FORECASTED VOLUME IMPACT SIMULATION ON STANDARD COSTS IN A PLASTIC PACKAGING COMPANY

Lappeenranta–Lahti University of Technology LUT

Master's Programme in Industrial Engineering and Management, Master's thesis

2026

Atte Lasmio

Examiners: Professor Timo Kärri

University teacher Leena Tynninen

ABSTRACT

Lappeenranta–Lahti University of Technology LUT

LUT School of Engineering Science

Industrial Engineering and Management

Atte Lasmio

Forecasted volume impact simulation on standard costs in a plastic packaging company

Master's thesis

2026

65 pages, 20 figures, and 3 tables

Examiners: Professor Timo Kärri and University teacher Leena Tynninen

Keywords: Standard cost, optimal production order quantity, forecasted volume impact, simulation, cash conversion cycle

This master's thesis studied the total impact of forecasted volume on standard costs. The aim of this thesis was to analyse the impact that the current sales forecast would have on the focal company's standard costs. This thesis was conducted by combining literature review, case study, and modelling and simulating. The literature review was conducted on cost accounting with a focus on standard costing, production planning with a focus on lot sizing, and working capital management with a focus on cash conversion cycle. The findings were used in creating the model together with the focal company's data.

The literature review found that standard costing information, and especially labour standards and the total standard costs, can be beneficially utilized in lot size calculations. Additionally, variance analyses were found to be highly effective tool for providing information with standard costing. The lot sizing models were found to be categorized into two categories of which the static demand models were found to better fit the nature of standard costing. The production lot size was also found to have a direct impact on the working capital management and especially the cycle time of inventory.

The simulation demonstrated that a standard costing update utilizing the latest sales forecast would have a great impact on reducing the standard costs of items. The impact was also noticeable in the company's forecasted profit and operational activities. The impact would increase the days inventory outstanding by increasing the production lot sizes which was not found to a have a negative impact on the company's profitability. The simulation model provided the production planning department with a tool for better visibility into the forecast and its impact on the costing.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT

LUTin insinööritieteiden tiedekunta

Tuotantotalous

Atte Lasmio

Kysyntäennusteiden vaikutuksen simulointi muovipakkausyrityksen standardikustannuslaskentaan

Tuotantotalouden diplomityö

2026

65 sivua, 20 kuvaa ja 3 taulukkoa

Tarkastajat: Professori Timo Kärri ja yliopisto-opettaja Leena Tynninen

Avainsanat: Standardikustannuslaskenta, tuotannon ajoerän optimoiminen, kysyntäennusteiden vaikutus, simulointi, pääoman kiertoaika

Tässä diplomityössä tutkittiin tuotteiden kysyntäennusteiden volyymivaikutusta tuotteiden standardikustannuksiin. Työn tavoitteena oli analysoida tämänhetkisten kysyntäennusteiden vaikutus case-yrityksen standardikustannuksiin. Työn tutkimusmenetelmät koostuivat kirjallisuuskatsauksesta, tapaustutkimuksesta, mallinuksesta ja simuloimisesta. Kirjallisuuskatsaus keskittyi kustannuslaskentaan pääpainona standardikustannuslaskenta, tuotannonohjaamiseen pääpainona ajoeräkokolaskenta, ja käyttöpääomanhallintaan pääpainona pääoman kierotaika. Kirjallisuuskatsauksen löydöksiä käytettiin yhdessä tapaustutkimuksen yrityksen datan kanssa mallin luomiseksi.

Kirjallisuuskatsauksessa huomattiin, että standardikustannuslaskennan informaatiota, ja erityisesti tuotteiden kokonaiskustannuksia ja standardityökustannuksia, voidaan hyödyntää tehokkaasti ajoerälaskennassa. Lisäksi varianssianalyysit todettiin tehokkaaksi työkaluksi standardikustannuslaskennan informaation tuottamisessa. Ajoerälaskennan malleista löydettiin kaksi pääkategoriaa, joista staattisen mallin todettiin sopivan paremmin standardikustannuslaskennan luonteeseen. Tuotannon ajoerällä huomattiin olevan suora vaikutus käyttöpääoman hallintaan ja erityisesti varaston kiertoaikaan.

Simulaatiolla löydettiin, että uusimpien kysyntäennusteiden vaikutus olisi pienentävä nykyisiin standardikustannuksiin. Vaikutus heijastui myös yrityksen kannattavuus ennusteeseen sekä tuotannon toimintaa. Vaikutus nostaisi varaston kiertoaikaa kasvattamalla ajoerien suuruutta, minkä ei kuitenkaan katsottu olevan yrityksen kannattavuutta heikentävä tekijä. Työssä valmistunut simulaatiomalli tuotti tuotannonsuunnittelulla työkalun, jonka avulla tuotannonsuunnittelulla on parempi näkyvyys kysyntäennusteisiin sekä niiden vaikutukseen standardikustannuksiin.

ACKNOWLEDGEMENTS

Special thanks to my girlfriend for her support during my studies and especially during this writing process, this thesis might still be in status “maybe later” if you hadn’t encouraged me. Thanks to my family and friends also for the constant support and advice.

I also want to thank the case company for the opportunity to write this thesis alongside my work. Special thanks to my supervisor for seeing my potential and giving me an awesome job opportunity while I was still a student.

Hämeenlinna, August 2026

Atte Lasmio

ABBREVIATIONS

ERP	Enterprise resource planning
SQL	Structured query language
DSR	Design science research
GAAP	Generally accepted accounting principles
IFRS	International financial reporting standards
FAS	Finnish accounting standards
IAS2	International accounting standards
BOM	Bill of materials
PPC	Production planning and control
PPS	Production planning system
MRP I	Materials resource planning
MRP II	Manufacturing resource planning
CRP	Capacity requirements planning
SCND	Supply chain network design
S&OP	Sales and operations planning
SCP	Supply chain planning
MTO	Make-to-order
MTS	Make-to-stock
ETO	Engineer-to-order
ATO	Assemble-to-order
OPP	Order penetration point/decoupling point
AI	Artificial intelligence

EOQ	Economic order quantity
POQ	Optimal production order quantity
LFL	Lot-for-lot
WCM	Working capital management
WCR	Working capital requirement
CCC	Cash conversion cycle
DSO	Days sales outstanding
DIO	Days inventory outstanding
DPO	Days payables outstanding
COGS	Cost of goods sold
PP	Polypropylene
PS	Polystyrene
SAP IBP	SAP integrated business planning
OEE	Overall equipment efficiency
FG	Finished good
SFG	Semi-finished good
Std. cost	Standard cost

Table of contents

Abstract

Tiivistelmä

Acknowledgements

Abbreviations

List of figures and tables

Declarations

1 Introduction 12
1.1 Background for the study 12
1.2 The aim and scope of the study 13
1.3 Research methods and data 14
1.4 Structure of the thesis 16
2 Theoretical framework 18
2.1 Cost accounting and costs 18
2.2 Cost accounting techniques 20
2.2.1 Process costing technique 21
2.2.2 Target costing technique 22
2.2.3 Standard costing technique 23
2.3 Production planning and lot sizing 26
2.4 Working capital management 34
2.5 Summary of the theoretical framework 36
3 Introduction to the focal company and analysis model 39
3.1 Focal company introduction 39
3.2 Explanation of the analysis model 43
4 Analysis of the results 47
4.1 The overall impact 47
4.2 The financial impact 49
4.3 The operational impact 52
4.4 The risk factors of the results 53

5 Conclusions 56
5.1 Suggestion for the case company 57
5.2 Future research possibilities 58
References 59

Figures

Figure 1. Design science research framework (Brocke et al. 2020).

Figure 2. Input-output chart of the thesis.

Figure 3. Cost classification categories (Kinney & Raiborn 2009).

Figure 4. Relationship between cost accounting and other business functions (Banerjee 2021).

Figure 5. Process costing example.

Figure 6. Example of a BOM (Tristancho 2024, modified by the author).

Figure 7. Variance analysis on profit (Drudy & Tayles 2024).

Figure 8. Standard costing review and update cycle (Dosch & Wilson 2010).

Figure 9. MRP II system (Chopra et al. 2022).

Figure 10. Different production strategies in relation to OPP (Logistiikan maailma 2025).

Figure 11. Total costs in relation to ordering cost and holding cost (Al-Dabbas 2021).

Figure 12. Extrusion process (Rauwendaal et al. 2014).

Figure 13. Thermoforming process (Lim, Auras & Rubino 2008).

Figure 14. Analysis model structure.

Figure 15. Example of the results.

Figure 16. The impact to FG items.

Figure 17. The impact to SFG items.

Figure 18. The change in profit on an item level.

Figure 19. Comparison of current and calculated std. costs with forecasted volume.

Figure 20. Difference between current std. cost and actual costs.

Tables

Table 1. Production planning parameters (Burtseva 2022).

Table 2. Cost structure used in the focal company.

Table 3. Comparison of current and calculated order quantities.

DECLARATIONS

Turnitin

The originality of this thesis has been reviewed with the Turnitin similarity checking service.

AI usage

The author of the thesis, Atte Lasmio, used the following AI-tools during the preparation of the thesis:

1. Microsoft Copilot (GPT-5)
    a. Purpose of use: Code debugging.
    b. Explanation of the use of the tool: Copilot was used to help identify coding errors and optimize the model's execution time. Additionally, Copilot was used to give suggestions about grammar improvements. Copilot did not make any direct changes or inputs to this thesis and all suggestions were evaluated and reviewed by the author.

Responsibility

The author, Atte Lasmio, takes full responsibility for the content of this thesis and has reviewed and edited the content generated by the possible use of AI tools.

1 Introduction

1.1 Background for the study

Cost accounting is an organizational function which links directly to all functions across the value chain (Banerjee 2021). The main purposes of cost accounting can be summarized to providing relevant and accurate information about the organization's current situation, relevant information for decision making about future improvement, and information to help management focus on correct topics and areas (Tayles & Drudy 2024). To be able to provide this information, cost accountants and cost management decided how costs are classified and which cost accounting techniques are implemented.

While standard costing is classified as a traditional costing technique and criticized by some for not being able to provide timely and accurate information, it is still one of the most used cost accounting techniques in some industries. The standards used in standard costing are most commonly updated semi-annually or annually (Marie, Cheffi, Louis & Rao 2010). Dosch & Wilson (2010) state that implementing known changes to standards is necessary for the standards to be up-to-date. Oh (2023) presents one of the major critiques with standard costing with a case study of a company where the demand had skyrocketed due to COVID-19 pandemic so the standards were also set to match the new demand but as the demand suddenly slowed down, the variances between the standards and actual costs started increasing.

This thesis studies the usage of continuously updating demand forecasts as part of a standard costing system in a company producing plastic food packaging solutions. The focal company changed their enterprise resource planning or ERP system in October 2024 resulting in the standard costing system also changing. Together with the new ERP system, the company also implemented a new software for demand forecasting and production planning which required at least 12 months of data to be able to forecast more accurately. The thesis is therefore combining a traditional cost accounting technique with modern software solutions for more accurate and relevant cost accounting information.

1.2 The aim and scope of the study

The aim of this thesis is to analyse how the demand forecast would impact the currently implemented standard costs by creating a model which uses the up-to-date demand forecasts and calculates the optimal production order quantities based on them. The calculated optimal production order quantities are then used to calculate new standard costs for each item. The analysis is conducted to determine how increases and decreases in demand could impact the budgeted standard costs. Additionally, having a better visibility and more accurate costing data can be utilized in production planning as the standard production order quantities might give misleading information if the forecasted demand varies greatly from the expected demand from the budget. To achieve this target, the following research questions are used:

- How can standard costing information be utilized in production lot sizing?
- How does production lot sizing influence the cash conversion cycle?
- What is the impact of demand volume changes on standard costs?

The focal company currently has approximately 1000 different finished goods with approximately 60 % of them being make-to-stock items. The analysis will be conducted for the make-to-stock items and does not include make-to-order items as for those items the production order quantities are assumed to match the customer order exactly. For the purpose of this thesis, the forecast data is assumed to be accurate and up-to-date. Additionally, the cost of bill of materials is assumed to be according to the standards to only showcase the effect of production order quantity changes to the standards, ruling out the possible changes to raw material prices. Additionally, labour rates, utility costs, and overhead costs are assumed to be according to the standards.

The theoretical section is conducted using a literature review where the literature used is restricted to be published in after the year 2000. Therefore some literature can be over 20 year old which is due to standard costing being a traditional cost accounting method. Theory for cost accounting mostly focuses on standard costing which is the preferred method used in the focal company. Production planning is mostly focused on lot sizing and system parameters which is the most relevant information for the model used. The theory for working capital management focuses on the cash conversion cycle and mostly on the inventory cycle. The analysis is performed using a combination of Python, Structured Query Language or

SQL, and Excel. However, the structure of the model used is only introduced shortly and no theoretical background related to the building of analysis models is included in this thesis. The analysis of the results is conducted using the real data from the model but to ensure that no trade secrets are leaked, the results are mostly showcased in relative changes and not in actual monetary results.

1.3 Research methods and data

This thesis consists of a theoretical section and an empirical section. The theoretical section of this study is conducted by doing a literature review. Literature reviews are used to present general knowledge of the topic, identify relationships between relevant topics, and showcase the historical development about the topic (Aromataris & Pearson 2014). The literature review of this thesis focuses on the general knowledge of the topics as well as identifying relationships between the topics. The literature used will consist of relevant scientific articles, books, and various internet sources. Information for the literature review will be mainly collected from Google Scholar, Elsevier's ScienceDirect, and using the using the university's academic library LUT Primo. The main search terms being used are: cost accounting, standard costing, production planning, order quantity, lot sizing, cash conversion cycle, and working capital management. The search terms will also be used simultaneously and in different combinations. Additionally, the information will be collected using both English and Finnish literature.

The main research method used in the empirical section is modelling and simulation. Fritzson (2011) showcases four types of models: mental model, verbal model, physical model, and mathematical model. The model used in this thesis can best be described as a mathematical model. In mathematical models, the variables are measurable quantities used to describe relationships between other variables inside the system (Fritzson 2011). Modelling is then used for simulations which can be defined as experiments performed on a model (Fritzson 2011). The purpose of simulations is to demonstrate how the changes in variables would affect the actual system without actually changing any parameters in the system. The simulation is expected to showcase how demand changes affect the standard costs of items directly and/or indirectly. In this thesis, direct effect is when the demand for the item A changes which can directly be seen in the standard cost of the item A. Indirect effect on the

other hand is when the demand of an item B remains unchanged but because it uses the same semi-finished good as item A, which demand changes, the standard cost of item B is also affected by the change of item A's demand change due to the change in the semi-finished good's standard cost. The model is created using the focal company's data. The two main sources for the data is the company's ERP system and the forecasting system.

Research methodologically the empirical section of this thesis is therefore a combination of a case study and design science research or DSR. Case study can be described as an intensive and systematic investigation to a single unit, group, individual or community with an aim of generalizing the relationship between several variables (Heale & Twycross 2018). The case study's focus is on the standard costing of a company operating in the food packaging industry producing thermoformed plastic products for various markets. The case study studies the impact of the company's sales forecasts on the optimal production order quantities and the impact's effect on the company's standard costs. While the data used in the case study is company specific, the findings could be utilized in other similar units or companies.

According to Brocke, Hevner & Maedche (2020), DSR utilizes innovative artifacts in problem solving. The goal of DSR projects is therefore to enhance technology and science knowledge by designing artifacts which can be models, methods, or constructs (Brocke et al. 2020). To answer the research questions, the artifact built in this thesis is the model used in modelling and simulations. The framework for design science research is demonstrated in Figure 1.

