Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Engineering
Department of Mechanical and Industrial Engineering

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Application of a Simplified Variant of the Systematic Layout Planning Procedure: A Case Study in the Beverage Industry

Master's thesis in Global Manufacturing Management
Supervisor: Marco Semini and Swapnil Bhalla
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Preface

I want to thank my supervisor Marco Semini and co-supervisor Swapnil Bhalla, for their continuous support, patience, and willingness to help me along the way. During the master thesis, I was able to see how lucky I am to have men of such high caliber by my side. Without the guidance of my supervisor, I would still be struggling with understanding the challenge, explaining my findings, and shaping the thesis in easy to fathom way, for which I am eternally grateful!

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I am also very grateful to all of the Ph.D. students and my office comrades Ali Akbari, Abhilash Ramanathapuram, Ham George Varghese, for their remarkable and helpful input during my work. It was a pleasure and an honor to share the experience of the challenge presented in writing the master thesis with them.

A big thanks to Jan Ola Strandhagen, Fabio Sgarbosa, and Anita Romsdal for their critical and constructive feedback helping shape the project during the presentations.

Last but not least, I would like to express my gratitude toward my family, which I love so very much. I thank them for their support and my father, Aleksandar Traykov Georgiev, for being a pillar of strength, inspiration, and an example of what an engineer and a man of world-class is!

Happy reading!

Warm regards,
Velin Aleksandrov Georgiev

Trondheim 10.06.2020

Summary

An actual industrial need stated by Snåsavann AS to analyze and suggest an improvement to their manufacturing facility layout inspired this master thesis. The method picked for satisfying that need was a systematic scientific literature study aimed at providing insight on what methods are currently existing for that particular need. The literature study clarified that based on the size, workforce, and turnover, the case company classifies as a small to medium-sized enterprise (SME). That further reduced the scope of the literature study, pinpointing that for those cases, the application of systematic layout planning (SLP) broadly takes place. However, due to the limited financial capabilities of SMEs, the procedural methods, which SLP is part of, are often time-consuming. The literature study showed that a simplification of the SLP exists, but only documented in one scientific paper.

Goal alignment took place between company needs and discovery of a gap in the literature leading to the pursuit of documentation of the simplified SLP. The overall research objective of this master thesis was to assess and document the applicability of the simplifies SLP by analyzing and suggesting an improved manufacturing facility layout of the case company. For the fulfillment of that objective, the creation of three research tasks (RT) takes place. The first one mapped the case company using a framework examining the product, market and manufacturing process-related variables and values profiling the company. Further, in-depth mapping took place during the actual application of the simplified SLP. The second task involved the full application of the simplified SLP in combination with three scenarios of an increase in customer demand (conservative, realistic, and optimistic) provided by the company. It resulted in three different layouts. Task three discussed the applicability of the simplified SLP to the case company and devised reasonable generalization for the food and beverage industry. It highlighted the importance of an efficient and easy to apply method for SMEs and not requiring special skills or tools.

Since the original and single scientifically documented application of the simplified SLP took place in a switchgear factory, some minor case company-specific modifications took place, however the integrity of the method not altered or compromised. Empirical data gathering took place in the form of open conversation and multiple factory visits. Affirmation and clarification of data were done by phone, email, and video meetings, due to the extra challenges offered by COVID19.

After presenting the findings and results of the master thesis to the case company, confirmation of the value of the analysis and holistic view offered by the method affirmed. The master thesis affirmed to be highly helpful and vital for the creation of the future expansion plans of the case company. Hidden areas of improvement were shed light on, such as reduction of process steps and creation of flow. The use of the framework was helpful and insightful for the case company in order to gain an understanding of different product characteristics and their implications on layout design.

The master thesis satisfies the research objective and tasks and adds to the existing literature on the applicability of a simplified variant of the systematic layout planning.

Sammendrag

Et industrielt behov som Snåsavann AS har for å forbedre deres produksjonsanlegg inspirerte denne masteroppgaven. Metoden som ble valgt er en systematisk vitenskapelig litteraturstudie som har som mål å gi innsikt i hvilke metoder som eksisterer for å tilfredsstille dette behovet. Litteraturstudien belyste at basert på størrelse, antall ansatte og omsetning klassifiserte casebedriften som en liten til mellomstor bedrift (SME). Dette reduserte litteraturstudiens omfang ytterligere, og påpekte at systematisk layout planlegging (SLP) er stort sett brukt for SME. På grunn av de begrensede økonomiske mulighetene til små og mellomstore bedrifter, er prosedyremetodene, som SLP er en del av, ofte tidkrevende. Litteraturstudien viste at en forenkling av SLP eksisterer, men bare dokumentert i en vitenskapelig artikkel.

