact on the project costs. Therefore, conducting a thorough analysis of the requirements before starting the system implementation will decrease the time required for internal alignment in the next project steps. This analysis should include a detailed understanding of the data structure and elements required by each process and any dependencies or interactions between them. By doing so, the organization can ensure the system is built to meet all the requirements and functions efficiently without any unforeseen delays or costs. As the project focuses on replacing an existing SAP ERP system with a newer version, the focus is on the technical changes between the version's impact on product management and two main functionalities impacting the future structures, configurable (configured) materials (Variant configurator) and batch management.

1.3 Scope and study objectives

A literature review will be conducted on the functionality and master data requirements of S/4HANA to support the ERP project of Metsä Tissue from the perspective of the Tissue Product Management organization. The review emphasizes recent academic

research and other ERP implementation and data management literature, focusing on SAP ERP products, variant configuration, and batch management.

The aim is to evaluate the current product data across different categories and identify key differences and requirements from nine mills in four regions. This analysis will serve as the basis for defining "TO-BE" requirements, data harmonization, and cleaning activities. To achieve this goal, the existing product data will be analyzed and compared across categories to identify patterns, outliers, or inconsistencies. By doing so, it can determine what changes need to be made to bring the data into harmony and make it more accurate and consistent. Any redundant and unneeded data will be documented separately to avoid unnecessary migration to the new system. The goal is to ensure that the product data scope for the new system only contains the mandatory elements and data objects. The research results and other knowledge gathered during the research will also be shared with other project team members, further contributing to understanding the current situation, upcoming changes, and change management requirements.

Table 1. Requirements to support the next project phases.

ID	Requirement	Rationale
REQ_D1	Identify product scope for the new system and product configuration.	Ensures that only needed content is taken into the new system.
REQ_D2	Identify needed characteristics for the products.	Identifying required characteristics allows easier system setup for configurable materials and material variants. It also enhances the user experience and understanding of required data.

REQ_D3	Identify data changes to current products when they are changed to material variants.	Enables faster implementation and mutual understanding about the upcoming change.
REQ_D4	Identify the requirements and data changes when batch management functionality is used.	Enables faster implementation and mutual understanding about the upcoming change.
REQ_P1	Identify a suitable preliminary product model approach that supports business requirements.	Ensures that the new model supports requirements in other processes and connected systems.
REQ_P2	Identify other changes coming to the product management organization.	Allows the organization to start change management and training in cases where needed.
Test Scenarios	To identify a suitable level for test scenarios in terms of material variants (products).	As product structures change, test scenarios suitable for identifying all variability are needed. Test Scenarios are a typical part of ERP implementations.

1.4 Structure of the thesis

The thesis is structured into five primary sections, as outlined in Figure 2. The purpose of this structure is to provide a systematic approach to addressing research topics. The first section is dedicated to the introduction, which overviews the thesis background, research objectives, and questions. The Research Methods section describes the quantitative (data analysis) and qualitative (interviews and observations) methods used in the thesis to answer the research questions. The third section focuses on the literature review, which combines existing academic research with the case company's project documentation and data, providing a comprehensive understanding of the subject matter.

The findings from the previous sections are presented in the Result section. In this section, the structural change areas, new and changing cross-process requirements, and data harmonization results are considered and combined to give the case company's product data organization a comprehensive overview of the focus areas in the system design phase. Required test cases for the following phases of the project are also reviewed and suggested from the product management organization's point of view.

The discussion and conclusion section interprets the research findings within the broader context of existing literature and theoretical frameworks. This chapter also evaluates the validity of the research results.

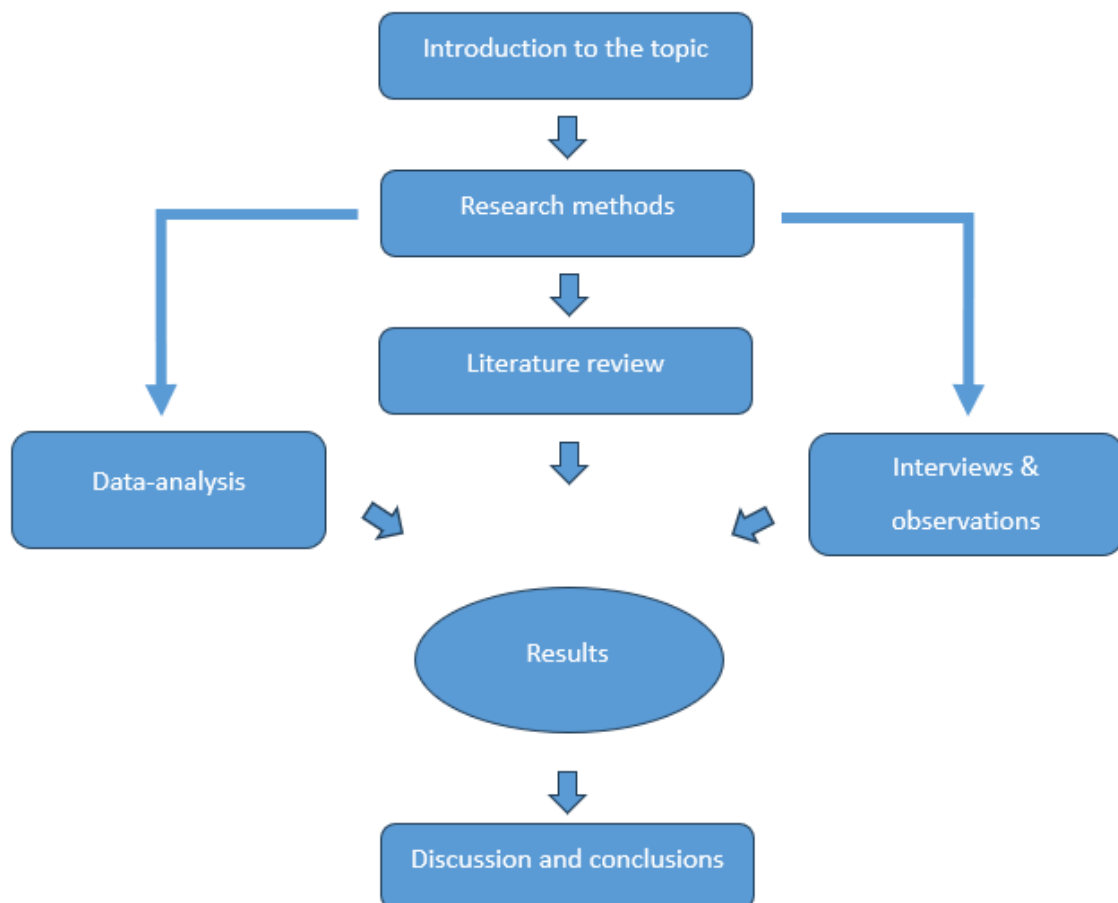


Figure 2. Structure of the thesis.

2 Literature review

2.1 Introduction to SAP ERP

SAP is one of the world's leading Enterprise Resource Planning systems (ERP) technology providers. ERP systems help organizations to manage large amounts of information and enterprise resources efficiently. Typically, all the core business processes, such as finance, manufacturing, supply chain management, project management, and human resources processes within an organization, can fully or partly be managed with the help of ERP software. ERP enables seamless integration of information shared across organizations' departments and processes, allowing the sharing and receiving of information from its key business partners. As the operations performed within the ERP are often complex, many companies have faced delays and challenges while implementing a new ERP system. (Li et al., 2017)

SAP was founded in 1972 and released its second-generation core product, R/2, in 1979. Over the years, SAP has added more core functionalities and module packages, such as Materials Management (MM), which allow companies to use the system in their particular operations area. (SAP SE, 2024)

In 2004, SAP released its first version of SAP ERP Central ECC; this particular software version later received several enhancement packages. The SAP ECC system was later replaced by the latest SAP system version, S/4HANA, which was initially introduced in 2015 but has evolved through updates to be one of the leading ERP systems used in the world. (PC World, 2015) (SAP SE, 2024)

2.1.1 Material Management (MM) and Product Data Management (PDM) as a part of SAP ERP

The Materials Management (MM) Module is a crucial aspect of SAP ERP software, serving as a cornerstone for the tool's logistics and supply chain operations. In addition,

the data produced and handled within the MM Module is deeply integrated and utilized in conjunction with other modules, including Finance (FI), Controlling (CO), Production Planning (PP), Quality Management (QM), Sales and Distribution (SD), and Warehouse Management (WM). (Murray, 2006)

The supply chain is the material flow from the supplier to the customer. The movement of materials within SAP ERP is known as material flow, beginning with procurement and ending with distribution to customers. Materials are received from suppliers and stored in inventory until needed for production, consumption, or distribution. Inventory/Warehouse (IM/WM) Management oversees the movement of goods within warehouses. For materials used in production, SAP provides production planning and manufacturing processes to schedule and manage resources. Quality Management (QM) allows for quality inspections to be conducted as per material and company-specific requirements. Once materials are ready for sale, they are distributed to customers through Sales and Distribution (SD) processes. SAP also supports return and reverse logistics functionalities, including inspections, related return and refund procedures, and regular inventory and warehouse management procedures. (Akhtar & Murray, 2020)

SAP ERP material flow allows organizations to better oversee and understand their ongoing Supply Chain Management (SCM) processes. SAP ERP empowers businesses to streamline their SCM processes and achieve maximum efficiency by providing real-time visibility into inventory levels, manufacturing processes, and logistics procedures. Furthermore, SAP material data is often exchanged between other systems in addition to SAP to enable and support seamless data exchange processes through the company's supply chain ecosystem.

2.1.2 Organizational structure in SAP Material management and master data

SAP arranges the record of material master data into separate views that different departments in the organization usually maintain. Apart from the structured views, the

Material Master also has a hierarchical structure that is typically based on the organizational structure of the company using the system. In SAP, the material data that is accessible at an organizational level depends on the organizational unit structure. Figure 3 shows an example of the possible organizational structure in SAP.

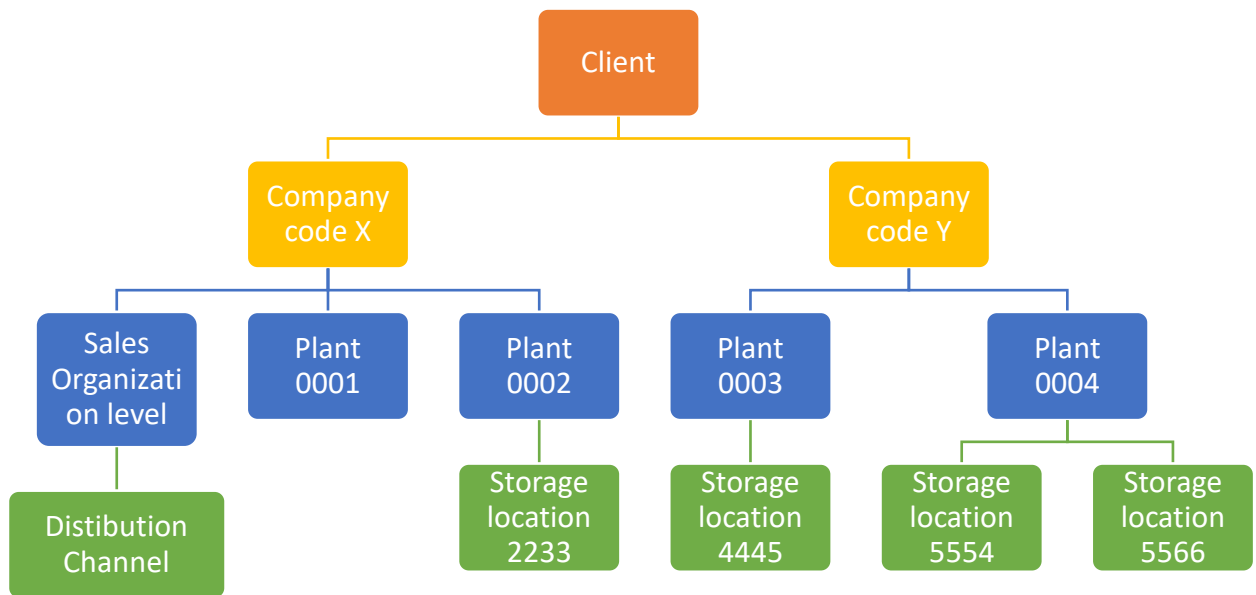


Figure 3. Simplified example of corporate to material data structure in SAP. (SAP, 2023)

Client level refers to the highest organizational level in SAP, which often refers to the corporate group or a separate SAP system. Client level in terms of material master data refers to the general material data that applies to the entire organization. In practice, this means that the data set on material master at this level will be available for all the lower levels in the structure (e.g., plant and sales level). Data managed on this, or lower level, can only be managed within the same client, meaning that the data in the system environment is client-dependent. (Akhtar & Murray, 2020)

The company code is the minimum organizational unit that can generate a complete set of accounts for external reporting. This involves recording all transactions and generating relevant documents for financial statements, such as balance sheets and profit and loss

statements. A company code can, for example, be a company or subsidiary of an organization. (Akhtar & Murray, 2020)

The plant organizational level usually refers to a company location where materials are stored, processed, or manufactured. This could be, for example, a mill manufacturing products, a retail store, or a distribution center. Data managed on this level could be, for example, purchasing, planning, or forecasting data, as the process and responsibilities for the same material or product can and often differ between different plants. As shown in Figure 3 above, several plants can be assigned to the same company code. (IBM, 2022)

Storage location in the SAP system is a physical location where the stock/goods are kept within a plant. The storage location level is the lowest level in the MM module, but depending on the organization's requirements, other location, and material requirements, SAP also offers different options for warehouse management. These additional Warehouse Management (WM) and Extended Warehouse Management (EWM) functionalities allow more enhanced inventory management by managing inventory quantities at additional storage type and bin level. If a company uses warehouse management, either WM or EWM, the warehouse is linked to a storage location managed within the MM Module. (SAP SE, 2023) (Sachan & Jain, 2022)

Sales area level data is a sublevel of material data relevant to a specific sales organization distribution channel, or area of sales. Typically, in SAP S/4HANA, this could be for sales price or sales organization-specific tax information for goods sold. (Murray, 2006) (Akhtar & Murray, 2020)

Purchasing organizations in SAP represent the department/group of employees dealing with material sourcing and procurement. Depending on the organizational structure, purchasing organizations can be connected to corporate, client, or one-to-many plants in SAP. (Ashfaq, 2014)

2.1.3 Material Master Data in S/4HANA

The material Master (MM) data record inside ERP is a repository that contains information about components and products. (Akhtar & Murray, 2020) Typical elements of material master data records are a unique key for the product or part and a name or description. The most important elements linked to this material record typically are a list of components (Bill of Material recipe), information about work processes for production activities (routing), allocation of product group (class), and structured information about product characteristics (classification). (Knapp & Hasibether, 2011)

It is also important to notice that even though the record is often called a material master record, it is used to store all sorts of material information, including raw materials, production consumables, finished products, spare parts, and so forth. (Wei et al., 2023) SAP Material master records are a “must-have”/required in many previously reviewed SAP functions (e.g., PO, IM, S&D, PP).

Different organizations' departments will create, maintain, and consume the material data depending on the organizational structure of the company and the type of operations. In SAP S/4HANA, the material master data is separated into views typically managed by different organizations or groups within the company in the same manner as in previous SAP versions (E.g., SAP ECC). The information stored in these views will contain data about the properties of the material (e.g., basic data, material classification, and characteristics) and data relevant to the material-related processes (e.g., sales, planning, quality, logistics, and accounting data). (Akhtar & Murray, 2020)

2.1.4 Data modeling considerations when moving from SAP ECC to S/4HANA.

In recent years, enterprise applications' data management needs have significantly changed. The conventional separation between analytical and transactional access patterns is no longer practical. Transactional queries are utilized to calculate overall

liabilities per customer or summarize delivered orders. In contrast, analytical queries require immediate access to operational data to gain accurate insights and make real-time decisions. Moreover, applications demand a detailed, consistent, comprehensive view of their underlying business processes. These requirements result in large data volumes that must be kept online and ready for queries and analytics. Additionally, non-standard applications such as simulations or planning require a flexible and graph-based data model to compute the maximum throughput of typical business relationships within a partner network. Modern data management platforms require text retrieval technology to link unstructured or semi-structured data or information retrieval query results to structured business-related content. (Franz, et al., 2012)

The range of application support required is highly diverse and presents various interaction patterns. Traditional SQL-based data management engines used with SAP's processor versions are too limiting for these application needs. SAP ECC system utilizes a traditional client-server third-party database, such as traditional Oracle, SQL and MaxDB. These Relational Database Management Systems (RDBMS) organize data into tables that consist of columns and rows, which are then tied with relationships using primary and foreign keys. (Hiquet, 2021) In ECC, the SAP modules access and manipulate the data using SQL-based transactions. This traditional database structure provides a reliable foundation for the system but has limitations in processing speed and latency between operations.