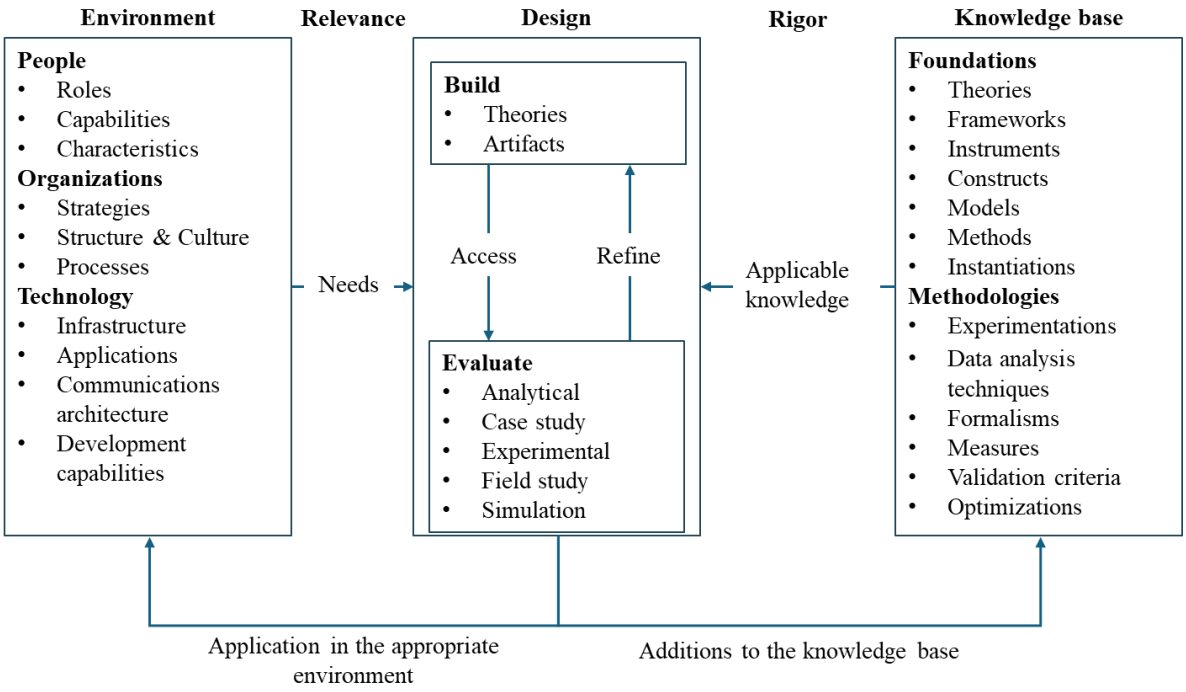


Figure 1. Design science research framework (Brocke et al. 2020).

1.4 Structure of the thesis

The first half of this thesis focuses on theoretical literature and previous studies related to the topics. The second half of this thesis is focused on the empirical section. This thesis consists of 5 chapters, of which the first chapter is the introduction. The second chapter is the theoretical section of the thesis which creates the theoretical framework used in the empirical section. The theoretical framework is also used to answer the first two research questions. The theoretical framework unites three key concepts: standard costing, lot sizing, and working capital management.

The third and the fourth chapters are the empirical section of this study. The third chapter is the introduction to the focal company and the created artifact. The focal company's costing structure, operational process, and the model's structure are also explained in the third chapter. The fourth chapter focuses on analysing the results from an overall perspective, financial perspective, and operational perspective. Additionally, the possible risk factors are analysed in the fourth chapter. The final chapter is the conclusion which also answers the final research question and fulfils the purpose of this study. Additionally, a suggestion is given to

the case company and future research possibilities are noted. The structure of the thesis can be demonstrated by an input-output chart in Figure 2.

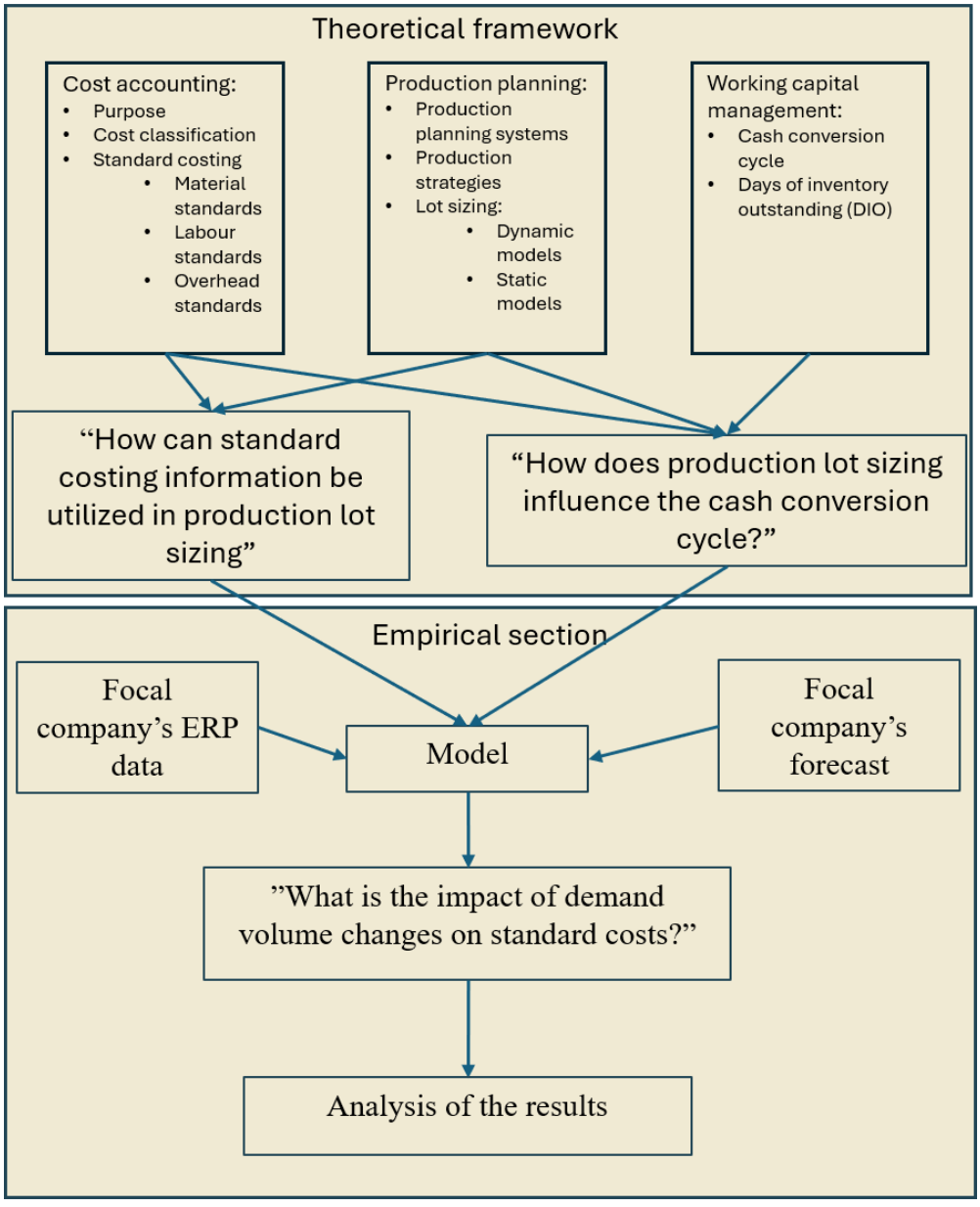


Figure 2. Input-output chart of the thesis.

2 Theoretical framework

The first section of this thesis focuses on creating the theoretical framework and background for the empirical section. This theoretical section is conducted by a literature review and is utilized in answering the first two research questions. This chapter focuses on cost accounting and standard costing information, production lot sizing, and working capital management.

2.1 Cost accounting and costs

The term cost can be defined as the economic value of resources consumed in producing or delivering the end product or service to the customer. In the definition of cost, value can refer to for example, the euro amount of electricity required for producing the finished good. (Khan 2022). The word value can indicate different things when defining the term cost. Therefore Kinney & Raiborn's (2009) definition of cost unit as anything that management wants to accumulate costs for requires the classification of costs first. Khan (2022) states that cost studies typically define cost classification as keeping effective recording and proper linkage between cost categories and cost objects. Khan (2022) also states that several types of cost classification can be used simultaneously depending on the purpose, time frame, relevance to planning, production quantity, and degree of controllability. Kinney & Rainborn (2009) divides cost classification to three categories: association with cost object, reaction to changes in activities, and classification on the financial statements. The different types of costs in each category is demonstrated in Figure 3.

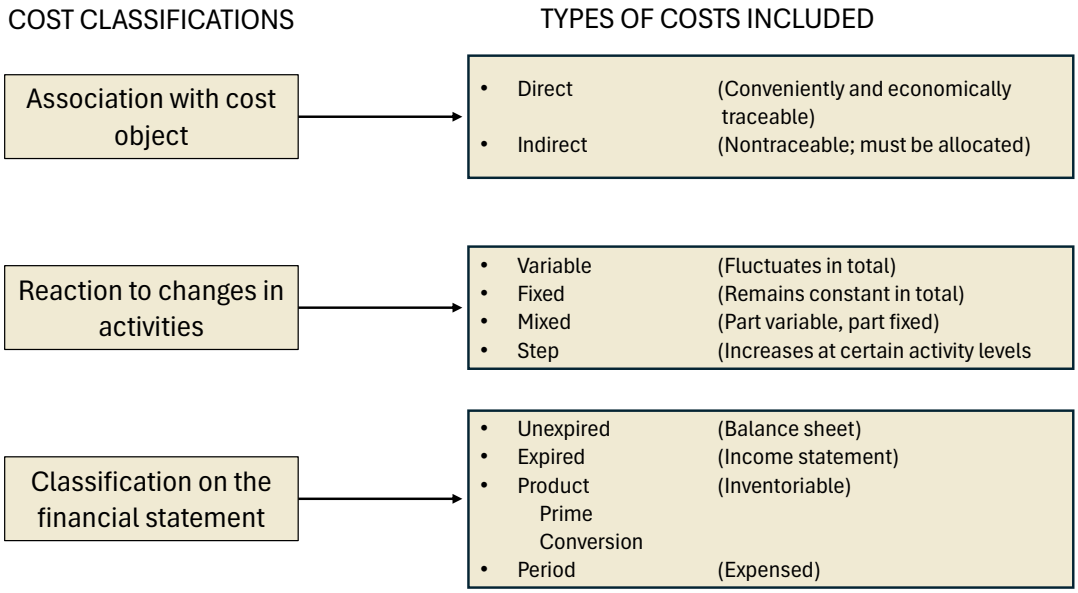


Figure 3. Cost classification categories (Kinney & Raiborn 2009).

The cost information is utilized in both financial and managerial accounting systems, as well as in other functions of the organization. Therefore classifying the costs accordingly is important as the usefulness of the cost information is dependant on the stakeholder. For example as shown in Figure 3, costing information is used in to financial statements of which the balance sheet and the income statement are the two most common (Kinney & Raiborn 2009). The financial information in the financial statements regulated and standardized, with the two major global reporting frameworks being the Generally Accepted Accounting Principles (US GAAP) which is maintained by the Financial Accounting Standards Board (FASB) and International Financial Reporting Standards (IFRS) which is maintained by the International Accounting Standards Board (IASB) (EY 2026). Additionally, the Finnish Accounting Standards (FAS) is the local accounting regulation in Finland and the accounting rules are laid down in the Accounting Act and Accounting decree (Azets 2025).

Inside the organization, the modern cost accounting function provides valuable information for other organizational functions as part of the whole value chain (Banerjee 2021). The relationship between cost accounting and other organizational functions is demonstrated in Figure 4 below.

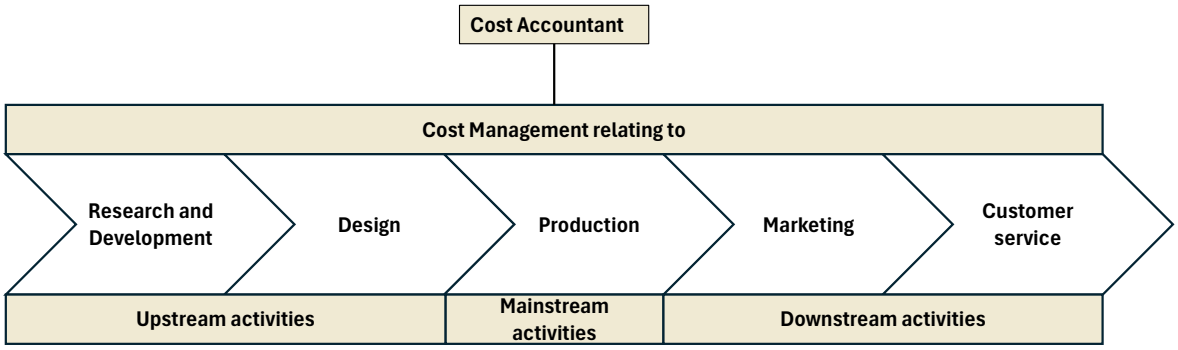


Figure 4. Relationship between cost accounting and other business functions (Banerjee 2021).

Ordynskaya, Silina, Dvina, Tausova & Bagova (2021) surveyed 26 experts who had over seven years of experience working with financial accounting. Based on the survey, they found that cost planning was the most used function of cost management system with 88,5 % of the experts using their systems for that. Friedl, Hammer, Pedell & Küpper (2009) did a similar survey on Germany's biggest companies where they found that the main purposes of cost accounting were higher level of efficiency of cost control, short-term decision support, and higher level of precision for planning. In the same survey, 86 % answered "We are not able to do without our cost accounting system" and only 2 % stated that "Currently, cost accounting is less important in our company than 10 years ago" (Friedl et al. 2009).

Tayles & Drudy (2024) summarizes the function of cost accounting and management accounting to three general requirements. Firstly, cost accounting should give information about how the company is currently doing, for example information about the current revenue and costs. Secondly, it should provide present and relevant information which can be utilized by internal stakeholders for improvements. Thirdly, it should help focus attention to urgent and most relevant activities. (Tayles & Drudy 2024)

2.2 Cost accounting techniques

Cost accounting techniques can be utilized in cost accounting to provide information for financial accounting and managerial accounting purposes. The international accounting standards or IAS2 allows companies to use costing techniques such as standard costing to valuate inventory as long as the technique approximates cost. Inventory is then measured at

normal level of output and efficiency using the predetermined rates for labour, overhead costs, and material. (Boissou & Kumah 2026)

Ekbatani & Sangeladji (2008) divides cost accounting techniques into two categories: traditional cost accounting techniques and emerging cost accounting techniques which can also be called modern cost accounting techniques. The more traditional cost accounting techniques include standard costing, process costing, and job order costing whereas the modern techniques include activity based costing and target costing. Tabithe & Ogungbade (2018) notes that even though the more traditional techniques have been criticized in the modern business environment for not being able to provide relevant information, they are still being practiced in many companies. A study by Badem, Ergin & Drudy (2013) found that a total of 74 % of Turkish companies in the automotive industry use standard costing with the main purposes being cost control and performance evaluation, inventory costing, budgeting aid, and product cost calculation for decision making. The focus of this thesis is on standard costing but a few other costing techniques are also shortly introduced to provide perspective on how standard costing differs from other cost accounting techniques.

2.2.1 Process costing technique

According to Bhimani, Horngren, Datar & Rajan (2012), in a process costing system, each costing unit is assumed to consume the same amount of direct materials, direct labour costs, and indirect manufacturing costs. Khan (2022) states that process costing is useful for companies where the production happens in a continuous flow and without variation between products, for example producing electricity. However, Khan (2022) also states that process costing can be used in situations where the products differ from each other as long as the processes can be measured in distinct units and the essential characteristics do not change in the production process. The unit cost calculation with process costing is demonstrated in Figure 5 for a company where the yearly production is 5000 units and the process consists of three parts.

	Total cost (€)				Unit cost (€)		
Cost category	Process 1 Cost (€)	Process 2 Cost (€)	Process 3 Cost (€)		Process 1 Cost (€)	Process 2 Cost (€)	Process 3 Cost (€)
Direct Materials	10 000	75 000	30 000	From previous process		9,70	68,70
Direct Labor	30 000	125 000	50 000	Direct Materials	2,00	15,00	6,00
Indirect Materials	2 000	15 000	5 000	Direct Labor	6,00	25,00	10,00
Indirect Labor	6 500	80 000	10 000	Indirect Materials	0,40	3,00	1,00
Total	**48 500**	**295 000**	**95 000**	Indirect Labor	1,30	16,00	2,00
				Total	**9,70**	**68,70**	**87,70**

Figure 5. Process costing example.