Det overordnede forskningsmålet for denne masteroppgaven var å vurdere og dokumentere anvendbarheten til det forenklete SLP ved å analysere og foreslå en forbedret design av produksjonsanlegget til casebedriften. For å oppfylle dette målet, opprettes tre forskningsoppgaver (RT). Den første kartla casebedriften ved å bruke et rammeverk som undersøker produkt-, markeds- og produksjonsprosessrelaterte variabler og verdier som profilerer selskapet. Videre skjedde en grundig kartlegging under selve anvendelsen av den forenklede SLP. Den andre oppgaven innebar fullstendig anvendelse av den forenklede SLP-en i kombinasjon med tre scenarier for økning av etterspørselen (konservativt, realistisk og optimistisk) laget av selskapet. Det resulterte i tre forskjellige layout. Oppgave tre diskuterte anvendeligheten av den forenklede SLP for casebedriften og utarbeidet rimelig generalisering for mat- og drikkeindustrien. Den fremhevet viktigheten av en effektiv og enkel anvendbar metode for små og mellomstore bedrifter som ikke krever spesielle ferdigheter eller verktøy.

Siden den eneste vitenskapelig dokumenterte bruken av den forenklede SLP fant sted i en fabrikk for bryterutstyr, ble det gjort noen forandringer, men helheten til metoden ble ikke sviktet. Empirisk datainnsamling skjedde i form av åpen samtale og flere fabrikkbesøk. Bekreftelse og avklaring av data ble gjort på telefon-, e-post- og videomøter, på grunn av de ekstra utfordringene COVID19 opprettet.

Funnene og resultatene fra masteroppgaven ble presentert casebedriften og bekreftet til å være svært nyttig og avgjørende for å lage fremtidige utvidelsesplaner for casebedriften. Skjulte forbedringsområder ble belyst, som for eksempel reduksjon av prosesstrinn og opprettelse av flyt. Bruken av rammeverket var nyttig og innsiktsfull for casebedriften for å få en forståelse av forskjellige produktegenskaper og betydning i produksjonsanlegget.

Masteroppgaven tilfredsstiller forskningsmålet og er et supplement til den eksisterende litteraturen om anvendeligheten av en forenklet variant av den systematiske planleggingen.

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List of Abbreviations

GMM – Global Manufacturing Management
SV - Snåsavann AS
FL - Facility Layout
ML - Machine Layout
MD - Manufacturing Department
ND - Nonmanufacturing Department
HSE - Health Safety and Environment
FLP - Facility Layout Problem
SLP - Systematic Layout Planning
PET - Polyethylene Terephthalate
BPH - Bottles per Hour
SKU - Stock Keeping Unit
SME - Small and Medium-Sized Enterprise
F&B - Food and Beverage
FLD - Facility Layout Design
BOM - Bill of Material
CEO - Chief Executive Officer
CTO - Chief Technical Officer
COO - Chief Operating Officer

1. Introduction

The introduction chapter begins with a background of this master thesis and the need stated by the case company, Snåsavann AS, to analyze and suggest an improvement of its manufacturing facility layout. That led to a closer examination of the case company, reveling them as being a small to medium-sized enterprise (SME), highlighting their importance in the aspect of generating a surplus for the local area and offering work to the people. Further examination placed them in the food and beverage industry, part of the process industry. The study of the known scientific literature on the topic of manufacturing facility layout design also took place, leading to the problem description, objective, task, scope, and the scientific contribution of this master thesis. Chapter one concludes with the holistic structure of the master thesis, summarized in table 2.

1.1 Background

The case company examined in this master thesis is Snåsavann AS. Small natural mineral water bottling company, 180 km north of Trondheim, becoming known for the purity and taste of their natural mineral water as well as their world renounce glass bottle design. Snåsavann AS was found in 2009 by Mohamed Sambou, inspired by his delightful experience with the water. His vision was to share nature's gift, found in those old Sámi lands with the rest of the world (Snåsavann Homepage, n.d).