With the latest version of SAP, S/4HANA introduces a HANA database structure that allows for faster transactions and higher operational workloads. This structure reduces data retrieval and processing times, allowing better real-time analytics, faster transaction processing, and quicker user query response times. Additionally, HANA supports relational and non-relational data models, providing support for SQL and other programming languages such as Python and R. These processing capabilities enable efficient handling of structured, semi-structured, and unstructured data, allowing

organizations to perform complex analyses and gain deeper insights from their data. (Akhtar & Murray, 2020)

The table structure in SAP ECC heavily relies on its header, linking, and item tables, which contain a considerable amount of repetitive data to conform to traditional database structures. This results in complex data model structures and a large number of tables. SAP has addressed this issue in the new HANA database by creating a flat database table structure that eradicates this redundancy, reducing the total number of tables required. (Vishal, et al., 2012). Regarding SAP's Material Management (MM) Module, the large number of tables used in SAP ECC will be replaced by Material Document (MATDOC), which is designed to manage all material movements and document them in real time. (Lau, 2022) MATDOC will introduce a data model that consolidates material documents into a centralized table format, making the data model more unified and straightforward. (SAP SE, 2024) This also benefits the reporting, as all core information about material movements can be optimized for advanced analytics and reporting inside or outside of SAP. (Deloitte Touche Tohmatsu Limited, 2016)

2.2 Product configurations, configurable materials, and material variants

Companies are offering more product variants to meet the diverse market needs and stand out from the increasing competition. This trend towards greater product variety is also driven by the growing demand for customization in established markets, leading to shorter product lifecycles due to faster innovation cycles. (Hochdörffer et al., 2022)

The requirements for configurable products depend heavily on the industry, market requirements, and the organization's operating model. Tiihonen et al. defines the basic properties of configurable products into the following categories:

- The product has customer-specific characteristics that meet customer requirements.
- Each delivered product has individual customer-specific configurations.

- Each product individual is specified as an arrangement of pre-designed components. The product is then further assembled based on the ordered configuration.
- The product has an architecture that has been pre-designed.
- No innovative or other additional design is needed during the sales-delivery process. Rather, an individual product can be specified routinely.

(Tiitonen et al., 1998)

Typically, the main reason for designing and manufacturing configurable products has been the ability to efficiently fulfill a wide range of customer requirements (Tiitonen et al., 1998) (Haug et al., 2012). Configurable products are also helpful in scenarios where the organization has many different components that go into a product. This approach allows the management of different combinations, called variants, without manually creating separate master data for each individual combination (configuration). As the configurable product and its variants typically have a one-to-many relationship, it also provides benefits in terms of component, BOM, and task list (routing) maintenance. (Blumöhr et al., 2023)

Haug and colleagues describe in their article that product configurators are systems that focus on product specification creation and management. Product configuration applications support structuring the possible product specification options into a sellable item by utilizing predefined configuration settings. Configurable products are easier to sell and manage as the possible combinations and characteristics of the product have been pre-defined in the configuration model. Proper configuration setup can take more time for the organization to establish than anticipated, and recent academic studies show that configurator-related projects do not often succeed on the first try due to the complexity. (Haug et al., 2012)

Typically, when setting up a product configuration model, the following questions must be answered to create a configuration model that supports both customer's needs and manufacturing organizations' operations. A study by Aldanondo and Vareilles suggests

that when product configurations are extended to include requirements and process configuration, the configurable product typically represents a family of products with various alternatives and options. To create a model, the relevant components and different variations need to be determined, along with a set of rules, constraints, and combinations (as shown in Figure 3). The model is then used to find at least one set of components that satisfies all constraints and customer requirements.” (Aldanondo & Vareilles, 2008)

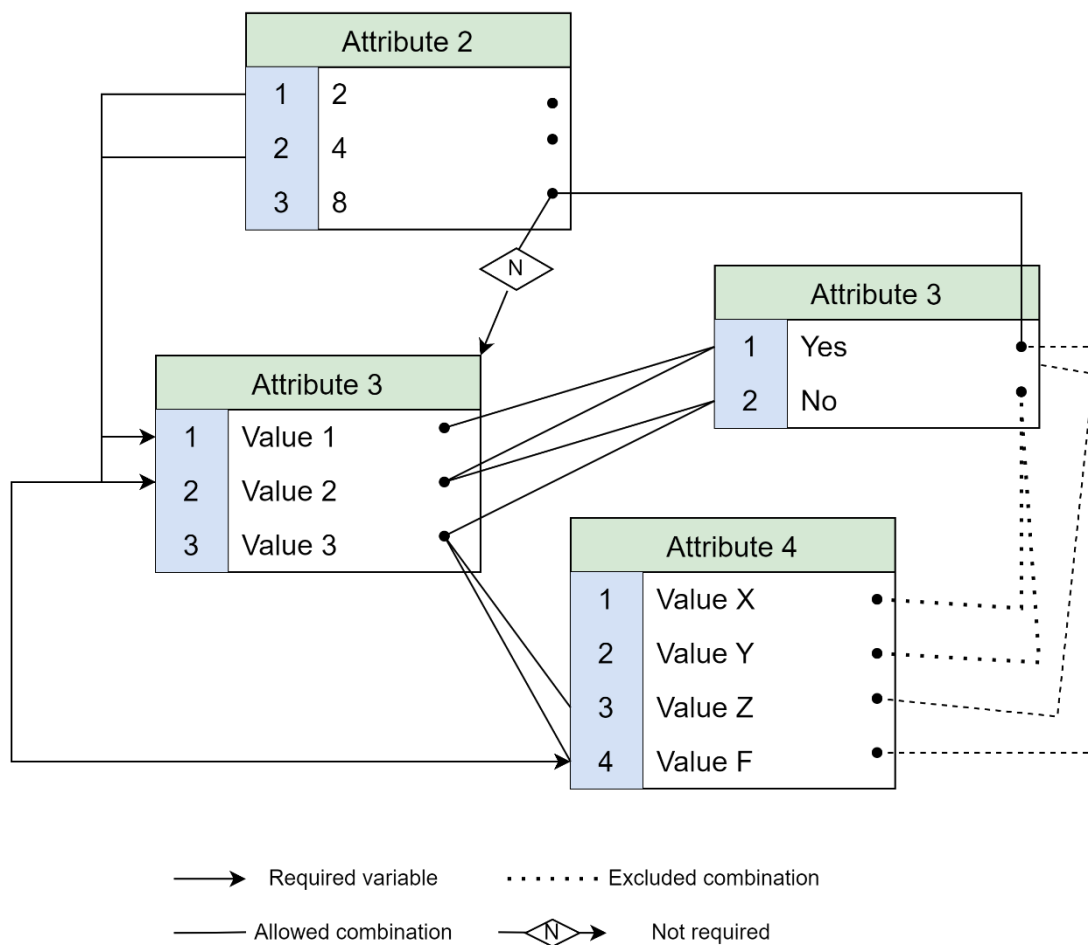


Figure 4. Example model of variable compatibility and constraints for configured product. Adapted from (Aldanondo & Vareilles, 2008).

Businesses can gain several benefits through product configurations. It helps manage product diversity efficiently, speeds up the sales-delivery cycle, improves product standards, and simplifies order acquisition and fulfillment tasks. According to various

studies, including Forza & Salvador (2007) and Kristjansdottir and colleagues (2018), product configurators help businesses better handle product variety. Similarly, Hvam and colleagues' (Hvam et al., 2013) research has established that it reduces the sales-delivery period. Further research by Trentin, Perin, and Forza (2012) has demonstrated the positive impact of product configuration on product quality. Lastly, Salvador and Forza (2004) have shown how it simplifies order acquisition and fulfillment activities.

When creating a customizable product configuration, it is important to pinpoint the market segments and their specific needs. It is up to the company to determine which segments the product and its various variations are intended for. This aligns with the product architecture and the possibility of variation with typical combinations of requirements. Failure to do so could make it difficult to sell and manage the product, as suitable alternatives may not be available through configuration. (Haug, et al., 2018)

In order to explore the different possibilities of a product, it is important to create a preliminary configuration model at the beginning of the product development process. This model is critical to the product's overall design, both conceptually and at the system level. To ensure that the configuration model is properly documented, it is essential to have a clear and well-defined configuration process in place. Depending on the different stages of the configuration process, such as sales and engineering tasks, there may even be multiple configuration models for the same product. Research done by Kristjansdottir, focusing on the ETO process-related configuration models, also highlights that even though the configuration model requires maintenance, the issues generated by the automation were smaller than those generated by the manual maintenance of the data. (Kristjansdottir, et al, 2018)

2.2.1 Configurable products and material variants in SAP

SAP Variant Configuration (VC) is an SAP ERP configuration tool/functionality that allows organizations to configure many different product versions using a single material master

number. VC provides an integrated approach to product configuration, including data validation, pricing, and manufacturing rule generation, such as BOM, routing, and costing (Figure 5). Blumöhr et al. highlights that organizations that produce products with different versions should pay close attention to the functionalities that the VC provides. (Blumöhr et al., 2023) Typically, the product considered for variant configuration should have one or several components that can be replaced with a similar yet different component. VC supports well the management of products that are sold, for example, at varying sizes or lengths. For VC configuration to work well inside SAP, the attributes used within the configuration model should be well-defined. (Piehl, 2017) In SAP terminology, this kind of material/product is called configurable material. (SAP Variant Configuration, 2023)

The company can configure the product in SAP by selecting characteristics or specific functions that fulfill customers' needs. Although the characteristics can technically be selected independently, the typical setup is often created so that a characteristic and value determination will have an impact on another selection (constraints). The possible combinations pre-configured into the system are called product model configurations. These define all possible combinations allowed for the configurable product/material, including bill of materials (BOM) and routing. (Kienzle, 2018) The complexity of the product will significantly impact on the needed configuration amounts. Also, the level of detail on which the configurable product is created will significantly impact the model configuration complexity.

Key variant configuration elements

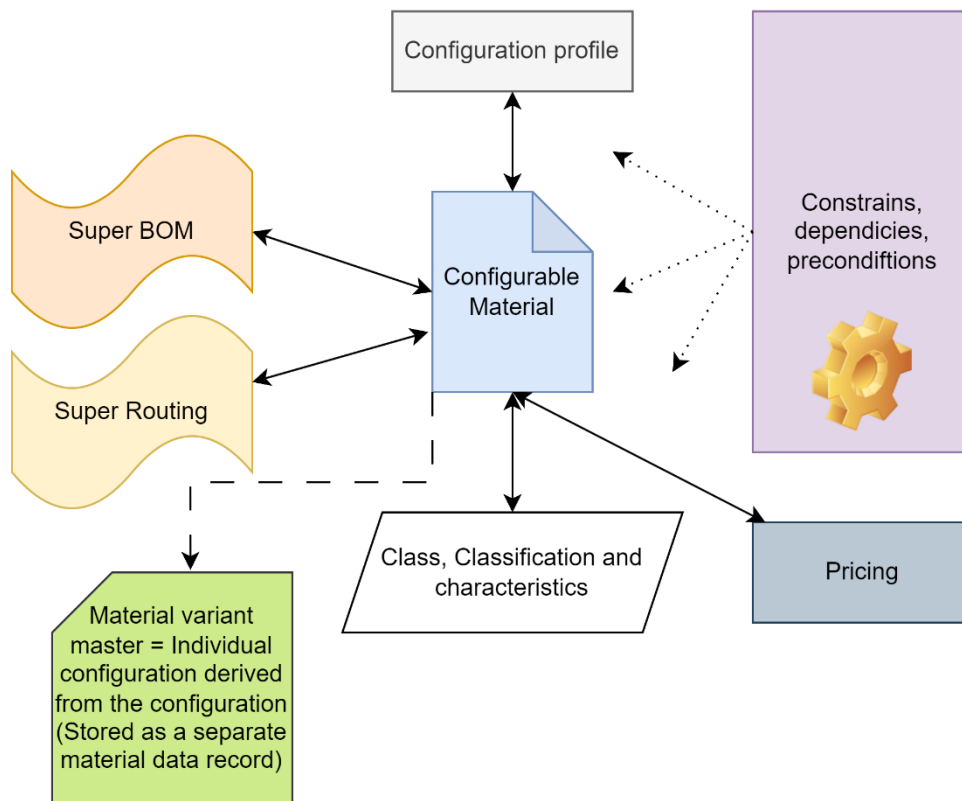


Figure 5. SAP Variant configuration elements combined, including material variant role.

(Aleksi Matilainen, 2024) adapted from (SAP Variant Configuration, 2023) and (Blumöhr, et al., 2023).

Variant diversity needs to be considered in SAP's master data management. If a configurable product contains only a few variant versions, the maintenance of product master data, including BOMs and routings, can be maintained separately for each product, due to the small number of variables. SAP variant configuration supports master data management in both simple and complex scenarios, depending on the organizations' requirements and manufacturing methods. If a configurable product has a high number of possible characteristic combinations, the number of possible variants will easily increase to such a large number that the manual maintenance of master data is not efficient or possible (Formula 1).

The number of possible configurations derived from a configurable material(product) is generally obtained by multiplying the number of possible and allowed characteristic value combinations. (Blumöhr, et al., 2023)

Equation 1. Number of potential configurations per available values and expressions

$$\text{Number of variants} = \text{characteristic value options}^{\text{possible expressions}} \quad (1)$$

The number of total possible configurations derived from one configurable material grows exponentially with the number of possible characteristics and options they contain. Managing the large variety of configuration options for the product requires a set of rules and restrictions to limit the number of variants to the extent of what the organization actually wants to offer. In the sales configuration process, a configurable model helps in viewing all the product options, and in the engineering configuration, it produces the technical details for manufacturing the product. The configurable model can be completely configurable, where all the variants that could be configured from that model are already designed, and their manufacturing feasibility is tested. Alternatively, in another case, the model could be partially configurable, where some features of the product are left for the customer to define (Forza & Salvador, 2007). The configuration profile rules set for the configurable material in SAP will restrict the combinability of the possible values, which also allows the pre-configuration of the master data. (Simulate Configuration Models, 2023)

Traditionally, when managing a wide variety of possible product variants, the changes to allowed components require a heavy workload as all the BOMs utilizing the changing component need to be updated. With configurable materials, changing the component for all the variants can be updated only on the configurable product level, which then applies to all possible variants. If the organization has in-house production, configurable materials products also require configurable BOM and routings representing a full set of possible components (Super BOM) and sequence of operations that the components follow during the production process (Super routings). These upper-level configurations

decide the parameters required for the components and operations to be set without manual maintenance for each variant, BOM, and routing.

A configurable product master acts as a central master data record for all possible product variants within the system. Master data maintenance should be done on the configurable product level, which allows easier data maintenance and harmonized data management in the system. (Blumöhr et al., 2023) Figure 6 demonstrates the importance of the configuration profile with a simplified configuration model example. The process of configuring consists of three distinct phases: First, determining the length; secondly, selecting the number of plies, and lastly, deciding on the pack size. Within each phase, there are three available options. If no constraints or dependencies were in place, the total number of configurations would be $3^3 = 27$. However, by implementing a couple of straightforward constraints, the number of possible configurations can be reduced down to seven. The suitable characteristics, dependencies, constraints, and values guide the user through the variant configuration process by presenting the available options. This approach limits the total number of variants that could technically be available for product creation with many characteristics.

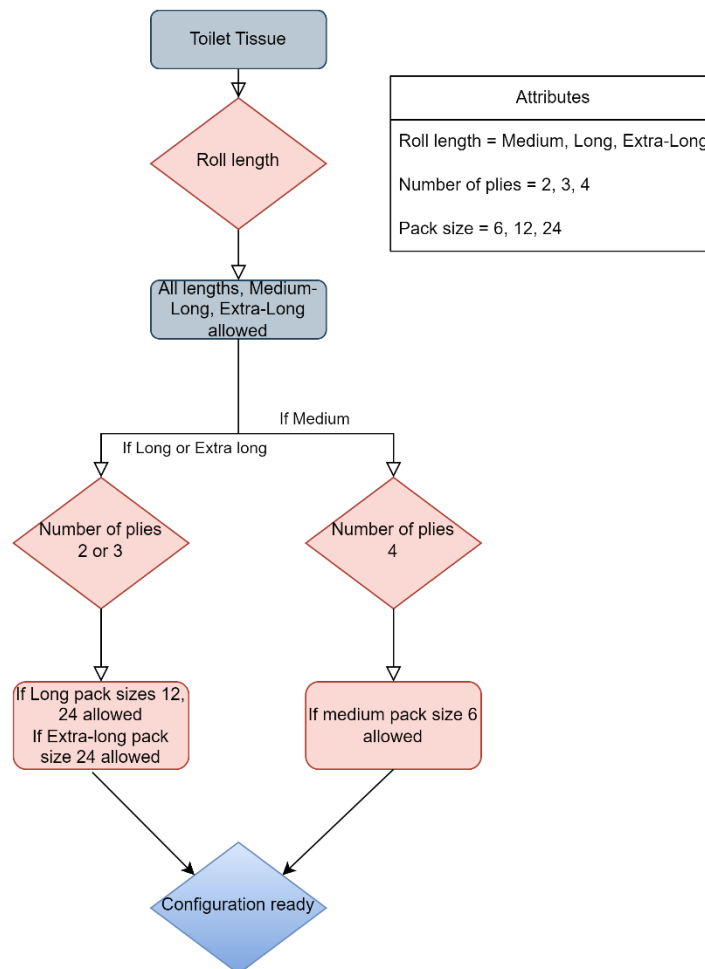


Figure 6. Example of simplified product configuration model with constraints limiting the total number of possible configurations. (Aleksi Matilainen, 2024)

2.2.2 MTS and MTO for configurable products

Make-to-stock (MTS) and Make-to-order (MTO) manufacturing approaches will also directly impact the configurable product characteristics and configuration modeling and complexity. In MTS, the products are manufactured based on the expected/planned quantity. Products are stored in the warehouse, where they are further sold and shipped to the customer. Production in MTS is done without a specific sales order, usually based on the forecast, and after production, the goods are stored in the warehouse. When a

customer orders a product, the stock is then taken from the warehouse and delivered to the customer. (Kaminsky & Kaya, 2009) This approach is usually used for products and stable markets with relatively stable demand.