2.2.2 Target costing technique

According to Banerjee (2021), target costing is a technique which is best suited for competitive environments where the costs are set before production is even started by calculating the difference between target price, which is often the market price, and target profit, which is the company's desired profit. Target cost can be therefore calculated with the following formula (Banerjee 2021):

$$Target\ costs = Target\ (market)\ price - Target\ (desired)\ profit \quad (1)$$

Banerjee (2021) also states that target costing is a core part of strategic cost management as it is often performed with value engineering which is a systematic evaluation of the whole value chain and encourages innovative approached to cutting costs. Identifying the value adding activities and non-value adding activities is necessary for creating customer value. Value adding activities can be defined as activities that the customer is willing to pay for and non-value adding activities as activities that increases the total cost of the product but are features that the customer is not willing to pay for (Kinney & Raiborn 2009). The process of reaching for cost reductions and achieving the target cost while retaining customer value can be divided into two stages. The first stage focuses on development phase and finding alternative design and material changes while providing the wanted functions. The second stage focuses on finding ways to increase the functionalities of the product at no extra cost or decreasing the costs of the product without losing the desired functionalities. (Sani & Allahverdizadeh 2012)

Benslimane & Benjelloun (2025) also states that as customer value creation is one of the key principles in target costing, target costing also includes other costing methods, such as Kaizen costing and activity-based costing. Activity-based costing for example can be defined as

a system where individual activities are identified as cost objects and product costs are calculated by calculating the cost from activities required for producing the product (Horngren, Datar & Rajan 2015). Horngren et al. (2015) also states that management use activity-based costing systems to identify areas and activities to reduce costs. According to Kinney & Raiborn (2009), other internal benefits from activity-based costing are improved efficiency in production, more accurate costing, and more efficient performance evaluation. Quesado and Silva (2021) also states that focusing on the costs of activities helps make more effective production decisions which leads to better profitability.

2.2.3 Standard costing technique

According to Tayles & Drudy (2024), standard costing is best suited for organizations where the operation is repetitive and the input required for output can be specified. Badem et al. (2013) states that standard costing is especially used in industries where the products produced are the same, such as automotive industries, fast food industries, and petroleum refineries. Standard costs are calculated to repetitive operations which are used to calculate product standard costs by combining the standard costs from the necessary operations required for producing the product (Tayles & Drudy 2024).

Standard cost generally consists of material standards, labour standards, and overhead standards (Kinney & Raiborn 2009). According to Tayles & Drudy (2024) material standards are typically recording in the bill of materials (BOM) and should include the optimal quantity of materials required to produce the product while taking into consideration any unavoidable wastage or loss. An example of an standard BOM is demonstrated in Figure 6.

Product name	**PC Desk**
Total cost	**116,60 €**

BOM level	Raw Materials, Part, or Components	Unit Cost	Quantity	Total Cost
1	PC Desk			
2	Desktop			
3	Wood board natural finish (120 cm x 60cm x 4cm)	50,00 €	1	50 €
2	Steel frame			
3	Steel square tube (2cm x 120cm)	12,00 €	2	24,00 €
3	Steel square tube (2cm x 75cm)	6,00 €	4	24,00 €
3	Steel square tube (2cm x 30cm)	3,00 €	4	12,00 €
4	C4 T20 5x40 bolt	0,40 €	12	4,80 €
4	M5X40 8.8 nut	0,15 €	12	1,80 €
		Total	**35**	**116,60 €**

Figure 6. Example of a BOM (Tristancho 2024, modified by the author).

Direct labour standards are set by analysing each operation and finding the most efficient methods for equipment, production, and operating conditions and standardizing them (Tayles & Drudy 2024). According to Kinney & Raiborn (2009), setting labour standards should follow the same principles of material standards, all unnecessary operations should be excluded and all production operations included. Unlike in material standards, labour costs cannot be calculated with standard material costs but rather by using labour rates which should include the wages, benefits, taxes, and other employee costs related to the labour needed for that operation (Kinney & Raiborn 2009). Additionally, unavoidable machine breakdowns and routine maintenance stops should be included in the standard time.

According to Kinney & Raiborn (2009), overhead costs should be assigned to separate cost pools and allocated from there to the products using cost drivers. Tayles & Drudy (2024) states that the overhead costs are typically assigned to products by overhead rate per machine hour of input or overhead rate per direct labour hour. The overhead rate is typically based on the budgeted overhead rate which is more accurate method of allocating overhead costs than using for example a monthly rate as the budgeted overhead rate is calculated once a year by the total amount of overhead costs and the total activity (Tayles & Drudy 2024). The total standard cost is then the sum of material standards, labour standards, and overhead standards.

To gain insight on the differences between set standard costs and actual costs, managers use variances where the standard is used as a benchmark or the point of reference for the

comparison (Bhimani et al. 2012). Hung & Shanmugam (2023) states that the goal of variance analysis should be to get data on how well and efficiently cost control has been implemented in production. Tayles & Drudy (2024) demonstrates Figure 7 the different variances affect the total variance to organization's profit.

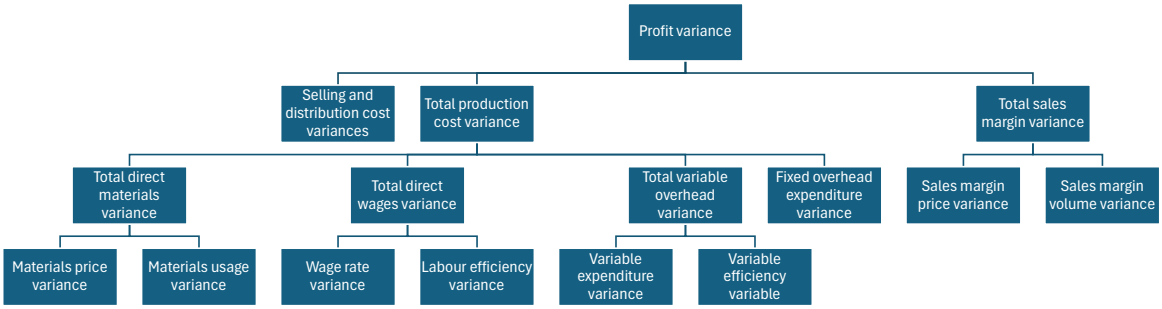


Figure 7. Variance analysis on profit (Drudy & Tayles 2024).

As demonstrated in Figure 7, the total production cost variance consists of multiple different variances which can be calculated by comparing the standard costs to the actual costs. For example, the total direct wages variance can be calculated with the following formula:

$$Total\ direct\ wages\ variance = (SR - AR) \times AH + (SH - AH) \times SR \quad (2)$$

Where *SR* is the standard wage rate per hour, *AR* is the actual wage rate, *AH* is the actual hours worked, *SH* is the standard labour hours, *AH* is the actual labour hours, and *SR* is the standard labour rate per hour. (Tayles & Drudy 2024)

Milojevic, Barjaktarovic & Milosev (2015) state that doing variance analysis monthly can help management make decisions and take corrective actions in order to minimize the total deviation to the planned result or budget. However, Marie et al. (2010) found that 39 % of Dubai's industrial companies had no formal method for investigating variances and the decision were based on managerial judgement. The same study found that the most important variances for Dubai's industrial companies were variances in sales volume, variances in material price, and variances in sales price, and variances in material usage (Marie et al. 2010).

Analysing the variances should also be done before updating the standards. Dosch & Wilson (2010) demonstrates the process of updating standards in Figure 8.

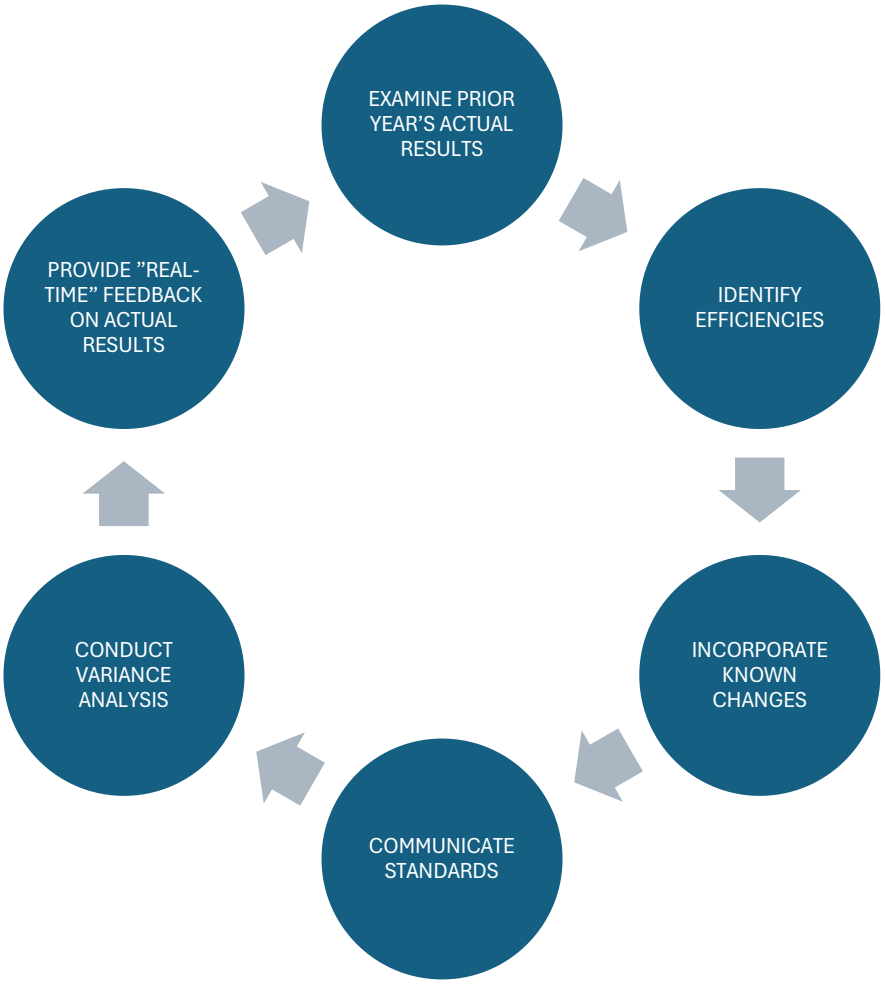


Figure 8. Standard costing review and update cycle (Dosch & Wilson 2010).

As seen in Figure 8, variance analysis, corrective actions, and improvements should be noted before updating the new standards. Kinney & Raiborn (2009) states that understanding variances and establishing tolerance limits is crucial for managers to know to understand which variances require attention and which can be ignored. Hung & Shanmugam (2023) adds that all known changes such as increases in labour costs should be reviewed and considered to ensure up-to-date and accurate standards. Without considering known changes, the information from variance analysis is not as useful.

2.3 Production planning and lot sizing

As demonstrated in Figure 4, cost accounting information can be utilized in each function of the value chain. With production planning and control (PPC) being the brain and nervous

system of the production department with the responsibility of making sure that the production schedule can be followed with the minimum possible costs by ensuring the availability of materials, components, and assemblies at the right time and in the right quantities, cost information can be seen to be highly important to the function (Kiran 2019). Luo, Thevenin & Dolgui (2022) also states that the whole PPC process includes multiple sub-processes, for example production planning and capacity planning. According to Chapman (2006), the base for most planning systems is the actual or expected customer demand. However, the actual demand is rarely known before starting production so production planning often relays on expected demand or forecasts (Chapman 2006).

In the modern business environment, the whole PPC is often done with appropriate systems with concepts such as Big Data, Internet of Things, and Industry 4.0 driving the development (Erol & Sihn 2017). McKay & Black (2007) summarizes the purpose of production planning systems or PPS to the following "take manufacturing requirements, match them with a model of the factory or the supply chain and, using various algorithms and technology, and craft a work sequence either automatically or with manual intervention." A study by Bründl, Stoidner, Nguyen, Baechler & Franke (2023) found that most studied companies used their ERP system's PPC features as their PPS. According to Chopra et al. (2022), manufacturing management and production planning in the ERP system can be divided into three main modules: materials resource planning (MRP I), manufacturing resource planning (MRP II), and capacity requirements planning (CRP). MRP II is a system used for planning all manufacturing resources, including MRP I, CRP, and costing information for finance (Chopra et al. 2022). The functions of MRP II are demonstrated in Figure 9 below.

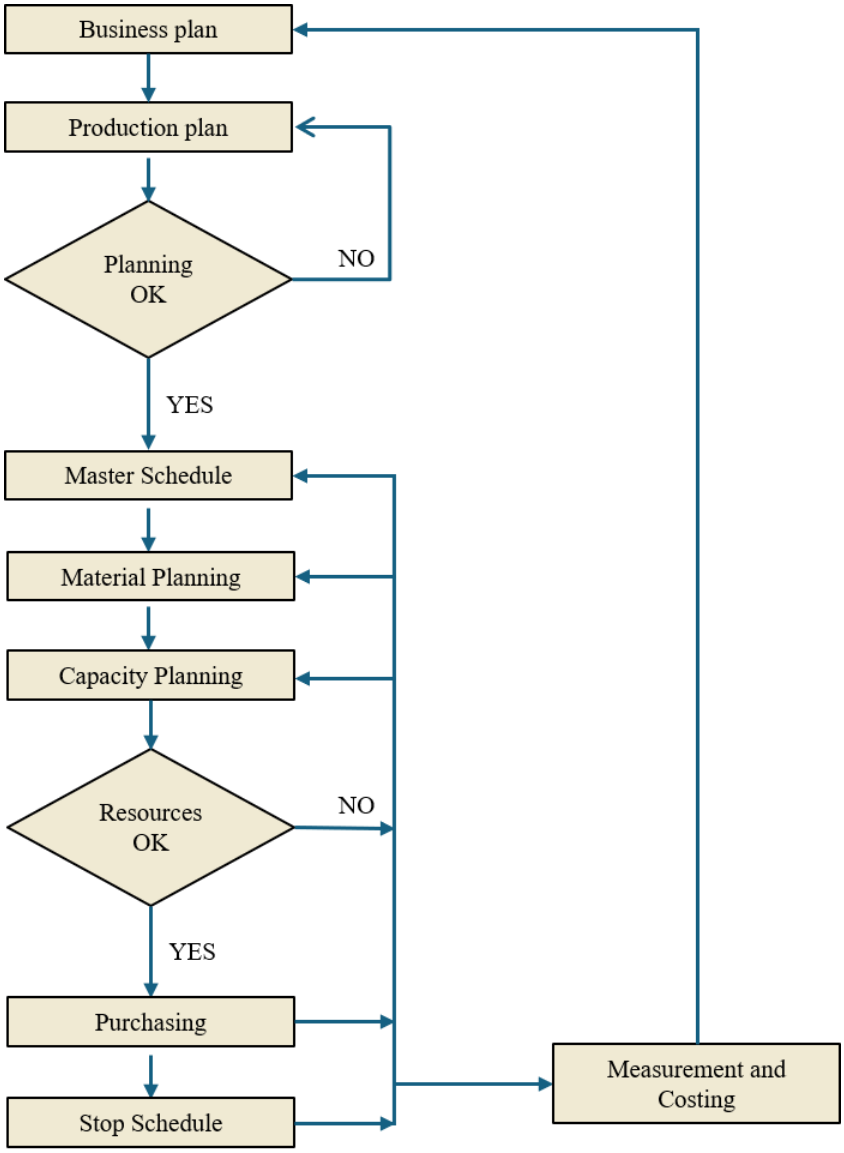


Figure 9. MRP II system (Chopra et al. 2022).

In the ERP system, PPS if often combines with supply chain network design (SCND) and sales & operations planning (S&OP) modules to for comprehensive supply chain planning (SCP) (Stüve, van der Meer, Agha, Entrup 2022). Additionally, ERP system have data from other function, such as inventory and finance, which can be utilized in production planning (Chopra, Sawant, Kodi & Terkar 2022). SCDN focuses on the strategy of the whole supply chain with functionalities emphasising strategies in different departments, such as product strategy and procurement strategy (Stüve et al. 2022). According to Tashakori & Arabsorkhi (2015), the most applicable production policies are Make-To-Order (MTO), Make-To-Stock (MTS), Engineer-To-Order (ETO), and Assemble-To-Order (ATO). Danilczuk, Gola &

Grznar (2022) states that the most traditional production strategies are MTO and MTS, while ETO and ATO can be seen as variants of MTO. The difference between MTS, ATO, MTO, and ETO can be demonstrated by using the order penetration point (OPP), or decoupling point, which determines how long the lead time to the customer is. The closer the OPP is to the customer, the shorter the lead time is. (Logistiikan maailma 2025) The relationship between OPP and different production strategies is demonstrated in Figure 10.