Snåsavann AS employes 12 people, and the turn-over in 2018 was around 736568 euros (Snåsavann AS Balance). Defined by EU recommendation 2003/361 in table 1, Snåsavann AS qualifies as Small and Medium-sized Enterprise (SME). Simply put, companies with staff headcount between 10 and 250, turnover between 2 and 50 million euro or with total balance sheet between 2 and 43 million euro (Commission, 20.5.2003) qualify as SMEs.

Company Category	Staff Headcount	Turnover	or Balance Sheet Total
Micro	< 10	≤ € 2 m	≤ € 2 m
Small	< 50	≤ € 10 m	≤ € 10 m
Medium-Sized	< 250	≤ € 50 m	≤ € 43 m

Table 1: Classification of SME (Commission, 20.5.2003)

A common characteristic described in literature on SME is financial limitations for research and development, promotion, marketing, and other activities. Lower market share, lower number of sales, limited workforce, and expertise is also highly prevalent (Diana-Rose and Zariyawati, 2019, Abu et al., 2017). Further on, scientific literature on SME examines and underlines their importance concerning the increase of stable, higher-quality, and more accessible employment and contributes to sustainability innovation, regional economic development, and exports (Grodach et al., 2017, Schrock et al., 2016).

Further examination of the case company places them in the process industry, which is usually characterized by high production volume, low variation, the inflexibility of the production system as well as high variability (Maalouf and Zaduminska, 2019). Processes are capital intensive, and throughput limited by equipment rather than labor. Further on production equipment is usually large, complex with additional process piping and infrastructural constraints, making it challenging to relocate. Processes are complicated to stop and restart due to their interconnectedness (Abdulmalek et al., 2006).

In the process industry, product changeovers are complicated and time-consuming because they involve system purging in addition to parts exchange (King et al., 2008). Yao and Ge argue that for the process industry to be profitable, the focus must go to the process safety and energy-saving due to tight connection with production throughput as well as production quality (Yao and Ge, 2018). Further on, a characteristic of the process industry is a fixed production routing and fixed layouts (Abdulmalek et al., 2006).

Figure 1 highlights the case companies' placement as a beverage manufacturer, and further literature study illuminated that challenges the F&B producers meet are demand fluctuation and scaling of production due to insufficient funds for purchasing of new buildings, machines, and storage facilities (Schrock et al., 2019). Scientific literature emphasized that shared characteristics of the food and beverage manufacturing are short-shelf life, complex production chain, inflexible machines. Other characteristics are buyers affect storage, processing, packaging and quality control, heterogenous raw material, strict hygienic regulations, high supply, and demand seasonality (Luning and Marcelis, 2006, Powell et al., 2017). For in-depth information regarding the companies characteristics, please refer to chapter four.

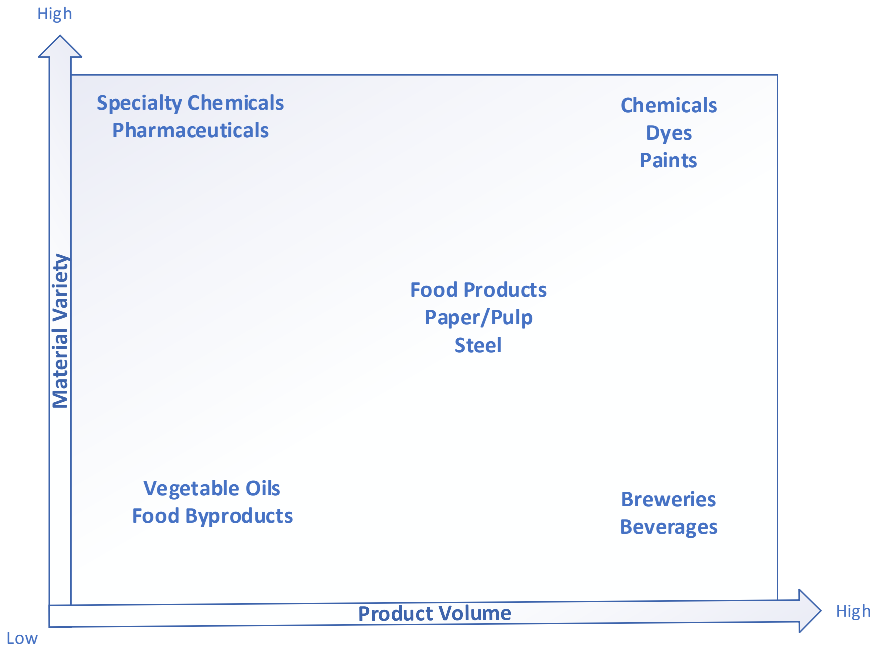

Figure 1: Examples of Process Industry (Abdulmalek et al., 2006)