In MTO, the product's manufacturing is usually initiated by a specific order from a customer (Figure 7). This approach works well for products sold non-regularly or with customer-specific characteristics. MTO allows companies to produce products that do not have regular demand without the risk of increased warehousing costs due to uncertain demand. In MTO, using SAP VC allows the production process to be triggered by the configured customer Sales Order (SO). A configurable material with the variant configuration model is used for this scenario to present the possible product options in the SO. (Franz, et al., 2012)

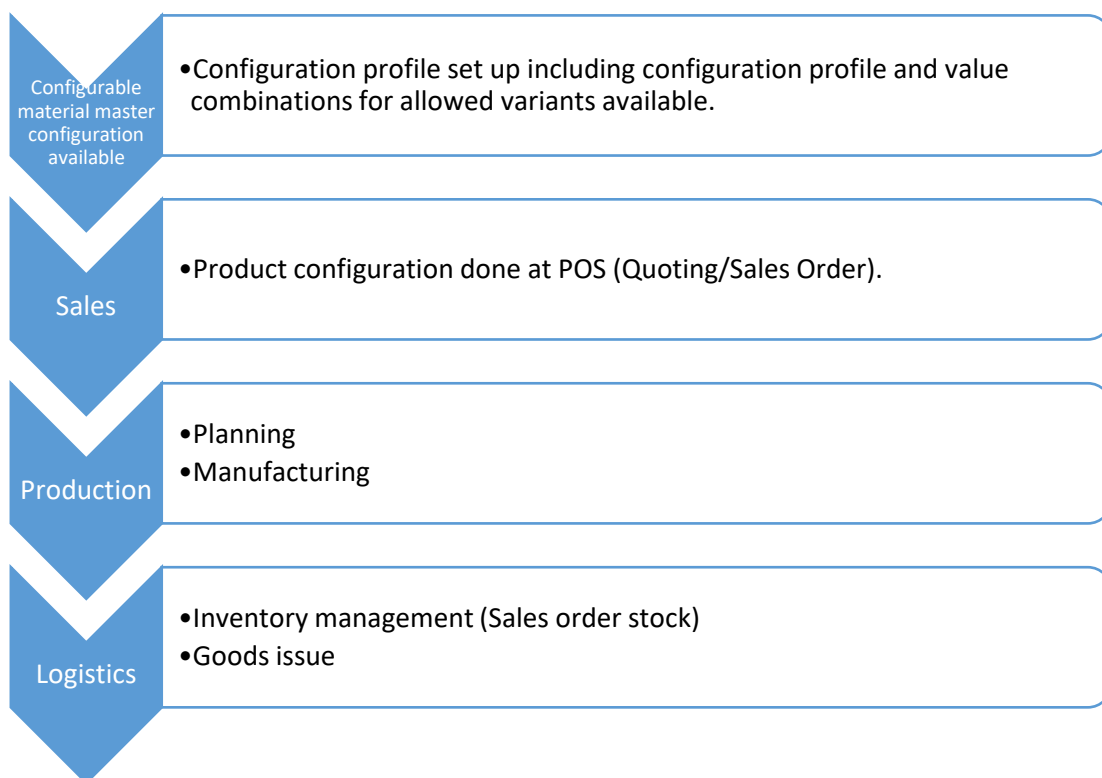


Figure 7. An example of a simplified MTO process with configurable material in SAP.
(Aleksi Matilainen 2024)

Blumohr and colleagues further separate the most commonly used MTO approaches into three categories: Assembly-To-Order (ATO), Configuration-To-Order (CTO), and Engineer-To-Order (ETO).

ATO involves having a set quantity of assemblies ready for the final product in the warehouse. Required standard components are procured based on the Make-to-Stock (MTS) principle, but the final assembly of these stocked components with the desired end product only happens after the receipt of an order. This means the assemblies required for the production process are derived from the order's product configuration.

CTO allows customers to decide the design and composition of the product according to the options offered at the time the order is placed. In this case, the manufacturing company does not create the product until the order has been received. This approach focuses on product configuration, and the product specification can be hierarchical, with individual assemblies parameterized according to customer specifications.

Lastly, the ETO approach involves making individual decisions that require special engineering based on the customer's needs. ETO complexity can vary depending on how much customer-specific configuration for the product is required. The ETO approach is often used in scenarios where the configuration sold for the customer involves, for example, project-specific requirements that require separate engineering activities by the manufacturer. (Blumöhr, et al., 2023)

When SAP's variant configuration is used to create fixed product variants, it can be used in a traditional MTS process. In MTS production, all parameters and information about the product must be available in the system. In SAP, a separate material record (Material variant) for this purpose is created (Figure 5) for each variant configuration, and the material master in these cases can be considered pre-configured instead of configurable. (Blumöhr et al., 2023). In MTS process (Figure 8), the individual variant is configured in the product master data instead of in the sales process (MTO) configuration. In these

cases where this master data record for the material variant is needed in the system, the difference between the material variant and traditional material master outside of the variant configuration module is that even though in both cases, the material master data record is available with the needed information in the system, the material variant is configured with the configuration set up in variant configuration (including configurable product). (Blumöhr et al., 2023) (SAP SE, 2023) Further, SAP allows partially specified material variants, which are helpful in cases where the product characteristics are primarily available and known, but certain characteristics are selected based on the customer's requirements. Configurable products will benefit MTS and MTO scenarios but are more often used to manage complex MTO scenarios. (Blumöhr, et al., 2023)

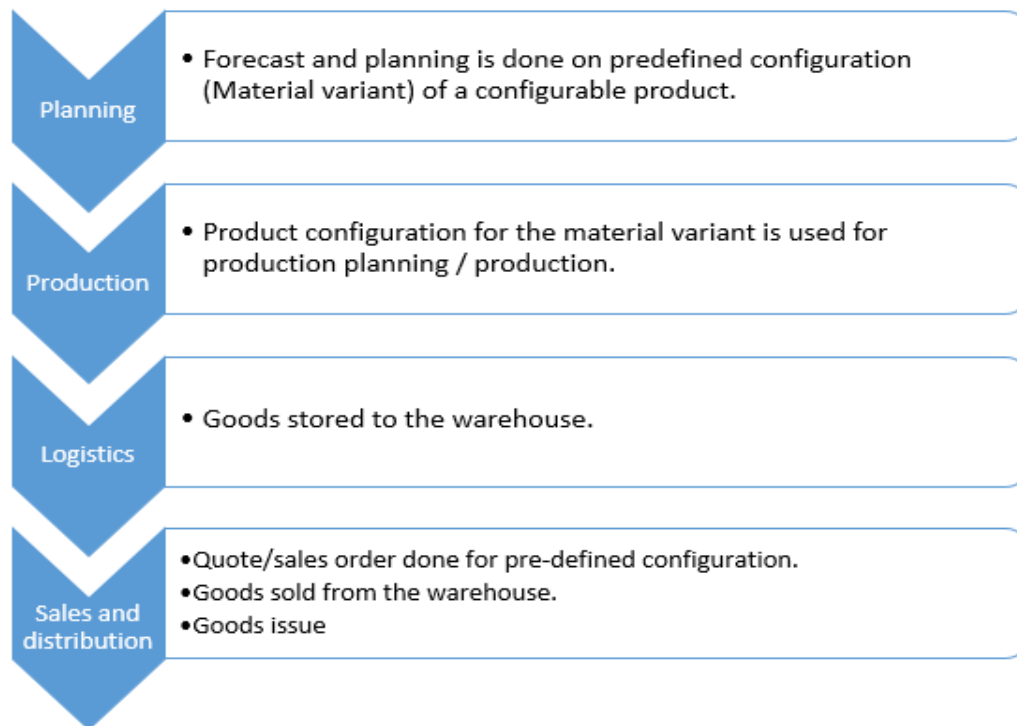


Figure 8. Simplified example of material variant use in MTS process (configured product).

2.2.3 Material master of configurable material

As described in the previous chapter, configurable materials are materials for which different options (variants) are possible. In SAP, these configurable materials/products have customization options that are defined using a variant configuration model. This model combines together the classes, characteristics, and values required to create a “one-of-a-kind” product configuration. (SAP SE, 2023)

Using a configurable material master in the system creates a unique configuration based on the selected options. In these cases, the configuration data and configurable material master are kept separate from the material master (variant) record representing an individual configuration. This approach simplifies data maintenance by eliminating the need for separate master records for each individual configuration. The configuration model typically stores the data needed for sales and manufacturing in configurable material cases. The separation of different approaches for configurable materials can be done based on whether the material is configurable (configuration done “on the fly”) or if the configuration is known (pre-configured). (Blumöhr, et al., 2023) (SAP SE, 2023)

BOM for configurable material should contain all items needed to cover all product variants applicable to the configuration (also called super BOM). Furthermore, certain BOM items may require object dependencies because they are needed only if the customer requests particular product features. The routings (operations) required to manufacture the specific product configuration are also dynamically determined with the settings created in the configuration model. (Blumöhr et al., 2023)

The individual configuration for configurable material is typically done as a part of the ETO or MTO process, where the configuration is based on customer order. SAP will use the specific configuration to trigger the required procurement and production activities for the required components. (SAP SE, 2024) In cases where the configuration is already known in advance, a material variant record can be created in the system to support MTS scenarios. (Blumöhr et al., 2023)

2.2.4 Material master of pre-configured material (Material variants)

A material master of a preconfigured product (Material variant) differs from a configurable material master as the specific configuration for the product variant being sold is already available in the system, meaning the product is not really a “configurable” one but rather “pre-configured”. (Blumöhr et al., 2023) In these cases, a separate material master record, called the material variant, is created into the system to represent individual configurations derived from the configurable material master, and it works similarly to normal material masters. It is important to notice that even when both configurable and configured materials use many of the same variant configuration functionalities available in SAP, the “material is configurable” option is not selected for individual material variants, and some of the other configuration settings also typically differ. (SAP SE, 2023) The key difference between pre-configured material variants and standard materials is that the variant is configured based on the configuration setup done on the configurable material master level (Figures 9 & 10). (SAP Variant Configuration, 2023)

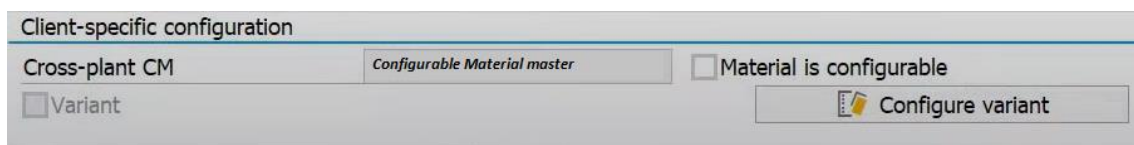


Figure 9. SAP S/4HANA Cross plant (client) specific configuration reference for material variant (Basic data 2 of Material master record).

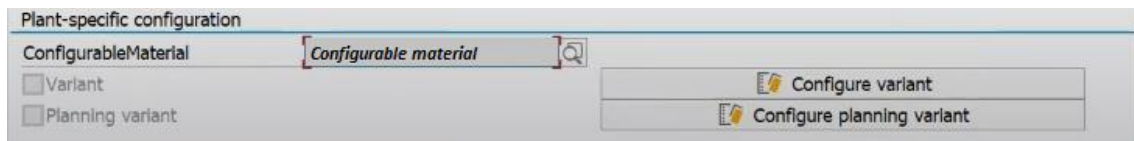


Figure 10. SAP S/4HANA Plant-specific configuration reference for material variant (MRP3 of Material master record). (Aleksi Matilainen, 2024)

Material variants require a BOM and routing setup in order to support production. This information can be managed similarly to standard materials on the material variant level. This means separate BOMs and routings, which can be set up separately at a variant level. In addition to the traditional approach used with standard materials, material variants can also utilize the super BOMs which can be set up on the configurable material level. In this case, the material variant is connected to the BOM or routing of the configurable material through a configurable material assignment transaction (CS40). (SAP SE, 2023), (Blumöhr et al., 2023)

This same logic also applies to the routing setup possibilities for the material variants. The traditional routings can be set up on a variant plant level without object dependencies to the configurable mater level (CA01/02). In addition, SAP allows the use of configurable material-level routing plans for the material variant. This is especially good in situations where the routing setup can be done on a higher level but utilized on a variant level. Separate routings can be done by utilizing the copy templates in the configuration simulation. In these scenarios, the configurable material-level routing setup can be altered for variant purposes. (SAP Variant configuration - Bill of Material (BOM), 2023)

2.2.5 Variant Configuration and Advanced Variant Configuration

In previous SAP versions, the variant configuration functionality was called LO-VC (Material variant configuration). In S/4HANA, SAP updated the variant configuration solution to a new version of AVC (Advanced Variant Configuration), which supports

Make-to-order, configure-to-order, make-to-stock, and engineer-to-order scenarios. S/4HANA also supports the usage of LO-VC but in a simplified form. (Blumöhr et al., 2023)

The functionalities provided by AVC are quite similar to those of the processor LO-VC, and some of the advanced variant configuration functionalities are still in use with S/4HANA. AVC brings certain user benefits regarding the UI (with Fiori) and user experience, as the design improves user experience in terms of characteristic/value selection, embedded applications, and transition scenarios between production methods. (SAP ERP Blogs by members, 2022) SAP also allows the transformation from LO-VC configurable materials and material variants to AVC managed with the help of pre-configured tools in S/4HANA, which further helps adopt the new S/4HANA for organizations already having configurable materials and material variants in use prior to implementation. (Blumöhr et al., 2023)

2.2.6 Using configurations in SAP CPQ

SAP CPQ (Configure Price Quote) is a quote configurator designed to support and automate quotation scenarios in SAP, especially in complex cases. Through SAP CPQ, the sales department can be supported in finding suitable products for configuration according to the customer's wishes and within feasible possibilities. (SAP SE, 2019)

SAP's variant configuration, together with a material master, is integrated directly into the CPQ tool. CPQ supports different kinds of business requirements in both simple and complex scenarios depending on the organization's requirements. (SAP SE, 2024) CPQ has available out-of-the-box integration to AVC, allowing SAP CPQ to reuse existing product models that correspond to product configuration models in SAP S/4HANA Cloud, making these configuration models available to sales for use in SAP CPQ. CPQ also allows the utilization of existing configurations (variants) and prices. Blumöhr and colleagues describe in their book that in the context of the configurable material configuration, two core tasks can be separated, the first being the actual master data product modeling for

configuration and the second being the sales configuration for the order processing. (Blumöhr et al., 2023)

With SAP CPQ, product configuration, pricing (with discounts), and quoting by connecting variant configuration and product master data streamlines a smooth quoting and ordering process. This allows organizations to simplify and reduce time spent on pricing, as the product variants created from the same configurable product can provide pricing suggestions based on the information available about the previous variants. (Blumöhr et al., 2023) This allows the sales to configure the product for quoting or sales order purposes based on the available configuration setup in variant configuration and SAP CPQ modeling. (SAP SE, 2024)