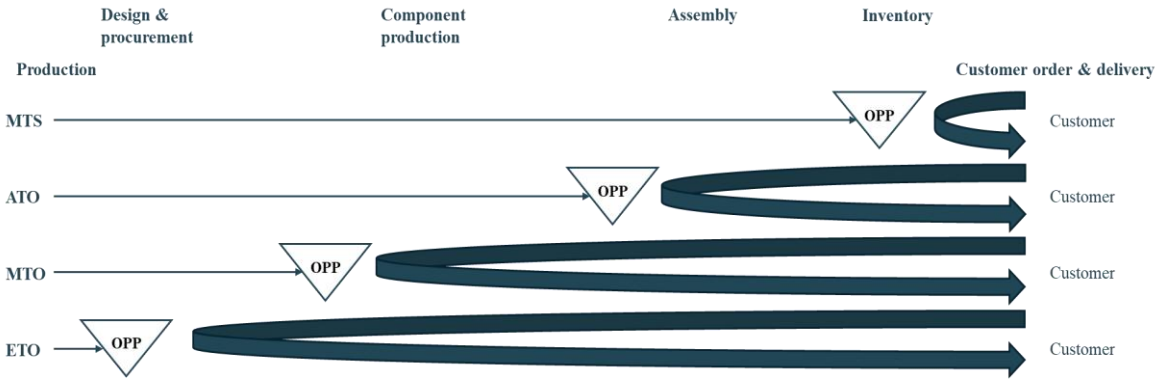


Figure 10. Different production strategies in relation to OPP (Logistiikan maailma 2025).

Activities before the OPP or upstream activities are typically forecast driven in typical push systems such as MTS. On the contrary, activities after the OPP or downstream activities are typically driven by customers in pull systems such as MTO. (Singh & Disney 2026) In MTS systems, customer demand is met by stocking finished goods accordingly which often leads to short lead times, limited customisation, and high inventory costs. Therefore, optimizing inventory holding costs with setup times is a crucial part of MTS production systems. In typical MTO systems, customer demand is met by production which is directly triggered by customer orders which often results in low inventory costs, high flexibility, and long lead times. Consequently, a hybrid of MTO and MTS system is often a more suitable option instead of a pure MTO or MTS system. (Peeters & van Ooijen 2020) Renna (2024) also states that a hybrid MTO/MTS system can reduce inventory costs from pure MTS system while also maintaining performance metrics at a similar level. Peeters & van Ooijen (2020) introduced three types of hybrid MTO/MTS systems:

1. Sequential hybrid MTO/MTS production system where products are produced using MTS production steps and MTO production steps in sequences.

2. Parallel hybrid MTO/MTS production system where at least one MTS and one MTO product are produced simultaneously.
3. Floating hybrid MTO/MTS production system where the OPP is allowed to move between production steps meaning that the production order can switch from MTS to MTO depending when the customer order comes.

S&OP provides relevant data for production planning and lot sizing with the focus being on forecasting, measuring, and analysing demand and bottlenecks. According to Kiran (2019), forecasting techniques can be divided into three categories: qualitative, quantitative, and time series based methods. Quantitative methods utilize historical data to simulate future demand using methods such as data mining where large datasets are analysed to identify patterns and relationships among variables and applying them to new data to generate expected outcomes (Kiran 2019). Time series based forecasts methods such as moving averages are used to study trends, seasonality, and cycles by analysing historical datapoints at regular intervals (Biela-Weyenberg 2023). Biela-Weyenberg (2023) also states that with machine learning and artificial intelligence (AI), the data-driven tools remove human bias and therefore helps managers plan better.

Stüve et al. (2022) states that the main functions in PPS focuses on automatic and manual scheduling, lot sizing, and controlling operations such as production orders. The main focus of this thesis is on lot sizing which has the aim of finding the optimal lot size or the point where the sum of ordering/setup costs and holding costs hits the minimum value. The impact of ordering costs and inventory holding costs in relation to the total costs be demonstrated in Figure 11.

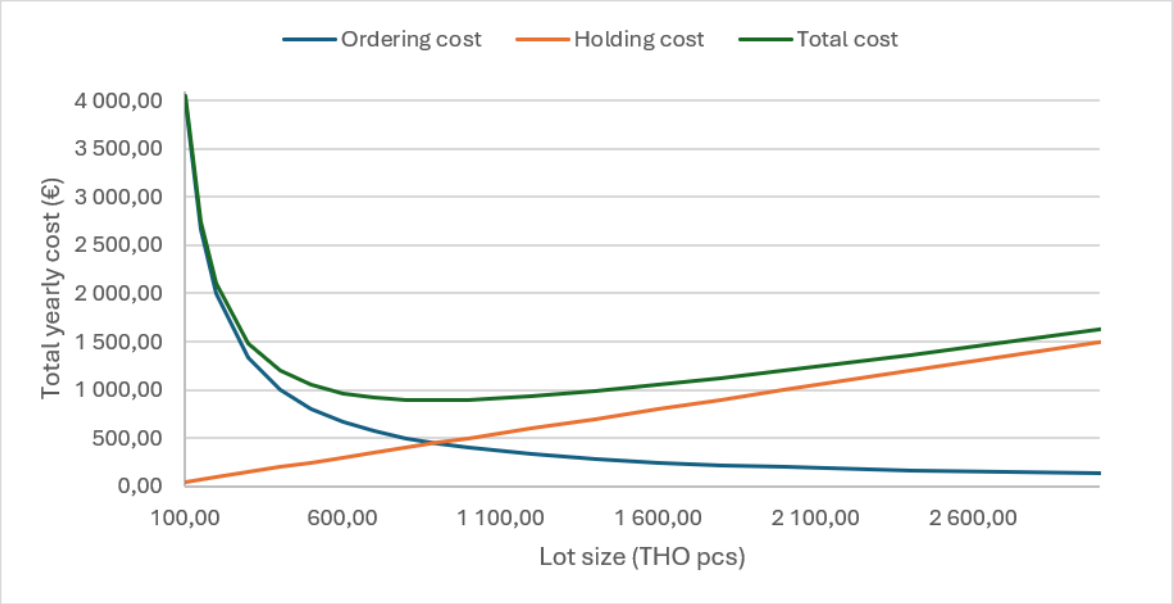


Figure 11. Total costs in relation to ordering cost and holding cost (Al-Dabbas 2021).

Peeters & van Ooijen (2020) states that optimizing inventory holding costs and setup costs is a typical feature in MTS production systems. Setup costs are costs accumulated from necessary activities related to preparing resources such as machines for executing task. These activities are for example cleaning, obtaining and setting up tools, and setting up the required fixtures. The setup activities are either sequence-dependant were the setup cost depends on both the task and the previous task or sequence-independent were the setup cost is only based on the task. (Allahverdi & Soroush 2008) The two major ways to reduce setup costs and the total machine downtime from setups are reducing the setup frequence and reducing the time needed to perfume the setup (Burtseva 2022). According to Gurtu (2021), inventory holding cost consist of multiple factors, such as cost of inventory space, inventory holding period, and inventory quantity.

Before determining the optimal production lot size, main production planning parameters must be determined. The main production planning parameters are showcased in Table 1. According to Burtseva (2022), these parameters have direct influence on the procedure and modelling of the lot size.

Table 1. Production planning parameters (Burtseva 2022).

Parameter	Description
Planning horizon and time scale	Planning period must be defined. Can be finite or infinite.
Levels	Distinguishing single-level or multi-level production systems.
Products	Determining the type of product produced which is linked to the chosen level.
Capacity or resource constraints	Determining the systems resource constrains if there are any.
Demand rate	The nature of the demand.
Setup structure	Determining how setups are handled, for example is the setup time dependent on the previous task or not.
Inventory shortage	Determining if inventory shortages are allowed and if backlogging is included.
Costs	Determining how setup and inventory holding costs are calculated.

To make decisions based on data, such as sales forecasts, reasonable and accurate, the planning horizon must be defined. Fye, Charbonneau, Hay & Mullins (2013) found that forecasts predicting shorter time periods are more accurate than those predicting longer time periods. Therefore, trying to optimize lot sizes for too long time period may lead to ineffective decisions. The level of the production system also has an impact on the lot sizing. In single-level systems, the finished product is simple to manufacture and the production often involves only one operation whereas in multi-level systems the products can require several processes. The demand in single-level systems is independent whereas the demand in multi-level system is dependent demand which means that the demand of the level is dependant on the parent level's demand which makes the system more complex. Additionally, examining the dependency of demand, the nature of the demand must be determined. Demand is often seen as either static, where the demand is constant, or dynamic, where the demand might vary over time. (Burtseva 2022)

After determining the production planning parameters, determining the lot size can be done with many different techniques. Robinson, Narayanan & Sahin (2009) divides lot sizing

models to two categories by studying the nature of the demand: deterministic static demand models and deterministic dynamic demand models. The static models assume a more static or constant demand whereas the dynamic models allow variations in demand. The deterministic models require the demand to be know for the planning horizon. (Robinson et al. 2009)

The economic order quantity or EOQ can be seen as a static demand technique which minimizes the balance between order costs and inventory holding costs. However, to calculate EOQ, some assumptions are required: firstly the demand is assumed to be constant and continuous, secondly the lead time is assumed to be constant, thirdly the order size is assumed to be unlimited by the inventory capacity, fourthly the order cost is independent of the order size, and lastly the inventory holding cost is known and not dependant on the quantity in stock. (Agarwal 2014) Bhattacharya & Bhattacharyya (2022) also states that the model assumes that the order quantity does not depend on the price, there are no planned shortages, and the order quantity is produced at once and is ready exactly when needed. According to Bhattacharya & Bhattacharyya (2022), the formula to calculate the EOQ is as follows:

$$EOQ = \sqrt{\frac{2*D*C_{or}}{C_c}} \tag{3}$$

Where C_c is the inventory holding cost, C_{or} is the order cost, as D is the annual demand. Bhattacharya & Bhattacharyya (2022) states that the EOQ can be applied to production order sizes by modifying the formula a bit. The optimal production order quantity or POQ can be calculated with the following formula:

$$Q_p = \frac{D}{N_p} \tag{4}$$

Where Q_p is the optimal production order size, D is the annual demand, and N_p is the optimal number of production runs per year. To calculate the Q_p, the optimal number of production runs must be calculated which can be done with the following formula:

$$N_p = \sqrt{\frac{i \times C_{fg} \times D}{2 \times S}} \tag{5}$$

Where i is the holding cost in per cent/per unit per annum, C_{fg} is the cost of the finished goods per piece, D is the annual demand, and S is the setup cost for the run. (Bhattacharya & Bhattacharyya 2022)

One of the most simple dynamic demand models is the Lot-for-lot or LFL method where the demand is matched precisely by ordering exactly the amount of demand. The aim is to have the opening and closing inventory value for the period to be zero. (Samak-Kulkarni & Rajhans 2013) However as van Kampen, van Donk & van der Zee (2010) state, the use of safety lead times and safety stock add flexibility and responsiveness to the production system to help deal with supply uncertainties, such as machine breakdowns, and demand uncertainties, such as short term demand spikes.

One of the more advanced dynamic demand models is the Silver-Meal heuristic method. According to Segerstedt, Abdul-Jalbar & Samuelsson (2023), the methods core idea is to have a new delivery after the average cost per period increases for the first time. The order quantity can therefore be calculated with the following formula:

$$If\ \frac{A+h\sum_{t=1}^{k+1}(t-1)\times X_t}{k+1} > \frac{A+h\sum_{t=1}^{k}(t-1)\times X_t}{k}\ then\ Q_{1,1} = \sum_{t=1}^{k} X_t \quad (6)$$

Where A is the ordering cost, h is the cost to keep one unit in stock for one period, X_t is the demand in period t, and Q is the suggested order quantity necessary to be delivered in time period t. (Segerstedt et al. 2023)

2.4 Working capital management

Bian, Lemoine, Yeung, Bostel, Hovelaque, and Viviani (2021) notes that working capital management (WCM) and more specifically the working capital requirement or WCR have drawn more attention in the recent years due to the direct link to the cash flow and the potential of generating more cash flow. Bian et al. (2021) states that WCR is often measured by the cash conversion cycle or CCC in the field of finance and accounting. The CCC measures the total time the organization's cash is tied within the business' operation (Wang 2019). Uyar (2009) states that the CCC can be calculated with the following formula:

$$CCC = DSO + DIO - DPO \quad (7)$$

Where *DSO* is the days of sales outstanding, *DIO* is the days of sales in inventory or days inventory outstanding, and *DPO* is the days of payables outstanding. According to Uyar (2009), the DSO can be calculated with the following formula:

$$DSO = \frac{Account\ receivables}{Sales/365} \quad (8)$$

And the DIO with the following formula:

$$DIO = \frac{Inventories}{COGS/365} \quad (9)$$

Where *COGS* is the cost of goods sold. The DPO can be calculated with the following formula:

$$DPO = \frac{Account\ receivables}{COGS/365} \quad (10)$$

Nobanee & Al Hajjar (2014) also presents the operating cycle and the net trade cycle as other metrics to measure company's working capital management. The operating cycle measures the time it takes for the company to collect the account receivables and acquire the raw materials used in the production. The net trade cycle is very similar to the CCC but it measures the CCC as a percentage of sales instead of the COGS. (Nobanee & Al Hajjar 2014) Tayo & Ojo (2023) found that with standard costing, the COGS can be calculated accurately and be used in assessing the financial performance and metrics. The usage of standard costs can therefore be implemented in calculating the CCC.

For this thesis, the DIO can be seen as the most important variable affecting the CCC. According to Lind, Pirttilä, Viskari, Schupp & Kärri (2012), the cycle time of inventory is more dependent on the chosen production and inventory management policies than purchasing and sales terms. Lind et al. (2012) also states that from the value chain point of view, the DIO mainly reflects the internal supply chain's efficiency and does not have a direct effect on other stakeholders. According to J.P.Morgan (2025), shorter CCC is typically seen as more efficient management of working capital. However, Lind et al. (2012) states that a longer DIO reduces the risk of price fluctuations, business losses due to product scarcity, and delivery interruptions. Overall, the benchmarks for CCC are very dependent on the industry and manufacturing companies might have longer CCC because of extended production cycles and longer inventory holding periods compared to retail companies (J.P.Morgan 2025).

Typically, CCC is calculated on a company level but it can be broken down to business unit level or even order level (Lind et al. 2012). Therefore, the DIO can also be broken down to

a production order level. Assuming that the demand remains constant, the production order finishes instantly when required, and that a new production order is produced only when the inventory quantity gets to zero, the effect of production lot size to the DIO of an item can be calculated:

$$DIO = \frac{\frac{Q}{2} \times COGS}{D \times COGS} \times 365 \quad (11)$$

Where Q is the production order quantity and D is the annual demand. The formula can be transformed into:

$$DIO = \frac{Q}{2 \times D} \times 365 \quad (12)$$

Pointing out that the COGS of the item does not have an affect on the DIO when analysing singular items. A study by Rey-Ares, Fernández-López & Redeiro-Pazos (2021) found that the relationship between the profitability of the company and the DIO can be described as U-shaped meaning that the initial increase in DIO has a negative effect on the profitability but after a certain period of time, the negative effect turns to a positive one. The initial negative impact is due to the increase in inventory and higher inventory holding costs. The cost of extra inventory is overcome by the benefits of avoiding potential price fluctuations and breaking costs after a certain period. (Rey-Ares et al. 2021)

2.5 Summary of the theoretical framework

The theoretical chapter of this thesis was conducted using a literature review as the chosen research method. The purpose of the literature review was to create a theoretical framework and the basis for the empirical section. The literature review also answered the first two research questions: “How can standard costing information be utilized in production lot sizing?” and “How does production lot sizing influence the cash conversion cycle?”

How can standard costing information be utilized in production lot sizing?