Because of Snåsavanns success in the local and probable penetration of the international market, an expected increase in forecasted demand leading to an increased focus on the manufacturing facility localized. A good facility layout is capable of reducing between 10%-30% of the total operating cost by reducing the cycle time resulting in increased productivity and profitability (PN and Onyancha, 2018, Wahid and Daud, 2020). The literature on manufacturing facility layout offers two possible methods of approaching the design of new or improvement of old layouts: procedural and algorithmic/simulation approach. The SLP approach (procedural) devised by Muther is broadly applied to SME (Huallpa et al., 2019, Sa'udah et al., 2015, Goyal, 2019) and was applied recently to the layout design of hospitals, construction, furniture manufacturing, restaurants, and food industry. Recently a simplified SLP (Ali Naqvi et al., 2016) was created and applied to a switchgear plant. For in-depth information regarding the literature study on manufacturing facility layout, please refer to chapter three.

1.2 Problem Description

The case company collaborated within this master thesis was interested in analyzing and improving the manufacturing facility layout aimed at holistic efficiency and gaining space for expansion on production within the current facility. A literature study on the topic of facility design showed that this initiative classified this master thesis as a cost reduction/ retrofit project (Stevenson et al., 2007) focusing on factory facility (aka detailed layout (Tompkins et al., 2010) / aka machine department (Kay, 2009)). Further study showed extensive use of SLP in the context of SMEs, and a simplified version of the SLP devised in 2016. The scientific literature study in this master thesis highlighted the existence of a gap regarding the documented application of the simplified SLP in the F&B industry, part of the process industry. The only documented application of that procedural method found in literature is a scientific paper with a case study in a switchgear factory (Ali Naqvi et al., 2016) and a conference paper with a case study in a textile factory (Ruiz et al., 2019). Even though it follows a renowned procedural method, we do not know what it can do in the food and beverage industry and what challenges one might meet while applying it. Explanation of the process around the application of the simplified SLP would take place in the discussion. Since the original application of the method took place in switchgear manufacturing with multiple steps and processes, it suggests modifications for the case of Snåsavann AS due to the high automation in the case company.

Further, the lack of knowledge regarding if the company understands the method and thinks they can apply it on their own would be compelling to examine. If they understand the method, it could imply that SMEs can reevaluate their layouts without help from consultants. The time it took to apply the method to Snåsavann AS would be essential to examine as well. Other aspects would be how much of an improvement can the simplified SLP offer (old layout vs. new layout based on company created evaluation and performance assessment criteria). For clarity purposes, a Framework (Buer et al., 2018) would be used as a guide to give the reader a holistic view of the case company focusing on product, manufacturing, and layout perspectives. The simplified SLP method combines lean tools and performance measures of the efficiency of the layout, making the method desirable to be tested in an SME in the food and beverage industry. This master project will contribute to the literature by documenting and examining the abovementioned points.

1.3 Scope

As explained in Chapter 1.1, the industry addressed in this master project would be the process industry and specifically the food and beverage. The company examined and worked within this master thesis is an SME wishing to analyze and improve their facility layout aiming at a more efficient manufacturing facility layout as well as space for expansion on production within the current facility.

This master thesis will analyze the current factory facility (Stevenson et al., 2007) (aka detailed layout (Tompkins et al., 2010) / aka machine department (Kay, 2009)) of the case company and apply a simplified systematic layout planning procedural method. As part of the method, the demand forecast for the future will be devised and used. Since the storage facility design, size, and placement are not part of the manufacturing facility layout, an in-depth examination will not take place. They will not be looked into detail but taken into consideration regarding the holistic flow inside the factory and the creation of the future layout alternatives.

1.4 Research Objective and Tasks

The overall research objective of this master thesis is to assess and document the applicability of the simplifies SLP by analyzing and suggesting an improved manufacturing facility layout of the case company (Snåsavann AS), an SME in the food and beverage industry. In order to achieve the overall objective, the creation of three research tasks (RT) took place:

RT1: Map the case company.