2.3 Batch management

2.3.1 Batch manufacturing process and batch management

Barker and Jawatar categorize typical production approaches into discrete, batch, and continuous processes. These processes may vary between manufacturing locations and product categories within the organization. Discrete manufacturing involves units that are manufactured in different volumes. Each process can be started or stopped in discrete manufacturing when needed. In this method, typically, the same specific standard parts are used to produce the end product(s). Also, the total volume of goods produced can be low or high. Batch-based manufacturing involves producing goods in specific groups or batches. The batch manufacturing method is highly flexible, making it suitable for medium production volumes and products that require customization, such as pharmaceuticals or specialty foods. (Barker & Jawahar, 2005) Batch management also allows good scalability depending on the market demand and requirements. In contrast, continuous manufacturing features an ongoing, uninterrupted production process where materials are continuously fed into the system, and products are continuously outputted. This approach is ideal for industries with high-volume production and consistent demand. Continuous manufacturing should be applied in scenarios where the

production rate is efficient from the market point of view. In a continuous process, the repetitive operations aid the process. Semi-continuous processes are processes where some production and/or assembly lines can be shut down and restarted. Typically, the manufacturing factory aims for a certain productivity, which can be measured in the quantity of products over time. The plant's productivity is measured by efficiently using available inputs to outputs, including materials, labor, machines, energy, costs, and products. (Singh, 2009)

As described in the previous chapter, batch manufacturing refers to a manufacturing method that focuses on specific quantities. (Singh, 2009) Batch management further refers to the tools, systems, and processes to ensure traceability, quality, and efficiency. The main objective of batch management is to provide insights into operations organized by raw materials, semi-finished, and finished products. This capability makes product tracking possible, as the transactions in each operational area of receiving, production, inventory movements, and shipments can be followed with the help of an audit trail for each batch produced. Batch tracking is also useful in investigating customer inquiries about a particular batch. Products produced in a batch should be numbered for identification and traceability. (Barker et al., 2005)

The batch numbering helps track batch production, quality, and other information, which can be based on business or regulatory requirements depending on the organization's business area. It is important that the batch numbering has a unique code to provide insights. Batch production provides several benefits for process industry companies due to requirements for product quality, production quality, variability, and efficient use of production equipment. (Kuikka, 1999) For example, according to the commonly used and known ISO 9001 standard for quality systems and other regulatory requirements, products must be identified by suitable means during all production, delivery, and installation stages. (SFS, 2015) Similarly, the Good Manufacturing Practice (GMP) guideline outlines requirements and recommendations for some industries

where the identification of this kind of information is needed. (European Commission, 2024)

The definition of batch differs among organizations, countries, and industries depending on the legal regulatory and customer requirements. (Akhtar & Murray, 2020) Typically, the batch needs to be identified by a batch record, which represents a quantity of materials with some common characteristics unique to that specific batch within the system(s). The batch could represent, for example, the entire quantity of goods procured with one production order or quantities of materials arriving to a location at different times. In addition to traceability and reporting, the batch history can provide good insight for optimizing the plant process performance. (Barker & Jawahar, 2005)

2.3.2 Batch management in SAP S/4HANA

Batch classification is a feature of the SAP system that enables the allocation of additional attributes or characteristics to batches of materials. These attributes can be configured at the material master level to provide information about the batch, including quality parameters, production data, or other additional information that the organization wants to track at the batch level. (Akhtar & Murray, 2020) The batch classification function has traditionally been used in industries where detailed batch tracking and management is critical; traditional industries for batch management are, for example, pharmaceuticals, chemicals, and food manufacturing (Barker & Jawahar, 2005). The batch settings allow batch management at cross-plant levels (organizational level) and plant level. (Vamsi, 2021)

Depending on the supply chain and the business requirements, SAP allows organizations to define the batch creation process based on their individual needs to start automatically, for example, at order creation/release or at the time of goods receipt (Figure 11) (procurement to own production process). Batches can also be created with the “create a batch” app in SAP S/4HANA (MSC2N). (SAP, Batch Management, 2023).

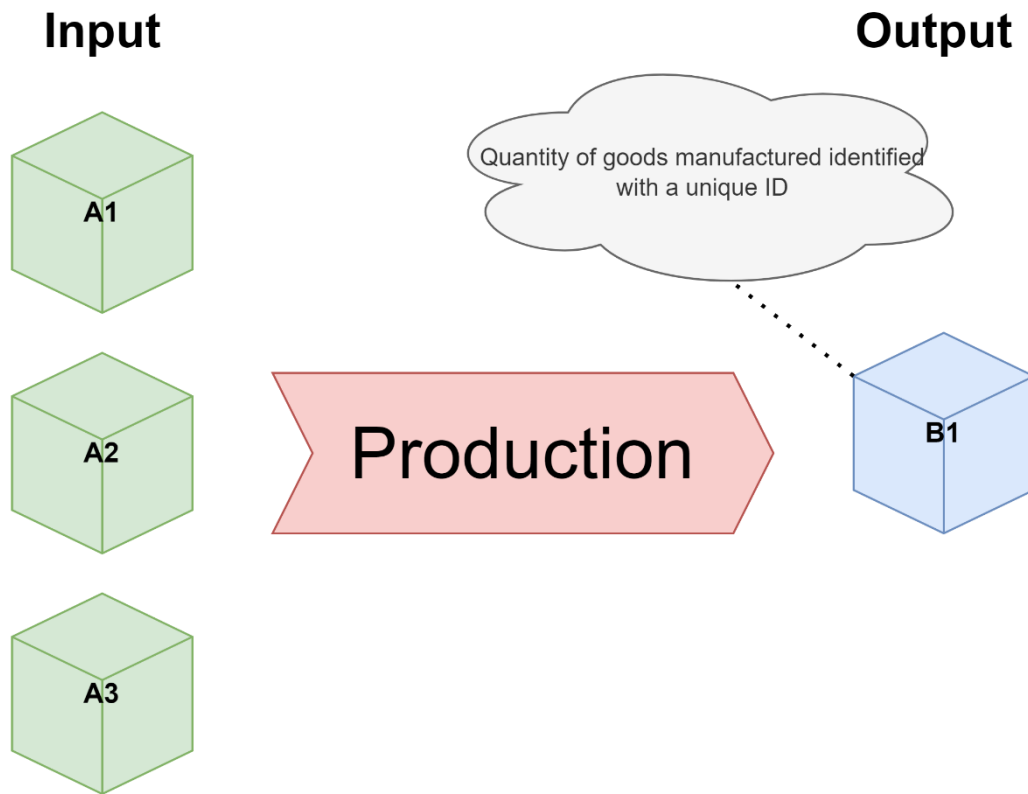


Figure 11. Simplified example of batch traceability through procurement to production to distribution.

2.3.3 Batch management and Material Master data

In SAP, each batch record is always dependent on the material master record. (SAP SE, 2023) Batch management can be activated in SAP for material/product record through General plant data (Figures 12 & 13), Purchasing, Sales and Distribution, and work scheduling views in S/4HANA (Activating the batch management for material in one of these views will activate it in all four places). (Akhtar & Murray, 2020)

There are three methods for batch number management in SAP: plant-level, material-level, and client-level. The material-level method only assigns unique batch numbers at the material level, meaning that different materials can have the same batch number inside the system. The client-level method ensures that the batch number is unique for

the client. The latter is particularly useful in scenarios where plant-to-plant stock transfers are used. (SAP, Batch Management, 2023)

The first step in beginning to use batch management for materials and/or products is to identify which items need to be batch-managed. (Barker & Jawahar, 2005) After the suitable materials for the batch management process have been identified, the material master records must be updated by setting the batch management requirement. To have a working batch management setup in SAP, the following configurations and data requirements have to be considered:

- **Batch management configuration** setup requires setting up a batch master record process that guides the batch creation process for available procedures in SAP. SAP allows the manual management of batches, but typically, batch master record data is created automatically based on the settings. SAP can automatically trigger the batch creation on the background. The most commonly available out-of-the-box options include receiving goods for the first time, production order creation, depending on quality management decisions, during an inspection, performing stock transfer postings, and at the time of generating a purchase order. (SAP, Batch Management, 2023)
- **Batch level** (client, material, plant) definition needs to be established depending on the organization's requirements. (SAP SE, 2023)
- **Batch class and characteristic** setup based on organization requirements. (Akhtar & Murray, 2020)
- **Material master data set up.** The batch management indicator in the material master has to be enabled to manage targeted materials in batches (Figures 9 & 10). The batch management functionality has been updated between ECC (Figure 9) and (Figure 10) to allow plant-specific batch management of a material. This enables organizations to allow batch management for materials, which are managed through many locations that operate differently (e.g., manufacturing site vs distribution center). (Akhtar & Murray, 2020)

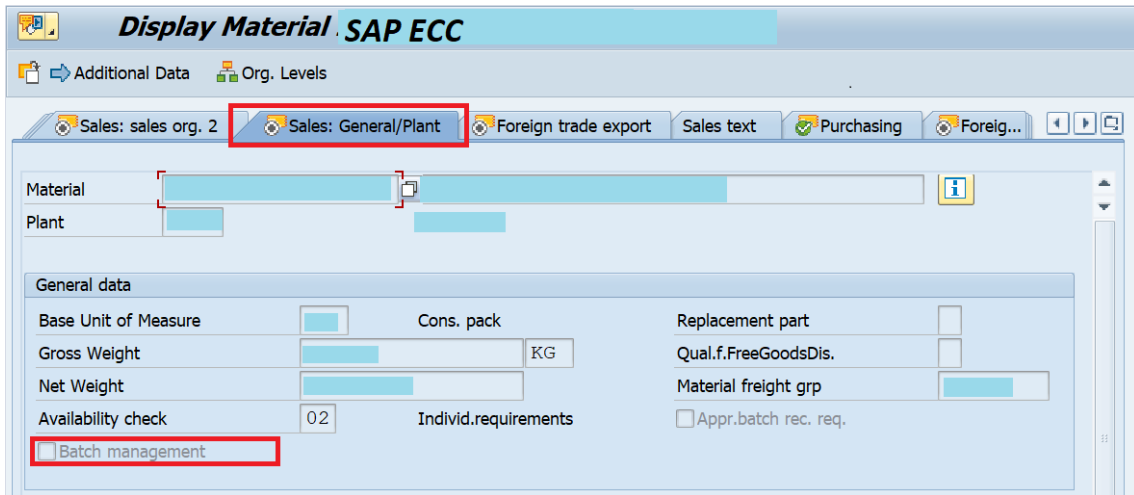


Figure 12. Batch management is only available at the cross-plant level in the SAP ECC Material master (MM03) example. (Aleksi Matilainen, 2024)

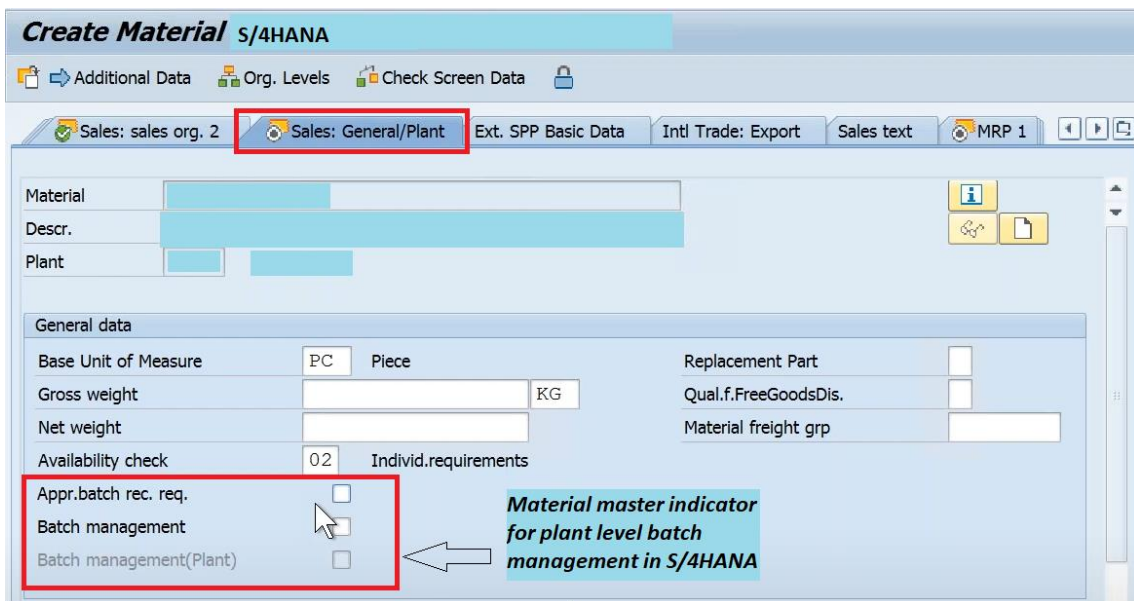


Figure 13. Batch management indicator available for cross-plant and plant-specific purposes in S/4HANA Material master (MM03) example. (Aleksi Matilainen, 2024)

2.3.4 Batch classification

The attributes or characteristics configured for a batch class vary depending on the industry, the type of material (product) produced, and the organization's requirements. Characteristics are used to classify the different types of materials according to their properties. These characteristics are created in the system under a class, which is further assigned to a material. Similarly to material and configurable material characteristics, classes are connected to characteristics, and materials are connected to classes (many-to-many relationships). (Akhtar & Murray, 2020) Nevertheless, some common characteristics that are typically established for batch classes are as follows:

Quality Parameters: Characteristics related to quality control, such as test results for physical properties, chemical composition, or other quality classification can be followed on batch level. These parameters (characteristics) ensure that the batch satisfies the quality standards before it is distributed for further processing or distribution. Batch information can also mark down the next quality inspection date for recurring inspections and be available from that date, which indicates if the material needs to be restricted from use until a certain date. (Akhtar & Murray, 2020)

Production Information: Batch classes may include attributes related to production data, such as the manufacturing date, location, expiration date, batch size, production line, or production order number. This information ensures traceability and helps track the batch's production history. (Barker & Jawahar, 2005)

Regulatory Compliance: Depending on the industry and regulatory requirements, batch classes may include characteristics containing information about safety standards, environmental regulations, or labeling requirements. (Akhtar & Murray, 2020) (Barker & Jawahar, 2005)

Storage Conditions: Batch classes may involve attributes related to storage conditions, such as storage temperature, humidity levels, or storage location. These parameters

guarantee that the batch is stored under suitable conditions to maintain material/product quality and integrity. (Akhtar & Murray, 2020)

Vendor or supplier Information: For materials procured by external suppliers, batch classes could consist of characteristics related to vendor or supplier information, such as the supplier's name, batch number, or analysis certificates. (Barker & Jawahar, 2005)

Customer-specific requirements: In some cases, batch classes may contain characteristics specific to customer requirements or preferences. In such cases certain customers may have distinct labeling or packaging requirements that demand monitoring at the batch level. (Akhtar & Murray, 2020)

Improved Internal tracking and reporting: Batch classes may include additional attributes as characteristics which can be utilized for internal tracking and reporting purposes, such as batch status, batch owner, or batch history information. (SAP, Batch Management, 2023) (Inciflo Blogs, 2024)

In addition to batch characteristics set internally in purchased material cases, the batch number assigned by the vendor can also be used to follow up on the batch inside the organization, as this helps to improve the traceability of goods and materials sources outside of the organization. (Barker & Jawahar, 2005) Batch classification (022 plant and 023 client level) in SAP allows organizations to capture information about batches of materials, which facilitates efficient tracking, traceability, and quality control throughout the production and distribution process. The attributes configured for batch classes can be customized to align with the organization's requirements and industry standards. (SAP SE, 2023)

2.3.5 Batch determination

To fully capitalize on the advantages of batches, it is necessary to establish supporting batch determination processes within the system. Throughout the logistics process, from procurement to sales, it is necessary to designate batches and batch creation processes for each required business transaction where batch information is utilized. Utilizing batch determination, organizations can effortlessly locate batches that fulfill specific requirements for all varieties of goods movements from the warehouse. (Akhtar & Murray, 2020)

In order to manage batches for various purposes, such as goods issued to production or customers, the system requires distinct strategy records. Batch is used in numerous functions, including goods movement, production and process orders, sales and delivery orders, cost center, and transfer order functions in IM, PP/PP-PI, SD, and WM (Surety Systems Inc, 2023) (SAP SE, 2024). The configurations for batch determination, such as inventory, production, sales, and stock transfers, are saved in search procedures for each application. As the batch determination procedure runs inside SAP, the relevant application entry is automatically accessed. The system then finds the relevant configuration entries (batches) based on the input it receives." (SAP, 2024)

2.4 Data management approach in ERP implementation for products and material master data

As enterprises grow and diversify their operations, the amount of master data they manage has also increased rapidly. Product and material data are key master data elements in ERP systems, as they ensure data consistency across different business processes and application modules. As the product and material data serve as the backbone for ERP, the quality of the data available in the system is crucial for achieving the full benefits that the ERP system can provide. The standard approach in SAP system testing usually involves configuration setup, master data setup, transaction testing, and

visibility testing for needed reporting. (Akhtar & Murray, 2020) Typically, the older the product is, the less systematically the data of the product has been recorded into the system in use. (Männistö et al., 2001)

Existing academic literature and research highlight that typically, the problems in the material master data area are often related to the understanding of the impacts of the data input done into the ERP system (correct or incorrect input) (Bingi et al., 1999). Product/material data errors often directly impact the entire process, leading to further problems in manufacturing or the supply chain. (Wei et al., 2023)

