Vaasan yliopisto
UNIVERSITY OF VAASA

Juhana Pohjonen

Production planning and product scheduling in an ERP system

How to schedule and release Enclosed Drives products in SAP ME

School of Technology and Innovations
Master's thesis in Industrial Management
Programme of Industrial Management

Vaasa 2024

UNIVERSITY OF VAASA
School of Technology and Innovations
Author: Juhana Pohjonen
Title of the thesis: Production planning and product scheduling in an ERP system : How to schedule and release Enclosed Drives products in SAP ME
Degree: Master of Science in Economics and Business Administration
Discipline: Industrial Management
Supervisor: Petri Helo
Year: 2024 **Pages:** 70

ABSTRACT :

Production planning means analyzing, designing and modifying the factors that affect a company's production in such a way that they best meet production requirements. Production planning can be seen as a tool for a company to optimize production in the way it wants. This study reviewed the literature review on production planning, supply chain and operations management, and conducted an empirical review of the practical process of production planning from the perspective of a power electronics manufacturing company. The aim of the study was to identify the theoretical framework within which production planning is carried out and the types of tasks that production planning performs. There were two research questions; how is the product under consideration structured in an ERP system and how does it work in terms of load?

The study was commissioned by Danfoss Drives Oy and involved several employees of the company. The study is qualitative, and the data used was obtained by testing the load on the product under consideration in the ERP system of the company. All data was analyzed, but some of the data collected is not published in this research report. The data examined provided information on the product load in the ERP system and was used to plan the product load. The findings of the study present the framework in which production planning is carried out and the planning work that production planners do when implementing a company's production strategy.

In the empirical section, results were partially obtained that supported the original idea of how load and scheduling should be implemented. Partially, however, the results changed the perception of how the parameters of the load should be changed for the product under consideration so that the load corresponds as well as possible to the production control's idea of loading the product. These changes are related to the load parameters used. With the theory section, it was understood why the interfaces between the different functions of the company are important in terms of the success of the production load. The measurement of the production load and the results obtained from it guide the basis on which the parameters of the load are set. The optimal production load aims to promote the smoothness of production and meet the requirements set for the performance of the supply chain.

KEYWORDS: Production planning, Enterprise Resource Planning systems, Scheduling, Production control

VAASAN YLIOPISTO
Tekniikan ja Innovaatiojohtamisen akateeminen yksikkö
Tekijä: Juhana Pohjonen
Tutkielman nimi: Tuotannon suunnittelu ja tuotannon kuormittaminen toiminnanohjausjärjestelmässä : ED tuoterakenne ja tuotteen kuormittaminen tuotantoon
Tutkinto: Kauppatieteiden maisteri
Oppiaine: Tuotantotalous
Työn ohjaaja: Petri Helo
Valmistumisvuosi: 2024 **Sivumäärä:** 70

TIIVISTELMÄ :

Tuotannonsuunnittelu tarkoittaa yrityksen tuotantoon vaikuttavien tekijöiden analysointia, suunnittelua ja muokkausta sellaisiksi, että ne parhaalla mahdollisella tavalla vastaisivat tuotannolle asetettuja vaatimuksia. Tuotannonsuunnittelun voi nähdä yrityksen työkaluna optimoida tuotantoa haluamallaan tavalla. Tässä tutkimuksessa tarkasteltiin kirjallisuutta tuotannonsuunnitteluun, toimitusketjuun ja toiminnanohjauksen liittyen, sekä toteutettiin empiirinen katsaus tuotannonsuunnittelun käytännön prosessiin tehoelektoriikkaa valmistavan tuotantoyrityksen näkökulmasta. Tutkimuksen tavoite oli selvittää, millaisessa teoreettisessa viitekehyksessä tuotannonsuunnittelua tehdään ja millaisia toimeksiantoja tuotannonsuunnittelu suorittaa. Tutkimuskysymyksiä oli kaksi; miten tarkasteltava tuote rakentuu toiminnanohjausjärjestelmässä ja miten se kuormitusmielessä toimii?

Tutkimus toteutettiin Danfoss Drives Oy:n toimeksiantona ja tutkimuksen teossa oli mukana usea kyseisessä yrityksessä toimiva työntekijä. Tutkimus on kvalitatiivinen ja siinä käytettävä data on saatu testaamalla tarkastelun kohteena olevan tuotteen kuormittamista toimeksiantajayrityksen toiminnanohjausjärjestelmässä. Kaikki aineisto analysoitiin, mutta osaa kerätystä aineistosta ei julkaista tässä tutkimusraportissa. Tutkitun aineiston perusteella saatiin tietoa tuotteen kuormittamisesta ERP-järjestelmässä, ja tietoja käytettiin hyväksi tuotteen kuormituksen suunniteltaessa. Tutkimustuloksissa esitellään sitä viitekehystä, missä tuotannonsuunnittelua toteutetaan ja suunnittelutyötä, jota tuotannonsuunnittelijat tekevät toteuttaessaan yrityksen tuotantostrategiaa.

Empiirisessä osiossa saatiin osittain tuloksia, jotka tukivat alkuperäistä ajatusta siitä, miten kuormitus ja skedulointi tulisi toteuttaa. Osittain tulokset kuitenkin muuttivat käsitystä siitä, miten kuormituksen parametrejä tarkasteltavan tuotteen kohdalla tulisi muuttaa niin, että kuormitus vastaisi mahdollisimman hyvin tuotannonohjauksen ajatusta tuotteen kuormittamisesta. Nämä muutokset liittyvät käytettäviin kuormitusparametreihin. Teoria osion myötä ymmärrettiin, miksi yrityksen eri toimintojen väliset rajapinnat ovat tärkeitä tuotannon kuormituksen onnistumisen kannalta. Tuotannon kuormituksen mittaaminen ja siitä saadut tulokset ohjaavat sitä, millä perusteella kuormituksen parametrit asetetaan. Optimaalisella tuotannonkuormituksella pyritään edistämään tuotannon sujuvuutta ja täyttämään toimitusketjun suorituskyvylle asetetut vaatimukset.

AVAINSANAT: Tuotannonsuunnittelu, Toiminnanohjausjärjestelmä, Skedulointi, Tuotannonohjaus

Contents

Figures

Tables

Abbreviations

APO: Advanced Planning and Optimization
APS: Advanced Planning and Scheduling
CTP: Capable-To-Promise
DM: Digital Manufacturing
E2E business: End-to-end business
ERP: Enterprise Resource Management
ED: Enclosed Drives -product
KPI: Key Performance Indicator
PLM: Product Lifecycle Management
PP: Production Planning
PPR: Product, Process and Resource
Q01/Q24: Quality Assurance System
SAP: Systeme, Anwendungen und Produkte in der Datenverarbeitung (ERP system)
SAP MES: SAP Manufacturing Execution System
SCM: Supply Chain Management

1 Introduction

The supply chain of a manufacturing company includes all those elements, either directly or indirectly, that are needed to meet customer requirements (Chopra, 2019, p. 15). Every manufacturing company seeks to optimize the supply chain surplus by minimizing costs while maximizing the value received by the customer. The success of a company depends largely on how well it succeeds in this objective.

It is essential for a company to measure the different activities to assess the value they add to the supply chain. Typically, it is possible to measure the quality, speed, flexibility or price of deliverables. These types of metrics are called KPIs (Key Performance Indicators). These measures can be used to set targets that should be met. However, it should be noted that supply chain management is not about good values for individual KPIs, but about good management of the whole entity (Slack and others, 2009, p. 429)

1.1 The structure of the study

The study consists of three distinct sections: the first section is a review of the existing literature, the second section is the empirical section, and the third section is the conclusions and findings. The literature review includes scientific literature on production planning, supply chain management and SAP ERP. The keywords used to search for material for the literature review are Sales and Operations planning, production planning and manufacturing, Execution Systems, Advanced planning and scheduling and SAP ERP. The empirical section includes a discussion of the case company's assignment and its implementing. The empirical part, it had made together with the people responsible for the production workload of the case company, as well as with the people who worked on the product under consideration. Together, we will examine the product, and its load on production, from the perspective of this study. Finally, the study will mirror the material from the literature review with the results of the empirical section and formulate findings and conclusions.

1.2 Objective and scope

This study explores, from a production planning and control perspective, how a product manufactured by a manufacturing company is structured in the case company's SAP ERP system and how it is loaded into production. A general literature review on production planning will be used as a basis. In the literature review, concepts such as production planning and supply chain are explained, as their understanding is a prerequisite for understanding the empirical problem under study. The description of the activities and operating models of the production company is mainly given from the perspective of a case study company to make the description relevant to the research questions.

The case company manufactures small and medium sized inverters mainly on a Make-To-Order basis. This is a strategy whereby the manufacturing company produces customized products against a confirmed customer order. The customers can be external customers who place purchase orders or internal customers (different plants within the same company) who place transfer orders. The aim of the make-to-order strategy is to minimize the capital tied up in stocks so that it can be allocated to the most productive uses, while reducing the need for storage space.

The main purpose of the thesis is to answer the research questions. In order to answer the research questions, it is necessary to have an understanding of the product load process in the ERP system and how to remedy any shortcomings that may be found. In addition, the research needs to outline how the different parts and sub-assemblies of the product under study would be produced in a timely manner (how to optimize their loading into production) so that they do not place a burden on the case company from a capital commitment and inventory management perspective. The substantive purpose of this thesis is to provide the reader with sufficient insight and understanding of the supply chain, production planning and ERP system of a manufacturing company to enable the reader to put the empirical part of the study into the right context.

The empirical problem is to which the research question also relates, is not the most significant in terms of supply chain management or production planning, but it is an example of the practical challenges of production planning and the issues that people working in production planning must deal with in practice. The empirical section describes production planning from the perspective of a real case study company, while the literature review is more of a scientific review of supply chain and production planning theory.

1.3 Research questions

The purpose of this study is to answer the following research questions. The research questions have been developed together with the case study company and are relevant and valid from their perspective:

- How is the Enclosed Drives product structured in the ERP system used by the company and how does it perform from a load perspective?

- How are the modules of Enclosed Drives scheduled in relation to the reinforced day of the final product?

The literature review provides a framework for examining these questions, but it is not intended to provide answers to these questions. I will be working with the people who designed the load, and I will try to find answers to these questions by working with them. It is expected that a fully comprehensive answer will not be possible.

1.4 Case company

The study was carried out at Danfoss Drives' Vaasa plant, where the Enclosed Drives product under investigation. Danfoss Drives is a Danish family-owned company founded in 1933, which as a global player has three different business segments: Power Solutions, Climate Solutions and Drives. Globally, the company has 97 factories in 20 countries and employs a total of approximately 42 000 people (Danfoss, 2023a). The company's revenue in 2022 was EUR 10.3 billion and EBITA EUR 1.224 billion (Danfoss, 2022, p. 7-8). Danfoss Drives is a global leader in AC/DC and DC/DC drives.

Danfoss uses SAP as its ERP system, which is used globally in all business segments. The same ERP system provides a single platform for planning, managing, controlling, reporting and recording of activities and supply chain management for the different factories and other units. For a company with global operations, this can be a business advantage, as it could be challenging to combine the functions of different ERP systems. The product family includes many different types of inverters with different power ratings, but we are only interested here in the Enclosed Drives -products.

Figure 1. Danfoss products (Danfoss, 2023b)

2 Literature

The company is gradually releasing the Enclosed Drives product to the market, and this created the need to explore the load of this product on the ERP system used by the company. The literature review of the study is structured around the topics of supply chain, production planning and product loading. These topics have been chosen because, in a study on production planning and product stress, they would provide the framework and context for the empirical part of the study.

The topic for the empirical part of the study came from the company, and they are interested in the outcome. The literature review provides a basis for the topic and answers the questions of why something is done and what different principles of production management and production planning can mean in practice as operational measures. The client has chosen to focus on the topic of production planning and workload management to identify the knowledge and skills related to this topic within the company.

2.1 Supply chain

The supply chain includes all the direct or indirect parts that enable the company to meet its customers' requirements (Chopra, 2019, p. 15). According to Chopra's definition, the supply chain means the whole of all the company's functions and activities, as well as other companies that influence the business and support the fulfillment of their customers' requirements and wishes. The force that maintains the supply chain is therefore the customer's requirements, which the company can fulfill. There is no specific rule on how a company can implement this. The way in which mainly all production companies carry out their business is understood as supply chain management.

It is important to understand the supply chain that it is about the effect of different functions on each other. Activities can be large or small, but the overall effect of their activities is what is called the output produced by the production company. The supply chain includes the actual production, but also purchasing, transportation, returns, cooperation with the customer, the company's financial sector and all other functions that the company needs to produce the actual product or service and to meet the requirements set by the customer.

From the point of view of the company's management, supply chain management is assignments given to different functions and activities. Good supply chain management involves management managing the whole and directing various functions, such as purchasing or production, to improve their operations. Each function / business unit is responsible for the details and strives to perform its own task in the supply chain well. At the same time, it would be desirable for each business unit to understand what role they play in the supply chain.

Chopra (2019, p. 15) describes the supply chain as starting, for example, when the customer needs a product or service from the company. The customer can contact the retailer and buy or place an order for the product. The entity that supplies the retailer is a production facility that manufactures products according to demand. The production facility needs material, transportation of goods and production facilities, warehouse, and the product to be manufactured, which has already been planned. The final product can be assembled from components supplied by different subcontractors, and each subcontractor also has its own supply chain around its own business. As a whole, the supply chain ends when the customer pays for the product/or service and gets to fulfill his own need for the product.

The supply chain is best described as a wide network of different, different types of actors linked to each other in different ways, who all have the same goal. At others, the activity is directly related to fulfilling the customer's need, and at other operators, the activity is indirectly/indirectly related to fulfilling the customer's need. Indirect and indirect activities can be to support other activities of the company.

A supply chain can be thought of as containing an innumerable number of different actors, functions, details and dependencies. In practice, all significant actors and functions may be known, but structuring and understanding all details and dependencies may be impossible, especially if it is a global actor like the case company. Understanding and managing actors and functions can be thought of as a basic condition for the controlled management of a company's supply chain (Chopra, 2019, p. 18), but also know-how related to details and dependency relationships is important.

Understanding the details helps the company to improve its own operations throughout the supply chain and helps to correct the problems that are perceived by either the customer or the company to need correction. This thesis also includes opening a detail of one supply chain, outlining its dependencies to other company functions and a proposal to solve the problem.
When building a functioning supply chain, it is necessary to understand how a good supply chain works. The business of many companies requires the movement of production factors. Factors of production can be material, information or people. When a company manages working modes of transport for both material and information, it gets more tools to manage the supply chain. Without good material flow and information flow, it is challenging to manage other aspects of the supply chain. The flow of information in this context does not mean a concrete flow of information, it is easy in today's world with the help of technology, but the flow of information is more of an organization's way of collecting, structuring and transferring information.