Tackling of research task one will happen in the case company introduction part in chapter 4.2. By using the framework to map the company, it would make the generalization of findings easier and give the reader a holistic view of the case company. Further on, in-depth mapping focusing on manufacturing facility layout would take place during the application of the simplified SLP in steps one to four found in chapters 4.3.1-4.3.4.

RT2: Develop a new layout design for each scenario using the simplified SLP.

Research task two involves the application of all steps of the simplified SLP, in-depth examined in chapter 4.3, and will combine specific constraints for the food and beverage industry as well as existing constraints such as bearing beams and hygienic walls required in the manufacturing department. Each of the three scenarios (conservative, realistic, and optimistic demand) would lead to a new layout design. The examination of research task three takes place in chapter 4.3.7.

RT3: Discuss the applicability of the simplified SLP for Snåsavann AS. Create reasonable generalization for the SMEs in the food and beverage industry.

Research task three will be addressed in the discussion chapter and attempt to draw some reasonable generalizations regarding the application of the simplified SLP to an SME in the F&B industry. It would attempt to discuss how modifications during the application will save even more time to similar SME companies wishing to apply it since it would make the simplified SLP tailored for an SME in the F&B industry. It would discuss the degree of self-assessment the SME could get by using the method. Dedicated to the examination of task three is chapter five.

1.5 Scientific Contribution

Contribution to literature would be that there are many SMEs with limited resources. A literature study suggested that for an SME, SLP is widespread; however, If a simplified method exists, it should be used due to the financial constraints of the company. The simplified SLP devised by Ali (Ali Naqvi et al., 2016) lacks documented application in the scientific literature. This project thesis will contribute to filling that gap by applying to an SME in the food and beverage industry. It would also discuss what the research means for the case company and how the findings would benefit them.

1.6 Master Thesis Structure

Chapter	Content
Chapter One: Introduction	It includes background, problem description, research objective and tasks, scope, and a short introduction to the empirical case company. It ends with a highlight of the gap in literature found and how this master thesis would attempt filling it.
Chapter Two: Methodology	The method picked for solving the problem described in chapter one. It includes a scientific literature study on the topic of facility layout as well as information about the empirical case study. Both parts of the method are in-depth, examined in chapters three and four.
Chapter Three: Scientific Literature Study	Literature study of the latest and broadly used publications on the topic of facility layout. The chapter splits into scientific definitions used in the project, and examination of types of layouts based on their planning department. The chapter continues with information about the methods found in the literature regarding the design of manufacturing facility layout, lean principles, and the importance of evaluation and performance assessment. It continues with a summary of all information available regarding the method, which contains the gap in knowledge and all scientific publications regarding it found by the date of writing. Chapter three concludes with a summary.
Chapter Four: Empirical Case Study	The empirical case study offers a short introduction followed by a framework-based map aimed at highlighting the company's product, market, and manufacturing characteristics. Further, an in-depth application of each step of the simplified SLP follows. Step one determines the plant capacity based on the PQRST key-model (Muther and Lee, 2015) (Product, Quantity, Routing, Time, Supporting Services). Step two analyses the operations. Step three examines the material flow. Step four looks into the relationship between different departments. Step five states the spatial requirements. Step six lists the block layout alternatives. Step seven evaluates the layout alternatives based on all constraints, and the company devised evaluation and performance assessment criteria. Chapter four concludes with a summary.
Chapter Five: Discussion	Chapter five includes an examination of the applicability of the simplified SLP for the case company and the food and beverage industry. It follows the satisfaction of all research tasks and fulfills the research objective. Further, the limitation and weaknesses of both the research process and layout creation perspective of this master thesis examined in detail.
Chapter Six: Conclusion	Chapter six concludes this scientific work by reviewing the research objective, tasks, and summarizes the main results. Further, it examines the contribution to literature and industry. It ends with suggestions for further research.

Table 2: Master Thesis Structure

2. Methodology

This chapter explains the methodology chosen to address the overall objective and three tasks of this master thesis. It examines the importance of the literature study, search terms, and results. It concludes with the approach of gathering empirical data.

2.1 Scientific Literature Study

Conduction of a literature study in order to gain a broad perspective on the topic of the master thesis took place(Karlsson, 2010). The process of scientific research assisted by:

1. Studying the current state of knowledge on the chosen topic.
2. Developing the questions to be answered in the project.
3. Giving a scientific ground of the research methodology.
4. Improving research skills and critical knowledge evaluation.

The literature study helped in those aspects and led to clarification and a better understanding of the scope, leading to the search terms placed inside table 3.