The main purpose of cost accounting can be summarized to providing relevant information about company’s current situation, helping guide attention to urgent and relevant activities, and providing information about areas of improvement for stakeholders. To achieve these objectives while using the standard costing technique, the standards should approximate costs as accurately as

possible. Additionally, variance analysis should be used to identify inefficiencies and areas where the standards are not met.

The principle of standard costing is to set long lasting standards which are typically updated semi-annually or annually to ensure that the made changes and known changes are included to ensure the comparability and accuracy of the standard costs. The standard cost of an item typically consists of material standards, labour standards, and overhead standards which are calculated using appropriate cost drivers, such as the BOM. For the whole production planning department, the whole cost structure of the item can be seen as important. The BOM is required to ensure the availability of all the necessary materials, the labour hours can be utilized in capacity planning, and the overhead standards include warehousing costs.

Purely for lot sizing purposes, the labour standards and the total cost of the item are the two main sources of information required. The main purpose of lot sizing is to optimize the setup costs and inventory holding costs to guarantee the most cost optimal production lot size. Lot sizing can be done with models which can generally be categorized as either static demand models or dynamic demand models with the nature of the demand being the deciding factor. With the modern PPS systems, the lot sizing can be done automatically or manually but in both cases, certain parameters need to be determined. Most commonly, the PPS is integrated with the company's ERP system where also the standard costing data is stored. The required parameters are for example the nature of the demand, the production system level, and determining how setup costs and inventory holding costs are calculated. Additionally, lot sizing decision are affected by the chosen production policy of the company with the most common policies being MTS, MTO, ATO, and ETO. The difference in the production policies can be determined by analysing the lead time to the customer.

The use of standard costing system has a direct influence on determining the lot sizing parameters. Compared to other costing techniques, such as process costing which focuses on allocating the total costs to the production processes, and target costing which focuses on achieving a certain predetermined costs for each business opportunity, standard costing provides detailed costing information which can be directly utilized in lot sizing. In standard costing, the setup costs should be included in the standard cost of the product and calculated using the predetermined costing rates. The labour time required for the setup should also be determined in the standard labour hours as part of the required necessary operations. While the standard cost of an item does also include overhead costs such as warehousing costs, the inventory holding cost can not typically be determined for the item solely based on the standard cost. As formula 5 states, the

holding cost in per cent/per unit per annum also needs to be determined which can then be used together with the standard cost of the item to calculate the optimal lot size. Additionally, the standard labour rates and machine rates could also be utilized in determining if there are any capacity or resource constraints.

How does production lot sizing influence the cash conversion cycle?

Working capital management in this thesis is measured by the CCC which measures the length of time the organization's cash is tied up in operations. The CCC can be calculated by measuring the cycle times of inventory, accounts receivables, and accounts payables. The cycle times for inventory and accounts payables is typically calculated using the COGS as the denominator but in same cases the sales is also used. With the usage of standard costing system, COGS can be used as the denominator as the standard costs should approximate the COGS accurately.

The DIO is main the section of the CCC which is affected by the change in lot sizes. However, the change in lot size in the standard costing update could also influence the DPO as the COGS changes with the lot size. In extreme cases, the changes in lot sizes could also affect the total allocatable overhead costs affecting both DIO and DPO indirectly. However for the purpose of this thesis, the influence of lot sizing on the CCC is studied by analysing the effect to the DIO. The DIO is mostly affected by the chosen production and inventory management policies which also affect the organization's lot sizing decisions.

Traditionally, a shorter CCC and therefore a shorter DIO are typically seen as more efficient management of working capital. However, multiple studies also found that a higher DIO has a positive effect on the profitability of the company. The increase in DIO lowers the risks of price fluctuations, business losses, and delivery interruptions. Additionally, the higher service rate might affect the stakeholders in the supply chain which can not be seen in the CCC calculation. Typically the CCC is analysed on a company level but analysing the impact of production lot size change is also possible. To analyse the impact of production lot size change for a single item, the following formula can be used:

$$\Delta DIO = \frac{\Delta Q}{2 \times D} \times 365 \tag{13}$$

Where ΔQ is the change in the production lot size. The result is the daily increase or decrease in inventory cycle time.

3 Introduction to the focal company and analysis model

This thesis is done in collaboration with a company operating in the food packaging industry. The company employs approximately 200 employees with a revenue of around 45 million euros. The factory is located in Hämeenlinna Finland where the company produces thermoformed food packaging products for multiple market segments, biggest segments being the dairy market and fresh meat market. The factory mainly produces PP or polypropylene and PS or polystyrene plastic products. The company is also a part of a global concern which employs over 5000 employees and supplies customers across 6 different continents. This chapter defines the production process, introduces the current costing model used in the case company, and explains the principles of the analysis model.

3.1 Focal company introduction

The production process in the focal company begins with extrusion process which typically happens in separate machines. According to Rauwendaal, Gramann, Davis & Osswald (2014), extrusion refers to a process where material is pushed or forced through an opening, in machines the opening is referred to as the extruder die. Rauwendaal et al. (2014) states that there are generally three categories of extruders: Screw extruders, disk or drum extruders, and reciprocating extruders. The focal company uses screw extruders which process is showcased in Figure 12.

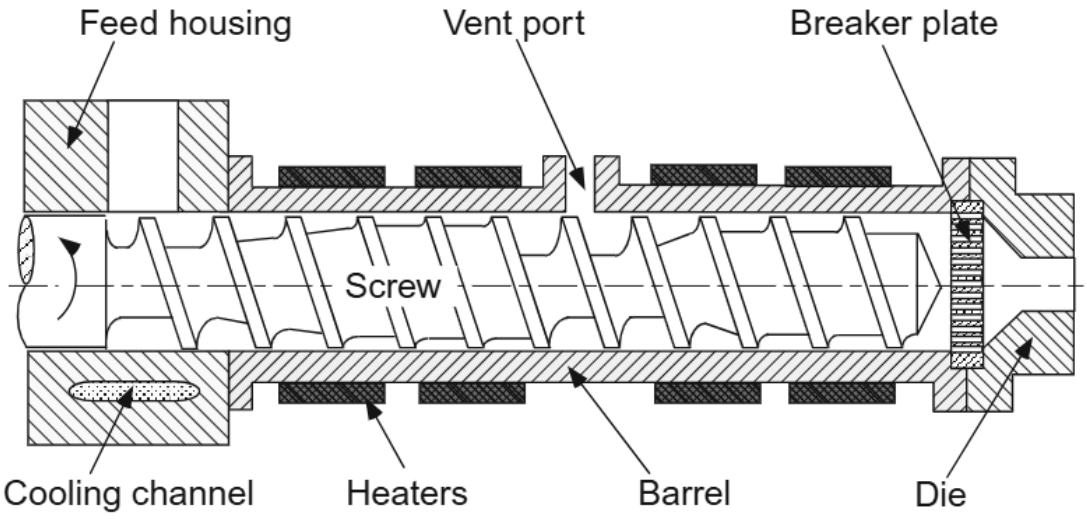


Figure 12. Extrusion process (Rauwendaal et al. 2014).

In the process, raw material (plastic pebbles) is inputted through the feed housing according to the items BOM. It is then heated and pushed through the die and formed to a sheet with a wanted thickness and width. In some machines, the extrusion process takes place in the same machines as the next process step, thermoforming, but generally the process is the same for producing the required sheet.

The next process step is thermoforming where the end products can be classified as finished good or semi-finished good depending on the following process steps. If the product from thermoforming process does not require any additional process steps, it is classified as a finished good. However, if the product goes into work-in-process inventory to wait for additional steps, such as decorations, the product is classified as a semi-finished good. Majority of the items sold the dairy market are classified as semi-finished goods after the thermoforming process and majority of the items sold to the fresh meat market are classified as finished goods. The process of thermoforming is demonstrated in Figure 13.

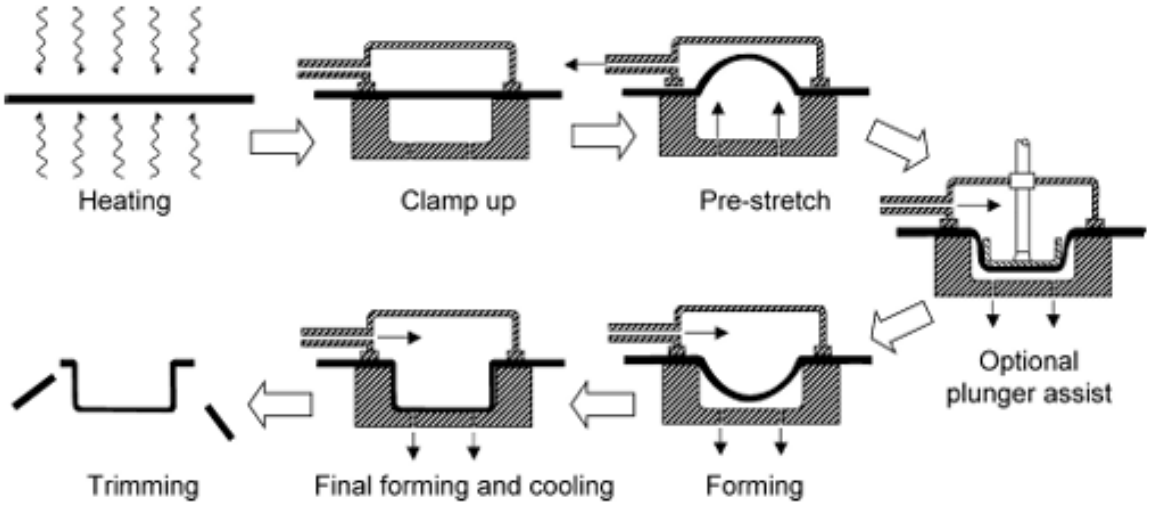


Figure 13. Thermoforming process (Lim, Auras & Rubino 2008).

In thermoforming, the plastic sheet is heated and pre-stretched before mechanically being pressed against the mold to achieve the wanted shape. Then the shape is cooled, removed from the mold, and trimmed. (Lim et al. 2008) The setup for preparing the thermoforming machine, sheet, and the mold can be up to 10 hours with the setup depending on, for example the number of cavities in the mold and the machine.

The add-on process is applied when any additional process steps are done for the thermoformed item. There are four possible processes that can be applied for the item: printing process, duosmart process, shrink sleeving process, and absorber process. Typically, only one of these processes can be applied to the item. In the printing process, decorations such as customer branding are printed directly to the item. The setup time in printing process can be up to 4 hours depending on, for example the complexity of the decoration and the number of colours used in the decoration. In the duosmart process, the semi-finished item is wrapped with a sleeve which is faster to setup and typically takes approximately 1 hour. Shrink sleeving process utilizes steam to shrink a plastic film around the semi-finished good. The setup times for shrink sleeving machines can be up to 2 hours. The absorbed process is different compared to the three other add-on processes as instead of a decoration being applied to the outer side of the item, an absorber pad is installed on the bottom of the item. The setup times for absorber machines can be up to 2 hours. The total setup times can therefore be up to 14 hours if the thermoforming and add-on processes require the maximum setup times. The

weight and size of the items being produces varies with the lightest items being around 2 grams and the heaviest items being up to 100 grams.

The focal company uses standard costing as the cost accounting technique standard. The standards are updated according to company policy and are based on historical data, known changes, such as changes in wages and electricity prices, and optimal performance which is currently achievable. The standard cost structure of an item in the case company is demonstrated in Table 2.

Table 2. Cost structure used in the focal company.

Cost Group	Cost example	Allocation to items
BOM	Raw materials used in production	Based on material price and usage quantity
Utilities	Electricity used for production	Based on work center usage
Direct labour	Worker salary	Based on work time usage
Overhead	Warehouse costs	Based on cost drivers and cost rates
Order cost	Setup cost	Based on order quantity
Standard cost		**Sum off all cost groups**

The cost groups consists of different and more specific costing components which are calculated according to the company's policies and are designed to make the costing more accurate for each item. For example, the setup cost are allocated to the item based on the order quantity, machine used, and setup time required for the process. The setup cost for add-on machines is a bit higher than thermoforming machines as the setup is often has more steps before the machine can be used. For example in the printing process, the setup might require multiple workers as on top of the machine being prepared, also the colours and printing materials need to be prepared where as in the thermoforming process only the machine needs to be prepared. Therefore, the setup costs cumulated to the item are higher if the item has a thermoforming process and a printing process compared to an item with only thermoforming process. The focal company uses two relevant systems for this thesis, their ERP system and their forecasting system. The ERP system used is Infor's M3 Cloud version and the forecasting system is SAP's SAP integrated business planning or SAP IBP.

3.2 Explanation of the analysis model

The model used in the analysis was built using programming language Python. Python is a popular programming language released in 1991 which can handle big data and connect to different databases. Python is often used because it has a simple syntax and it works on different platforms, such as Windows and Mac. (W3Schools 2026) According to a survey with over 30 000 respondents from multiple continents, Python was found to be the fourth most popular language. In the same survey, SQL was found as the third most popular. (Stack overflow 2025) Python was chosen for its simplicity, readability, and performance. The model uses data from two different SQL databases, from the ERP system's database and from the forecasting system's database. The data is loaded to Python from SQL using the Pyodbc library in Python which allows to connect to specified databases and execute specific SQL statements. The data is stored in separate DataFrames using the Pandas library in Python.

The forecasting system is used to get the forecast for the next full 12 months using the user's system date as the filter. The data in the forecasting system uses qualitative methods in expert's judgement, field insight, and real forecasts from the customers. The company employs one demand planner responsible for overseeing the forecasts and ensuring their accuracy. According to SAP (2026), the SAP IBP also uses AI for history based classification, outlier detection and correction, and algorithms to create accurate forecasts. However, the system only has forecasts for finished goods so combining the ERP system's data is necessary to also analyse the semi-finished goods.

From the ERP system, the current inventory quantity, costing data, BOM, production system for the item, and production parameters are used. These production parameters include for example the number of items required for a full pallet to ensure that production order sizes are rounded to producing only full pallets. The calculated production order quantities are rounded up to the nearest full pallet. Said, Shahzad, Zamai, Hubac & Tollenaere (2016) found that product mix fluctuations caused by high-mix low-volume production and short production life cycles cause unstable corrective and preventive maintenance actions leading to unstable capacity and worse overall equipment efficiency (OEE). The order quantities are rounded up to mitigate this risk. Additionally, each item has a minimum and maximum order quantities set by company's master data and production teams which must be followed.

The production system is a multi-level system so the demand for the semi-finished goods is calculated by using the finished goods forecast and finished goods BOM. The total demand for the semi-finished goods is calculated by multiplying the finished goods demand with the BOM consumption for each item and then summing the total need for each semi-finished good. While the production order quantity is only calculated to MTS finished goods, all the semi-finished goods are handled as MTS items if they have at least one finished good which is classified as a MTS item. The current inventory quantity is then subtracted from the demand to calculate the final production need for the next 12 months which is then used in the production order quantity calculation. No safety stock is considered in this model. Additionally, the setups are considered to be sequence-independent.

The optimal production lot size is calculated by modifying the POQ to fit the focal company's standard costing method. A static model was chosen as the preferred way to calculate the production lot size due to the static nature of standard costing. The chosen static model is Bhattacharya & Bhattacharyya (2022)'s POQ model demonstrated in formulas 4 and 5.

However as shown in Table 2, the standard cost of the item is also dependent on the order quantity and therefore the formula must be modified. The total setup cost consists of maximum of three different tasks: tool maintenance, tool preparation, and tool setup. The tool maintenance and tool preparation tasks are only required for thermoforming items where the mold needs to be changed before a new production run can be started. Therefore the total setup cost S can be calculated with the following formula:

$$S = A + B + C * t \tag{14}$$

where A is the cost of tool maintenance, B is the cost of tool preparation, C is the cost of one setup hour, and t is the total time required for the setup. The total setup cost is then divided by the order quantity and allocated to the item level. Therefore the standard cost of an item can be calculated with the following formula:

$$C_{fg} = E + \frac{S}{Q} \tag{15}$$

Where E is sum of BOM cost, utilities cost, direct labour cost, and overhead cost, S is the setup cost and Q is the order quantity. Therefore the original POQ formula is transformed into the following formula:

$$Q = \frac{D}{\sqrt{\frac{i*C_{fg}*D}{2*S}}} \tag{16}$$

which can be transferred to:

$$Q^2 = \frac{D^2}{\frac{i*C_{fg}*D}{2*S}} \tag{17}$$

which can be solved to get the final formula:

$$E * Q^2 + (A + B + C * t) * Q - \frac{2*D*(A+B+C*t)}{i} = 0 \tag{18}$$

Where Q is the optimal order quantity, D is the demand, and i is the holding cost in per cent/per unit per annum. Because the formula is quadratic, the quadratic formula can be used to solve Q for the optimal production lot size. As the production lot size cannot be negative, only the positive answer is considered. According to Vieta's formula, the quadratic formula will always give a negative and a positive answer as E, S, D, and i are all greater than 0, and the product of the roots is negative. Therefore, the formula will only give one viable answer which is then rounded up to the nearest full pallet while also applying the minimum and maximum order quantity rules. The structure of the model is demonstrated in Figure 14 below.