If the company's operating model is such that it does not lend itself to flexible and fast information gathering and transfer between different actors, the real process may face such big challenges that the company's profitability suffers. The flow of material is also technically easy, but it is still worth investing a lot in its planning, because dysfunctional material flows cause chain reaction-like problems in supply chains. When there are thousands of parties in the supply chain and millions of moving materials per year, the logistics processes must work. (Chopra, 2019, p. 19)

2.2 Production planning

In a situation where all available resources would be unlimited; production, transportation, storage, and raw materials would cost nothing, and companies would not need to operate within limited resources; then production planning would be useless. In the real world, everything has a price and companies must make decisions about investments, inventory levels, procurement of labor and raw materials, and implementation of production. The company must consider the prevailing market situation, the demand for its products and adapt its own operations in the long term to changing conditions. Because of this, it has been noticed that companies need production planning to solve these problems. (Chopra, 2019, p. 219)

As definition, production planning is a process where a company plans the levels of capacity, production, subcontracting, storage and pricing for a limited time horizon to maximize the company's result (Chopra, 2019, p. 220). It is a function of the company, which is responsible for directing operational activities in the manner defined by the management. Production planning can be a separate function in the company, or it can be integrated into, for example, the operations of production management. Regardless of how production planning is organized, its purpose as a sustaining part of operational activities does not change.

As a productive business consists of several different functions and activities, it is not possible to rank them against each other, because each one is important in its own way. The absence of even one function makes it impossible to carry out production. However, from the point of view of efficiency, well-implemented production planning helps the company manage and organize its own operations so that each different function supports production operations in an optimal way.

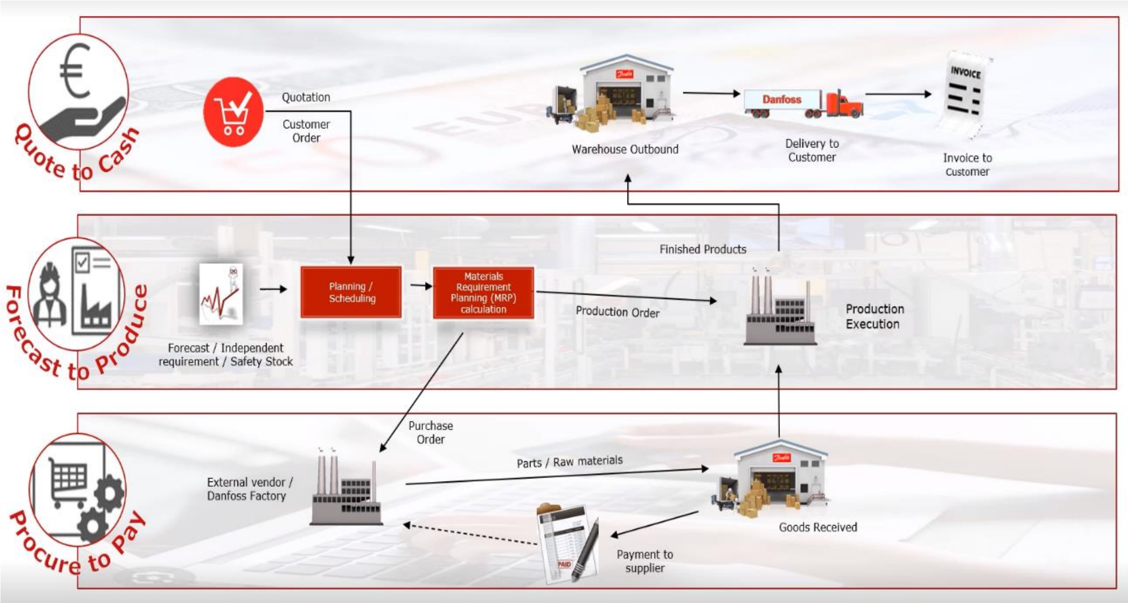


Figure 2. The role of PP in E2E flow

Figure 2 shows the role of production planning in End-to-end business. All operations start with the customer's order, followed by production planning and scheduling. Production planning operations are partly guided by forecasts and safety stock, but also by material requirement planning calculations and the implementation of the production strategy. In the process diagram, the active part of production planning ends when the order goes into production and the product is made for the customer.

From the point of view of usefulness, production planning is significant for companies. If expands the perspective to cover not only production planning, but also sales and operational planning; which are directly affected by production planning and vice versa; it can be noticed that everything affects everything. There is no separate island in the company that can function without the influence of others, or in such a way that it does not influence the actions of others. Benefits in the comprehensive planning of production, sales and operational activities can be the following: a more stable operating environment for production, faster lead times and higher productivity; better visibility into the future resource situation, i.e. whether there will be a lot or little work in the future;

streamlines the operations of teams at the executing levels and standardizes operating methods.

The entity responsible for overall planning in the company can plan and build the internal programs of the production control system, which can be used to implement the production load. It is possible to create forecasts and models of what the future of the company or production facility will be like, and according to these forecasts the measures to be carried out can be agreed in advance. The most significant benefit brought by overall planning is better control over one's own business, which is related to all the benefits mentioned above. (Wallace and others, 2008, p. 9-10)

A stable operating environment for production means the environment in which production is carried out. Factors that increase the instability of the operating environment can be, for example, uncertainty about how the company manages to acquire the production factors it needs, such as raw materials and materials needed for production, or uncertainty about the direction in which the company's overall order book is developing. With the help of production planning, these factors that destabilize the operating environment can either be eliminated or at least their effect can be mitigated.

A faster turnaround time is basically an advantage for the company, if it is not done at the expense of any other production factor, for example compromising quality. Improving the turnaround time speeds up processes and shortens order response times. Higher productivity means that with the same production input you can reach a result that produces greater added value, and in practice it can be seen in the fact that the company can get a better result for the same amount of money invested. The better visibility into the future obtained through overall planning gives the production management time to plan measures going forward, and the production plant does not have to face unexpected situations, the management of which would have required earlier preparation. Overall planning streamlines the operations of the performing teams and standardizes operating methods, as the production processes can be standardized to a certain type.

It has been noticed that production is probably easier and cheaper to execute when production is standardized and teams at the executing level are able to implement preplanned measures (Xiao-Feng, 2020, p. 7).

The earning logic and profitability of many production companies as well as other companies are based on the fact that the companies are able to efficiently and at low costs produce something that others cannot. In the case of a production facility, it can be either completely or partially that the product they manufacture is so unique that no other company makes a similar product. A product made by a production company can also be such that it competes not with a completely unique product, but with low costs and production efficiency. A production company is more easily able to meet the demands of customers when their operations are as standardized as possible and there are as few variables as possible that destabilize the production operating environment. This is achieved through standardization.

The profitability of the production company is sought by all possible means. The longer the company has been operating, the greater the probability that it has been able to refine all its processes as good as possible. This has not necessarily happened, but the probability is higher. With the help of production planning, it is especially possible to detect the processes that should be developed to make production as profitable as possible, i.e. the profitability rate of production would be as high as possible.

In this master’s thesis, there are practically two issues as research questions. 1) The structure of the product in the enterprise resource planning system and 2) How the product works in terms of load. It would be recommended that the structure of the product in the enterprise resource planning system and the way the product is loaded should be the same as possible in all the company's products, because any new variation increases the probability of errors and duplicating a proven way is cheaper than inventing a new way. The empirical section discusses two different ways of loading production, one of which is local and is not applicable to the operation of the company's other factories, and the second loading method is weaker in terms of functionality, but possibly better than the first in terms of its integrability. In companies, the general desire is to design and implement systems and methods that are an integral part of the whole, and not separate from each other. Separate systems do not support smooth business operations and supply chain management.

Whether it's about simple operating methods in production, or the operation of more complex programs within the enterprise resource planning system, repeatability and duplication reduce costs and increase efficiency. Developing new methods is expensive and time-consuming, and it is also not profitable if there is already a ready-made solution. In that situation, when there is no ready-made solution, and no existing method is suitable for use, it is profitable to develop a new one.

Production planning as a concept can be understood in many ways. It can mean the planning of the production facility in terms of production facilities, i.e. planning the layout and logistics, for example. In addition to that, production planning can be understood as a way of organizing production in an already existing production space. Understanding the concept in different ways does not result from a conceptual error, but from understanding the concept at different levels. Production planning as a top-level concept can be very non-specific and deal with large entities. The sub-level of the concept may reciprocally contain very specific planning of the details of the production in relation to its orders and the details of the order.

The production time horizon means a specific period for which the production is planned. The time horizon can be a few months, or it can go on "forever". Production planning looks at the chosen time horizon of the company and tries to adapt the requirements that guide the operation to it. The first requirement is the forecasted demand, i.e. the amount that the production should be able to produce in the selected period. Depending on the business, restoring demand can be very stable, or completely impossible.

Another requirement is the cost of production. It includes labor costs, subcontracting costs, raw materials, production equipment costs, and costs resulting from production fluctuations. Incorrect demand forecasting can lead to a situation where the production capacity is too high or too low and this causes costs for the company, at least reducing the profitability of the operation. Other requirements that guide the operation are the cost of running out of stock, costs arising from the order backlog (too large an order backlog can reduce sales due to increased delivery times), and restrictions on overtime, layoffs, capital or other parties in the supply chain. (Chopra, 2019, p. 221)

Basic compromises in overall production planning contain fundamentals that guide the choice of design strategy. The chosen strategies each have their own characteristics, and each of them aims at the efficient implementation of production in a slightly different way. If the company's goal is to keep as little stock as possible for both raw materials and finished products, which can be profitable from the point of view of capital commitment, this can backfire if the supply chain is prone to disruption, and production suffers from material shortages, for example.

Larger warehouses tie up capital and space, but at the same time, the company is not so prone to various disruptions in the supply chain and is potentially capable of very short delivery times if they have the opportunity to manufacture the products in the warehouse and send the product from the warehouse to the customer as soon as the order arrives. (Chopra, 2019, p. 222)

Chopra (2019, p. 222) tells how the fundamental compromises that production planning can affect are capacity, inventory value and order backlog/loss of sales due to long delivery time. When these compromises prevail, production planning must choose a strategy to implement production. There are three different types of strategies, but typically the strategy is a combination of these, and varies depending on the production's ability to meet market demand. The strategies are as follows:

1. Chase Strategy - using capacity as the lever. The aim of this chosen strategy is that the production capacity can be regulated depending on the market situation. The regulation is implemented by calculating the performance of the means of production and either hiring or laying off the workforce. The strategy can be expensive if production ramp-down or ramp-up is expensive and time-consuming. Such a strategy also has an impact on employee retention; it has been noticed that employees do not find it attractive a company that greatly varies the number of its workforce. This chosen strategy is best suited for a company whose product demand fluctuates a lot and production can be scaled down and ramped up quickly at low costs. This would be a bad alternative strategy for a company that does not meet the two afore mentioned requirements. (Chopra, 2019, p. 222)

2. Flexibility Strategy - using utilization as a lever. This strategy is suitable for a company with unused production capacity, as well as the possibility of flexible use of the workforce. The amount of labor may be constant, but the use of labor is uneven depending on the prevailing demand. Production can be planned flexibly, but this is not necessarily the most efficient economic way, as the strategy's functionality requires insufficient production capacity. The strategy is particularly well suited to a situation where production costs are low and storage costs are high. The flexibility strategy is somewhat like the Chase strategy, here the regulation of the amount of production is not only done at the expense of the flexibility of the workforce, but at the expense of the capital tied to the production capacity. From the company's point of view, it doesn't matter where the costs come from, they are equal and out of the company's result, but from the production point of view, it may be more sustainable to make a productivity-reducing loss through capital tied up in production capacity, than by laying off and ramping up production regularly. (Chopra, 2019, p. 222-223)

3. Level Strategy - using Inventory as a lever. The purpose of the Level strategy is to keep both production and the need for labor stable. The variable in the chosen strategy is the size of the inventory value. During periods of high demand, inventory levels are reduced,

and when demand decreases, inventory sizes are increased for future demand spikes. It is a risky strategy in the sense that it requires constant future increases and corresponding decreases in demand. For that reason, the strategy as such has not been very commonly applied in production companies. A large inventory value is also capital-binding, and capital productivity is not necessarily the best possible. In a business where the average demand remains constant regardless of the national or world market situation, it is possible to use a production planning strategy based on the level of stocks. Production costs can also be kept low when production is steady. (Chopra, 2019, p. 223)

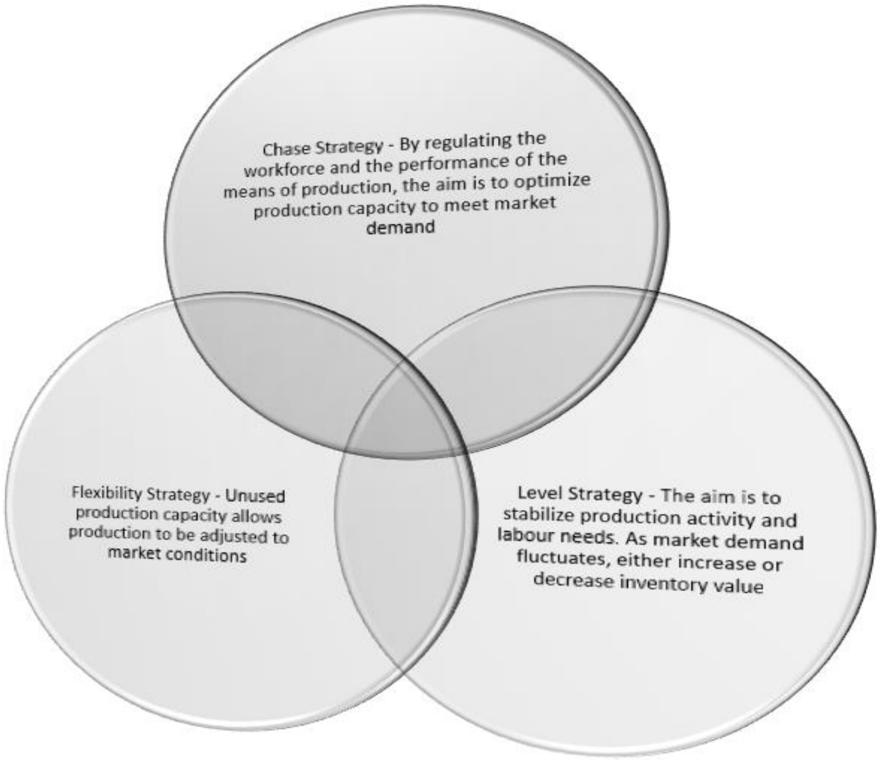


Figure 3. Production planning strategies. (Chopra, 2019, p. 222)

As such, the strategies presented in Figure 3 (Chopra, 2019, p. 222) are not suitable as a production planning strategy for many companies, because production planning consists of several different factors affecting the supply chain, and these three strategies are very straightforward and prescriptive methods of operation. The purpose of the strategy models in question is to present the structured operating methods of production planning, which can be used to reach the desired result. The final strategy has considered factors outside of these models, and the production planning strategy can live and change, it is not tied to a decision made at a certain moment in time.

The strategies in question are top-level operating methods and are a guiding element behind the operational production planning, but not among the daily procedures of the production control teams. In the same way as in Figure 1, the strategy guides the operational activities at the lower level, and without a strategy, there are no controlled actions in the company.