The data quality of material data records can be addressed by creating a suitable strategy within the organization. This strategy can act as a base for improving the data quality within existing systems. Typically, data cleaning is required, at least in system implementation projects, as the data from the legacy systems is moved to the new environment(s) and structures. Knapp provides a simple (Figure 14) but efficient improvement concept for material master data quality improvement, taking into consideration both the content (what = Data) and the context (How = structures) of the data. (Knapp, 2011)

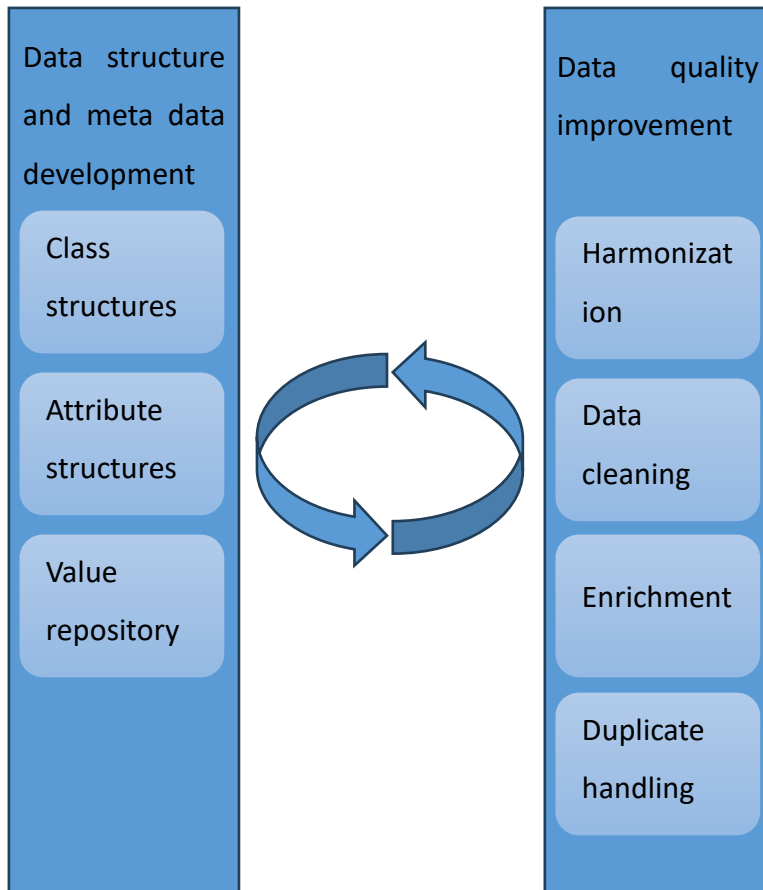


Figure 14. Material master data improvement concept. (Knapp, 2011)

The main data structure for material master data can be considered very complex as it has a direct impact on the main business flows. Data structure and metadata development (Figure 14) aim to support streamlined data management throughout the system's processes to enhance the data quality. Typically, in ERP systems, guidance for the data creation process is done with the help of material templates, which define the basic structure of the needed data while reducing complexity and manual workload. (Wei et al., 2023)

Wei and colleagues highlight the typical material master data management challenges in their article, highlighting the importance of mutual understanding of data specification and system support for the data work. A typical issue also is the lack of

understanding of the big picture of “where data is really” used. (Wei, et al., 2023) This is typical, especially for larger organizations where the persons typically are working within one or two systems or system modules, with no clear view of the impact on the next process steps utilizing the data inputs done. (Maedche, 2010)

Jonker and colleagues highlight that when planning the future implementation of a data management system, the current maturity level and the targeted maturity need to be evaluated in the company context. In addition, governance practices, systems, processes, and data content need to support the targets set. (Jonker et al., 2011)

2.4.1 Preparing the product data for the data migration

Understanding the data is important for the successful use of the ERP system. It is also important to ensure that no unnecessary data is transferred from the legacy system to the new system. The growth of businesses and the availability of more information have led to a significant increase in the volume of master data stored within the ERP (and other) systems. This surge has brought about several operational challenges for various business processes. Some of these hurdles include inconsistent sizing of items, multiple variations of the same item, non-standard material descriptions, and more. Such issues can adversely affect the efficiency of material distribution and create communication barriers between different departments. (Wei et al., 2023)

Typically, the implementation requirements for data structures have been approached by identifying the current practices, systems, roles, and data structures in use and restructuring them into suitable data objects for the target system or structure. (Ginige, 2011) (Jonker et al., 2011) (Väre, 2019) Väre categorizes the master data into three main elements; this structure can easily be recognized also in the SAP ERP system. Company/Enterprise level master data is data that is shared throughout the organization, operation, and product area. Specific master data is data that is relevant only for a certain part of the organization, for example, for a product group or for a business area.

System and process specific master data is data which is essential to a certain system or process. (Väre, 2019)

2.4.2 Comparing SAP ERP and SAP S/4HANA

This section discusses feature differences between SAP ERP 6.0 and SAP S/4HANA that are not unique to the material management module or material/product master data. SAP ECC ERP includes many components and is known for its uniform database and central data storage, which help avoid redundancies. It has several SAP Business Suite solutions that can be connected in an integrated manner. The choice of the database is free, and the User Interface (UI) of transactions and functions is quite like that of the predecessor product SAP R/3.

However, some disadvantages of SAP ECC ERP include high memory requirements, weak support for digital transformations, extended training periods for new employees, and a UI that no longer meets modern requirements. SAP S/4HANA introduces improvements such as using the SAP HANA in-memory database, which enables transactions, predictions, recommendations, and simulations to be completed in real time. The database's total memory requirements are significantly reduced, and the optimized role and authorization system reduces the effort required for system administration. The responsive UI, SAP Fiori, can be easily operated on multiple mobile devices.

SAP R/3 and SAP ECC faced criticism for their operating concepts. While power users appreciated the SAP GUI UI, those who did not use the software regularly or undergo training found it less favorable. For this reason, SAP S/4HANA brought about a big shift by introducing the new, browser-based UI: SAP Fiori. With its simpler and consistent design, SAP Fiori apps allow for intuitive work and can be accessed via various terminal devices. The introduction of SAP Fiori impacts directly on how people work with SAP's software solution, allowing organizations to make more of their business-specific enhancements to the user interfaces. The SAP Fiori launchpad is the central entry point for accessing these apps and relevant data related to the roles inside the organization.

The basic design principles of SAP Fiori are adaptability, coherence, simplicity, appealing design, and role-based access. (Blumöhr et al., 2023)

3 Method

The basis for the research utilized the Design Science Research (DSR) approach for information systems, which focuses especially on developing systems and improving functions by producing additional information on open problems or questions. Research utilizing a DSR method typically starts with problem identification, where more understanding regarding the development is needed. It takes into account people, organizations, and existing or newly planned technologies. The requirements for the technology are assessed within the context of organizational requirements, processes, culture, and structures in order to close the gap between the technology and the needs. DSR also aims to analyze existing knowledge regarding similar kinds of cases to identify available solutions that might solve the problems or questions at hand. J. vom Brocke categorizes the DSC process into six different stages: (1) where first, the problem or question needs to be identified. (2) Then, the objectives for the solution need to be defined. (3) After this, the actual development and design to solve the problem or question takes place. After the design has been developed, the solution is demonstrated (4) and evaluated (5) to see the solution's fit for the open question(s) or problem(s). Lastly, communication (6) ensures that the problem and the targeted design approach are communicated to relevant stakeholders. (Brocke, 2020)

The research uses a mixed-method methodology, including quantitative and qualitative approaches. This research method was chosen for the thesis to understand the impact of system change on the product data, including the case organization context. Quantitative data analysis allowed for objectively assessing the current situation and existing data patterns. However, quantitative data alone would not have been sufficient to provide the underlying reasons for the required structures and structure changes. To explain the quantitative trends and requirements, qualitative semi-structured interviews provided additional contextual insights.

3.1 Literature review

The literature review conducted for the research was done to understand the theoretical concepts around data management in ERP renewal projects, configurable materials, and batch management. These concepts were then reviewed and studied more in-depth from the SAP ERP system point of view by utilizing the existing academic literature, SAP technical documentation, and books focusing on SAP functionalities.

The literature review findings and best practices were then used to conduct the data analysis phase, which allowed the capabilities and theoretical framework to be matched to the case company context. Literature was collected by utilizing existing academic research available in academic databases such as Ebook Central Proquest, SpringerLink, and ScienceDirect. Furthermore, books focusing on these areas by various groups, as well as technical documentation available by SAP SE were reviewed to get insights into the system's capabilities. The approach to answering research questions was more data-oriented regarding the product data configuration modeling. The batch management results were categorized based on the identified best practices from similar-a-kind industries to make a suitable proposal for the organization's use.

3.2 Data collection

The quantitative data analysis phase was initiated at the start of the research to understand the current data, data quality, and structures used at the case company. The quantitative analysis is used as a starting point to understand the current volumes, data quality, and variations between the product structures. As a basis, the obsolete materials and products were excluded from the more in-depth analysis with the help of material status. The active product and material data were assessed to get an understanding of the current class type, class, and characteristic setup available in the system to identify and categorize the required and no-longer required classes and characteristics. This was done by aggregating the data based on different variables. In addition to the TO-BE

structure-related analysis, the same data exports were used to identify additional areas for data cleaning.

The product master data, excluding characteristic-specific tables, was taken from the case organization's SAP ECC production environment by SAP analysis Excel plug-in and Quickviewer (SQVI and SQ01/02) ABAP Standard queries, allowing client-dependent reports to be generated from database tables (Table 2). All extracted data was further filtered and also cross-evaluated based on organizational structures, class to characteristics, relationships, and volume of usage considering the past history.

Table 2. Data amounts extracted and analyzed.

Table(s)	Table role	Amount analyzed
MARA, MAKT, MARC	Entity, products, and materials, technical objects	9930 (client level) amount was further filtered to get the required product scope.
CABN	Entity, characteristics	1055
KLAH	Reference, Class to Classification	19
AUSP	Reference, Characteristic values	411772
KSSK	Bridge, Characteristic values to Class	22264
KSML	Bridge, Characteristic to class	1083
CAWN+CAWNT	Reference, Characteristic values, CAWNT	Reviewed separately only for particular characteristics when needed.

The basic material master data (MARA = Material Basic data, MAKT = Material descriptions, MARC = Plant data, MARM = Unit of measure for Material) from the current SAP ECC system was extracted by using the SAP Analysis tool which allows analysis of the SAP data via a real-time integration to the database. The data table structure between the class header tables (KLAH/KLAT), Class to Characteristic (KSML), characteristic descriptions from (CABN/CABNT), and actual characteristic values (AUSP) assigned to objects (KSSK Object to class) tables were combined with the standard product master data tables (MARA/MAKT/MARC) export by replicating the database. (Figure 15).

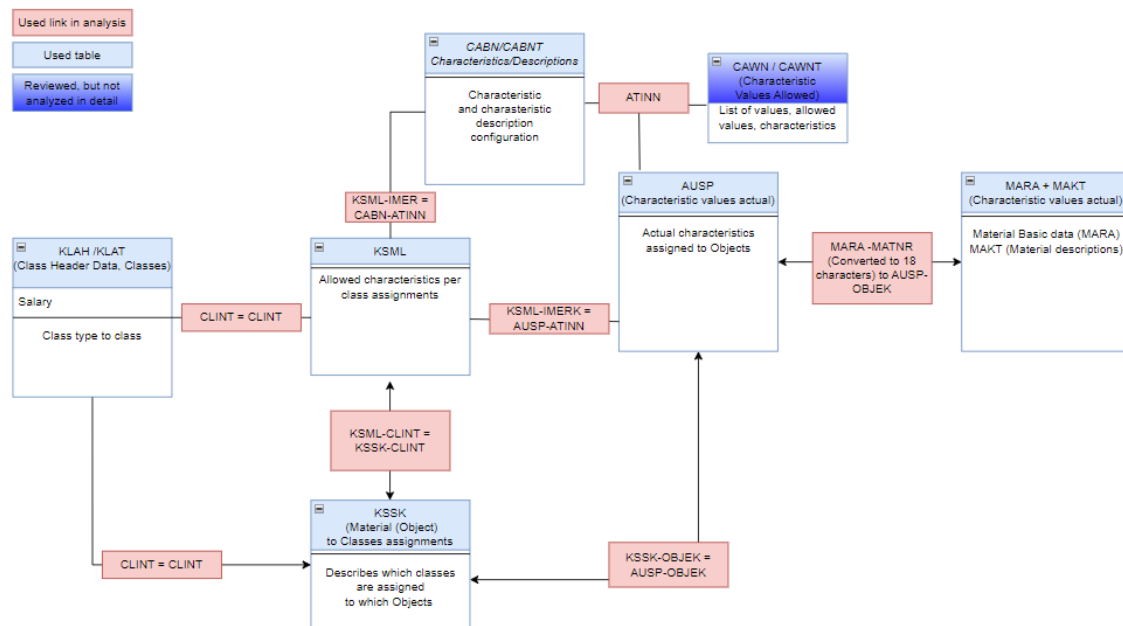


Figure 15. SAP Class, Classification, Characteristic, and Material data tables used.

The exported data (Figures 15 and 16) was then combined into an Excel Powerquery data model, which allowed the information to be pivoted as needed. This information was used to re-structure the current products to the targeted structure. Excel Powerquery allows the utilization of data modeling to establish relationships between the tables and manage large volumes of data exceeding the typical row limitations of standard Excel. As the analysis provided good insights into the current product data quality, the same

exports, and models were used to identify areas for data cleaning and harmonization throughout the research period.

The figure shows six SAP data browser windows with the following data tables and relationships:

- Table AUSP Select Entries (1):** Columns: OBJEK, ATINN. Relationship: AUSP-OBJEK TO KSSK-OBJEK.
- Table KSSK Select Entries (4):** Columns: OBJEK, KLAB, CLINT, ADRES, LAEHL, STATU, STUCL, HESR, AENNR, DAT. Relationship: KSSK-CLINT - KSML CLINT.
- Table KSML Select Entries (2):** Columns: KLAB, ADRES, STATU, HESR, AENNR, DAT. Relationship: KSML-IMERK - CABN ATINN.
- Table CAWN Select Entries (9):** Columns: ATINN, ATINN, ADRES, ATINN, ATINN, ATINN, AENNR, ATINN, ATINN. Relationship: CABN-ATINN TO CAWN-ATINN.
- Table CABN Select Entries (1):** Columns: ATINN, ADRES, ATINN, ATINN, ATINN, AENNR, ATINN, ATINN. Relationship: KSML-CLINT TO KLAH-CLINT.
- Table KLAH Select Entries (2):** Columns: KLAB, CLASS, STATU, KLAB, HESR, HESR, HESR, NAME, STATU, NAME, DATU.

Figure 16. Example of relationships from SAP data browser view.

The hypothesis selected was to identify needed characteristics by monitoring the usage of the characteristics available in the system. If a characteristic were available but has not been used for any of the active objects in scope, it would be marked as unnecessary in terms of the new system configuration. It is also good to note that when analyzing the classifications, characteristics, and their usage per product, SAP allows several classes to be connected to the same characteristic. As characteristics represent individual variables or options, which in cases of product can be, for example, product dimensions, brand, or other information that the company wants to store about the product, the relationship is many-to-many by its nature. The AUSP table represents each characteristic value set, meaning that one product typically stores information of various kinds depending on the organization's needs. A simple example can explain the large number of individual database records that need to be analyzed to get a holistic view of the requirements. A material/product can have a characteristic for dimensions. The dimension characteristic (in a classification) is then further available for many products. As many products are assigned to use a classification with characteristics representing

dimensions, the same characteristic exists 1-N number of times in the A USP table containing the actual assignment values. The usage of characteristics with additional context, such as data required in connected systems and data required for specific categories, was selected as a basis for the future model building.

3.2.1 Data analysis

The SAP standard field, material status, was used to exclude obsolete materials and products that are not needed in the analysis. Furthermore, as the data model (Figure 15 & 16) was replicated and built into the Excel power query, the data could be further analyzed to get insights into data patterns, usage of data elements, and other requirements regarding the future structure. In the first phase, a general overview gave an understanding of data volumes belonging to different organizational structures, plants, categories, and product families. This phase also gave insight into specific categories or higher-level structures outside of individual product characteristics to point out data that can be considered as “legacy data” in terms of past organizational or product changes. Furthermore, the usability of different characteristics was identified by each location, product type, category, and usage. In SAP, the default/standard material data structure typically remains pretty similar, and the classification and characteristics setup are used to store additional information depending on the organization's requirements. The literature also showed that understanding the required characteristics is important when considering the product configuration setup, as it typically contains the variability required for the organization's purposes.