Primary Search Term	Secondary Search Term
Literature study	Purpose, application, definition
Facility layout/planning	Definition, case study
Tradeoff theory	Implication, benefits
Product layout	Challenges
Bottling company	Decisions
Manufacturing facilities	Design
Beverages	Processing industry
Product layout	Definition, principles, importance
Plant layout	Processing industry, design, methods
Lean	Facility layout, principles, philosophy,
Process industry	Water bottling, food, and beverage
Case research	Operations management
Demand increase	Effects implications
Manufacturing Facility Layout	Water bottling, process industry, discrete
Simplified SLP	Case study, application, food and beverage
Process Industry, Food and beverage industry	Characteristics, definition
SME	Food and beverage

Table 3: Search Terms for Manufacturing Facility Layout

Search terms from table 3 were used in scientific sources of information to acquire the necessary background knowledge for the project. The information was acquired through the search engines ProQuest, Scopus, Google Scholar, NTNU library, and Oria. Connection to the search topic, keywords, authors, citations backtracked for additional sources of information. If the topic of the article or book sounded close to the topic, it was captured, explored, and relevant information extracted.

Cited-by analysis for the most relevant articles, as well as an exploration of the reference list, was employed. Citing of books took place for the majority of theories, but relevant articles, not older than five years, were used to examine the current state of the topic literature wise. All relevant papers applied during the earlier courses at NTNU harvested for information and some used in the master thesis.

The number of citations and credibility was a considerable aspect. However, keeping in mind that the articles from the past 1-3 years cannot have the same number of citations like the older ones, due to a long time it takes for a journal article to appear as relevant reference (Karlsson, 2010).

Besides relevant publications, literature studied during the master's program was utilized. Robert H. Hayes (Philip Caldwell Professor of Business Administration, Emeritus) and Steven C. Wheelwright (Edsel Bryant Ford Professor of Business Administration, Emeritus) are renowned and cited authors of manufacturing strategy and operations management literature (Wheelwright). Their work used as the foundation of the majority of textbooks on Manufacturing strategy and competitiveness in the industry. Due to that knowledge combined with a recommendation from the supervisor, their work explored. The books that had the highest impact on the project were (Tompkins et al., 2010),(H. HAYES et al., 2004) (Kay, 2009), (Stevenson et al., 2007) and (Stephens, 2019) from world-renowned professors with over 9000 quotations combined.

Table 4 contains a summary of the software utilized during the project.

Software Used	Area Used
EndNote	Citations
Microsoft Word	Project Writing
Microsoft Excel	Tables
Microsoft Visio & Power BI	Figures
ConceptDraw Diagram	Layout Creation
Grammarly	Grammar Check
CamScanner	Notes Digitalization

Table 4: Software Used During Project

2.2 Empirical Case Study

An empirical case is a detailed description of an organization (Karlsson, 2010, Yin, 2017) meant to give holistic and meaningful retention of characteristics of organizational or managerial processes. As argued by Eisenhardt in the early 1989s (Ravenswood, 2011), the case study approach also generates novel and testable theory, understands the dynamics present within a single setting, and compares with existing research. Also, It is a powerful method in developing a new theory (Voss, 2010).

Approach to the empirical case study of Snåsavann AS was a qualitative study of firsthand data. Qualitative approaches focus on interpretation and perception of reality (Ravenswood, 2011, Karlsson, 2010) and their usefulness in understanding the dynamics in a relationship. Quantitative data gathering took place in the form of charts and demand forecasts. Qualitative in the form of observations and open dialogs.

Currently, there are 12 people employed. The turn-over of the case company in 2018 was around 736568 euro (Snåsavann AS Balance) and, in combination with having twelve employees, qualifies as an SME (refer to chapter 1.1 for the definition of SME).

The data acquisition used in this master thesis took place between 20th to 27th November 2019, while taking the course TPK4530 Production Management. Affirmation and confirmation of the data took place before departure from the company. The observations, data, and models were also shared with the management and workers for affirmation, as shown in table 5. Further on, all data was reevaluated and revalidated by mail and phone in April 2020. Physical data gathering was planned in April 2020 but canceled due to the COVID19 outbreak. From this point onward, all further communication with the data providers, showed in table 5, was remote and digital.