The chosen strategy is significantly related to the logic of loading the production, but it does not affect the technical operating mechanism of the load in the enterprise resource planning system. Both automatic and manual measures of the operational control system are set to work in such a way that it supports the selected production planning strategy. If the strategy is to load production only against the order, it should not be possible to implement measures contrary to this strategy in the system. Production loading can be studied a lot in terms of its technical implementation, and all its different technical variations can be presented in different production loading scenarios. The idea of this master's thesis is to study the philosophy of production loading from the point of view of scientific literature, and in the empirical section to study a single technical implementation method related to production loading.

It is easier in terms of production load if the production planning strategy does not change regularly. When the load is designed to correspond to a certain strategy, changing the strategy can also affect the need to change the load method. Changing the strategy can lead to many such changes in the production plant that were not initially thought to be necessary.

2.3 Enterprise Resource Planning -system

The operational control system, i.e. the Enterprise Resource Planning system, is an information system whose purpose is to integrate all the different functions of the organization together. The ERP system is a way to manage the organization's information so that all information can be found in the same place and real-time sharing of information would be possible. (Monk & Wagner, 2013, p. 1)

Typically, companies have divided their operational activities into different functional sectors, such as Sales & Marketing, Supply Chain Management, Accounting & Finance and Human Resources. Quite different types of functional areas are easily connected with the help of a common ERP system. (Monk & Wagner, 2013, p. 2)

The ERP system contains all the information that the company has, and for each different functional area or system user, valid information or modules that the area needs or the user needs in their work can be selected. Even when acquiring an ERP system, a company can customize a package from the ready-made EPR system that is just right for them; it is not necessary to include all functions and features of the system in the company's enterprise resource planning system. (Magal & Word, 2012, p. 26)

Production planning belongs to the Supply Chain Management sector. For the ERP system, Supply Chain Management includes the creation and implementation of production plans, ordering raw materials from suppliers, manufacturing products, maintaining the production plant and sending products to customers.

The APS system typically contained in an ERP system is intended specifically for production planning. APS stands for Advanced Planning and Scheduling, and its purpose is to be a platform for production workloads. In the ERP system SAP used by the case company, the APS system in question is APO (Advanced Planning and Optimizer). APO is a SAP module that supports efficient production planning in supply chain management (Monk

& Wagner, 2013, p. 73). APO's mission is to ensure high-level customer support through global available-to-promise capability.

Factory automation applications, Manufacturing Execution System, can also be connected to the ERP system. The MES system is used to manage operational functions and with it, it is possible to transfer detailed production data directly to the ERP system.

2.4 SAP S/4HANA and loading the orders into production

The SAP S/4HANA used by the Case company is a new and more advanced version of SAP's ERP systems. The system has been manufactured by the German software manufacturer SAP SE (Systeme, Anwendungen und Produkte in der Datenverarbeitung), which is the world's third largest in its field. (SAP, 2023)

SAP S/4HANA is therefore a software developed by SAP, and it offers more advanced solutions for the company's operational management than the previous versions, SAP R/2 and SAP R/3. S/4HANA has been implemented in such a way that it aims to be a more modern and efficient ERP solution for large companies whose supply chain management becomes more complex over time (SAP, 2023). SAP S/4HANA includes some features that make it better than previous SAP ERP systems.

Figure 4 shows a timeline of the development of the ERP system from the 1960s to the 2010s. The development has been rapid and exponential, especially in recent years. The transition has been from the management of individual areas of production towards an all-encompassing modern ERP system based on cloud services.

Figure 4. History of Enterprise Resource Planning. (Himashu, 2022, p. 3)

S/4HANA uses the SAP HANA database, which is an in-memory database in terms of functionality. This enables faster data processing and real-time analytics. The time it takes to save and retrieve data is a significant factor in the use of an enterprise resource planning system, because the slowness or speed of the performance depends on it. The in-memory database enables fast data retrieval. (Himanshu, 2022, p. 4) Speed and system efficiency is a general characteristic that is thought to be important in large information systems.

In terms of its software architecture, SAP S/4HANA is more simplified and its user interface is more scalable for different purposes. SAP S/4HANA simplifies traditional SAP ERP systems, as its user only connects to the databases they need, of which the system contains several. (SAP Hana Platform, 2023, p. 15) Production planning belongs to the supply chain area, as well as to the advanced planning area.

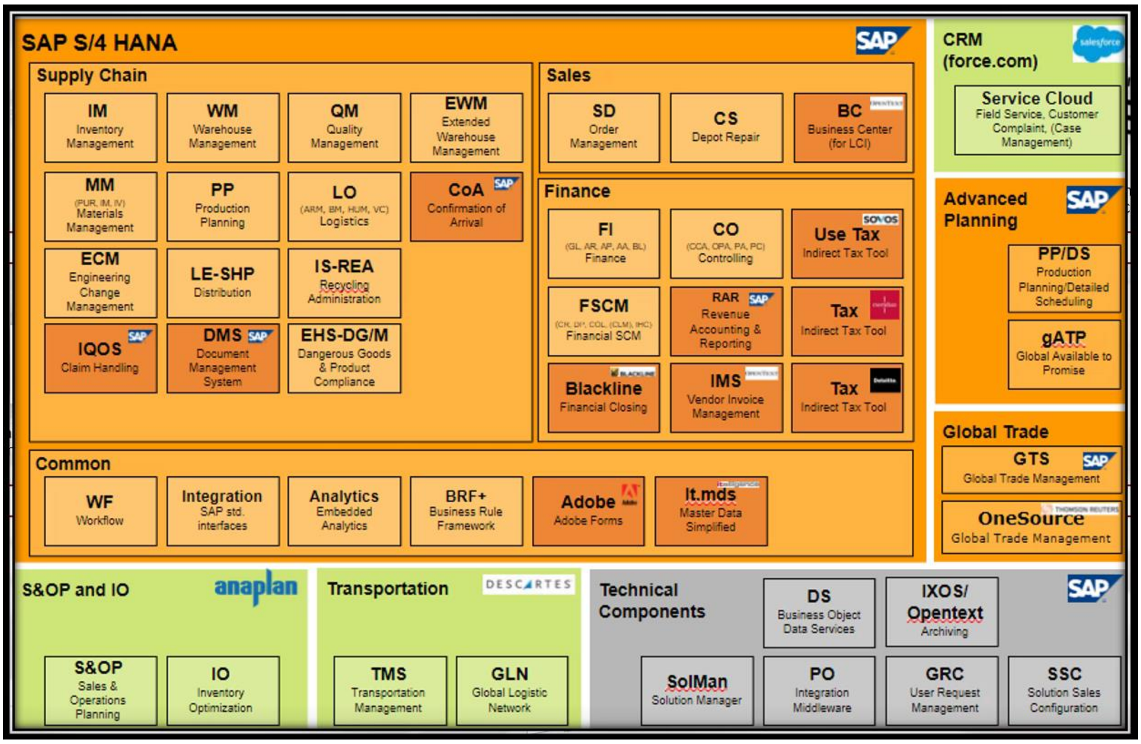


Figure 5. SAP S/4HANA flowsheet (Zhang, 2023)

S/4HANA offers efficient and real-time analytics to the user. The most up-to-date information and production monitoring enables the organization to have a better view of the current state of business processes and creates the conditions for valid decision-making. SAP S/4HANA includes a lot of reporting and analytics tools. Transactions and analytics must be kept separate in the system, because analytics could be delayed if they were integrated together (Pattanayak, 2017, p. 1).

Reporting and analytics are largely because the information that supports the solution of a question or problem encountered in production is filtered from a large amount of data in the way the user wants; or what information is specifically desired to know. With the help of reporting and analytics tools, it is possible to get detailed information about individual small things, or alternatively a broad understanding of the current situation of production. A single small thing can be, for example, one production order, and the related master data. A broad understanding of the current situation of production can mean, for example, the number and development of the entire factory's order backlog.

By widely managing various SAP transactions and tools, it is possible to filter out of all the existing information exactly the information based on which production can be led and managed "optimally". (Himanshu, 2022, p. 425-456)

SAP S/4HANA is designed to help organizations streamline their business processes, improve efficiency and make better decisions with real-time information. It is especially popular in large and complex organizations that need comprehensive business solutions. Providing a better user experience than previous versions, SAP S/4HANA is modern and designed to provide users with quick access to important information and functions. It is essential for the person using SAP to understand that the work he does in the enterprise resource planning system also affects the work of other operators and that not all functions in SAP are visible to every user. Figure 5 describes the subroutines contained in SAP, and all of these interact with each other in some way. This is why it is important that the ERP system is used in accordance with standardized processes.

In SAP S/4HANA, the loading of production orders usually takes place via the SAP Production Planning (SAP PP) application, which is part of the extensive functionality of SAP S/4HANA. Loading production orders means planning and scheduling the manufacturing process in order to ensure that the products are manufactured efficiently and within the required deadline. Here is a general step-by-step process for loading production orders in SAP S/4HANA (SAP Help Portal, 2024b):

Creating orders: The first step in the process is to create production orders based on customer orders or contracts between customers. The creation of orders can be manual or automated, and typically the order is placed by the customer/sales company, and against this order the system generates a production order, based on which the manufactured product is sent to the customer.

Production planning: In SAP S/4HANA, you can use Production Planning to optimize the use of production resources. In it, you can determine in detail how many products should be produced in a certain period of time and what kind of resources are available for that. Production resources can mean, for example, human resources or material resources. There is no reason to include all the resources needed for production in this system, only relevant resources that can be used to regulate production.

Capacity management and production scheduling: Capacity management checks the existing production capacity. In the capacity based on the number of pieces, the system looks for a place where a new order can be placed based on the number of pieces. In the case of time-weighted capacity, it is a similar process, but the unit of capacity is not pieces, but the individual time calculated for the order.

The aim is to schedule the production order in production so that it is completed just before it can be sent to the customer at the earliest. The aim is to automate all these functions in the system because it reduces the manual processing of orders and makes production planning more efficient.

The system can precisely define the allocation of used resources. There you can define which machine or tool performs a certain work step and which employee has done work steps with which tool. A lot of detailed information can be collected from the production for the subsequent review, but also for the purposes of production planning.

One of the most important things in production planning is materials management, because without existing materials and components, it is impossible to carry out production as it is supposed to work. The operational control system can be used to ensure that all necessary materials are available for the production order. Conditions can be set in the system that it is not possible to generate new production orders for orders for which not all material can be found.

Production is monitored in real time and the ERP system makes it possible. Otherwise, it would be completely impossible to monitor the progress of production if a system like

SAP S/4HANA was not in use. The system can be used to ensure that production orders proceed as planned and on schedule.

SAP S/4HANA offers comprehensive reporting and analysis tools that allow you to monitor production performance and make changes to the production plan if necessary. When practical problems arise, the solution is often found by searching for the cause of the problem in SAP, and through that we get to the solution of how to eliminate the problem. It can be an error in the information system, but even more often it is caused by human factors.

Here was the general load process in SAP S/4HANA. Please note that the exact steps and functionality may vary depending on your organization's needs and SAP S/4HANA configuration. As a global organization, Danfoss has production units operating with different operating models, and although the same principles are used all over the world, the production planning and load processes are not completely one-to-one in all the different factories.

Order loading means setting the production input to be produced for a specific time interval using selected production resources. As a rule, loading is carried out by someone other than the performing entity, for example by the entity responsible for production planning, and the purpose of loading is to be part of the overall production planning. The overall production planning can contain an innumerable number of load events, and the goal of the overall planning is to plan the use of existing resources as efficiently as possible within the selected time horizon.

From the point of view of production plants, the ideal situation would be if the production could be loaded so that the products are manufactured as close as possible to the customer's desired delivery date, and the products would not have to be stored ready for a long time. In addition to that, it would be in the interest of the production facility if the production capacity could match the demand as closely as possible. In this case, the production facility would not have unused production capacity, and product delivery times would not be too long either.

The load is an option to organize in different types in the MES system. ISA95 is an international standard with specifications for how production control systems and the functions they contain can be connected to the enterprise resource planning system (The Factory Science, 2023). Production processes are so extensive that it is necessary to be able to handle them as system-level processes, without this, the implementation of the supply chain could not be sensibly managed. The ISA95 standard facilitates the integration of operations from operations management to the ERP system.

According to the ISA95 standard, the company's operations are divided into different levels in the enterprise resource planning system (The Factory Science, 2023). The lower-level functions performed in the ERP system form a whole, which the upper-level company managers use in their decision-making, and the lower-level practical operations are carried out according to the instructions given by them. ISA95 has standardized how information must be transferred between different systems so that the whole is good and functional. Without standardized processes, some information could remain untransmitted from a lower level to the company's management, or from management to the executive level. With the help of the ISA95 standard, the processes related to the company's information systems are aimed at seamlessly merging in order to be able to use the system as efficiently as possible.

The ISA95 standard is related to production planning and loading so that the standard can be used to manage e.g. structure and procedure for loading the product in the ERP system. In loading and scheduling, there must be a common interface between different operations, which is provided by standardization and the enterprise resource planning system (Harjunkoski & Bauer, 2014). In their research, Harjunkoski and Bauer (2023) also state that a common interface facilitates cooperation between different units (production planning as one part of the supply chain) and makes it possible to find comprehensive solutions to problems that previously had to be found over and over again.

With the help of standardization, the planning and loading of production can be achieved in such a way that it serves the operation of the entire supply chain as well as possible. In scheduling and scheduling, it is important that information about the current state of production passes as accurately as possible and in real time to the entities that control production (Harjunkoski & Bauer, 2014). Therefore, ISA95-type standardization serves both production planning and the entire supply chain organization.

The manufacturing execution system (MES) connected to the operational control system serves the supply chain in such a way that it is used to implement the planned scheduling for the product and to direct the operational operation of the production to the way the production planning wants it (Mahmoud and others, 2015, p. 111). In practice, MES in SAP is where the products are actually loaded into production and through SAP the E2E process is managed at the system level. When the product is loaded in the form of an order, it receives the guiding parameters in the ERP system, but the practical implementation is in the ME system.

Figure 6 shows the Digital Manufacturing tools. The loading of the product is related to each of the 5 areas of the picture. ERP is a system where, for example, a customer can place an order, and a production order is generated for the MES system. In order for the order, i.e. the physical product, to be placed, tools and production maintenance are needed, which are marked in the picture under the PLM category.

The finished products are transferred to the inventory contained in the SCM. A key part of this picture is how production control activities can make the process so smooth that all these different areas "focus" on each other. The production load cannot be achieved without these sub-areas containing a common interface. When that interface exists, it is already a significant factor in terms of production scheduling. Data transfer between different areas should be standardized. If it is not, then the supply chain is not functioning as it is intended to function (Choi and others, 2016).