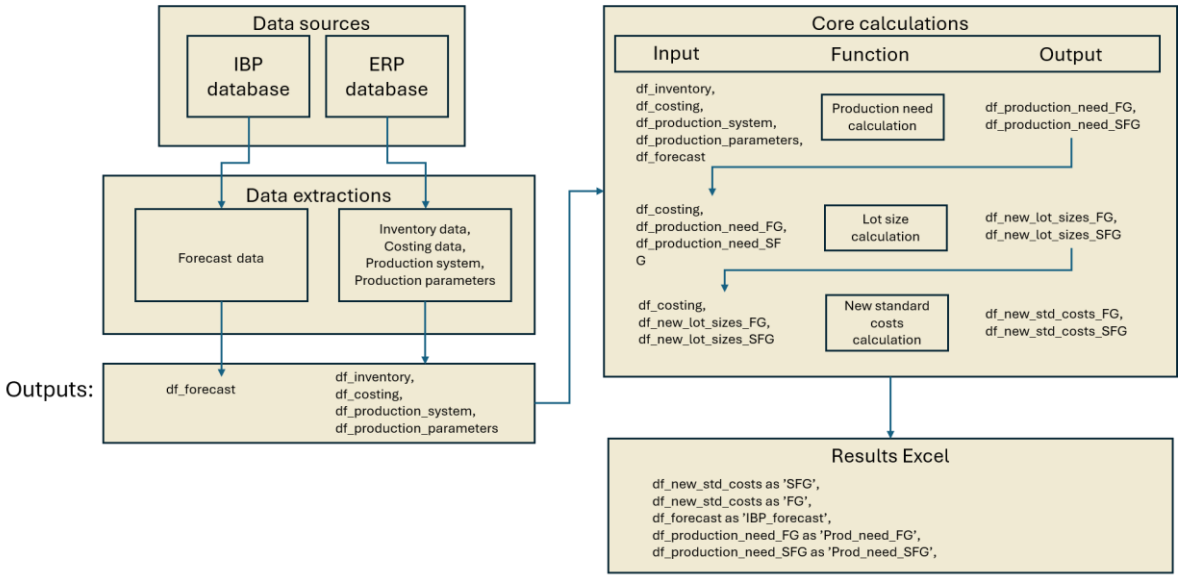
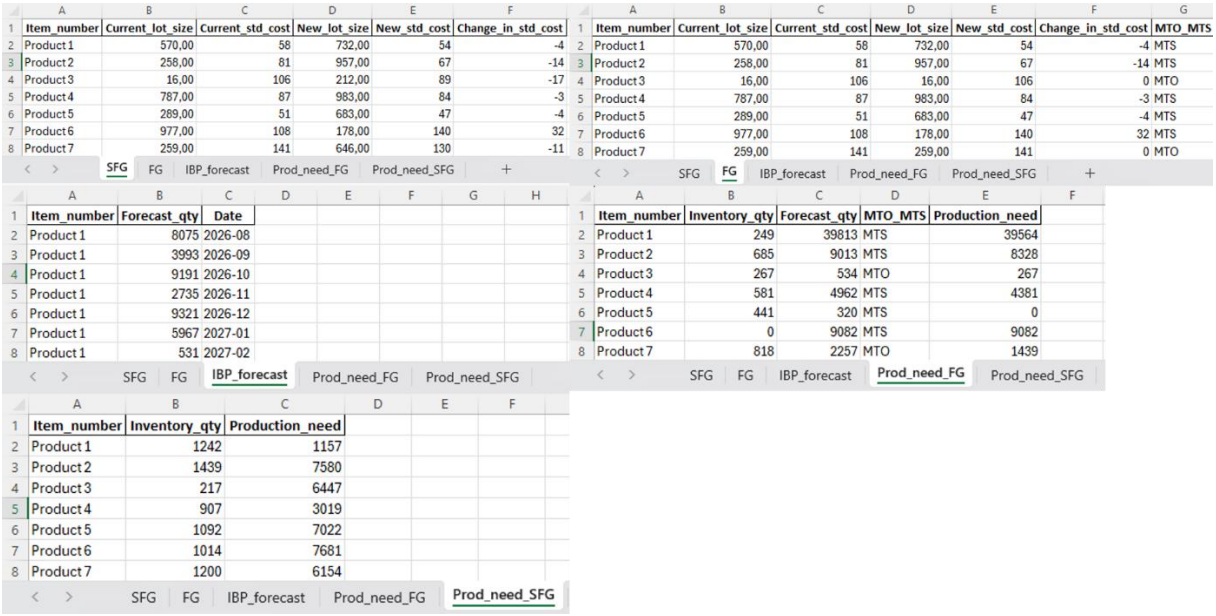


Figure 14. Analysis model structure.

The final result of the model is one Excel worksheet where each item number, next 12 months demand, current standard cost, new calculated standard cost, current lot size, and new calculated lot size are listed and the difference in costing compared. The difference in current and calculated standard costs can then be used to calculate the possible savings for the next 12 months, as well as used in analysing the current lot sizes. The result Excel worksheet is demonstrated in Figure 15 below with illustrated items and numbers.



Item_number	Current_lot_size	Current_std_cost	New_lot_size	New_std_cost	Change_in_std_cost
Product 1	570,00	58	732,00	54	-4
Product 2	258,00	81	957,00	67	-14
Product 3	16,00	106	212,00	89	-17
Product 4	787,00	87	983,00	84	-3
Product 5	289,00	51	683,00	47	-4
Product 6	977,00	108	178,00	140	32
Product 7	259,00	141	646,00	130	-11

SFG | FG | IBP_forecast | Prod_need_FG | Prod_need_SFG

Item_number	Current_lot_size	Current_std_cost	New_lot_size	New_std_cost	Change_in_std_cost	MTO_MTS
Product 1	570,00	58	732,00	54	-4	MTS
Product 2	258,00	81	957,00	67	-14	MTS
Product 3	16,00	106	16,00	106	0	MTO
Product 4	787,00	87	983,00	84	-3	MTS
Product 5	289,00	51	683,00	47	-4	MTS
Product 6	977,00	108	178,00	140	32	MTS
Product 7	259,00	141	259,00	141	0	MTO

SFG | FG | IBP_forecast | Prod_need_FG | Prod_need_SFG

Item_number	Forecast_qty	Date
Product 1	8075	2026-08
Product 1	3993	2026-09
Product 1	9191	2026-10
Product 1	2735	2026-11
Product 1	9321	2026-12
Product 1	5967	2027-01
Product 1	531	2027-02

SFG | FG | IBP_forecast | Prod_need_FG | Prod_need_SFG

Item_number	Inventory_qty	Forecast_qty	MTO_MTS	Production_need
Product 1	249	39813	MTS	39564
Product 2	685	9013	MTS	8328
Product 3	267	534	MTO	267
Product 4	581	4962	MTS	4381
Product 5	441	320	MTS	0
Product 6	0	9082	MTS	9082
Product 7	818	2257	MTO	1439

SFG | FG | IBP_forecast | Prod_need_FG | Prod_need_SFG

Item_number	Inventory_qty	Production_need
Product 1	1242	1157
Product 2	1439	7580
Product 3	217	6447
Product 4	907	3019
Product 5	1092	7022
Product 6	1014	7681
Product 7	1200	6154

SFG | FG | IBP_forecast | Prod_need_FG | Prod_need_SFG

Figure 15. Example of the results.

4 Analysis of the results

The analysis was performed on a total of 970 finished good (FG) item and 86 semi-finished good (SFG) item. This chapter focuses on analysing the result on three different levels, the overall level, the financial level, and the operational level. On the overall level, the focus is analysing the total impact to items from recalculating the order quantities in the middle of the year. On the financial level, the focus is on analysing the profitability of the company level and on the item level. Both historical profitability and forecasted profitability will be analysed. The operational level focuses on analysing how the new order quantities would effect operations, for example the amount of production orders. Additionally, the potential risks related to the implementation of the model are analysed.

4.1 The overall impact

Out of the 970 FG items, the standard cost (std. cost) decreased for 46,4 %, increased for 26,1 %, and remained the same for 27,5 %. A total of 25,1 % FG items were indirectly affected, meaning that the order quantity remained the same for the FG level, but the change in SFG level affected the final std. cost. Additionally, a little over 2 % of the currently stocked items were at a level where the current inventory quantity would cover the next 12 months' forecast. For SFG items, the std. cost remained the same for 40,7%, increased for 25,6 %, and decreased for 33,7 %. The impacts of recalculating the order quantities based on current sales forecast are illustrated in Figure 16 and Figure 17.

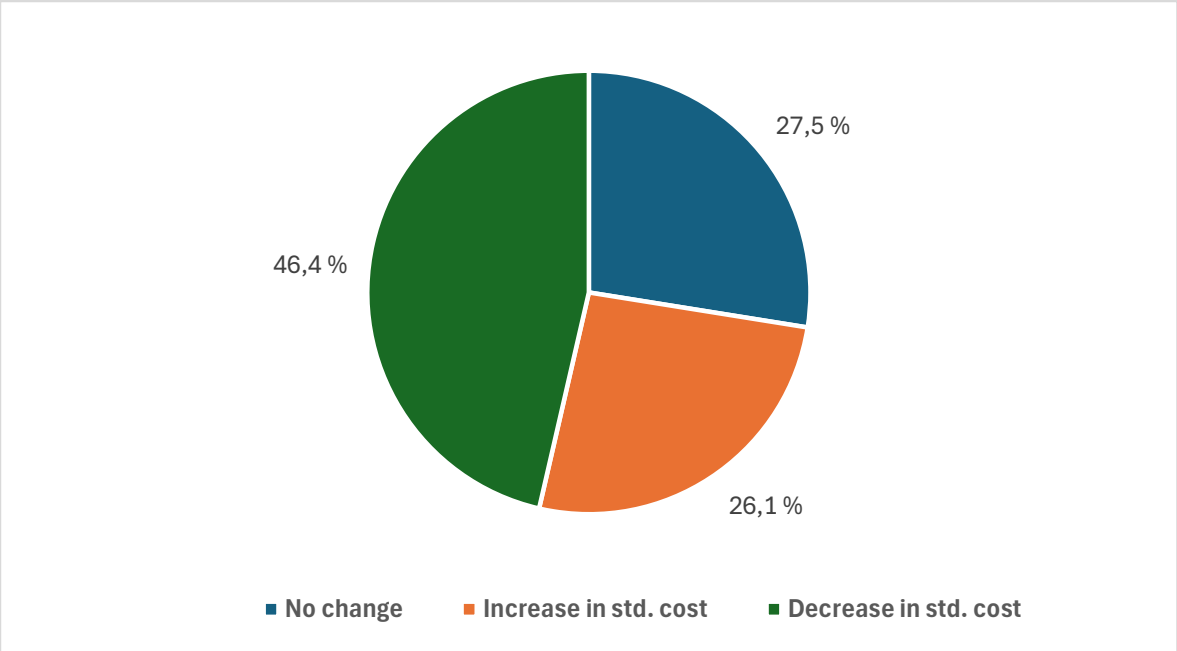


Figure 16. The impact to FG items.

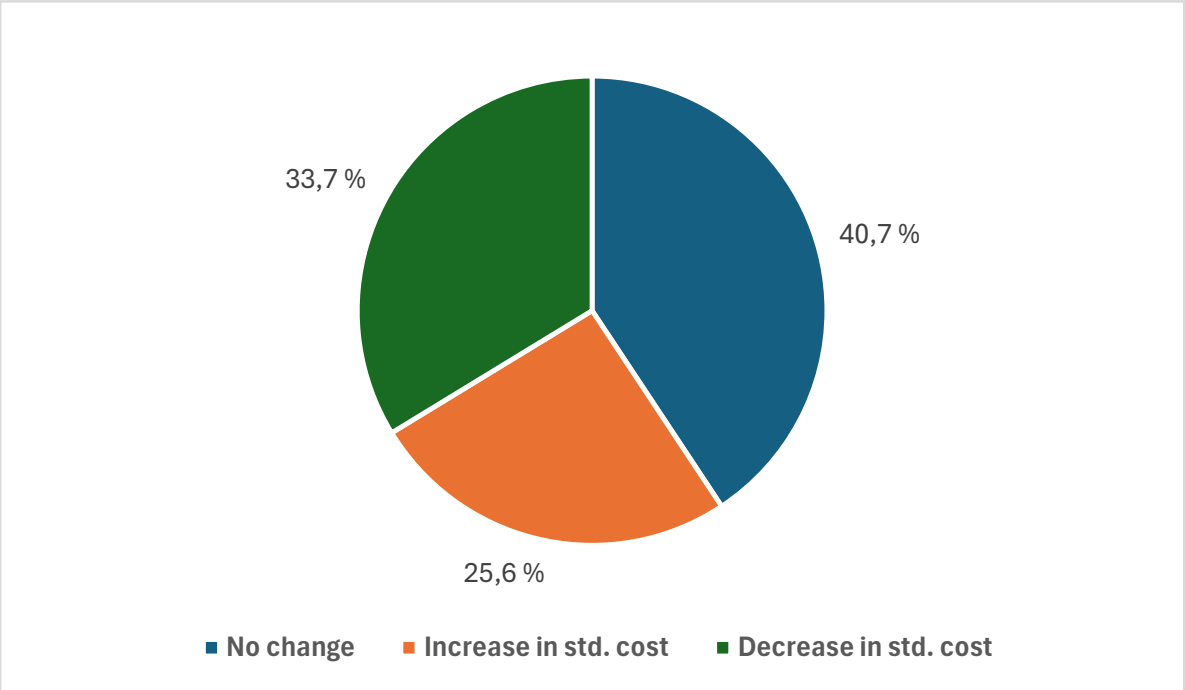


Figure 17. The impact to SFG items.

The biggest increase in std. cost (measured in Euros) was for an item with an increase of 27 % in the std. cost due to the forecast being extremely low and the new order quantity being rounded to the minimum production quantity allowed for that item. On the other hand, the biggest decrease in std. cost (measured in Euros) was 25 % for an item where the production order quantity increased from 19 THO units to 170 THO units. This specific item has an forecast of approximately 385 THO units and a setup time of 6,5 h meaning that the change in production order quantity would save 18 production runs and 117 h of setup time. The biggest increase in order quantity (measured in THO) was an increase of 200 % from 495 THO to 1482 THO. With a forecast of over 10 million pieces, the increase in order quantity would save approximately 14 production runs and 60 h of setup time. The biggest decrease in order quantity (measured in THO) was 71 % for an item where the new order quantity changed to the minimum allowed by the production parameters due to the current inventory being at a level to fulfil the sales forecast.

4.2 The financial impact

The recalculation of the std. costs had a direct impact on the profitability of each item and therefore the whole company. The profitability can be analysed utilizing historical sales data as well as sales forecasts to analyse the effect of recalculating each item's std. cost. Based on the historical sales volume and assuming other factors such as freight remain the same, the new std. costs would have given a better sales profit for 54 % of the sales products, a worse profit for 24 % of items, and no change on profit for 22 % of the items. The change is between -5 % and 5 % for most of the items with only a few exceptions. The biggest increase for a single item in profit being approximately 26 % and the biggest decrease for a single item in profit being almost 69 %. In total, 1 % of the sold items would change from profitable to unprofitable due to the change in std. cost. On the other hand, 3 % of the sold items would become profitable if they were to be produced with the calculated std. costs. The change in profit is demonstrated in Figure 18 where the items are classified based on the impact to the items profit.