The usage of characteristics (how often and where) and available classifications and characteristics in the system were compared based on the product categorization, location, and organizational structure to identify a suitable structure level for future purposes. This analysis further gave insights into characteristics that could be excluded from the new system due to old or non-required data. This evaluation method, where the available combinations are evaluated by their usage over time, is suitable to get a good overview of the focus areas. As the usability of the characteristic is a good indicator

for the required elements, the identified not-used and low-volume characteristics were aligned with the future ambitions in terms of connected systems. Furthermore, certain classifications and their characteristics, which are used to group similar characteristics, were identified separately as areas requiring changes. These changes were typically related to improvements in terms of data structures. SAP characteristics can contain, for example, integers, a list of values, and free text. The best data quality option is to avoid as many free text characteristics as possible to allow better utilization in the case of automation and configuration models in the future. Identified characteristics required for the new system was done by analyzing all available characteristics in the system (Total number of characteristics analyzed), then comparing them to characteristics in use per different operational area and product family. Further, the low-priority cases to be checked separately due to low usage or other documented reasons were identified for variability (Equation 2). In addition to this quantitative data analysis, certain characteristics were separately managed and reviewed to identify suitable approaches for future purposes.

Equation 2. Configurable material characteristic variability equation.

$$\text{Variability range} = \frac{R}{T} \times 100 - \left(\frac{R-D}{T} \right) \times 100 \quad (1)$$

T = Total number of characteristics analyzed

R = Characteristics used by preliminary configurable material level

*D = Characteristics identified for further check (data
+ separately identified characteristics)*

The approach in formula (4) allows the grouping of required characteristics for suitable structures while also providing an overview on the required next steps. Lastly, as data relevance, accuracy, and consistency help to promote understanding of the required future structures while also reducing the clutter and improving efficiency, the following approaches for the cleaning activities were identified and partly conducted during the spring, further supporting the data-related work for the project:

- Identified inaccurate and invalid values were identified from the dataset based on product type and family. These data elements were updated (and/or documented) based on current specifications.
- Outlier detection (Ilyas & Chu, 2019) with Z-Score (Equation 3.) was further tested to identify anomalous data points in certain numerical data elements (fields), allowing the identification of unusual data points compared to the rest of the group. The Z-score tells the standard deviations of a data point from its mean.

Equation 3. The Z-score formula for anomalous data point identification.

$$Z = \frac{x - \mu}{\sigma} \quad (1)$$

Z = Result Z – Score,

X = Value of the individual data point,

μ = mean of the data set

σ = Standard deviation of the data evaluated

- The data objects no longer relevant to the business were also identified and delivered (or documented) separately for further cleaning activities.

The data cleaning journey is a continuous work within the organization, so the focus was to identify cleaning needs that are relevant in terms of the structure changes or can be considered to be out-of-scope for the regular cleaning activities. The understanding collected through the literature review, data, and discussions of the preliminary product structure was modeled.

3.2.2 Interviews & observations

A short qualitative part was conducted after the data collection and analysis phase, involving semi-structured interviews. These interviews were used to gather and assess additional requirements from other processes and bring in-depth business context

related to the data. A total of 4 interviews with process area experts in master data, order-to-invoice, supply planning, and production planning were conducted to get an overview and mutual agreement for the upcoming product data requirements. The interviews were used mostly to understand the fit and requirements for the upcoming product structure.

The interview sessions started with a presentation about the proposed preliminary structure, highlighting the critical product change areas. In addition, the impact of the product-related changes was discussed to gain mutual understanding about the upcoming change. These additional data-related requirements were then documented and noted as specific requirements for the new structure.

3.3 Research process

The research process can be summarized into four main stages. In the first stage, a literature review was conducted to better understand the research questions and problems. This stage also gave insights on the different technical capabilities and technical structure requirements required to be done in order to make the agreed changes between the legacy system and the new system. In the second stage, data was extracted, categorized, and analyzed. In this phase, also existing projects and other available materials were used to pinpoint upcoming requirements for certain parts of the structure. In the third stage, the preliminary model was aligned with stakeholders to document and consider the additional requirements. Finally, in the last stage, the validity of the results was evaluated. Throughout the research, starting from the first data extract phase in the second stage, a supportive related preparation, including enhancements to current data and data cleaning activities, was conducted and separately documented further to support the on-time delivery of the new system. This work is expected to continue also after the research is finalized, as data cleaning and preparation activities should be and are continuous by nature.

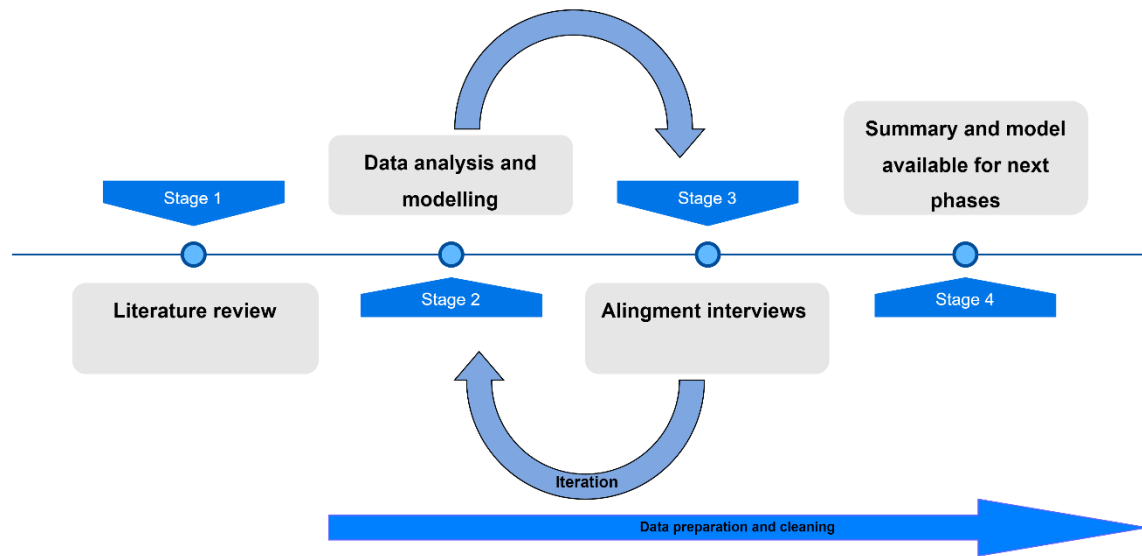


Figure 17. Research process stages.

The reliability of the data used in the analysis can be considered good as it was the latest data available about the current representation of the information. As the model is preliminary, the data should be re-extracted at least once before the implementation to check the validity of characteristics in and out of the model's scope. As the model has been internally validated, it can be considered suitable for the next project stages, while still considering that some adoptions are most likely expected to happen due to the nature of the project being in progress. As product master data structures play a key role, changing other related processes (in case if needed) might require adaptations to the product structure. When considering the external validity of the results; the research results highlight the importance of looking into the usage and validity of current configurations and structures before the migration.

4 Results

In the case of a company organization, the preparation phase allowed project participants to gain an in-depth understanding of upcoming system changes. Data-related preparation and understanding of the change have been identified as key to the successful on-time delivery of large-scale ERP system projects. This thesis used academic literature and SAP technical documentation to identify the capabilities and best practices related to material variant configuration and batch management, as these areas involved known upcoming structure change requirements. The current product data of the case company was reviewed, analyzed, and categorized into a structural model that can be used as a starting point for testing and system-building in the next project phase. Requirements set for the DSR research are compared to the status achieved during the research in Table 3. The results are further elaborated in detail in the next chapters.

Table 3. Requirements compared to results.

ID	Requirement	Status of the target result
REQ_D1	Identify product scope for the new system and product configuration.	Met. Product scope identified and documented (Table 3 anonymized without exact numbers).
REQ_D2	Identify needed characteristics for the products.	Partially met. The suitable level of required characteristics was categorized and documented. Data validation for the identified “variability” characteristics needs to be re-evaluated after the additional organizational check (Chapter 4.2, Figure 2, and Table 4)

REQ_D3	Identify data changes to current products when they are changed to material variants.	Met. Different considerations when converting standard products to material variants were documented. (Chapters 4.1 and 4.41)
REQ_D4	Identify the requirements and data changes when batch management functionality is used.	Met. Different requirements for product structure in a new system regarding batch management were documented. (Chapters 4.3 & 4.41)
REQ_P1	Identify a suitable preliminary product model approach that supports business requirements.	Met. The preliminary product model was reviewed with stakeholders. When considering the project phase, adjustments to the model are likely needed in the testing phase. (Chapter 4.1)
REQ_P2	Identify other changes coming to the product management organization.	Partially met. Identifying changes to the organization was only considered from new SAP systems point of view. (Chapter 4.4)
Test Scenarios	To identify a suitable level for test scenarios in terms of material variants (products).	Partially met, A suitable level for test scenarios was identified for all products and material variants. (Chapter 4.1 and Table 4)

4.1 Standard materials to material variants

As the company uses an additional master data management tool that can also be configured to support data constraints and dependencies, it is suggested that some of the required constraints and dependencies for SAP master data are partially configured here. This approach brings more flexibility on the SAP configuration (Variant configuration) side but would still guide the product data creation process in the needed manner for SAP and other connected systems.

As the organization's products are preconfigured by nature, the approach of setting the variant configuration profiles to support pre-defined variant creation was seen as a suitable approach for most products. SAP's configurable material master records (with configuration profile) in the system would guide the creation process for material variants (pre-configured products) in a company context. The suitable configuration levels were achieved by categorizing the needed configured materials and material characteristics for material variant creation. The suggested configuration profile set up in SAP (Figure 7) with the class assignment is done on the same level as the profile set up for the MDM tool. This allows the additional master data management tool to support additional constraints and dependencies when needed. In the suggested model, the configurable material level can be considered a combination of the processing type for product and operational area, while still considering the mandatory data elements for supply chain (and other) processes. This modeling approach allows the usage of configuration profiles for, e.g., class and classification settings, reporting purposes, and constraint/mandatory values settings for processes such as production and sales (CPQ), but it should also bring simplicity for products and product groups with relatively stable variants. The model approach above was seen as a suitable option due to:

1. The supporting MDM tool process allows the utilization of all existing configurations (material variants) and characteristics as templates inside the respective configuration area. As the company's products are mostly preconfigured, utilizing existing product configurations or the pre-defined configuration model as a guide base for the new configuration is relatively easy and efficient. This process allows more flexibility for product creation, which is also suitable for products with a limited number of variants that do not change frequently.
2. The operation area and high-level product category allocation of configurable materials allow a suitable class and characteristic setup level, providing extra

possibilities for the organization without causing larger changes on a variant configuration level when moving from standard materials to the new system.

3. Preconfigured materials have a fixed configuration (material variant) with a material master inside SAP. Hence, they are easier to manage (with case organization products) than configurable materials, which require more management and maintenance through configuration setup profiles.
4. SAP Standard materials, with a separate material master for each product, were used in previous SAP versions and ERP-connected systems. The material variants with material master records approach allow organization to adopt new ERP with fewer change requirements on connected systems (Including less change management).

In the proposed solution (Table 4), the SAP's configurable material level would guide the classes and characteristics allowed for the material variants, further representing an individual configuration inside the system. This approach will ease the configuration setup for each individual variant. In addition to this variant class and characteristic setup model, the other mandatory elements required for the company processes are guided mainly on this configurable material level. Identifying the needed characteristics for material type and operations area reduces the total characteristic amount per variant class and configurable material, further improving the data quality input of future system users and resulting in improved process efficiency. The configuration profile would also be set to guide some mandatory parameters, such as the allowed unit of measure and packaging instructions that would further apply to material variants under the configurable material. Table 4 highlights the identified characteristics percentage needed per configurable material when comparing all the legacy system characteristics. The variability has been calculated based on the identified low-priority cases to be checked separately.

Table 4. Targeted preliminary structure levels for testing (anonymized). With variant classes.

Operations area	Production strategy	Configurable material	Variant class	Characteristics required per configurable material level comparison
OP1	MTS	CM_001	VC_BP1VAR01	< 20%.
OP1	MTS/ Preconfigured MTO	CM_002	VC_BP1VAR02	23.30% (-2.06% variability)
OP1	MTS/ Preconfigured MTO	CM_003	VC_BP1VAR02	33.92% (-12.16% variability)
OP1	MTS	CM_004	VC_BP1VAR03	50.31% (-5.15% variability)
OP2	MTS/ Preconfigured MTO	CM_005	VC_BP2VAR01	31.75% (-6.91% variability)
OP2	MTS/Preconfigured MTO	CM_006	VC_BP2VAR01	31.75% (-6.91% variability)
OP2	MTS	CM_007	VC_BP2VAR02	36.80% (-6.19% variability)
OP2	MTS	CM_008	VC_BP2VAR03	31.75% (-6.91% variability)
OP3	Standard material	-	-	-
OP1&2	Standard material	-	-	-

As the configurable materials and configuration profiles can be further adapted to the business requirements even in the later stages, it is suggested that the maximum amount of possible constraints and mandatory values are set on the configuration profile. Further, on the material variant creation process, managed by a supporting MDM system to SAP S/4HANA, the data content quality criteria would be built to support the consistency and accuracy between the variants. Due to the high requirements for quality, reporting, planning, and other process-required attributes and data, the increased systematic taxonomy was identified as an area that would benefit long-term data quality. This metadata structuring is derived from the data content and the selected approach level for constrained hierarchy (figure 18), which will be used as a guide to develop the metadata. Each of the preliminary structure levels (Table 4) requires separate testing on a plant level. The dependency and constraints profiles in both MDM and SAP need to be regression tested in order to check the suitability of the models built.

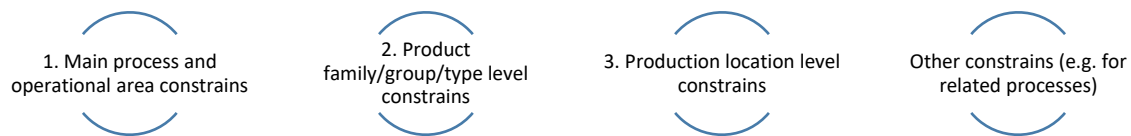


Figure 18. Suggested constraint and dependency priority.

During the review of classes and characteristics assignment, mandatory characteristics were identified for the new system requirements (Figure 19). Re-reviewing the mandatory characteristics for each suggested constraint level during the system-building phase is preferable. This will ensure that the data stored about the product is complete and that the need for further enrichment is reduced. It is also good to point out that as data in the ERP system is constantly changing, a re-review will ensure adaptation in terms of changes between the data exports.

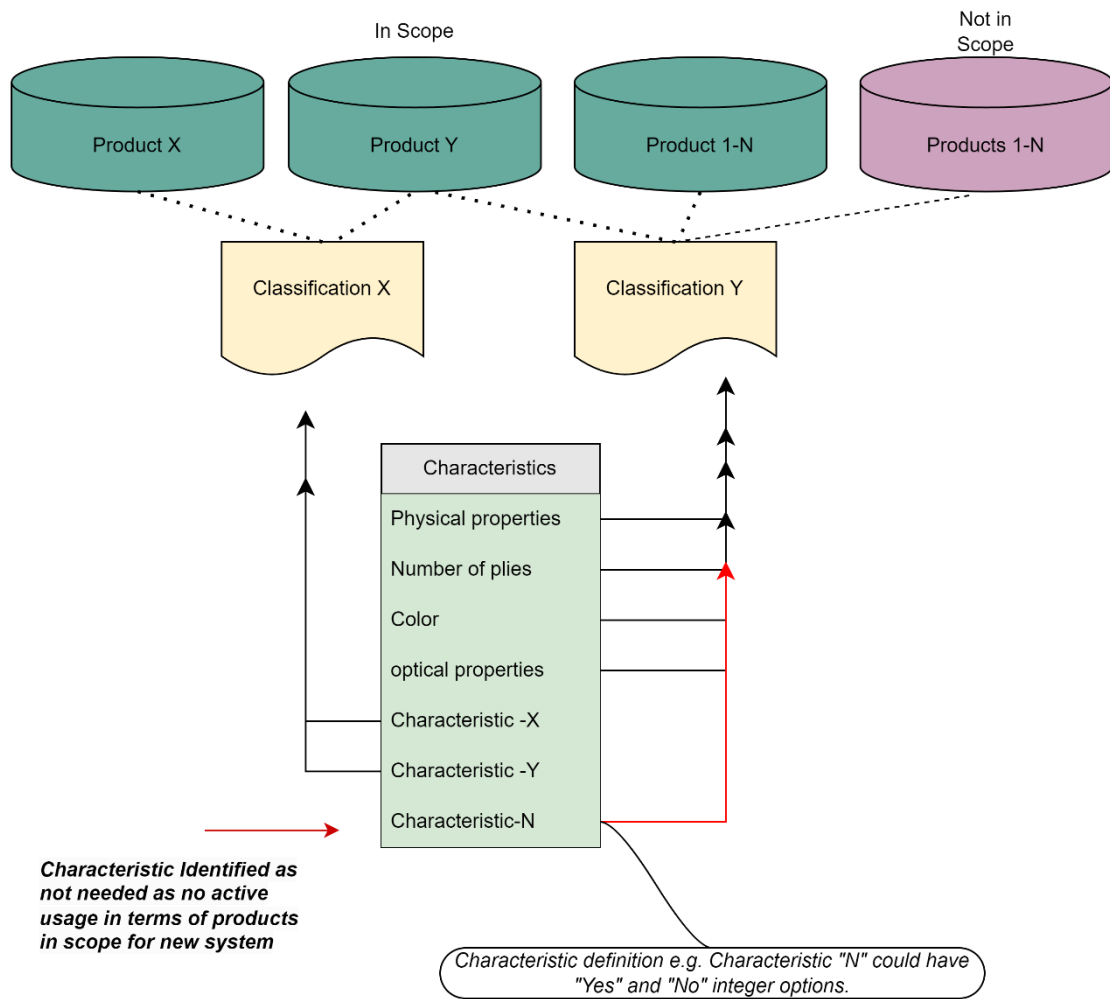


Figure 19. Examples of characteristics to classify products and their relationships with products.