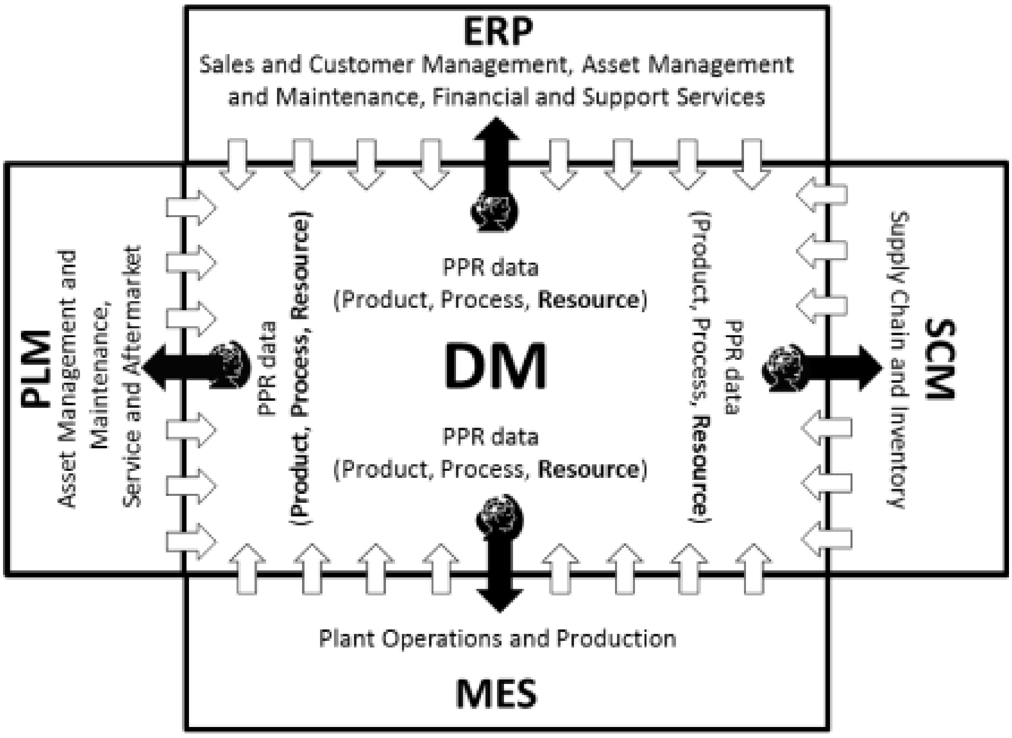


Figure 6. Digital Manufacturing (Choi and others, 2016, p. 428)

In order to find an effective interface between different systems, it requires solutions like the ISA95 standard, which ensure integration between business and readiness levels (Prades and others, 2013, p. 115). You can make the production load as perfect as you want, but it doesn't matter if the cooperation of the systems used in the supply chain is not in order. The ISA95 standard has been shown to enhance and coordinate the different parts of the supply chain sufficiently well, so that it can be considered important also in terms of production load (Prades and others, 2013, p. 122).

The loading and scheduling of products is very important in the success of the supply chain because production must be more dynamic and flexible year by year as the needs of the customers become more specific. You have to be able to customize the products to suit the customer and, despite that, load the production sensibly. Reasonable loading means that it is not appropriate to create a separate material code for each variant within the product, which would then be loaded into SAP ME. The load must be managed in such a way that when loading one product, it is still possible to meet the customer's need, and he gets a product that is as customized as possible. In any case, scheduling plays a key role, as it ensures that all processes and activities are integrated with each other. (Alemao and others, 2021)

2.5 Key Performance Indicator

What is the aim of loading the manufactured products at the right time? There are many answers to this, depending on the companies and their needs. Timely loading of production is not equally necessary for all companies, but in a significant part of serial production companies, methods are used to optimize production as efficiently as possible.

One of the principles of Lean synchronization is efficiency, and timely loading plays a significant part in achieving efficiency. The purpose of lean synchronization is to create a steady flow of manufactured products, so that customers can be delivered "exactly the right amount, the right quality product, at the right time, to the right place and at the lowest possible price" (Slack and others, 2009, p. 348).

The realization of the goals according to the Lean synchronization philosophy is measured with key performance indicators. Key performance indicator means a measure used to monitor the achievement of one's own goals or the development of performance in the company (Slack and others, 2009, p. 429).

Good or bad performance is always relative to the existing strategy. Without a clear strategy of what production should be like, I cannot target performance measurement to the company's operations. This is because performance measurement has superordinate concepts such as quality, flexibility, price and speed. The upper concepts are divided into smaller concepts, and these concrete measures form a picture of the achievement of goals or the development of performance. Lower-level meters can be e.g. order delivery time, scope of product selection, efficient use of production capacity and as little inventory of finished products as possible. The strategic goal is directly linked to performance metrics, as shown in Figure 7.

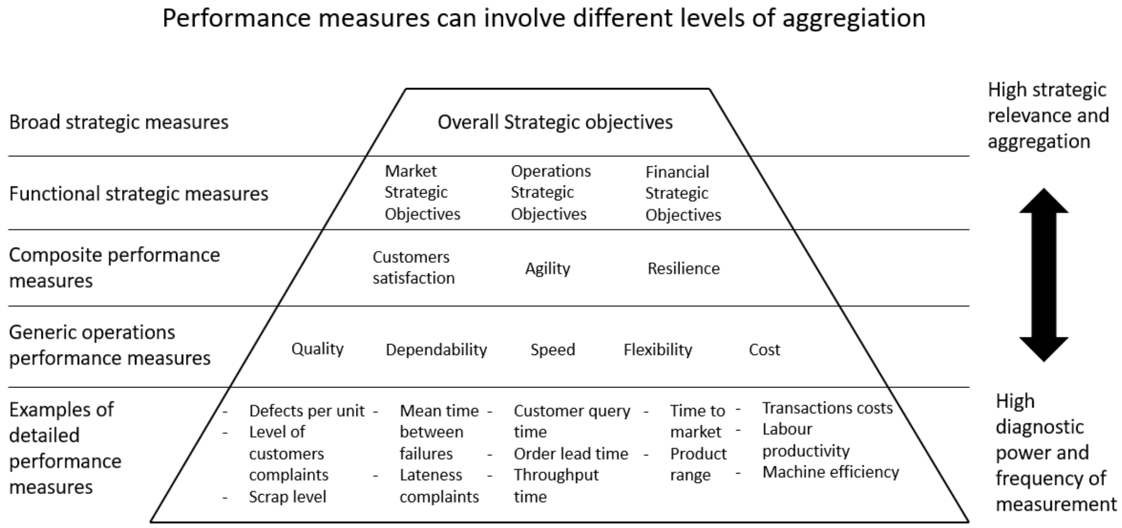


Figure 7. Different levels of aggregation (Slack and others, 2009, p. 430)

One task of the company's senior management is to implement the strategy at the operational level. Key performance indicator does not increase the implementation of the strategy, but they give senior management an idea of what the current situation is like. A realistic understanding of the current state is thought to be a prerequisite for upper management to be able to take the right measures to achieve the goals. Management at the operational level or business management can target the right measures at the executing level of the company when they receive assignments based on the right situational picture from the upper management.

In a suboptimal situation, the performance indicators have been chosen incorrectly, or for some other reason, the company's senior management gets the wrong picture of the current situation. Based on a wrong picture of the situation, they give the operational management measures that do not take the business in the desired direction, and the goals set for themselves are not achieved. It is also possible to have a situation where the perception of the current situation created by performance metrics is correct, but assignments or measures fail. In any case, the desired effect requires both the right picture of the situation and the right kind of measures.

Load production means investing work input into production for a selected period. In other words, it means to produce / provide the selected product or service in a certain period. The production load level can be measured by dividing the planned capacity utilization by the maximum capacity in use.

From the point of view of production load, many KPI indicators are related as an essential part to its effective implementation. Based on key performance metrics, it can be shown that the load has not been successful as planned. In such a situation, the company's management may issue an order to the party responsible for production planning to fix the problem. (Wallace & Company, 2008, p. 9) It also depends on the point of view and the measure, whether production planning is seen as successful. The implementation methods of some meters are such that they do not necessarily measure the real efficiency of the operation, but the meter is designed incorrectly with the purpose of use in mind. In these situations, on a case-by-case basis, it is more important to understand the overall situation and the operating principles of the various metrics, than to blindly trust the results of the KPI metric.

One task of the production facility is to strive to fulfill the customer's wishes and to increase the added value received by the customer through its own operations. To be able to bring the greatest possible added value to the customer at the lowest possible costs, the production plant must be able to manage its own operations in a planned manner.

Planning manifests itself in a way that the production plant can meet several, if not all, parameters measuring production at the same time. Profitability arises from the fact that all other production indicators are not improved at the expense of one parameter, but each one can be kept at the desired readings. The contribution of production planning to increasing the customer's added value is to plan the order book of the production plant in a way that satisfies the entire customer base in the best possible way. In addition to this, production planning must consider the production's own needs, which may conflict with the customers' needs.

Response time describes the length of time it takes for the customer to receive the order after the customer has placed the order. A long response time can mean that production planning is planned sub-optimally from the perspective of KPI metrics (Chopra, 2019, p. 85). If there is a low production availability rate with a long response time, it can be concluded that the production capacity is not being used efficiently enough and customer orders are not progressing in production quickly enough. Production must therefore be able to be planned in such a way that several different production metrics and parameters are monitored, and their interdependence effects are understood. Without a sufficient understanding of the dependency effects between metrics, it is not possible to eliminate the root causes that make it difficult to improve the results of KPI metrics.

3 Methodology

The purpose of the empirical section in this work is to model practices related to production planning through the observation of the research object and its development. Empirical research is not only modifying and repeating existing theoretical knowledge, but it also includes studying a unique research object.

The purpose of the empirical part of this study is to create conditions for the consistent loading of Enclosed Drives products in SAP in accordance with the production strategy. There are several ways in which loading could be done, and one way is chosen to be implemented.

The empirical section compares two different methods for loading production at Danfoss' Vaasa plant. The starting point for the comparison is that the second method is a local way of implementing the load, and it has already been applied, slightly modified, to other products in the factory. The disadvantage of this method is that it is not possible to apply it to the production load of other factories. If the ED product were to be manufactured in another factory, a new method for loading production would have to be developed there. However, if the method is better than another non-local method during testing, then it can be recommended to be implemented at the Vaasa factory. The latter method is basically easier to implement for all Danfoss factories, but its functionality is not necessarily as good as the first method.

The empirical part is a small detail in supply chain management. It is a practical example of what it means when production planning is implemented during the ramp-up of a new product and a new production line. When comparing two different production loading methods, the selection of the better method is influenced by the already existing loading methods, the ERP system used, the principles and implementation methods of production planning, and at the upper level, how the supply chain is managed. All the topics discussed in the theory section are not directly related to the comparison and selection of production load methods, but they create a picture of how the company works and what all must be considered in production planning.

3.1 Methods

The research method is a comparative case study. The client wants to find out which loading method is better for loading the Enclosed Drives product, and as the person carrying out the research, I will test the properties of both methods as they would work in practice, and after that I will give a recommendation to implement the other method. The research is carried out in the client's ERP system, and as the person carrying out the research, I get guidance from them on how to carry out the work correctly.

Two separate capacities will be created in the testing environment of the client's ERP system, which will be used to carry out the research. Capacities are loaded so that different types and sizes of orders are placed on them for different periods, orders are moved, and their confirmed dates are changed. Orders are removed and consolidated to be shipped in larger batches. This is all implemented with both different loading methods.

This kind of research method can be used to find out how the orders would behave with the production capacities of the ERP system. Before carrying out the study, no one knows for sure, and the client wants to find out the characteristics of the load method to be chosen, so that they could correct existing errors and make the system work smoothly. The testing environment of the ERP system, where the study is carried out, is identical to the LIVE environment of the ERP system, where real customers can place orders.

In order to replicate the study as it stands, the same product or a similar product would have to be loaded with the same parameters as those used in this study. The replicated study could be varied by changing, for example, the max lot sizing and heuristics in it.mds, so that some other factors affecting the loading of the product could be used to test how the test performs. From the point of view of reproducibility of the study, it would be desirable to have knowledge and understanding of the system used to perform the testing and product loading.

There is need to access to the system to repeat the survey, so it cannot be repeated by just anyone. In addition, the parameters (such as heuristics) used by the sponsoring company must be available to replicate the study. As such, the study cannot be replicated by anyone other than a person working for this sponsor company, i.e. it cannot be freely replicated. The basic principle of doing science is that it should be possible to reproduce the studies carried out. In this way, the reliability and objectivity of the research will be improved when the research is carried out in an open and transparent manner, rather than on the basis of secrecy. Replicating research can either lead to new findings or to the confirmation of existing ones. Both of the above scenarios for replicating a study demonstrate the importance of conducting a study in terms of reliability.

However, this study cannot be considered unreliable because it is not freely reproducible by everyone. The study describes the measures taken and allows any outsider to assess its reliability and objectivity.

4 Results

4.1 Product structure in ERP system

Product structure typically means in the SAP environment how the product is defined. The "building blocks" of the product from which it is assembled are the factors that are needed from the system's side to manage the final product. The product structure (BOM, Bill of Material) covers the basic information of the product, i.e. the components that make up the product. The components can be anything, and when they are connected to each other using work steps, the components can be made into a final product. A product structure is needed in SAP to manage the structure of different products in a structured way and to define what each product consists of. When there are many products, and multiple components included in the products, the product structure of the ERP system is the only way to manage the components and the production process in a structured way. (SAP Help Portal, 2024a)

The time required to manufacture the product is calculated based on the components contained in the product, work shifts, and working time. This time may partly depend on the number of people on the production line and the number of production shifts, but endlessly increasing the number of people cannot reduce the production time below a certain limit. Based on the production time, it is determined how much one product burdens the production. Of course, this also depends on what the production capacity is set to. The load of the product is therefore the ratio between the production capacity and the resource consumed by the product. For the product under investigation, the labor time is 638 minutes, and depending on how the parameters of the product structure are set (number of people, efficiency, maximum wait time, etc.), the product loads the day by x percentage.

The load is controlled in the enterprise resource planning system by several parameters, based on which the system automatically loads the products. Parameters can be created and set so that the desired load effect is optimal. For example, the order can be loaded from the moment of creation to the end of the desired days, we are talking about a planning time fence, which protects the next few days of production from being burdened by new orders. The order can also be split into small parts, or other guiding rules can be set for its load.

4.2 Alternative scheduling methods

The study compared the load from the point of view of which parameters it should be implemented for the load to be desired and correspond to the idea of production planning and production management. The production strategy of the factory is of a certain type, and the load of each product should correspond to it. In the case of the Danfoss factory in Vaasa, the strategy is, among other things, that the products would not be manufactured too early, but that the product could be sent to the customer immediately after it is manufactured.

There were no clear-cut two or three different methods that were compared as a whole. The comparison was made between different parameter options, the most suitable of which were selected for the live implementation of the ERP system.

4.3 Modelling capacity and scheduling

Efforts were made to realistically model the product load and order scheduling so that as much as possible could be known in advance about the behavior of the production orders within the capacity of the ERP system. During the testing, we tried to notice possible flaws that would be good to fix before the system is opened to everyone. There were no major problems and the findings provided detailed information for the load planners. Mainly, the system and product capacity in ERP worked exactly as it was supposed to work. However, the testing was useful, because during it some details were noticed that should be considered when loading the products. The modeling was performed in the SAP "sandbox" environment.

The following SAP transactions were used to test the product.