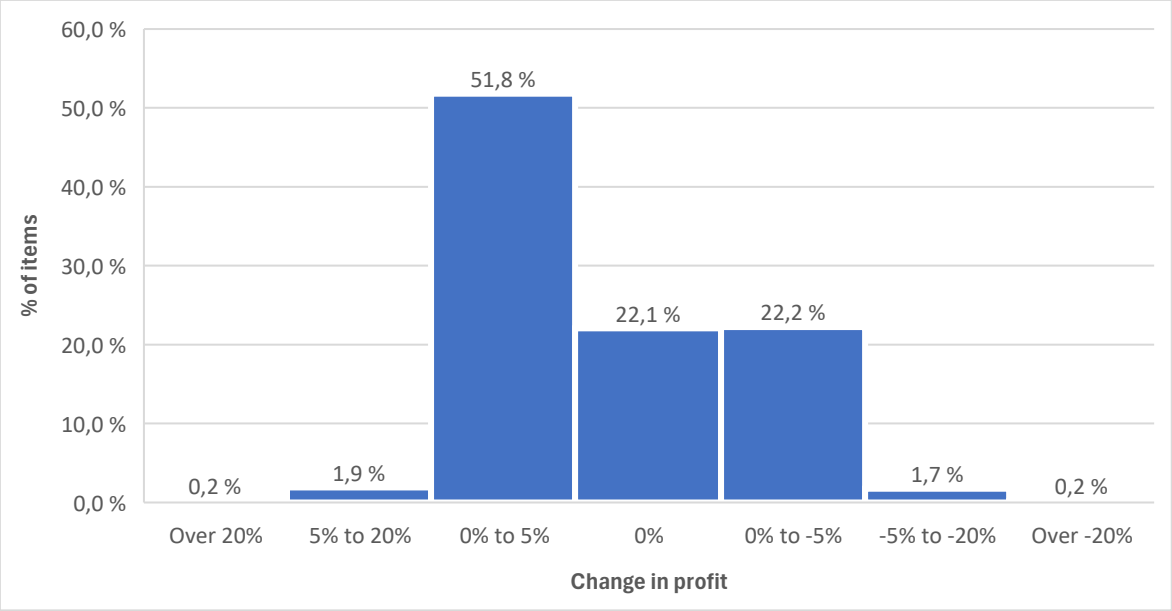


Figure 18. The change in profit on an item level.

The total profit for the whole company would have been approximately 3 % higher if the newly calculated standard costs were used instead of the budgeted std. costs. However, analysing historical data might not give an accurate measurement as the new order quantities are calculated with forecasted data. Therefore, the better comparison is to utilize the sales forecast. The comparison of the current std. costs and the calculated std. costs is showcased in Figure 19.

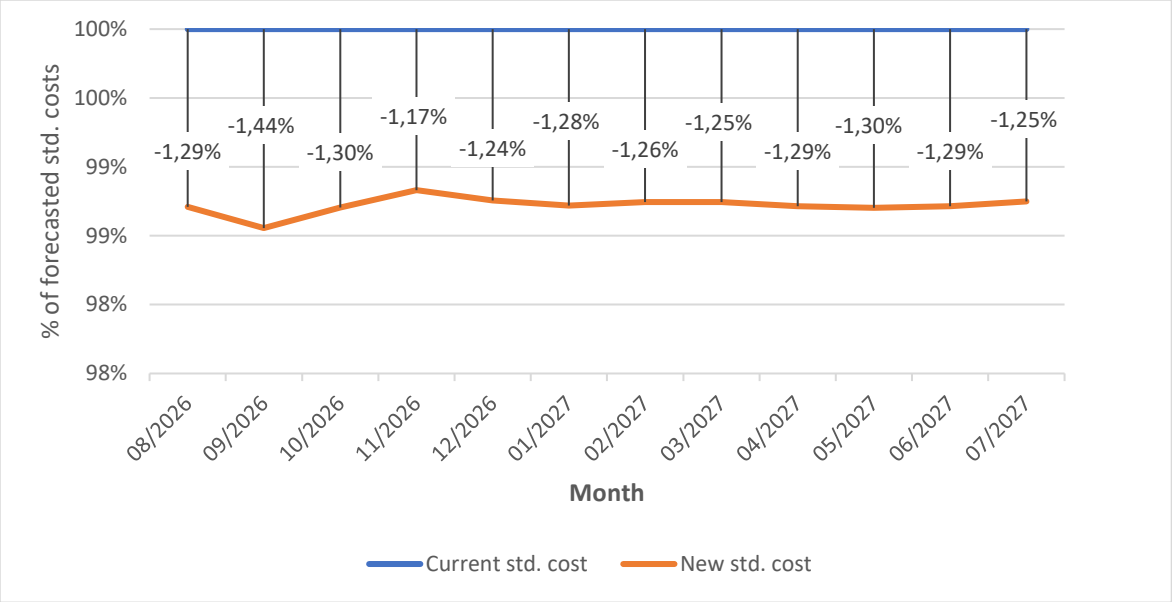


Figure 19. Comparison of current and calculated std. costs with forecasted volume.

In Figure 19, the current std. cost represents the forecasted costs when supplying the exact forecasted demand with the current std. costs of items. The new std. cost line matches the demand with the std. costs calculated in the model with the total possible monthly savings highlighted as the difference between the lines. On average, 1,3 % of the total cost of goods sold (COGS) could be saved with the new production order quantities according to the standards.

The international accounting standards or IAS2 allows companies to use costing techniques such as standard costing to valuate inventory as long as the technique approximates cost. Inventory is then measured at normal level of output and efficiency using the predetermined rates for labour, overhead costs, and material. (Boissou & Kumah 2026) Therefore, if the case company is to utilize the standard costing method in valuating of inventory, the recalculation also has an affect on the total inventory value. With the current inventory balance, the recalculation of std. cost would decrease the inventory value of FG items by approximately 0,2 %. On the other hand, the new std. costs would increase the inventory value of SFG item by approximately 2,3 %. The total impact to the current inventory would be only 0,03 % as the decrease in FG value would cancel out the increase in SFG value making the total impact almost negligible.

The overall increase in production order quantities does have an affect on the CCC of the company. Using the formula 13 with the following assumptions, the influence of recalculating the order quantities can be simulated to the focal company's DIO: the demand is assumed to be constant and the production order finished at once precisely when the inventory quantity hits zero. The average change in DIO for the biggest volume items is approximately an increase of 2 days meaning that capital would be tied to inventory a slightly longer amount of time with the calculated order quantities.

4.3 The operational impact

Recalculating the std. costs does not have a direct impact on the company's operations and operational performance. However, the calculated order quantities should guide production planning towards a more cost efficient production planning. Based on historical production data, the current standard production order quantities have not been properly utilized with only approximately 15 % of production orders in 2026 being according to the standard. 45 % of the production orders have been lower in quantity than in the standards. On the other hand, 40 % of the production orders where above the standard. Based on the std. costing structure of the company, the production orders with a quantity below the standard order quantity lead to negative cost variances as the setup costs are allocated to fewer items for the order.

The operational impact of recalculated std. costs can be done utilizing the sales forecast. To match the forecasted sales demand, the order quantity has a marginal impact on the amount of production runs and setup time required. The comparison between currently active order quantities and calculated new order quantities in relation to the total production need is illustrated in Table 3.

Table 3. Comparison of current and calculated order quantities.

		FG	SFG
Current order quantity	Total production runs required	4427	340
	Total setup time required (h)	9091	1844
Calculated order quantity	Total production runs required	2947	207
	Total setup time required (h)	5653	1069
Difference in production runs		**- 1 480 (- 33%)**	**- 133 (-39 %)**
Difference in setup time (h)		**- 3 438 (-38 %)**	**- 775 (- 42%)**

The recalculation of production order quantities could save up 38 % of setup time for FG items and up to 42 % of setup time for SFG items. Additionally, the change in order quantities would decrease the amount of production runs required by 33 % for FG items and 39 % for SFG items. For FG items, the maximum decrease was 42 production runs and 132 h in setup time while the biggest increase was 8 production runs and 14 h in setup time. For SFG items, the maximum decrease in setup time was 89 h with 17 production runs saved. The highest increase for SFG items was only 2 production runs and 10 h in setup time. Overall, the calculated std. costs drive toward longer production runs.

4.4 The risk factors of the results

The biggest risk factor related to the utilization of the analysis and the created model is the accuracy and reliability of the sales forecast. In this thesis, the forecast was assumed to be 100 % accurate and complete. However if this is not the case, the calculated production order quantities would be misleading and therefore the calculated std. costs would not be accurate and would not approximate costs. The analysis also showcased that the forecast data had some false item numbers which were deactivated in the company's ERP system meaning that they should not be produced anymore and therefore could not have sales any more. The count of these item numbers was marginally small and could therefore be ignored in this thesis. The forecast is also assumed to be constant in the calculation model which may create supply challenges if there is no safety stock or no fixed safety lead times, especially if there is sudden demand spikes.

Another major risk is related to the update of the production order quantities and especially the increase in order quantities. The increase in production order quantities decreases the flexibility of production planning because the production runs are longer and the number of stops is smaller. Any sudden changes in production can therefore be more challenging to implement without creating large variances. The historical production data has also showcased that the current standard production order quantities have not been fully utilized with majority of production order quantities being below the standard production order quantity.

The yearly update in standard costing also poses a risk to the analysis. The model utilizes the active cost drivers to calculate the std. costs. The currently active std. costs have approximated the actual costs precisely as can be seen in Figure 20. With only approximately 1 % difference in the total estimate from std. costs and actual costs, the update in the middle of the year might increase the variance between the estimated std. cost and actual cost making planning and decision making more challenging, for example cash flow estimates.

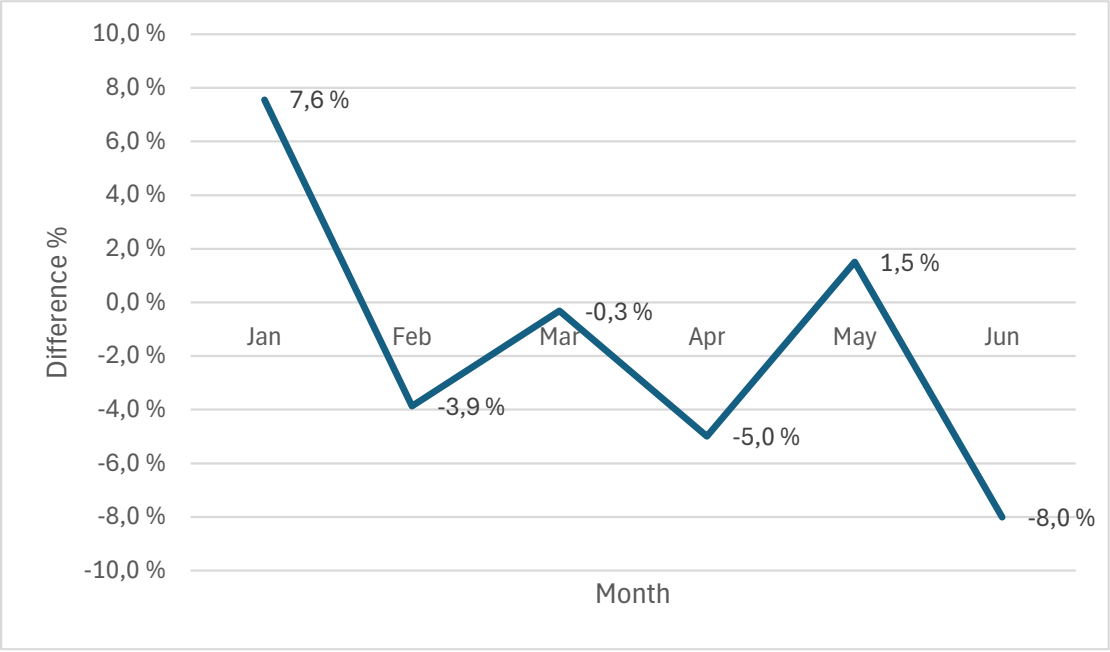


Figure 20. Difference between current std. cost and actual costs.

With the update of cost drivers and the possible update in labour rates, overhead costs, and warehouse costs, the previously calculated production order quantities might become invalid after the change in std. costs. The production planning department might therefore have to

update the production plan with short notice and the already planned production run might need to be replanned. The setup cost is also dependent on the required setup time which is updated once a year together with the std. cost update. Therefore, any improvements to the actual setup and the required setup time will be delayed until the next std. cost update which might affect production planning slightly.

The financial impact of recalculating the std. costs was mitigable to the current inventory. However, due to a majority of item having an updated std. cost, the value of the inventory could increase or decrease. Additionally with the calculated increase in DIO, the effect to the company's CCC could propose a risk if the effect is not monitored. The production order quantity calculation also included assumptions which are unrealistic in real-life situations, such as infinite inventory space and no capacity constraints on machines.

5 Conclusions

Research methodologically the empirical section of this thesis was a combination of a case study and DSR. The empirical part of this thesis was conducted by creating an artifact which was used for modelling and simulating and applying the artifact to a case company operating in the food packaging industry. The artifact was built using Python where data from multiple SQL databases was combines and handled. The results from the model are then exported into a single Excel file which is named based on the date of the simulation. The artifact was based on the findings of the literature review about standard costing and optimal production order quantity calculations. The artifact was then used to answer the final research question.

What is the impact of demand volume changes on standard costs?

Normal standards should be updated only once or twice a year for them to be comparable to the actual production efficiency and used in variance analysis. The labour costs in standard costs are calculated using labour rates which are also updated with the standards. Therefore it was determined that a deterministic static demand model was best suited to be used alongside standard costing method as the analysis should not be performed excessively to retain the main purposes of standard costing. With deterministic dynamic demand models, the simulation would required constant updating which could make the standards not comparable with continuous changes to them.

To assess the total impact of demand volume to the standard costs, a simulation was performed to a multi-level system. The simulation was performed using the case company's data to all active FG and SFG items. As the sales forecast only included the forecasted volume for FG items, the BOM was used to determine the forecasted volume for SFG items. The order quantity was calculated for the SFG items first, as the impact of the SFG cost change could directly affect the FG items' standard cost. After the calculation of the FG items, the results of the simulation were analysed from an overall perspective, a financial perspective, and an operational perspective.

The overall results showcased almost 75 % of FG and 60 % of SFG items were effected by the change in demand volume. The change in calculated production order quantity was between -71 % and 200 % compared to the production order quantity in the current standards.

For majority of the FG items, the current standard production order quantity was lower than the calculated. However, the operational analysis found that majority of the produced production orders have been under the standard quantity. Comparison of the current standard production order quantity and the calculated order quantity showed that the calculated order quantities could possibly save up to 4200 h of setup time and up to 1600 production runs. The calculation was based on the next 12 months forecasted sales assuming that the produced quantity would all be sold and no safety stock acquired. The addition of safety stock or safety lead times could add some flexibility to the production planning which was slightly affected by the increase in order quantities and decrease in production runs.

The financial perspective of the analysis found that the increase in production order quantity could have a positive impact on the total profit of the company. Based on the historical sales data, the calculated standard costs would have given increased the sales profit approximately 3 %. The change in standard cost would increase the profit for majority of the sold items with the impact being between 0 % and 5 %. For the next 12 months, the calculated standard could save approximately 1,3 % monthly compared to the current standard costs. The financial impact would also be to the inventory value of the company. The change to the current inventory value would be very minor but the days inventory outstanding for the biggest volume items would increase slightly. The increase in DIO could have an effect on the future inventory value as well as the cash conversion cycle of the company. Additionally with the increase in order quantities, the risk of obsolescence would increase.

5.1 Suggestion for the case company

Based on the overall results, implementing the created artifact could be beneficial to the case company. Based on the forecasted financial benefits, the potential for monthly cost savings could improve the overall profitability of the company. In addition, the potential to save a marginal amount of setup time for other operational tasks could improve the production efficiency as well as reduce the stress to the production machines caused by constant setups and small production runs. Even though the update in standard costs should remain at the current cycle, the simulated update can provide more accurate information for finance and production planning to guide towards positive variances which could then be taken into account in the next standard costing update.