To summarize the approach, mandatory process and operation area constraints (Figure 18) should be configured at SAP's configurable material configuration model level (Table 4). This will guide the suitable product type, family, group level, and other attributes allowed for the individual variants. Additional supporting constraints and other necessary data dependencies can be configured for both systems (SAP or MDM tool). However, as the MDM tool will be the primary place for product-related data maintenance, keeping these lower-level constraints there is suggested.

4.2 Class type, class, and characteristics for material variants

As the class and class-to-characteristic relationships play a key role in setting up the necessary configurations for the configurable materials, which are further used to guide the material variant creation process, the current (Class 001) characteristics used for the material master data records were reviewed and mapped for future purposes (Table 5). Other SAP Class types other than 001 were not directly in scope. As the current system has been in use for several years, and the requirements for products and product data have also been changing throughout the system's lifecycle, it was expected that some of the assigned characteristics would no longer be needed/valid for the new S/4HANA system.

Table 5. Type 1 class to characteristics assignments in SAP ECC.

Type	Class	Characteristics to class
Type 1	TYPE001_CLASS01	13
Type 1	TYPE001_CLASS02	49
Type 1	TYPE001_CLASS03	860
Type 1	TYPE001_CLASS04	1
Type 1	TYPE001_CLASS05	15
Type 1	TYPE001_CLASS06	16
Type 1	TYPE001_CLASS07	16
Total	-	970

These type 001 classes (TYPE001, 01-07) and their assigned characteristics (Table 5) to individual active products and materials (Figure 20) were analyzed. As expected, the main product categories had the most distinct characteristics and individual values assigned to them (ZAWA with 378 distinct characteristics assigned, ZFP with 645 distinct characteristics assigned, ZFSP with 478 distinct characteristics assigned). As these three groups also act as a base for future configurable materials and material variant modeling,

it was decided to review these product types (SAP Material types) and the characteristics currently assigned to them in more detail.

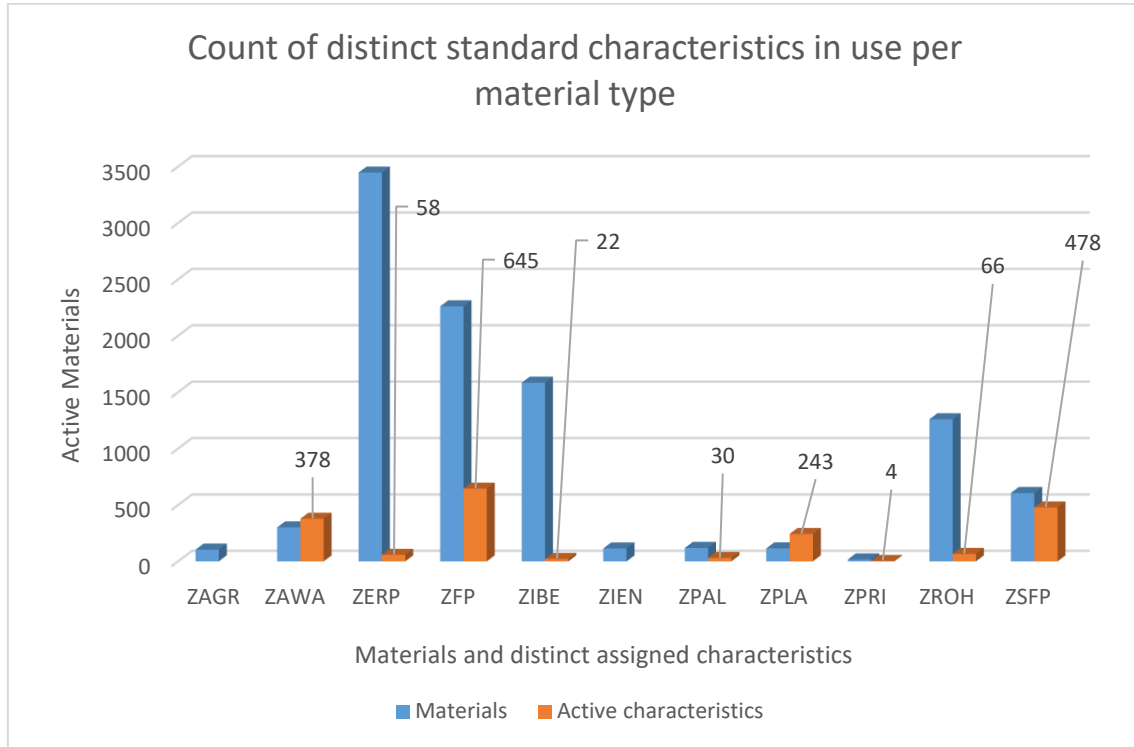


Figure 20. Active characteristics are assigned per material type.

This approach was also backed up by looking into the total amount of individual characteristic assignments done (Figure 21). Out of 411772 individual assignments, these three groups (ZFP, ZAWA, ZSFP = total of 395411 assignments) cover 96 % (395411 assignments) of all characteristic assignments done for the data in scope.

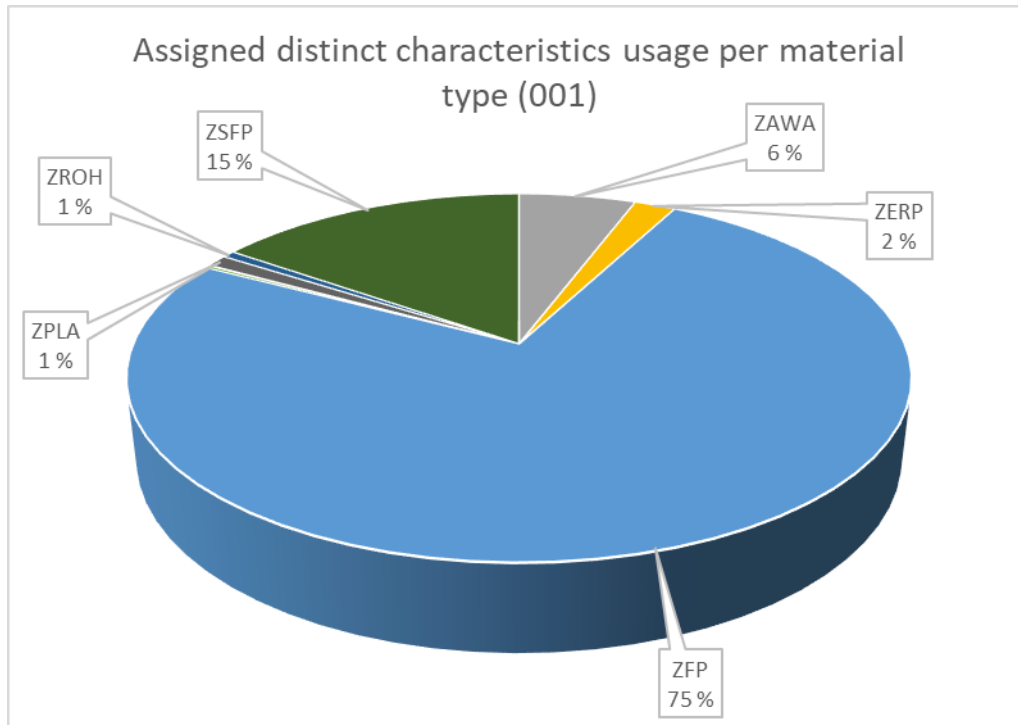


Figure 21. Assigned distinct characteristics usage per material type.

When each individual characteristic and their usage were reviewed, they were grouped into priority groups, while also considering the operation area of the product. This priority group staging allows further understanding for mapping of legacy system characteristics to the new variant and standard classes. Priority class selection was made on product type and operation area level by grouping:

Product groups containing more than 20 products with characteristic values assigned = high priority, medium-high between 10-20 assignments, medium 3-10 assignments, and low if there were less than 3 active assignments (Figure 22). This approach allows each manufacturing location and responsibility group to separately check the “low priority” characteristics that potentially can be left out from the migration further simplifying the migration and data structures of products in S/4HANA.

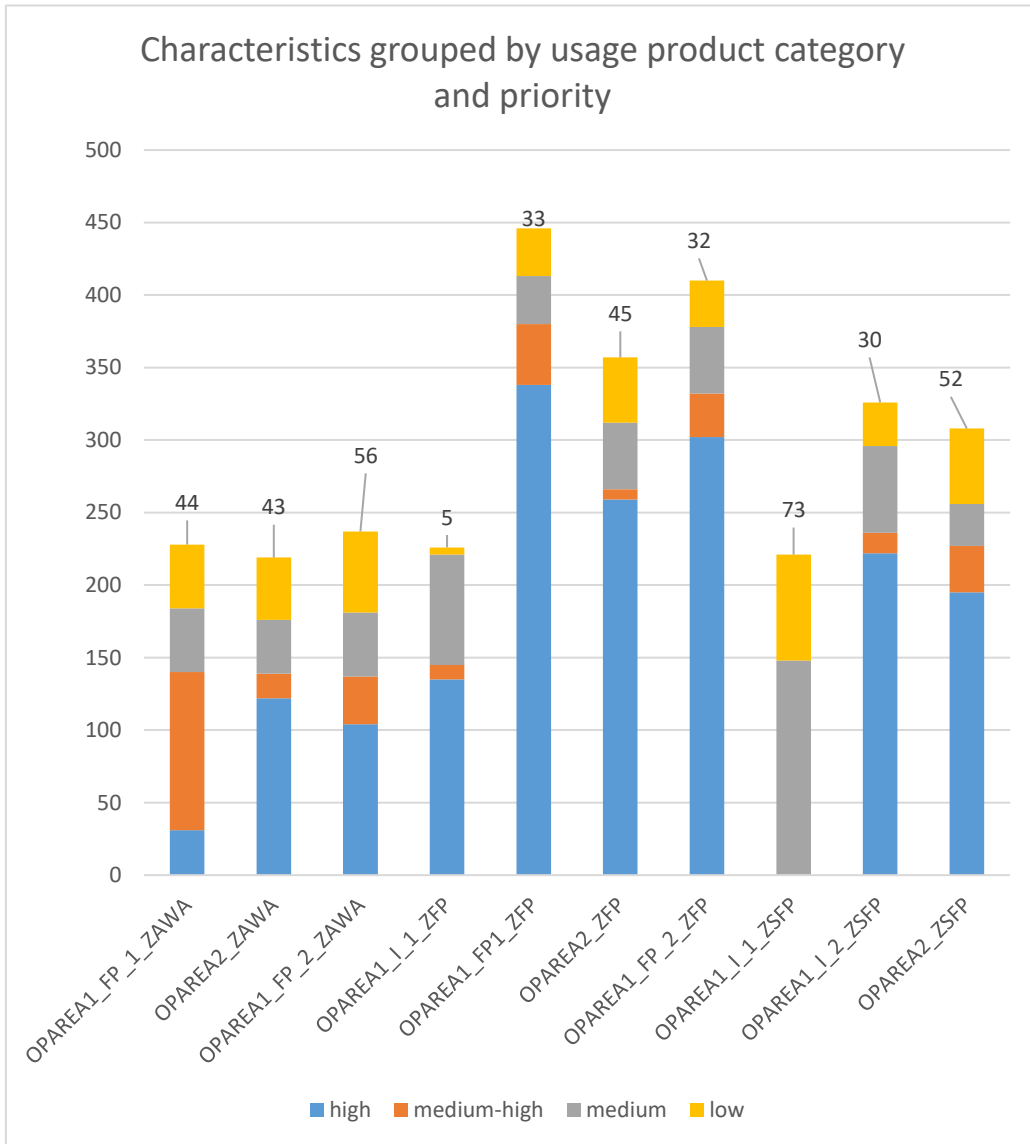


Figure 22. Distinct in-use characteristics grouped by usage, product category, and priority.

When comparing the legacy system, allowed characteristic assignments for the standard materials, and the required assignments per material type, it is seen that the actual required used characteristics amount per needed configurable material level drops significantly. Complexity vice (Figure 23), OPAREA1_Finished1, and OPAREA2_Finished products had the most complexity within the characters used, which was partly expected.

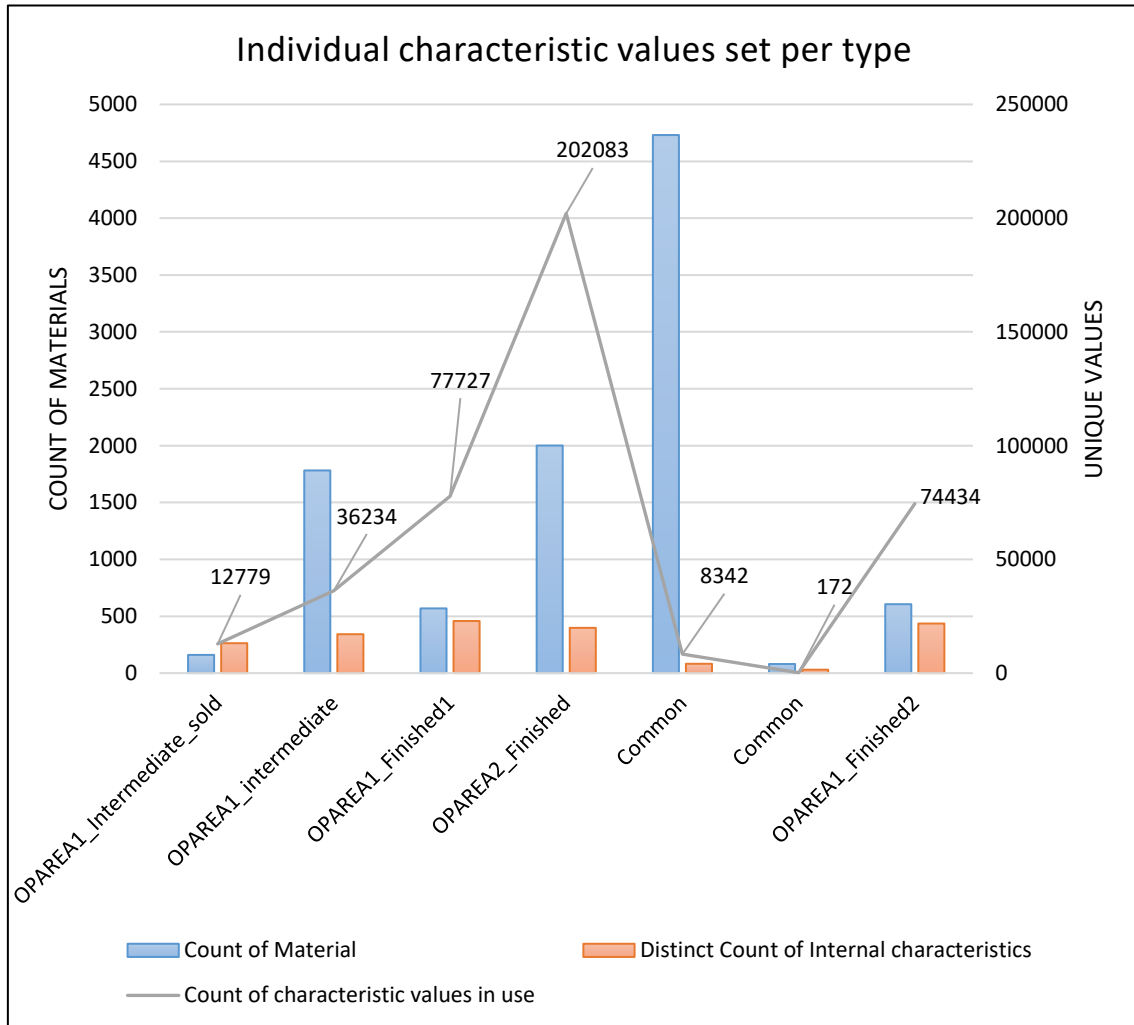


Figure 23. Individual values are set for active objects per operation area.