QO1 (One ERP Quality Assurance System)

Table 1. One ERP Q01 Transactions

VA02
CA02
CA03
CA12
CO41
CR03
CR02
ZBS008
ZBS009
MM03
/N/MDS/START

Q24 (APO Quality Assurance System)

Table 2. APO Q24 Transactions

RPT
RRP3
CURTO_SIMU
BOP
RES01

The aim of testing in testing part; There are 11 points of interest related to the scheduling of the order. These items are being tested to provide information on the behavior of orders when the system schedules them into the order book.

We are interested:

1) Create and delete order. We are interested in whether it is possible to create a new order and remove it from the system.

2) Check item availability. We will test whether it is possible to set a confirmation date for the created order to be ready for production.

3) Create order with multiple positions and set complete delivery. We are interested in whether it is possible to create several different positions, or order lines, for a single order, and set the same confirmed date for these order lines.

4) Using delivery group. Is it possible to group order lines so that orders belonging to the same group receive the same confirmed date?

5) Multiple orders in a small-time frame, how system schedule them. We want to test and see how the system loads the orders if several different orders are loaded in a short period of time. We are particularly interested in the scheduling of large orders and the timeframe over which large orders are loaded if they cannot be produced within one day.

6) How splitting and headcount changes affect lead times. From the system's point of view, the workload of people can be distributed so that splitting can be used to increase or decrease the number of steps running at any one time. A split means that the capacity of an entire production line can be limited, even with an unlimited number of workers. We tested how changes in headcount and splitting affect the scheduling of orders.

7) Order rescheduling, fixing and firming, and BOP. We are interested in whether the start date of the order can be postponed, whether the order can be "locked" so that the system cannot change its location in the order database. We also want to know if BOP (Backorder processing) works.

8) Delivery Group and complete delivery are used to test whether planned orders are automatically transferred, if using heuristics B and D. Using different heuristics, we test whether production orders are automatically transferred, if with the heuristic enabled, all order lines in the order are set to either complete delivery or delivery group.

9) Early. Early means that the production order goes into production too early from the point of view of production control. From the point of view of the production facility in question, it is too early when the order is ready more than 5 days before the "First Date". First Date is the date when the order can be sent to the customer at the earliest, but never before that. It is possible to confirm the order on the First Date at the earliest, but the production order may nevertheless go into production too early. The reason for going into production too early can be that right before the order's First Date there are many other existing orders, which is why the system schedules the new order to go into production too early. We are trying to demonstrate a situation where the order backlog includes a production order that goes into production too early. Wait time. The longest time that may pass before the material in processed in the next operation or order.

10) Wait time is the longest time that may pass before the material in processed in the next operation or order. We are interested in what effect it has on production scheduling if this parameter is changed.

11) Max lot size / max lot sizing. Lot sizing means that we try to limit how large orders it can receive in the system and whether there is a parameter with which the number of products contained in one order line can be split into production orders of the size of one piece. For example, a new order line of 4 pieces would generate 4 one-piece production orders in the system. We tested various max lot sizing parameters and observed their effect on production scheduling.

We wanted to know these things and we set out to find them out in the testing. The testing took place in such a way that the situation corresponding to each of the 11 points was described in the system and capacity, possibly comparing different scenarios and then drawing conclusions. A file containing all the detailed information and methods of the testing has been delivered to the client company.

There is a list of all testing activities, their objective and conclusion below.

1) Create and delete order. We are interested in whether it is possible to create a new order and remove it from the system.

Target: Create and delete an order. Let's do a test to see if this is possible.

Conclusion: The order was created and deleted successfully.

2) Check item availability. We will test whether it is possible to set a confirmation date for the created order to be ready for production.

Target: We are testing whether it is possible to confirm a date for the new order that is as close as possible to the customer's desired shipping date, however, so that the confirmed date can never be before the customer's desired First Date. In that procedure, the system searches the order book for the closest free time to the First Date, when it would be possible to place the production order.

- First day: the order is set on a day when you want it to be ready. Before the First Date, the order cannot be sent.

Conclusion: Confirmation of the order is successful

3) Create order with multiple positions and set complete delivery. We are interested in whether it is possible to create several different positions, or order lines, for a single order, and set the same confirmed date for these order lines.

Target: Create several order lines for one order and test whether it is possible to set the order lines to complete delivery. This would mean that the confirmed date (the day the orders would be shipped) of each order line would be the same.

Conclusion: Orders that have already been released for production cannot be set for complete delivery. Other production orders can be placed, and they will have a new confirmation date, which is determined by the latest order to be completed. In the case of complete delivery as every other case, confirmation date cannot be earlier than First Date.

4) Using delivery group. Is it possible to group order lines so that orders belonging to the same group receive the same confirmed date?

Target: Is it possible to group orders so that the confirmed date for all order lines is determined by the latest First Date. It is like complete delivery, but it only applies to a certain part of the order lines.

Conclusion: Creating a Delivery Group is successful

5) Multiple orders in a small-time frame, how system schedule them. We want to test and see how the system loads the orders if several different orders are loaded in a short period of time. We are particularly interested in the scheduling of large orders and the timeframe over which large orders are loaded if they cannot be produced within one day.

Target: How does the system load order, if their desired dates are close to each other, and it is not possible to produce the orders just before the First Date due to the number of pieces in the orders.

Conclusion: Based on a few orders, the system does not overload the days, but tries to schedule the production of the product so that it is ready by the confirmation date, while spreading the order over several days if it does not fit on a single day. The system schedules the larger order on consecutive days before the first date, rather than splitting it into smaller parts with other orders. There are short days/empty days between the confirmed date and the end date if the order cannot fit completely consecutively on one day.

6) How splitting and individual capacity changes affect net duration? From the system's point of view, the workload of people can be distributed so that splitting can be used to increase or decrease the number of steps running at any one time. A split means that the capacity of an entire production line can be limited, even with an unlimited number of workers. We tested how changes in headcount and splitting affect the scheduling of orders.

Target: How splitting and individual capacity changes affect net duration?

Conclusion: Split determines how many work steps can be running on the production line at the same time. Even if the individual capacity is increased, the split prevents its possible use in production, so when making changes in the individual capacity, the split must be taken into account. Otherwise, the system calculates the net durations of the products incorrectly. The split must be equal to the individual capacities in the production line, however at most the number of production steps. Note: if split is grater than individual capacity, check item availability is not possible.

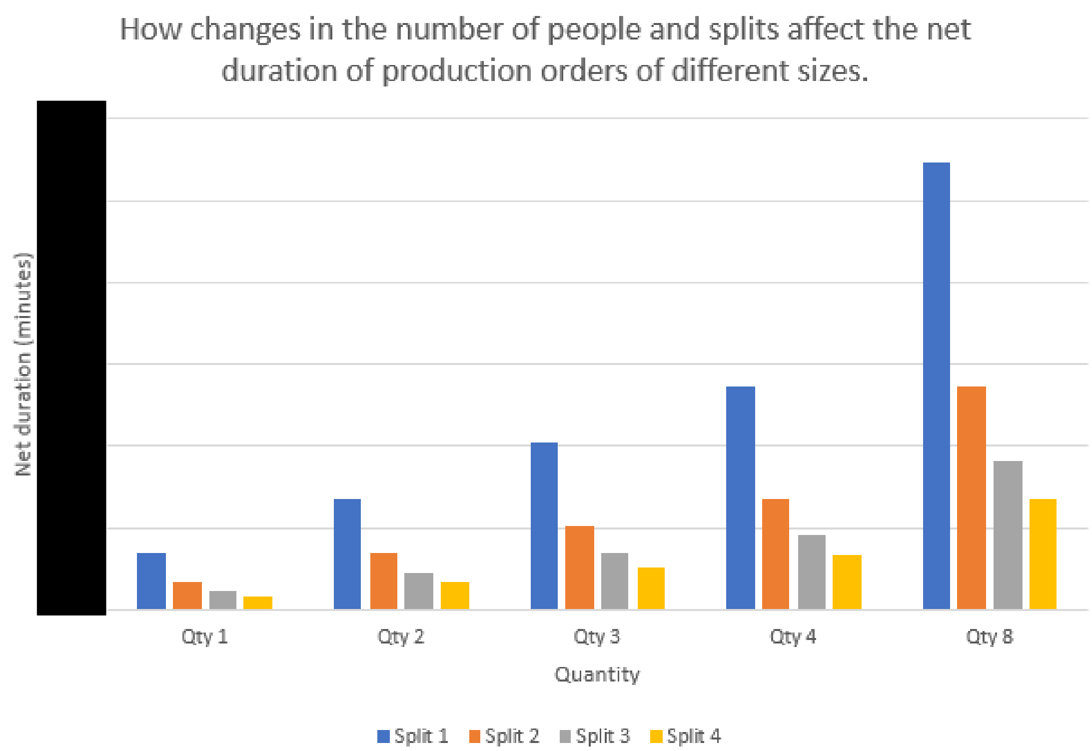


Figure 8. The effect of the split and the change in the individual capacity on the net duration of the production order

7) Order rescheduling, fixing and firming, and BOP. We are interested in whether the start date of the order can be postponed, whether the order can be "locked" so that the system cannot change its location in the order database. We also want to know if BOP (Backorder processing) works.

Target: Does BOP work for orders. BOP is a background run, every day the order information is up-to-date. In addition to that; can the order be transferred manually, and the setting to locked (fixed) and the setting to the status of the production order, which does not allow any changes to the order (firmed). No one can change the date of the order, the number of copies or any other details before the firmed has been removed. Locked status means that the order does not move from the locked day.

Conclusion: BOP works and the order can be both locked and signed. The order can be transferred manually.

8) Delivery Group and complete delivery are used to test whether planned orders are automatically transferred, if using heuristics B and D. Using different heuristics, we test whether production orders are automatically transferred, if with the heuristic enabled, all order lines in the order are set to either complete delivery or delivery group.

Target: Are the production orders automatically moved to correspond to the new confirmed days of the delivery group or complete delivery, if "heuristic run" is selected in transaction RRP3, and either heuristic is used: Z_PP_CTP_B or Z_PP_CTP_D

Conclusion: Both heuristics loaded production orders close to the group's common delivery date.

Steps in detail: The functionality of heuristics B and D is tested from the point of view of automatic scheduling, so that the heuristics optimally load the production orders placed in the delivery group or complete delivery in real time, or whether they have to be manually moved to the desired locations. At the start, the orders are scheduled optimally for the desired day. Now, when placing orders in a group or as a complete delivery, it wanted to be known, whether the heuristics will automatically move planned orders as close as possible to the new start date.

The first scenario uses the Z_PP_CTP_D heuristic:

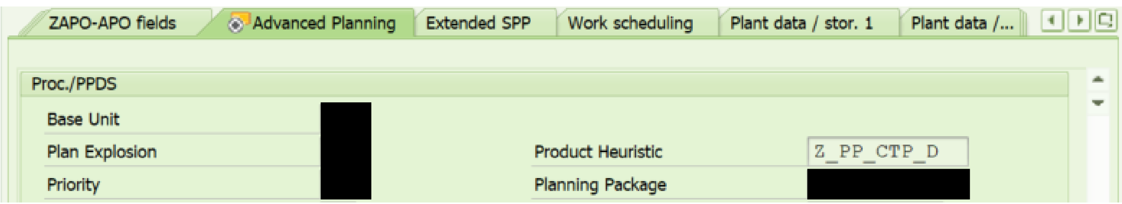


Figure 9. Z_PP_CTP_D -heuristic

The basic load is shown below:

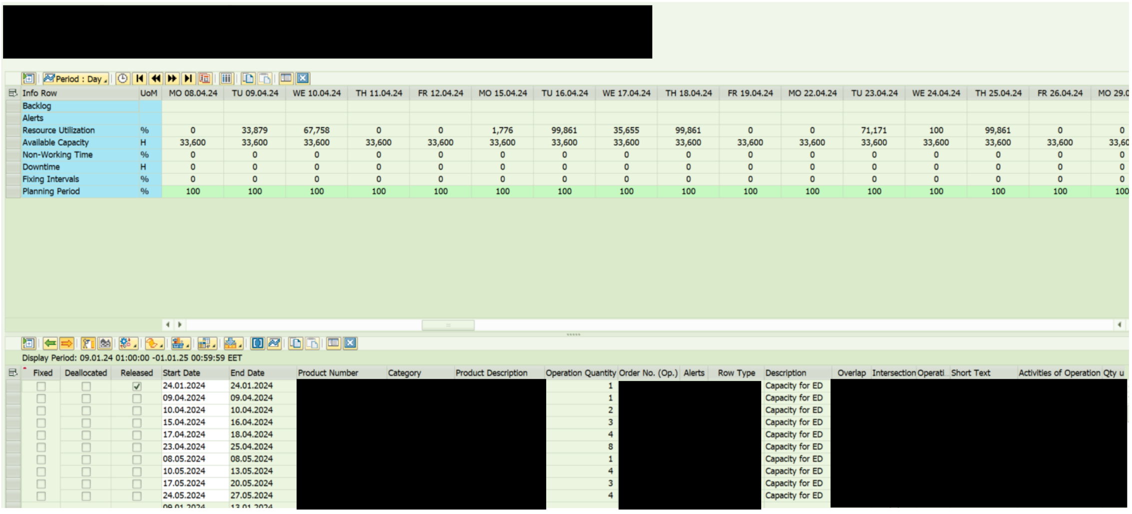


Figure 10. Basic load for ED -product before Z_PP_CTP_D -heuristic (1)

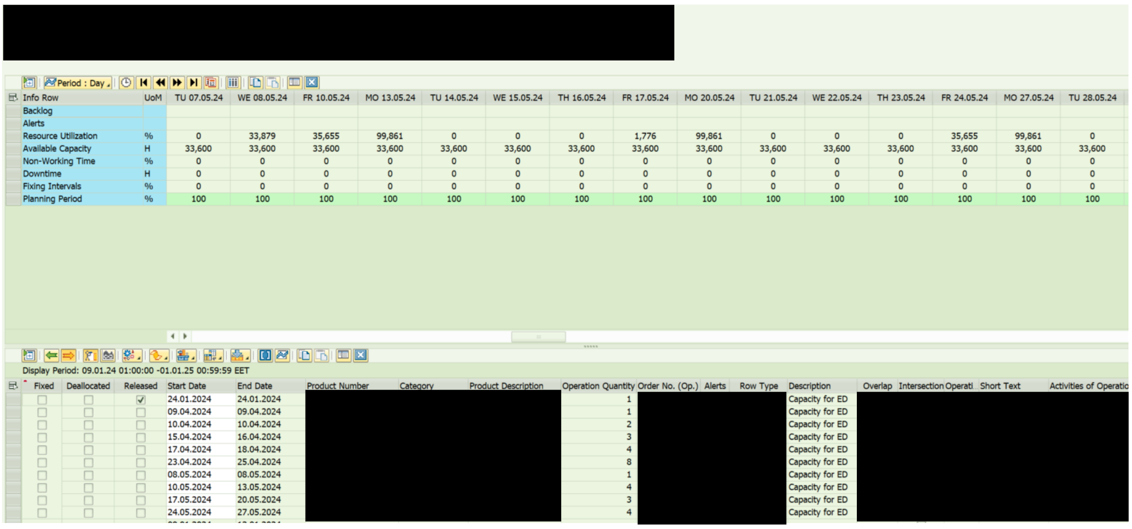


Figure 11. Basic load for ED -product before Z_PP_CTP_D -heuristic (2)

Now 2 different groups are created, which means that within a group all orders have the same departure date. Group 1 contains the April load and group 2 contains the May load. In the third column of the figure below the delivery groups are defined. Two order lines are on the schedule line, one for group 1 and one for group 2. These orders are on days with a departure date for the entire group. The other order lines are marked as "not schedule lines" because they have a confirmation later than the desired date.