It should also be noted that the analysis is based on standard costs, not actual costs. Therefore the results are guiding and not absolute. The created model also relies on the accuracy and reliability of the sales forecast data, BOM data, and made assumptions related to the order quantity calculations. For example, no capacity constraints were included in the model, the inventory space is assumed to infinite, and the setups are considered to be sequence-independent with the setup time always being according to the standard setup time. The setup time could therefore be optimized if there is a possibility of sequence-dependency. The calculated order quantities should also be validated together with the sales forecast. It is suggested that the simulation is only run a limited number of times in a year, for example once a quarter or after the first 6 months of the year to avoid each production run being different quantity which makes the variance reason hard to properly analyse. The model could also be utilized on a monthly basis to identify the items with the biggest change in the production order quantity and therefore the biggest potential for savings.

5.2 Future research possibilities

The future research possibilities and development areas are directly related to the created model. For the purpose of this thesis, the model worked well and the results were easy to analyse. However, the model is still a Python code without a proper user interface which is not the optimal format for sharing the model. Future research should also focus on reducing the possible risks related to the use of the model. Most important feature is to access the accuracy of the sales forecast and developing the model to include different risk scenarios. The forecasting system is still quite new which may explain some inconsistencies found in the data but fixing the inconsistencies and building validation procedures should be a high priority as the sales forecast could be useful to almost every function in the organization. Additionally, building resource constrains and inventory restrictions could further improve the results and accuracy of the total impact of demand forecast to the standard cost of items. The possibility of saving setup time from setup sequence-dependency should also be studied and analysed.

References

Agarwal, S. 2014. Economic order quantity model: A review. International Journal of Mechanical, Civil, Automobile and Production Engineering. Vol. 4. No. 12 pp. 233-236.

Al-Dabbas, M, A, A. 2021. In a Jordanian industrial factory, inventory procedures were enhanced: a case of study. Journal of Mechanical Engineering Research and Development. Vol. 44. No. 8 pp. 78-100.

Allahverdi, A. & Soroush, H, M. 2008. The significance of reducing setup times/setup costs. European Journal of Operational Research. Vol. 187. No. 3 pp. 978-984. DOI: https://doi.org/10.1016/j.ejor.2006.09.010

Aromataris, E. & Pearson, A. 2014. The Systematic Review: An Overview. The Joanna Briggs institute: systematic reviews. Vol. 114. No. 3.

Azets. 2025. IFRS or FAS – Which financial reporting to choose when operating in Finland?. [Web article]. [Referred to 17.3.2026]. Available at: https://www.azets.com/en-fi/insights/blog/ifrs-or-fas

Badem, A, C., Ergin, E. & Drudy, C. Is Standard Costing Still Used? Evidence from Turkish Automotive Industry. International Business Research. Vol. 6. No. 7 pp. 79-90. DOI: https://doi.org/10.5539/ibr.v6n7p79

Banerjee, B. 2021. Cost accounting – theory and practice. 14th edition. Delhi: PHI Learning Private Limited.

Benslimane, I. & Benjelloun, S. 2025. Target costing: what do we know, and what do we still need to know?. Contemporary Research Analysis Journal. Vol. 2. No. 1 pp. 55-68. DOI: https://doi.org/10.55677/CRAJ/08-2025-Vol02I01

Bhattacharya, R. & Bhattacharyya, A, M. 2022. Supply Chain Analytics: Strategies, Models and Solutions. Los Angeles: SAGE.

Bhimani, A., Horngren, C, T., Datar, S, M. & Rajan, M, V. 2012. Management and cost accounting. 5th edition. Harlow: Financial Times Prentice Hall.

Bian, Y., Lemoine, D., Yeung, T, G., Bostel, N., Hovelaque, V. & Viviani, J. 2021. An EOQ-Based Lot Sizing Model with Working Capital Requirements Financing Cost. APMS 2021: IFIP International Conference on Advances in Production Management Systems, Sep 2021, Nantes, France. pp.159-166

Biela-Weyenberg, A. 2023. Planning and Forecasting Using Predictive Planning. Oracle. [Web article]. [Referred to: 9.7.2026]. Available at: https://www.oracle.com/erp/predictive-planning-forecasting/

Boissou, V. & Kumah, P. 2026. Inventory accounting: IFRS® Accounting Standards vs US GAAP. [Web article]. [Referred to 29.7.2026]. Available at: https://kpmg.com/us/en/articles/2026/inventory-accounting-ifrs-accounting-standards-vs-us-gaap.html

Brocke, J, V., Hevner, A. & Maedche, A. 2020. Introduction to Design Science Research. Cham: Springer Nature Switzerland AG.

Bründl, P., Stoidner, M., Nguyen, H, G., Baechler, A: & Franke, J. 2023. Challenges and Opportunities of Software-Based Production Planning and Control for Engineer-to-Order Manufacturing. IFIP Advances in Information and Communication Technology. Vol. 691. Pp. 67-79. DOI: https://doi.org/10.1007/978-3-031-43670-3_5

Burtseva, L. 2022. Production planning and scheduling for lot processing. Newcastle upon Tyne: Cambridge Scholars Publishing.

Chapman, S, N. 2006. The fundamental of production planning and control. New Jersey: Pearson Prentice Hall.

Chopra, R., Sawant, L., Kodi, D. & Terkar, R. 2022. Utilization of ERP systems in manufacturing industry for productivity improvement. Materials Today: Proceedings. Vol. 62. No. 2 pp 1238-1245. DOI: https://doi.org/10.1016/j.matpr.2022.04.529

Dosch, J. & Wilson, J. 2010. Process Costing and Management Accounting in Today's Business Environment. Strategic Finance. Vol. 92. No. 2 pp. 37-43.

Ekbatani, M, A. & Sangeladji, M, A. 2008. Traditional Vs. Contemporary Managerial/Cost Accounting Techniques Differences Between Opinions of Educators and Practitioners. International Business & Economics Research Journal. Vol. 7. No 1 pp. 93-112. DOI: https://doi.org/10.19030/iber.v7i1.3213

Erol. S. & Sihn, W. 2017. Intelligent production planning and control in the cloud – towards a scalable software architecture. 10th CIRP Conference on Intelligent Computation in Manufacturing Engineering - CIRP ICME '16. Procedia CIRP. Vol. 63. Pp. 571-576. DOI: https://doi.org/10.1016/j.procir.2017.01.003

EY. 2026. US GAAP versus IFRS Accounting Standards. [Web article]. [Referred to 17.3.2026]. Available at: https://www.ey.com/content/dam/ey-unified-site/ey-com/en-us/technical/accountinglink/documents/ey-ifrs29540-261us-01-21-2026.pdf

Friedl, G., Hammer, C., Pedell, B. & Küpper, H. 2009. How do German Companies Run Their Cost Accounting Systems?. Management accounting quarterly. Vol. 10. No 2 pp. 38-52.

Fritzson, P, A. 2011: Introduction to modelling and simulation of technical and physical systems with Modelica. Hoboken, New Jersey: A John Wiley & Sons, Inc.

Fye, S, R., Charbonneau, S, M., Hay, J, W. & Mullins, C, A. An examination of factors affecting accuracy in technology forecasts. Technological Forecasting and Social Change. Vol. 80. No. 6 pp.1222-1231. DOI: https://doi.org/10.1016/j.techfore.2012.10.026

Gurtu, A. 2021. Optimization of Inventory Holding Cost Due to Price, Weight, and Volume of Items. Journal of Risk and Financial Management. Vol. 15. No. 2. DOI: https://doi.org/10.3390/jrfm14020065

Heale, R. & Twycross, A. 2018. What is a case study?. Evidence-based nursing. Vol. 21. No. 1 pp. 7-8. DOI: https://doi.org/10.1136/eb-2017-102845

Horngren, C, T., Datar, S, M. & Rajan, M, V. 2015. Cost accounting: An Managerial Emphasis, 15th edition. Harlow: Pearson.

Hung, T, C. & Shanmugam, J, K. 2023. The Relevance of Standard Costing and Variance Analysis in Global Industries Today. East Asian Journal of Multidisciplinary Research (EAJMR). Vol. 2. No. 2 pp.525-542. DOI: https://doi.org/10.55927/eajmr.v2i2.2840

J.P.Morgan. 2025. Your cash conversion cycle – what it is and how to optimize it. [Web article]. [Referred to: 31.7.2026]. Available at: https://www.jpmorgan.com/insights/treasury/receivables/understanding-and-optimizing-your-cash-conversion-cycle

Khan, A. 2022. Cost and optimization in government: an introduction to cost accounting, operations management, and quality control. 3rd edition. New York: Routledge.

Kinney, M, R. & Raiborn, C, A. 2009. Cost Accounting : foundations and evolutions. 7th edition. Mason: Thomson/South-Western.

Kiran, D. R. 2019. Production Planning and Control : A comprehensive approach. Oxford: Butterworth-Heinemann.

Lim, L, T., Auras, R. & Rubino, M. 2008. Processing technologies for poly(lactic acid). Progress in Polymer Science. Vol. 33. No. 8 pp. 820-852. DOI: https://doi.org/10.1016/j.progpolymsci.2008.05.004

Lind, L., Pirttilä, M., Viskari, S., Schupp, F. & Kärri, T. 2012. Working capital management in the automotive industry: Financial value chain analysis. Journal of Purchasing & Supply Management. Vol. 18. No. 2 pp. 92-100. DOI: https://doi.org/10.1016/j.pursup.2012.04.003

Logistiikan maailma. 2025. Tuotantomuodot: tilauksen kohdennuspiste (OPP). [Web page]. [Referred to 10.4.2026]. Available at: https://www.logistiikanmaailma.fi/tuotanto/tilauksen-kohdennuspiste-opp/

Luo, D., Thevenin, S. & Dolgui, A. 2022. A state-of-the-art production planning in Industry 4.0. International Journal of Production Research. Vol. 61. No. 19 pp. 6602-6632. DOI: https://doi.org/10.1080/00207543.2022.2122622

Marie, A., Cheffi, W., Louis, R, J. & Rao, A. 2010. Is Standard Costing Still Relevant? Evidence from Dubai. Management accounting quarterly. Vol. 11. No. 2.

McKay, K, N. & Black, G, W. 2007. The evolution of a production planning system: A 10-year case study. Computers in Industry. Vol. 58. No. 8-9 pp. 756-771. DOI: https://doi.org/10.1016/j.compind.2007.02.002

Milojevic, M., Barjaktarovic, L. & Milosev, Z. 2015. Variance analysis in manufacturing companies. Finiz 2015 – Contemporary financial management. Pp. 102-110. DOI: https://doi.org/10.15308/finiz-2015-102-110

Nobanee, H. & Al Hajjar, M. 2014. An Optimal Cash Conversion Cycle. International Research Journal of Finance and Economics. Vol. 120. Pp. 13-22.

Oh, J. 2023. A Problem with Standard Costs. The Association for Financial Professionals. [Web article]. [Referred to 20.4.2026]. Available at: https://www.financialprofessionals.org/training-resources/resources/articles/details/a-problem-with-standard-costs

Ordynskaya, M, E., Silina, T, A., Divina, L, E., Tausova, I, F. & Bagova, S, A. 2021. Functions of Cost Management Systems in Modern Organizational Management. Universal Journal of Accounting and Finance. Vol. 9. No. 3 pp. 498-505. DOI: https://doi.org/10.13189/UJAF.2021.090324

Peeters, K. & van Ooijen, H. 2020. Hybrid make-to-stock and make-to-order systems: a taxonomic review. International Journal of Production Research. Vol. 52. No. 15 pp. 4659-4688. DOI: https://doi.org/10.1080/00207543.2020.1778204

Quesado, P. & Silva, R. 2021. Activity-Based Costing (ABC) and Its Implication for Open Innovation. Journal of Open Innovation: Technology, Market, and Complexity. Vol. 7. No. 1. DOI: https://doi.org/10.3390/joitmc7010041

Rauwendaal, C., Gramann, P, J., Davis, B, A. & Osswald, T, A. 2014. Polymer extrusion. 5th edition. Munich: Hanser Publishers.

Renna, P. 2024. Comparison of Dynamic Decoupling Point and Dynamic Buffer Level for Flexible Flow Shops in a Hybrid MTS-MTO Production Model. Applied Sciences. Vol. 14. No. 17. DOI: https://doi.org/10.3390/app14177975

Rey-Ares, L., Fernández-López, S. & Rodeiro-Pazos, D. 2021. Impact of working capital management on profitability for Spanish fish canning companies. Marine Policy. Vol. 130. DOI: https://doi.org/10.1016/j.marpol.2021.104583

Robinson, P., Narayanan, A. & Sahin, F. 2009. Coordinated deterministic dynamic demand lot-sizing problem: A review of models and algorithms. Omega. Vol. 37. No. 1 pp. 3-15. DOI: https://doi.org/10.1016/j.omega.2006.11.004

Said, B, A., Shahzad, M, K., Zamai, E., Hubac, S. & Tollenaere, M. 2016. Experts' knowledge renewal and maintenance actions effectiveness in high-mix low-volume industries, using Bayesian approach. Cognition, Technology & Work. Vol. 18. Pp. 193-213. DOI: https://doi.org/10.1007/s10111-015-0354-y

Samak-Kulkarni, M. & Rajhans, N, R. 2013. Determination of Optimum Inventory Model for Minimizing Total Inventory Cost. Procedia Engineering. Vol. 51. Pp. 803-809. DOI: https://doi.org/10.1016/j.proeng.2013.01.115

Sani, A, A. & Allahverdizadeh, M. 2012. Target and Kaizen costing. International Journal of Mechanical and Industrial Engineering. Vol. 6. No. 2 pp. 171-177.

SAP. 2026. SAP Integrated Business Planning – Demand Planning. [Web page]. [Referred to 22.5.2026]. Available at: https://www.sap.com/products/scm/integrated-business-planning/features/demand-planning.html

Segerstedt, A., Abdul-Jalbar, B. & Samuelsson, B. 2023. Reformulated Silver-Meal and Similar Lot Sizing Techniques. Axioms. Vol. 12. No. 7. DOI: https://doi.org/10.3390/axioms12070661

Singh, Y. & Disney, S, M. 2026. On the transition from make-to-stock to make-to-order. European Journal of Operational Research. Vol. 330. No. 2 pp. 444-457. DOI: https://doi.org/10.1016/j.ejor.2025.08.053

Stack overflow. 2025. 2025 Developer Survey. [Web page]. [Referred to 8.5.2026]. Available at: https://survey.stackoverflow.co/2025/

Stüve, D., Van der Meer, R., Agha, M, S, A. & Entrup, M, L. 2022. A systematic literature review of modelling approaches and implementation of enabling software for supply chain planning in the food industry. Production & Manufacturing Research. Vol. 10. No. 1 pp. 470-493. DOI: https://doi.org/10.1080/21693277.2022.2091057

Tashakori, L. & Arabsorkhi, A. 2015. A Survey on Marketing Characteristics and Production System Startegies-Case Study: Cans production. International Journal of Engineering Research. Vol. 4. No. 9 pp. 510-517.

Tayles, M. & Drudy, C. 2024. Management and cost accounting. 12th edition. Andover: Cengage Learning, EMEA

Tayo, A, G. & Ojo, O, J. 2023. The Impact Of Standard Costing On The Financial Performance Of Listed Consumable Goods Companies In Nigeria. Fuoye Journal of Accounting and Management. Vol. 6. No. 1 pp. 30-49.

Tristancho, C. 2024. What is a Bill of Materials? (Example & Template included). [Web article]. [Referred to 24.3.2026]. Available at: https://www.projectmanager.com/blog/bill-of-materials

Uyar, A. 2009. The Relationship of Cash Conversion Cycle with Firm Size and Profitability: An Empirical Investigation in Turkey. International Research Journal of Finance and Economics. Vol. 24. Pp. 186-193.

Van Kampen, T, J., van Donk, D, P. & van der Zee, D-J. 2010. Safety stock or safety lead time: coping with unreliability in demand and supply. International Journal of Production Research. Vol. 48. No. 24 pp. 7463-7481. DOI: https://doi.org/10.1080/00207540903348346

Wang, B. 2019. The cash conversion cycle spread. Journal of Financial Economics. Vol. 133. No. 2 pp. 472-497. DOI: https://doi.org/10.1016/j.jfineco.2019.02.008

W3Schools. 2026. Python Introduction. [Web page]. [Referred to 4.5.2026]. Available at: https://www.w3schools.com/python/python_intro.asp