As in variant configuration, a class holds the characteristics of a configurable material. Linking class 300 (variant class type) to the configurable material allows the material to be configured using the characteristics of the class. The suggested variant class levels (Table 1) would store the required variant class-specific attributes (allowed characteristics) for all individual configurations. Standard classes would still be used in the future to represent the predefined characteristics and values that apply to multiple configurable materials (and thus variants). By grouping configuration-specific attributes together into these variant type 300 classes, variant class characteristics streamline the configuration process for each material variant. This approach allows system users to navigate through the needed attributes and select options within each class, reducing

complexity and potential errors while creating new material variant records (=Individual product configurations) into the system.

By attaching a standard class to a configurable material master of material variants along with a variant class, greater flexibility and efficiency in configuring material variants can be achieved (Figure 24). This setup allows for leveraging common characteristics and attributes (standard class characteristics) across multiple configurable materials while still providing the ability to define unique characteristics for variant class level, which are used to configure the material variant. As standard classification cannot be used in product configuration the variant class stores the characteristics mandatory for the configurable material level. Standard classifications can be optional or mandatory by their nature, but the configuration model would not guide their usage, their usage would be guided through the supporting MDM tool. This setup promotes consistency, standardization, and reusability in variant configuration processes. Characteristics from legacy ERP, which are unique to suggested to-be variant class levels, were identified during the spring.

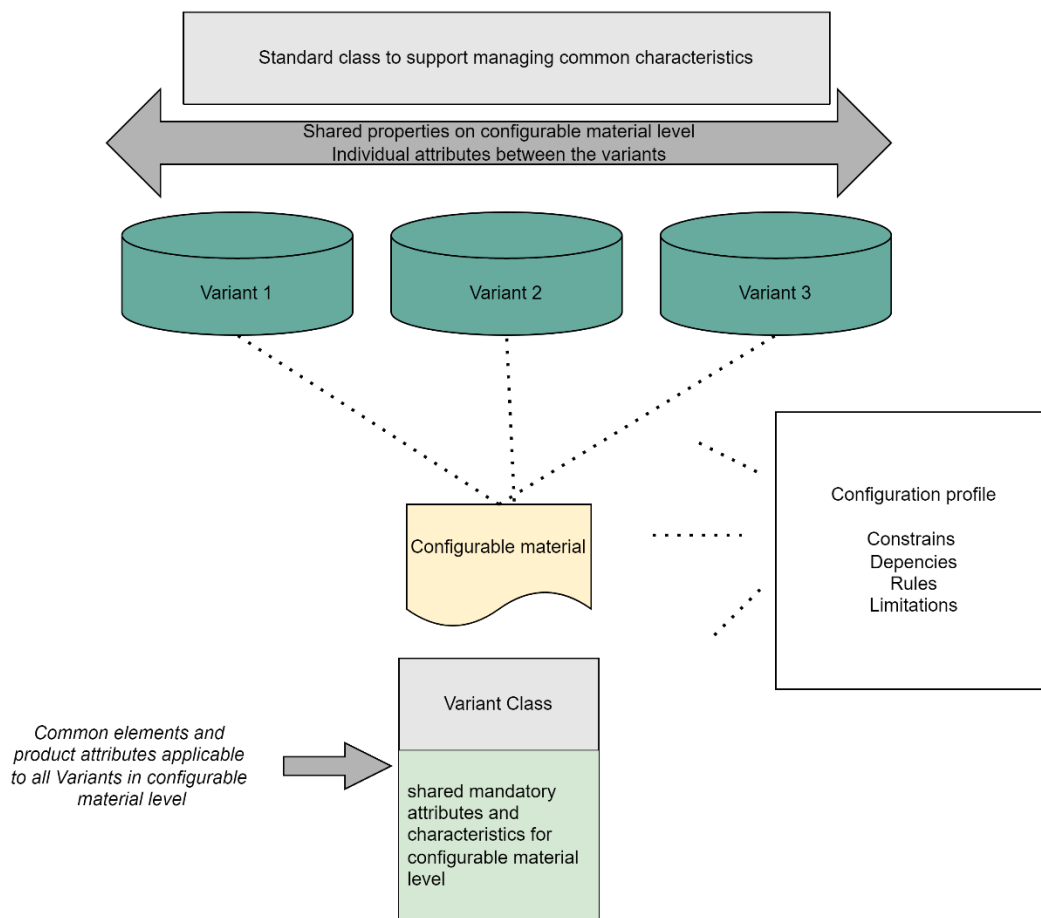


Figure 24. Suggested approach for material variant classes.

The literature review also provided information on the object dependencies that must be considered during the system setup and data migration phase. Configurable materials and material variants derived from the product master require a configuration profile in SAP together with suitable classes, characteristics, and configurable materials. Sufficient configuration profiles must be established before standard materials can be created as material variants with the help of a variant configuration profile. The company already has constrained and dependency profiles in use with the standard materials (with supporting MDM system). These constraints, and dependencies are used as a starting point to guide also material variant creation.

4.3 Batch Management

As the case company organization is already closely monitoring the quality of the products and goods movement, the batch management change requirements were considered more from the master data configuration perspective. The typical batch characteristics that would further support traceability for a company doing continuous manufacturing industry were categorized as follows in Table 6.

Table 6. Suggested information to follow up on batch level.

Area	suggested information to follow up on batch-level
Procurement & Quality Management	<ul style="list-style-type: none"> • Quality specifications with acceptance levels for purchased goods and materials. • Expiration date of goods received. • Basic information about the specific batch and transaction, e.g., including date, time, size, and date of goods receipt. • Tracking of compliance-related information for the batch. • Vendor batch number. • Storage conditions in cases where special requirements for conditions (e.g., temperature) are set. • Next inspection date.
Production & Quality Management	<ul style="list-style-type: none"> • In cases where externally sourced materials are batch-managed, it is suggested that the batches consumed per batch manufactured is traced. • Goods receipt from production: Country of origin, Location (Mill), production line, manufacturing date, and time.

	<ul style="list-style-type: none"> • Set up quality specifications with tolerances for acceptance level, including inspection results and next inspection dates (if applicable to product type). • Regulatory compliance information tracking. • Expiration and availability date, including restrictions on batches.
Sales & Distribution	<ul style="list-style-type: none"> • Batch determination to identify customer-specific batches and/or restrict batch quantity for customers. • Dispatch prioritization based on batch ID. • In certain categories, FIFO & LIFO determination if applicable. • Utilization of batch-level information on recall management.

Batch comments are further suggested to highlight further information regarding the specific batch (e.g., exceptions). Furthermore, as batches allow the traceability of a quantity within the supply chain, it is suggested to utilize information gained on the batch level to gain additional insights over time to identify areas for improvement. For example, the impact of batch size produced on costs, the impact of batch size on quality, and quality exceptions over time. These metrics can be followed with KPIs focusing on purchasing, manufacturing processes, inventory turnover, and production yield.

It is suggested that batch search strategies and procedures are kept as similar as possible on a client level while also considering the exceptions that apply only to specific processes and plants. This approach makes implementing organization wide KPIs and process improvements on batch utilization in the long term easier. Also, as in SAP, the goods in the inventory are followed on a handling unit level (SAP Standard), typically

referring to pallets or containers; the information of which handling units belong to which batch is suggested for logistics operations.

4.4 Identified changes to data

4.4.1 Data Configuration and setup requirements identified

The data structure changes, and model mentioned in the previous chapter should not bring any complexity to the product creation process for the end user as material variant setup can be configured to guide the product (variant) creation process in a flexible manner. The reduced amount of allowed characteristics, supported with constraints, would guide the creation process more, which further should improve the understanding of the specific requirements for the data. When comparing the technical capabilities of the current SAP ECC to SAP S/4HANA in terms of product data and material management modules, the new system version S/4HANA does not introduce big changes to the material (product) master data structures. Even though the data structures available between the system versions do not significantly change, it was identified that the migration and change from standard materials to material variants and batch management require changes to the product master data.

Standard materials to material variant change requires the following changes:

- Setting up the new configurable material master records (Material master).
- Setting up the allowed classes and characteristics. Class type 300 for configuration profile, and class type 001 for standard classes. The characteristics are then further connected to these classes.
- Setting up the configuration profile with required constraints, dependencies, and rules.
- During the migration, the current SAP ECC standard materials, which will be material variants in the future, will require data conversion to variants.

- As the Material variant is created based on configuration done on the configurable material master level, and all variants are derived from this configuration, the data creation process in the data management system must also be adapted to support configurable materials. The suggested approach for the testing is to manage the creation process in the MDM tool on the same level as the configuration is done on the SAP variant configuration tool.

Batch management activation requires the following changes:

- Material master configuration to enable batch management for product types.
- SAP Batch Level configuration needs to be established (Define Batch Level) to support suitable management of batches either on material, plant, or client level.
- Class type batch classes and characteristics must be established and connected to the products (and materials) managed in batches.
- In the Material Master, batch management box is enabled for all products/materials managed in batches.
- Batch Number assignment to support unique identification of each batch created during the processes.
- Batch determination configuration for inventory management, production, sales, distribution, and warehouse management needs to be configured to set up the search and allocation strategies within SAP to allow suitable selection criteria and handling of batches in different transactions and processes.

4.4.2 Other changes impacting on day-to-day work

The expected bigger changes in the new S/4HANA system compared to the ECC relate to the Fiori user interface that replaces the traditional SAP GUI. In Fiori, the system “looks and feels” will change drastically. This change can be considered one of the biggest changes for SAP systems between the versions when considering a regular system user. SAP has also introduced apps designed for different roles, including material and product management apps that will be taken into use for product management organizations. In

the old SAP ECC, the materials and products were always considered materials, but in the Fiori user interfaces, the manage material master and manage product master interfaces were separately designed to manage these two categories.

From the end user's point of view, changing naming conventions and terms with S/4HANA requires training effort. Several basic concepts for the product management organization will be changing from used application transactions (SAP GUI to Fiori) to terminology used because of variant configuration, material variants, and batch management. Some key users will still most likely use the traditional SAP GUI that utilizes the transactions, but the target is to utilize standard Fiori applications for the regular users as an SAP best practice. As Fiori will introduce various applications, it is important to highlight the differences and similarities between the transactions and the apps.

5 Discussion and conclusion

Based on the case study findings, it is evident that the more time spent on preparation activities such as business requirements mapping, identifying key changes within the processes, and data-related cleaning and restructuring that can be done prior to the actual system building phase, the more aware the organizational stakeholders and project organization are of the common targets. The awareness of the technical capabilities allows the organization to challenge and evaluate the approaches taken by (usually) external implementation partners during the system-building phase.

The case study investigated and revealed possibilities available to the case company with SAP's technical capabilities focusing on variant configuration, configuration model building, and batch management. As a result, the required configuration steps and data changes were identified and documented for the products in the migration scope.

When comparing the case study findings to the existing literature, the similarities between the common questions the organizations must be able to answer before the implementation were drawn. Heiskala and colleagues cover the typical benefits and challenges of configurator usage to organizations in their article and highlight the importance of guiding the configuration process, further reducing the problems in the later stages of production and sales. (Heiskala et al., 2007) Also, as in today's organizations, data lays the foundation for successful transactions and business processes in highly integrated business environments; the data modeling targets and end goals are often similar. Identifying the unused legacy data elements will simplify structures and streamline processes while allowing the organization to focus on the needed data objects and elements. The goal is often to have a data set up that will improve time spent on data input while providing high-quality information for all the necessary processes. Wei and colleagues have drawn similar conclusions highlighting the importance of continuous improvement of data maintenance activities for material

master data and training of the organization's resources working with it. Wei, et al., 2023)

“What are the required product data structure and/or data element changes to fulfill all cross-process area needs?”

Within the case company context, the biggest change impacting data structures when moving from system to system is moving from standard material master records to material variant master records, which result from configuration derived from the configurable material master and configuration model. In the case of company context, the number of dependencies and constraints governing the suitable combinations can be considered relatively low in the model suggested in this research, as the products are not typically complex by their nature. The benefits achieved by using configurable materials, with material variants instead of standard materials, come from the fact that some configurations (set up) for the product creation have already been “pre-decided” in the configuration model. This approach will improve the data quality (and understanding of the required data) while still allowing flexibility in cases where it is needed. It is further suggested to re-evaluate the need for different kinds of configurable material setup for a few identified product categories, changing more often compared to the rest of the products. In cases where the possible configurations can change often, the configuration model is suggested to restrict and guide each configuration to the last detail, allowing a quicker response to the organization's needs.

The typical challenge highlighted in the literature is finding a suitable amount of dependencies and constraints while still allowing the users to have all the needed options available. As described in the result section, for the case company, the approach suggested is to guide mandatory parameters on the configuration profile while still leaving some flexibility on product creation (material variant configuration). This approach is seen as suitable for product variations where additional rules to govern combinations are not needed. Together with SAP, the data creation process is done through an additional MDM tool in case the company's lower-level constraints and

dependencies can be kept outside of the SAP configuration profile, allowing more characteristic combinations to be more valid in SAP while still guiding the creation process for data in a streamlined manner

The following conclusion can be drawn when comparing the benefits of SAP's material variant master records instead of standard materials for products: Material variants are ideal for managing products with multiple variations or configurations. If products come in different sizes, colors, or in many other configurable options, using material variants allows efficient management of these variations through a higher-level configuration. The aforementioned applies when a company's portfolio is relatively stable.

Material variant masters offer greater flexibility in configuring and customizing product variations. Organizations can define configurable characteristics and configuration profiles to specify the available options for each variant, allowing them to identify the suitable level of options, constraints, and dependencies for efficient operations. This approach further allows the configuration to guide the data creation process, which further results in better data consistency. Also, as data is modeled for the configurable material master, changes can be auto-updated and applied to all the variants, making updates applicable to the entire product type, group, and product family easier. Forza and colleagues have also identified similar benefits and challenges in their article when managing product variants that require a high amount of information related to the products. (Forza & Salvador, 2001)

"What are the implications of the newly introduced batch management functionality on the organization responsible for managing the products?"

When considering the use cases and benefits of batch management, they come foremost from traceability, quality control, and inventory management as the information generated in different phases of the goods movements contribute to the "data trace"

which can further be used in business transactions based on the organization need (e.g., Last In First Out (LIFO) or First In First Out (FIFO)). In the case company context, batch management will allow more automated processes than the processor SAP ECC. As this kind of information is available in a more automated way (with automated batch creation and batch determination) valuable insights regarding production performance, product quality, and inventory utilization can be generated with less effort than methods requiring more manual work. As highlighted in the results, the identified suggested characteristics for the operations will cover the material flows from procurement to production to sales. The utilization of suggested batch characteristics was not evaluated in the research, as the topic is heavily related to many other processes than also to product management. Results provides insights when considering the system configuration and future possibilities that can be considered in the next project phases.

“What relevant products from the current system will be used in the future ERP and batch management?”

When evaluating the thesis results, the main goal of mapping the required data in scope and the changes to product data structure was identified. Based on the alignment interviews and previous project material, the two larger impact areas on the data structures were identified and further investigated. As variant configuration directly impacts the product management organization responsible for products and the way how SAP products are managed, more effort was put into understanding the possibilities and technical decencies of the configurable materials, configuration model, and data modeling. The number of required material variants in the future system can be considered based on the standard products in SAP depending on their lifecycle status (at the time of migration). In terms of material variants, considerations regarding configurable materials were highlighted.

When considering the potential limitations of the research results, the data elements that are currently not used but are still potentially needed in the future must be

considered separately. These characteristics and other data elements are configured into the current system but not actively used for the products or material at the time of analysis. Also, specific characteristics for information purposes might still be required in future systems, even though they are currently unused. It is suggested that the preliminary model characteristics are combined with any additional required characteristics for new connected systems to ensure a good fit.

When considering the research from an academic point of view, the amount of literature available on variant configuration and configurable materials clearly seems to point out an ongoing trend within different organizations aiming to take advantage of the configuration modeling tools available in ERP and other systems. (Forza & Salvador, 2007) As an organization's operation model, range, and complexity of products directly impact the configuration, the background work can be considered unique to each organization while still having common elements. These common elements include thinking through the required (relevant) data structures and elements for the future model while considering the suitable number of characteristics and configuration model strictness to support the day-to-day operations. As the research results can be used to support the current ongoing project, some variations and adoptions to the suggested preliminary structures are expected to be applied based on the understanding gained in the next project phases. Since product master data plays a vital role for organizations that work with ERP systems such SAP, it is recommended to continuously re-evaluate and adopt business requirements to the existing configuration structures. This approach ensures that the structures remain adaptable to the changing business needs rather than changing the needs to fit the existing structures. Zhang mentions in his research that past research focusing on product configurations provides additional insights and understanding, along with the context for configuration model builders for the future. (Zhang, 2014) The results of this research aim to provide this kind of input to other organizations that are restructuring their product structures.

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