Item	Material	Delivery Group	DlvDateForGrp.	N...	Delivery Date	Mat.Av.Dt.	Loading Date	Plnt	Ship...	Route
10	[redacted]		04.03.2024	☑	04.03.2024	04.03.2024	04.03.2024	[redacted]		
20		1	27.04.2024	☑	27.04.2024	26.04.2024	26.04.2024			
30		1	27.04.2024	☑	27.04.2024	26.04.2024	26.04.2024			
40		1	27.04.2024	☑	27.04.2024	26.04.2024	26.04.2024			
50		1	27.04.2024	☑	27.04.2024	26.04.2024	26.04.2024			
60		1	27.04.2024	☐	27.04.2024	26.04.2024	26.04.2024			
70		2	28.05.2024	☐	28.05.2024	28.05.2024	28.05.2024			
80		2	28.05.2024	☑	28.05.2024	28.05.2024	28.05.2024			
90		2	28.05.2024	☑	28.05.2024	28.05.2024	28.05.2024			
100		2	28.05.2024	☑	28.05.2024	28.05.2024	28.05.2024			

Figure 12. All order lines (Z_PP_CTP_D -heuristic)

Sales A | Sales B | Contract data | Shipping | Billing Document | Conditions | Account Assignment | Schedule lines | Partner | Texts | Order Data

Fixed Date and Qty [redacted] Order Quantity [redacted] PC
Delivery Time Delivered qty

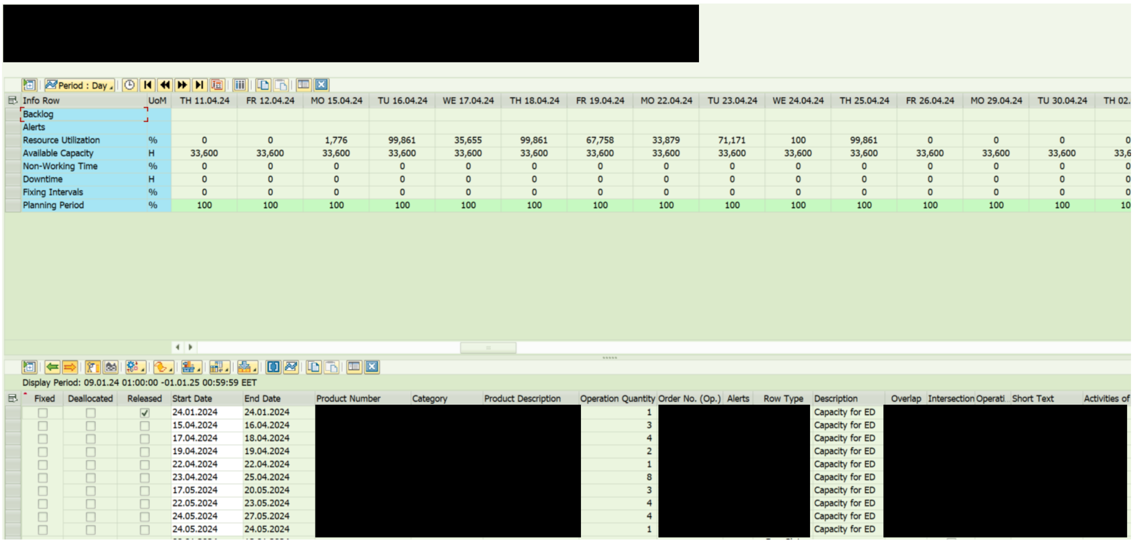
Sales | Shipping | Procurement

Quantities/Dates

P.	Delivery Date	Order Quantity	Rounded qty	Confirmed Qty	Sal...	Delivery Block	Delivered qty	Sche...
D	11.04.2024	2	2	0	PC			CP
D	27.04.2024	0	0	2	PC			CP

Figure 13. Schedule lines (Z_PP_CTP_D -heuristic)

Next, we run a heuristic on the orders and see if it schedules the production orders close to the group's start date. Group 1 departure date is 27 April and group 2 departure date is 28 May.



[redacted]

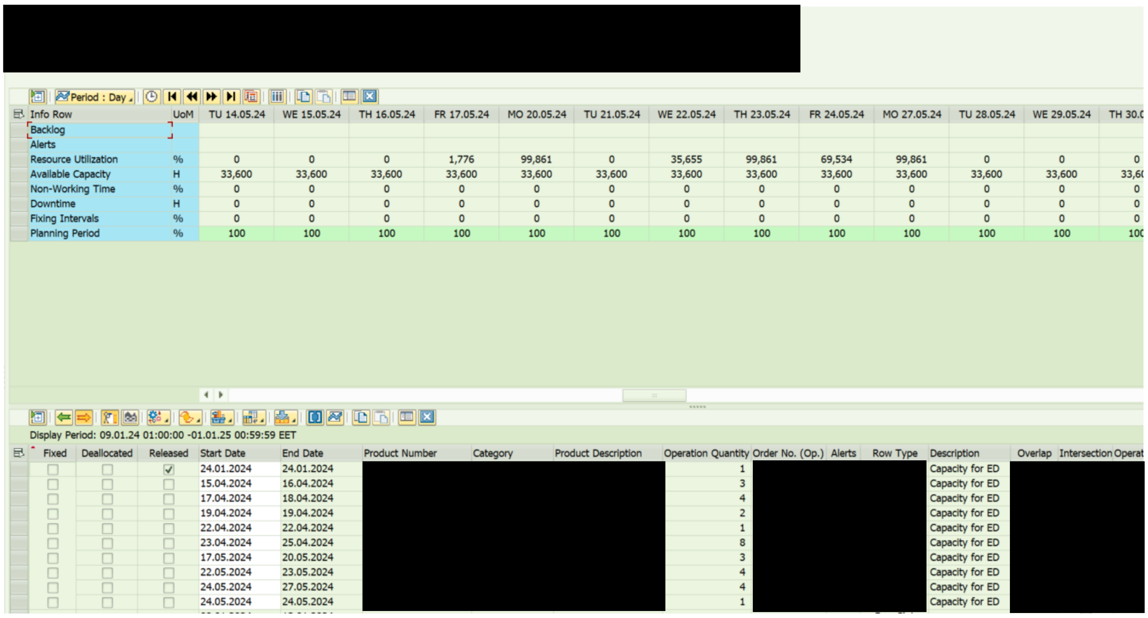
Period : Day

Info Row	UoM	TH 11.04.24	FR 12.04.24	MO 15.04.24	TU 16.04.24	WE 17.04.24	TH 18.04.24	FR 19.04.24	MO 22.04.24	TU 23.04.24	WE 24.04.24	TH 25.04.24	FR 26.04.24	MO 29.04.24	TU 30.04.24	TH 02.
Backlog																
Alerts																
Resource Utilization	%	0	0	1,776	99,861	35,655	99,861	67,758	33,879	71,171	100	99,861	0	0	0	0
Available Capacity	H	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,6
Non-Working Time	%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Downtime	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fixing Intervals	%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planning Period	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	10

Display Period: 09.01.24 01:00:00 -01.01.25 00:59:59 EET

Fixed	Deallocated	Released	Start Date	End Date	Product Number	Category	Product Description	Operation Quantity	Order No. (Op.)	Alerts	Row Type	Description	Overlap	Intersection Operati	Short Text	Activities of
☐	☐	☑	24.01.2024	24.01.2024	[redacted]			1	[redacted]			Capacity for ED	[redacted]			
☐	☐	☐	15.04.2024	16.04.2024				3				Capacity for ED				
☐	☐	☐	17.04.2024	18.04.2024				4				Capacity for ED				
☐	☐	☐	19.04.2024	19.04.2024				2				Capacity for ED				
☐	☐	☐	22.04.2024	22.04.2024				1				Capacity for ED				
☐	☐	☐	23.04.2024	25.04.2024				8				Capacity for ED				
☐	☐	☐	17.05.2024	20.05.2024				3				Capacity for ED				
☐	☐	☐	22.05.2024	23.05.2024				4				Capacity for ED				
☐	☐	☐	24.05.2024	27.05.2024				4				Capacity for ED				
☐	☐	☐	24.05.2024	24.05.2024				1				Capacity for ED				

Figure 14. Basic load for ED -product after Z_PP_CTP_D -heuristic (1)



[redacted]

Period : Day

Info Row	UoM	TU 14.05.24	WE 15.05.24	TH 16.05.24	FR 17.05.24	MO 20.05.24	TU 21.05.24	WE 22.05.24	TH 23.05.24	FR 24.05.24	MO 27.05.24	TU 28.05.24	WE 29.05.24	TH 30.0
Backlog														
Alerts														
Resource Utilization	%	0	0	0	1,776	99,861	0	35,655	99,861	69,534	99,861	0	0	0
Available Capacity	H	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,6(
Non-Working Time	%	0	0	0	0	0	0	0	0	0	0	0	0	0
Downtime	H	0	0	0	0	0	0	0	0	0	0	0	0	0
Fixing Intervals	%	0	0	0	0	0	0	0	0	0	0	0	0	0
Planning Period	%	100	100	100	100	100	100	100	100	100	100	100	100	10(

Display Period: 09.01.24 01:00:00 -01.01.25 00:59:59 EET

Fixed	Deallocated	Released	Start Date	End Date	Product Number	Category	Product Description	Operation Quantity	Order No. (Op.)	Alerts	Row Type	Description	Overlap	Intersection Operat
☐	☐	☑	24.01.2024	24.01.2024	[redacted]			1	[redacted]			Capacity for ED	[redacted]	
☐	☐	☐	15.04.2024	16.04.2024				3				Capacity for ED		
☐	☐	☐	17.04.2024	18.04.2024				4				Capacity for ED		
☐	☐	☐	19.04.2024	19.04.2024				2				Capacity for ED		
☐	☐	☐	22.04.2024	22.04.2024				1				Capacity for ED		
☐	☐	☐	23.04.2024	25.04.2024				8				Capacity for ED		
☐	☐	☐	17.05.2024	20.05.2024				3				Capacity for ED		
☐	☐	☐	22.05.2024	23.05.2024				4				Capacity for ED		
☐	☐	☐	24.05.2024	27.05.2024				4				Capacity for ED		
☐	☐	☐	24.05.2024	24.05.2024				1				Capacity for ED		

Figure 15. Basic load for ED -product after Z_PP_CTP_D -heuristic (2)

Compared to the starting situation, the heuristics have compressed the orders in both groups to close to the starting date (for some reason group 2 has one empty day in between)

The second scenario uses the Z_PP_CTP_B heuristic:

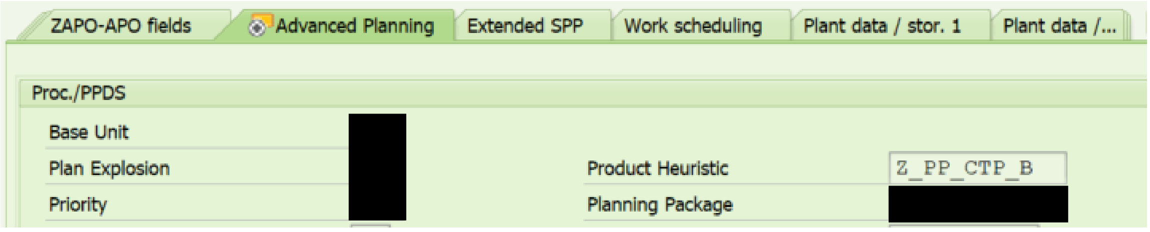


Figure 16. Z_PP_CTP_B -heuristic

Initial status Z_PP_CTP_B, orders are confirmed for the desired dates:

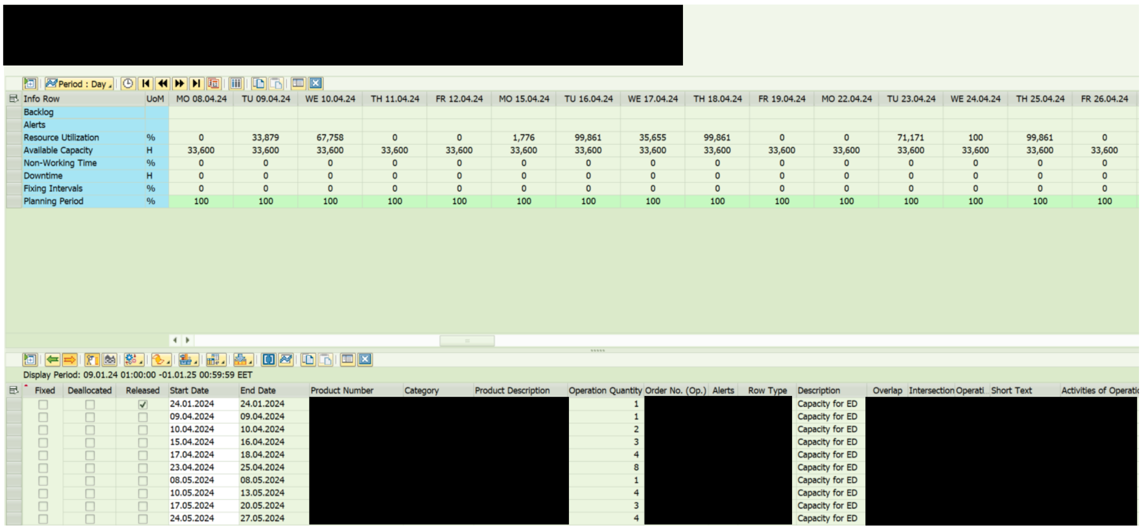


Figure 17. Basic load for ED -product before Z_PP_CTP_B -heuristic (1)

[redacted]

Period : Day

Info Row	UoM	TU 07.05.24	WE 08.05.24	FR 10.05.24	MO 13.05.24	TU 14.05.24	WE 15.05.24	TH 16.05.24	FR 17.05.24	MO 20.05.24	TU 21.05.24	WE 22.05.24	TH 23.05.24	FR 24.05.24	MO 27.05.24	TU 28.05.24
Backlog																
Alerts																
Resource Utilization	%	0	33,879	35,655	99,861	0	0	0	1,776	99,861	0	0	0	35,655	99,861	0
Available Capacity	H	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600
Non-Working Time	%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Downtime	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fixing Intervals	%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planning Period	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Display Period: 09.01.24 01:00:00 -01.01.25 00:59:59 EET

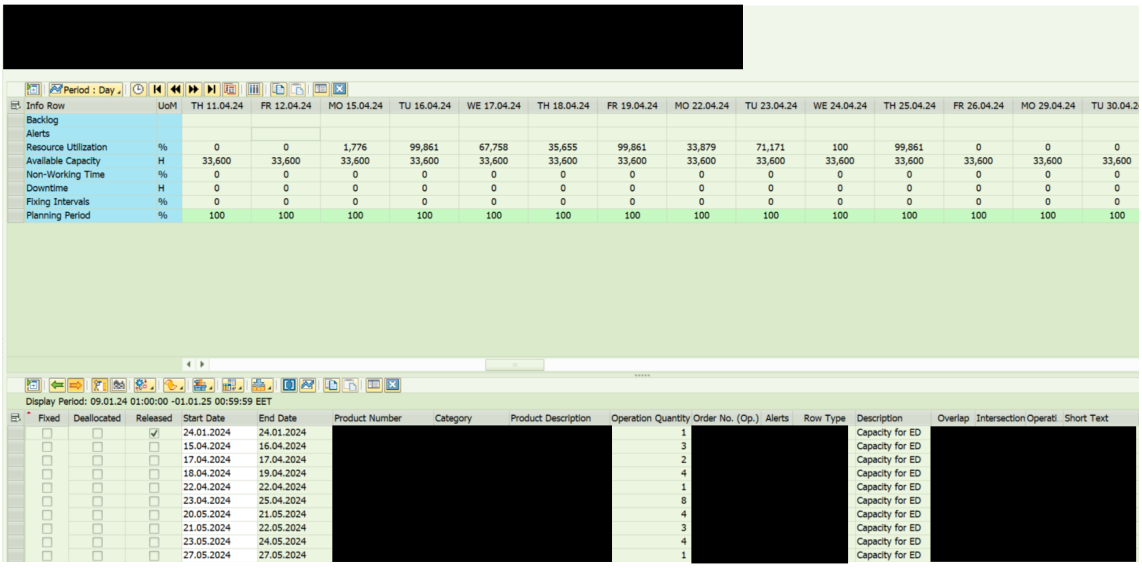
Fixed	Deallocated	Released	Start Date	End Date	Product Number	Category	Product Description	Operation Quantity	Order No. (Op.)	Alerts	Row Type	Description	Overlap	Intersection	Operati...	Short Text	Activities of Operatic
☐	☐	☑	24.01.2024	24.01.2024	[redacted]			1	[redacted]			Capacity for ED	[redacted]				
☐	☐	☐	09.04.2024	09.04.2024				1				Capacity for ED					
☐	☐	☐	10.04.2024	10.04.2024				2				Capacity for ED					
☐	☐	☐	15.04.2024	16.04.2024				3				Capacity for ED					
☐	☐	☐	17.04.2024	18.04.2024				4				Capacity for ED					
☐	☐	☐	23.04.2024	25.04.2024				8				Capacity for ED					
☐	☐	☐	08.05.2024	08.05.2024				1				Capacity for ED					
☐	☐	☐	10.05.2024	13.05.2024				4				Capacity for ED					
☐	☐	☐	17.05.2024	20.05.2024				3				Capacity for ED					
☐	☐	☐	24.05.2024	27.05.2024				4				Capacity for ED					

Figure 18. Basic load for ED -product before Z_PP_CTP_B -heuristic (2)

Create 2 different groups in the same way as in the first scenario and test whether the heuristics load the production orders close to the group's delivery date.

Item	Material	Delivery Group	DlvDateForGrp.	N...	Delivery Date	Mat.Av.Dt.	Loading Date	Plnt	Ship...	Route
10	[redacted]		04.03.2024	☑	04.03.2024	04.03.2024	04.03.2024	[redacted]		
20		1	27.04.2024	☑	27.04.2024	26.04.2024	26.04.2024			
30		1	27.04.2024	☑	27.04.2024	26.04.2024	26.04.2024			
40		1	27.04.2024	☑	27.04.2024	26.04.2024	26.04.2024			
50		1	27.04.2024	☑	27.04.2024	26.04.2024	26.04.2024			
60		1	27.04.2024	☐	27.04.2024	26.04.2024	26.04.2024			
70		2	28.05.2024	☐	28.05.2024	28.05.2024	28.05.2024			
80		2	28.05.2024	☑	28.05.2024	28.05.2024	28.05.2024			
90		2	28.05.2024	☑	28.05.2024	28.05.2024	28.05.2024			
100		2	28.05.2024	☑	28.05.2024	28.05.2024	28.05.2024			

Figure 19. All order lines (Z_PP_CTP_B -heuristic)



[redacted]

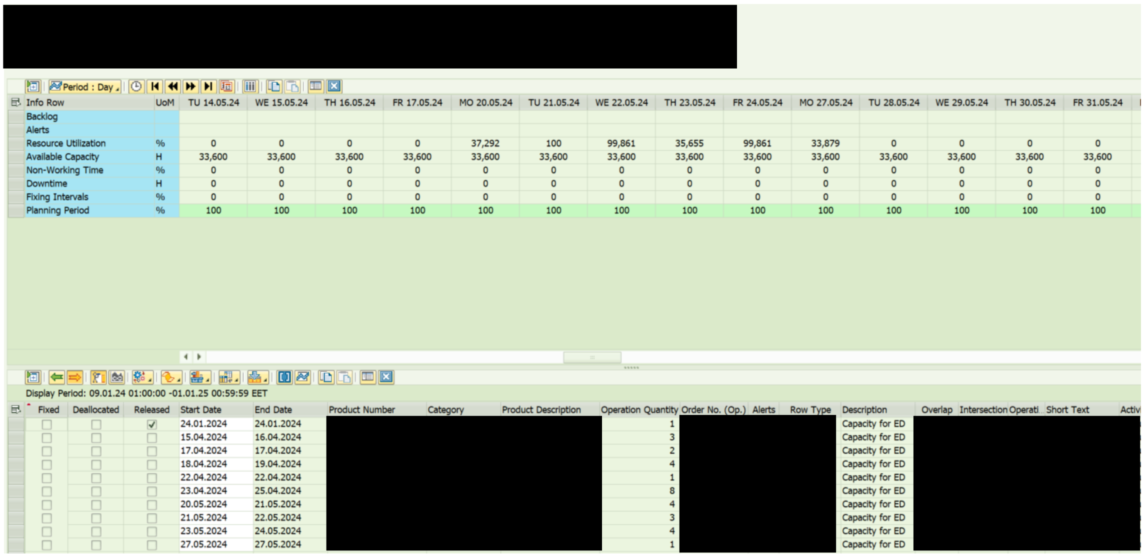
Period : Day

Info Row	UoM	TH 11.04.24	FR 12.04.24	MO 15.04.24	TU 16.04.24	WE 17.04.24	TH 18.04.24	FR 19.04.24	MO 22.04.24	TU 23.04.24	WE 24.04.24	TH 25.04.24	FR 26.04.24	MO 29.04.24	TU 30.04.2
Backlog															
Alerts															
Resource Utilization	%	0	0	1,776	99,861	67,758	35,655	99,861	33,879	71,171	100	99,861	0	0	0
Available Capacity	H	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600
Non-Working Time	%	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Downtime	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fixing Intervals	%	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planning Period	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Display Period: 09.01.24 01:00:00 -01.01.25 00:59:59 EET

Fixed	Deallocated	Released	Start Date	End Date	Product Number	Category	Product Description	Operation Quantity	Order No. (Op.)	Alerts	Row Type	Description	Overlap	Intersection	Operati...	Short Text
☐	☐	☑	24.01.2024	24.01.2024	[redacted]			1	[redacted]			Capacity for ED	[redacted]			
☐	☐	☐	15.04.2024	16.04.2024	[redacted]			3	[redacted]			Capacity for ED	[redacted]			
☐	☐	☐	17.04.2024	17.04.2024	[redacted]			2	[redacted]			Capacity for ED	[redacted]			
☐	☐	☐	18.04.2024	19.04.2024	[redacted]			4	[redacted]			Capacity for ED	[redacted]			
☐	☐	☐	22.04.2024	22.04.2024	[redacted]			1	[redacted]			Capacity for ED	[redacted]			
☐	☐	☐	23.04.2024	25.04.2024	[redacted]			8	[redacted]			Capacity for ED	[redacted]			
☐	☐	☐	20.05.2024	21.05.2024	[redacted]			4	[redacted]			Capacity for ED	[redacted]			
☐	☐	☐	21.05.2024	22.05.2024	[redacted]			3	[redacted]			Capacity for ED	[redacted]			
☐	☐	☐	23.05.2024	24.05.2024	[redacted]			4	[redacted]			Capacity for ED	[redacted]			
☐	☐	☐	27.05.2024	27.05.2024	[redacted]			1	[redacted]			Capacity for ED	[redacted]			

Figure 20. Basic load for ED -product after Z_PP_CTP_B -heuristic (1)



[redacted]

Period : Day

Info Row	UoM	TU 14.05.24	WE 15.05.24	TH 16.05.24	FR 17.05.24	MO 20.05.24	TU 21.05.24	WE 22.05.24	TH 23.05.24	FR 24.05.24	MO 27.05.24	TU 28.05.24	WE 29.05.24	TH 30.05.24	FR 31.05.24
Backlog															
Alerts															
Resource Utilization	%	0	0	0	0	37,292	100	99,861	35,655	99,861	33,879	0	0	0	0
Available Capacity	H	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600
Non-Working Time	%	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Downtime	H	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fixing Intervals	%	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Planning Period	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Display Period: 09.01.24 01:00:00 -01.01.25 00:59:59 EET

Fixed	Deallocated	Released	Start Date	End Date	Product Number	Category	Product Description	Operation Quantity	Order No. (Op.)	Alerts	Row Type	Description	Overlap	Intersection	Operati	Short Text	Activ
☐	☐	☑	24.01.2024	24.01.2024	[redacted]			1	[redacted]			Capacity for ED	[redacted]				
☐	☐	☐	15.04.2024	16.04.2024	[redacted]			3	[redacted]			Capacity for ED	[redacted]				
☐	☐	☐	17.04.2024	17.04.2024	[redacted]			2	[redacted]			Capacity for ED	[redacted]				
☐	☐	☐	18.04.2024	19.04.2024	[redacted]			4	[redacted]			Capacity for ED	[redacted]				
☐	☐	☐	22.04.2024	22.04.2024	[redacted]			1	[redacted]			Capacity for ED	[redacted]				
☐	☐	☐	23.04.2024	25.04.2024	[redacted]			8	[redacted]			Capacity for ED	[redacted]				
☐	☐	☐	20.05.2024	21.05.2024	[redacted]			4	[redacted]			Capacity for ED	[redacted]				
☐	☐	☐	21.05.2024	22.05.2024	[redacted]			3	[redacted]			Capacity for ED	[redacted]				
☐	☐	☐	23.05.2024	24.05.2024	[redacted]			4	[redacted]			Capacity for ED	[redacted]				
☐	☐	☐	27.05.2024	27.05.2024	[redacted]			1	[redacted]			Capacity for ED	[redacted]				

Figure 21. Basic load for ED -product after Z_PP_CTP_B -heuristic (2)

When tested with complete delivery, it was successfully created. When deleted the complete delivery, the system told you that 1 position is in production and it is not possible to save the function. It is because one of the order lines of the order was released for production, and after that it is not possible to make a change to complete delivery if there is a released order in the set.

9) Early. Early means that the production order goes into production too early from the point of view of production control. From the point of view of the production facility in question, it is too early when the order is ready more than 5 days before the "First Date". First Date is the date when the order can be sent to the customer at the earliest, but never before that. It is possible to confirm the order on the First Date at the earliest, but the production order may nevertheless go into production too early. The reason for going into production too early can be that right before the order's First Date there are many other existing orders, which is why the system schedules the new order to go into production too early. We are trying to demonstrate a situation where the order backlog includes a production order that goes into production too early.

Target: Let's show one reason why orders are released and prepared too early for production.

Conclusion: It is not possible to manufacture the order right before First Date

10) Wait time is the longest time that may pass before the material in processed in the next operation or order. We are interested in what effect it has on production scheduling if this parameter is changed.

Target: We are interested in what effect this parameter has on production scheduling.

Conclusion: maximum wait time does not change the load/scheduling.

11) Max lot size / max lot sizing. Lot sizing means that we try to limit how large orders it can receive in the system and whether there is a parameter with which the number of products contained in one order line can be split into production orders of the size of one piece. For example, a new order line of 4 pieces would generate 4 one-piece production orders in the system. We tested various max lot sizing parameters and observed their effect on production scheduling.

Target: Let's find out what effect different lot sizing procedures have on the load. Based on the initial data, the assumption is that with the FX procedure, with the fixed lot size value being 1, the system should split an order larger than one piece into production orders of one piece. According to the source data, when the maximum lot size of the EX-procedure is one, the system should not allow creating and confirming orders larger than one.

Conclusion: With the FX procedure, when the fixed lot size value is 1, the system did not split orders larger than one piece into one-piece production orders. The EX-procedure also allowed larger orders to be created and confirmed with a maximum lot size value of 1. If the willing is that an order larger than one piece to be divided into production orders of 1 piece, then it should use the procedure ZL and the maximum lot size value 1.

4.4 Design load for Enclosed Drives

The purpose of the testing was to investigate the load behavior of the Enclosed Drives and to try to find the right parameters for how the load could be built. The load is implemented in a time-weighted capacity, which means that the order, depending on its size, loads the order deck based on time. For an order lead time of x, this time is distributed according to the production capacity (e.g. number of people) and loads the capacity as a percentage of the capacity set for one day. From a load perspective, the optimal situation means that new orders are scheduled as close as possible to the desired date, the First date, and do not release into production too early. An order should be in production on consecutive days for the sake of production flow if it would not fit within a single day in terms of load. The order is to be confirmed on the First Date and the linked orders (complete delivery and delivery group) are to be confirmed on the same day.

The output of this testing is to present a summary and parameters for the entities considered. Almost all parameters related to production scheduling and loading are not discussed here. There are 11 issues in the test that we were interested in and sought to clarify. For each issue discussed, it is not possible to suggest a specific parameter, e.g. the handling of an order that goes into production too early described a phenomenon and did not seek a solution to the problem. Also, for those issues discussed where a parameter is suggested, there is no absolute and absolute answer, but the setting of the parameter depends on what is desired from the load. The test was to ensure that the load parameters work as originally intended at the design stage, and if any deviations occur, a solution must be found. The starting point for the load is when production has not yet been fully ramped up to the level it will be in the future, that the load would have to be implemented in small batches and with a small individual capacity. The test and its results are related to the manufacturing of the Enclosed product at the Danfoss factory in Vaasa. In terms of the load on the product, it was desired to test the functionality of various parameters, and partly based on these test results, the parameters have been fed into the ERP system.

Proposed parameters:

1) **Check item availability:** For the item availability check, it is recommended to use the XT parameter, which was successfully tested.

2) **Heuristic:** The test used two different heuristics, and examined which would work better from a load perspective, Z_PP_CTP_D or Z_PP_CTP_B. No major functional differences were found between the heuristics, and it is recommended to use Z_PP_CTP_D as the load parameter, as it is used in other similar products, and there is no reason to change the heuristic for the ED.

Both heuristics loaded production orders close to the group's common delivery date.

Table 3. Z_PP_CTP_D Heuristic

Z_PP_CTP_D -heuristic	**Load at first**	**Load after heurestic**
Group 1	9.4. – 25.4.	15.4. – 25.4.
Group 2	8.5. – 27.5.	17.5. – 27.5.

Table 4. Z_PP_CTP_B Heuristic

Z_PP_CTP_B -heuristic	Load at first	Load after heurestic
Group 1	9.4. – 25.4.	15.4. – 25.4.
Group 2	8.5. – 27.5.	20.5. – 27.5.

3) **Maximum wait time:** During testing, no differences were found when varying the maximum wait time, so it is set to 5, the same value used for other similar products.

4) **Individual capacity and split:** Individual capacity at the beginning is 2 persons and the split should be equal to the individual capacity. In this case, the total production capacity is distributed over the production line so that the set production efficiency requirement can be achieved. With two people and split 2, the system divides the product lead time by two and the daily capacity can be loaded to 100 %.

5) **Max lot sizing:** If it wants only one order per batch for capacity, it is recommended to use the maximum batch sizing parameter ZL with the value "maximum lot sizing 1". If there is no such requirement, it is recommended to use the parameter EX with the value "maximum lot sizing 1".

6) **Delivery group and complete delivery:** Delivery group and complete delivery can be used. When using these, it must be considered whether the positions in the order are either partially or fully released for production.

The client company is most interested in a few things in this study: whether the product is loaded as it is intended to be loaded; whether there are any problems with the loading; what parameters should be used (e.g. what is the most appropriate heuristic) and whether, based on the study, the loading works in such a way that the product can be released for ordering in the system.

- The product loaded essentially as it was intended to load. Certain details came up that need attention, including the fact that max lot sizing did not work as expected, so it needs to be set to match the production control implementation. Individual capacity and split should be the same so that the load is evenly distributed. Z_PP_CTP_D should be used as a heuristic.
- No major problems with product loading were encountered in this study, so there are no reasons for major changes on this basis. Other phases of the project or challenges encountered are not considered.
- Based on this study, the product could be released for ordering. The process is affected by many things outside the scope of this study.

4.5 Further research and improvements

The tests and results of the study will mainly show which existing options could be applied to maximize the success of product loading. This relatively limited scope of testing was appropriate for this situation, where the client company publishes the ordering process in stages so that it is ultimately freely available to all.

A deeper understanding of the ERP system and production workload would have better prepared us to investigate in more detail what all is involved in order workload and what it affects. For further research, it could be interesting to investigate what effects different load options and scenarios would create. In addition, examining the load from the point of view of production indicators would provide a better understanding of how orders should be loaded in order, for example, to maximize plant reliability.

Further research could also be done on how to automate the workload so that it requires as little manual work as possible. Although the process of placing an order and its load are automated steps, one could look at the big picture and investigate how production should be controlled to minimize the need for manual changes to the automatically generated load. Manual work may nevertheless be a necessity due to external factors such as material shortages.

The study did not look at the very long-term effects on the load on the product, but instead focused on the moment when the product is about to be released for ordering, and wanted to know what the load on the product is. It might be worthwhile to investigate whether the load will change if the production line and its capacity increase in the future, and whether there will be any unexpected reasons for the load that are not yet known.

5 Conclusion

The aim of the study was to investigate the loading and related parameters of the Enclosed Drives product. The study was carried out in the ERP system used by the client company and in its "sandbox" section, where it was possible to model realistic scenarios that could be encountered when loading the product. The study was qualitative in nature, as it sought to understand the characteristics of the object under study. It is not possible to answer the research questions precisely, as the answers are context-specific and depend on the parameters set for the system.

The actual research and the empirical part were introduced by discussing production planning and its principles. This allows the reader to place the empirical study more easily in its proper context, as one process in production planning. The tests carried out provided results that could be used for load planning. Nothing exceptional or particularly significant was found, and this was positive, as the parameters functioned largely in the way they were intended to function.

The survey produced reliable results. Many parameters and functions were found to work, and for some parameters it was possible to choose a better alternative between the tested functions. The study could have been of higher quality if the literature review had focused in more detail on the detailed level information of the ERP system, but this would have changed the nature of the study. As such, the study was more of a practical overview of ERP as a functional function of the factory, and introduced the reader to the principles of ERP and how it translates into practical work and product loading.

Production planning must consider how the new product and its load-bearing characteristics will behave in production. In the case of the product under study, this would mean the impact of the observed load characteristics on production and all other activities involved in manufacturing the product. For example, tying different order lines of the same order together by means of a complete delivery or a group could in some situations mean that individual finished products may have to be stored for long periods of time in order to complete all the orders that are tied together. It is good to be aware of such scenarios at the planning stage, so that you can prepare for any eventualities that may arise.

The production process places demand on the design. From the point of view of product loading, this may be, for example, that an order cannot be confirmed if not all the product information is correct. In the empirical part, the order validation was tested, and it was found that if the parameters were set incorrectly or the order information was not correct, the order could not be validated for production. An order without confirmation means that it does not generate a production order for the capacity. The production controller may also impose requirements on the loading of the product, for example that the order must not be loaded into production until x days after the order has been created. The above methods can be used to shape the production to match as closely as possible the strategy that production management has in mind.

The production planning processes, and the implementations made must not be completely dependent on individual persons, in this case the production planners, but all measures must be able to be integrated into the system so that when the planner changes, the next person has the opportunity to continue where the previous one left off. If all the information is known to the employees but not described in documents and systems, it is very difficult to know afterwards how something was planned or implemented. If the findings of this study had not been recorded but had simply been passed on verbally to the designer, who might have used them in his own work, it would not have been possible to make use of this information in the future. Perhaps in the case of this research topic it would not be such a major setback, but in more complex research topics it is even more important that the documentation is well done.

The empirical part was to examine whether the local approach is better from a production planning perspective than the global approach. The local way was the one that would have been suitable for the Vaasa factory and the global way was the one used by the other factories of the company. The difference between the two ways of loading is that the factories have different operational ideas. In choosing a loading method that fits the strategy of the Vaasa plant, the question had to be asked whether it was possible to deviate from the general method simply because it would better serve Vaasa's operations, or whether in any case loading should be carried out in the same way as in the other plants. Without going into the differences between the methods, the emphasis in this case was more on the fact that the loading methods used at the Vaasa plant should be in line with the idea of the production management.

Chase Strategy means that production capacity can be adjusted depending on market conditions. Capacity adjustment would mean, from the point of view of the sponsoring undertaking, a change in the quantity produced per day. It is possible to adjust capacity, but this must take account of the fact that orders are confirmed during the load phase and cannot necessarily be maintained when capacity is adjusted. It is advisable to find a level of capacity that best matches both the orders placed and the production capacity, since this is a large product compared with other products in the factory and changing capacity is not as simple as for smaller products.

Flexibility Strategy means using labor as a variable to regulate production depending on the prevailing demand. This is the normal way in a manufacturing company, either to increase or decrease the workforce depending on the demand. In a large company, there is also the possibility to develop the professional skills of the workforce at an operational level, so that the workforce can be transferred between different production lines. For the product under consideration, it can be noted that the accumulation of labor skills is slower to produce more complex products than for simpler products. In production planning, it is useful to consider the availability of a sufficient number of skilled workers in relation to the workload.

A level strategy is to use the value of inventory as a variable and use it to regulate production. In the case of the client company, the strategy is to be able to load production so accurately that there is no need for large inventories for the existing order book and load, but rather a fast inventory turnover. Therefore, it may be somewhat difficult to regulate production by controlling the value of the inventory, at least in the long term. When loading, it must be remembered that all material is ordered for the coming days, weeks and months. If you make major changes to the load for the next few weeks or months, the impact on other functions of the business will be significant and it would therefore be useful to be able to plan a reliable load for the long term. The technical implementation of the production load is not affected.

Efficiency as a Key Performance Indicator is important in measuring production performance. In terms of production workload, efficiency is the extent to which existing capacity can be utilized within the schedule. By designing the load parameters so that production is smooth in terms of scheduling, moments when production is not running at full capacity can be minimized. Good or bad performance in load is relative to the existing strategy. KPI metrics can potentially be used to assess if production is not loaded efficiently. However, it may be that the KPIs are not measuring what the production strategy is aiming for and the situation is reflected in inefficiency. It may also be that the various internal interests do not coincide and conflict with each other. However, one of the functions of KPIs is to measure whether the customer's wishes are being met, as this is a fundamental objective of the production company. In terms of load, this means whether orders are successfully loaded just before the date the customer wants.

For this study, two research questions were posed and the aim of the study was to find out the answers to them. A literature review was conducted to establish the context and framework in which the issues of these questions are set, and the empirical part involved testing an ERP system to provide answers to these questions. The research questions were:

- How is the Enclosed Drives product structured in the ERP system used by the company and how does it perform from a load perspective?

- How do the modules of the Enclosed Drives product load in relation to the fixed day of the final product?

The product is constructed in such a way that, against an order placed, a production order is generated in the ERP system for a capacity that time-dependently loads the production resource set. The production resource consists, among other things, of the number of people on the production line, the time calculated for the work steps and the work efficiency set in the system. To ensure smooth production, these values should correspond as closely as possible to reality in the system. The ordering process involves scheduling a new order to be completed on a specific date and confirming it on that date. Confirmation means for the ordering party that on the confirmed date the order is ready and is dispatched from the factory.

A production order behaves with capacity so that it is loaded for consecutive days as close as possible to the First Date set by the ordering party. At the time of testing, there was no heuristic in place to prevent the order from being scheduled too far away from the First Date, which could result in the order going into production too early according to the factory's production strategy. In this case, too early means 1 week. From a load perspective, it might be sensible in some cases to limit the number of individual orders that are too large, especially when the order book and production line capacity are already very full. This could ease the burden on production and prevent a situation where the production schedule deviates significantly from the First Date set by the ordering party.

The literature review described the nature of production planning within the supply chain and the methods that can be used to do it. Production planning is guided by principles and management's idea of how to organize production, all of which need to be considered when planning the details of production. In this study, the production load of Enclosed Drives and the parameters affecting it were examined. The practice that these parameters and plans implement must fit with the idea of production management and the global requirements of manufacturing the product.

References

Alemao, D., Rocha, A. D. & Barata, J. (2021). *Smart Manufacturing Scheduling Approaches-Systematic Review and Future Directions.* Applied sciences 2021, Vol. 11. DOI: 10.3390/app11052186

Chopra, S. (2019). *Supply Chain Management - Strategy, Planning and Operation.* Harlow, United Kingdom. ISBN: 978-1-292-25789-1

Danfoss. (2022). *Annual Report 2022*. Danfoss homepage. Retrieved 18.10.2023 from https://files.danfoss.com/download/CorporateCommunication/Financial/Annual-Report-2022.pdf

Danfoss. (2023a). *Danfoss at a glance*. Danfoss homepage. Retrieved 2023-09-15 from https://www.danfoss.com/en/about-danfoss/company/danfoss-at-a-glance/

Danfoss. (2023b). *iC7 Automation*. Danfoss homepage. Retrieved 2023-10-17 from https://www.danfoss.com/en/products/dds/low-voltage-drives/ic7-drives/ic7-automation/#tab-overview

Choi, S., Jung, K., Kulvatunyou, B. & Morris, K. C. (2016). *An analysis of technologies and standards for designing smart manufacturing systems*. Journal of research of the National Institute of Standards and Technology, Vol. 121, p. 422-433. DOI: 10.6028/jres.121.021

Harjunkoski, I. (2014). *Sharing data for production scheduling using the ISA-95 standard*. Frontiers in Energy Research 2. DOI. 10.3389/fenrg.2014.00044

Himanshu, G. (2022). *Handbook for SAP PP in S/4HANA: Production Planning and Execution in SAP S/4HANA.* Scopus. DOI: 10.1007/978-1-4842-8566-4

Magal, S. R. & Word, J. (2012). *Integrated Business Processes with ERP Systems*. Hoboken. ISBN: 978-0-470-47844-8

Mahmoud, M. I., Ammar, H., Hamdy, M. & Eissa, M. (2015). *Production operation management using Manufacturing Execution Systems (MES).* IEEE/IET Electronic Library (IEL). DOI: 10.1109/ICENCO.2015.7416334

Monk, E. & Wagner, B. (2013). *Concepts in Enterprise Resource Planning*. Course Technology. ISBN: 978-1-111-82039-8

Pattanayak, A. (2017). *SAP S/4HANA Embedded Analytics: An Overview.* Journal of Computer and Communications, Vol. 5, No. 9. DOI: 10.4236/jcc.2017.59001

Prades, L., Romero, F., Garcia-Dominquez, A. & Serrano, J. (2013). *Defining a Methodology to Design and Implement Business Process Models in BPMN According to the Standard ANSI/ISA-95 in a Manufacturing Enterprise.* Procedia engineering, Vol. 63, p. 115-122. DOI: 10.1016/j.proeng.2013.08.283

SAP Hana Platform. (2023). *SAP HANA Administration Guide for SAP HANA platform*. SAP Help portal. Retrieved 18.10.2023 from https://help.sap.com/doc/eb75509ab0fd1014a2c6ba9b6d252832/2.0.07/en-US/SAP_HANA_Administration_Guide_en.pdf

SAP Help Portal. (2024a). *BOM Basics*. SAP Help Portal. Retrieved 18.1.2024 from https://help.sap.com/docs/SUPPORT_CONTENT/plm/3363506119.html

SAP Help Portal. (2024b). *Production planning and detailed scheduling*. SAP Help Portal. Retrieved 24.1.2024 from https://help.sap.com/docs/SAP_S4HANA_ON-PREMISE/f899ce30af9044299d573ea30b533f1c/aa35c95360267514e10000000a174cb4.html

SAP. (2023). *What is SAP*. SAP homepage. Retrieved 17.10.2023 from https://www.sap.com/about/what-is-sap.html

Slack, N., Chambers, S., Johnston, R. & Betts, A. (2009). *Operations and Process Management - Principles and Practice for Strategic Impact*. Harlow: Financial Times. ISBN: 978-0-273-71851-2

T. F. Wallace & Company. (2008). *Sales & operations planning: the how-to handbook: how it works, how to implement it with low risk and low cost, how to make it better and better.* Cincinnati, OH : T. F. Wallace & Company. ISBN: 9780967488455.

The Factory Science. (2023). *ISA-95 Standards*. The Factory Science. Retrieved 2024-02-08 from https://thefactoryscience.com/isa-95-standards/

Xiao-Feng, S. (2020). *What is the right production strategy for horizontally differentiated product: Standardization or mass customization?* International journal of production economics 2020, Vol. 223. DOI: 10.1016/j.ijpe.2019.107527

Zhang, N. (2023). *SAP general introduction*. Danfoss Global SharePoint. Retrieved 24.1.2024 from https://danfoss.sharepoint.com/:p:/r/sites/BOCKTraining/_layouts/15/Doc.aspx?sourcedoc=%7B73E89364-1C70-4D3B-B91D-C47764F8962E%7D&file=20230905%20SAP%20general%20introduction.pptx&action=edit&mobileredirect=true&DefaultItemOpen=1