Name	Position
Mohamed Sambou	CEO
Roy Kolås	CTO
Torild Kjenstadbakk	Accountant
Erlend Seljelid	Chief of Finance
Jon Kåre Knutsen	Production &Storage Worker
Ida Marie Dravland	Production Worker
Patrick Ånonli	COO

Table 5: Data Providers

Internal Skype post-meeting discussion with supervisor and co-supervisor was essential to develop the understanding of the project, topics, and discuss challenges. A follow-up phone call and email with the company reconfirmed the data and results before delivering the project.

3. Scientific Literature Study

This chapter contains the pivotal scientific literature study regarding facility layout. It examines the definition of facility layout and reasons for design projects. Further on the types of departments and their respective layouts examined. Chapter three continues with methods of approaching the creation of facility layout, the combination of lean principles during the design projects and evaluation, and performance assessment of facility layout. Further on, a step-by-step examination of the simplified SLP takes place, offering the reader a broader and better understanding of its components. The chapter concludes with a summary.

3.1 Facility Layout

Facilities planning Is a part of the strategic decisions a company can take in order to develop its competitive advantage or pursue a goal. It combines analytical, empirical, traditional, and contemporary concepts (Tompkins et al., 2010, Canen and Williamson, 1996). Facility planning includes the decision for the location and design of the plant, facility system, material handling, and layout, as visualized in figure 2.

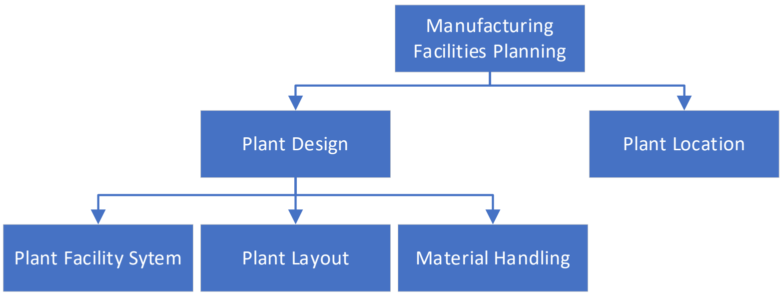

Figure 2: Manufacturing Facilities Planning Steps (Tompkins et al., 2010)

In the literature (Stevenson et al., 2007), motivation for the manufacturing facilities design projects could be due to the need for a *new facility*, *new product*, *design changes*, *cost reduction,* or *retrofit* of the existing facility.

The *new facility* design offers fewer restrictions and constraints. *New product* design sets aside a corner of the plant incorporating into the flow of the rest of the plant, sharing some conventional equipment with old products. *Design changes* projects aimed at reducing the cost and improving the quality of the product. *Cost reduction* aims at layout improvement, which will produce more products with less worker effort. *Retrofit* projects are for old and poorly laid out plants. Manufacturing facilities designers may spend most of their time working on making these facilities more productive. The procedure for retrofit is the same as for a new plant—except there are more constraints: existing walls, floor pits, low ceilings, and any other permanent fixtures that may pose an obstacle to efficient material flow (Stevenson et al., 2007).

Scientific literature uses different definitions for the grouping of facility layout, and this project will shed light on three ways of defining it.

The first grouping of the facility layout is into two sub-categories the **storage facility** (also referred to as the ***nonmanufacturing department***) and the **factory facility** (or ***manufacturing department***) (Stevenson et al., 2007). Both are vital for the medium to long-term planning horizon and are decided based on different criteria. A good layout should minimize the length of flow through the operation and exclude crossing or backflow. It is also capable of reducing between 10%-30% of the total operating cost by reducing the cycle time resulting in increased productivity and profitability. (PN and Onyancha, 2018, Wahid and Daud, 2020)

The second grouping of the facility layout is into two-subcategories: **block layout** (location, shape, size of planning departments), and **detailed layout** (exact location of all equipment, workbenches, storage within each department). Block layout focuses on macro flows, and a detailed layout focuses on microflows (Tompkins et al., 2010).

The third grouping argued by Kay (Kay, 2009). is into the **machine** and **department layout**. The machine is entities with fixed and unchangeable shape. The department is offices, production areas, and work centers. The flow pattern within the manufacturing department depends on the machine layout, as examined in subchapter 3.1.1. A manufacturing department is a group of machines or workstations considered as a single activity for facility layout purposes. Nonmanufacturing departments are shipping/receiving areas, storage areas, offices, cafeteria, restrooms, and others.

Further on, the design of storage facilities (Stevenson et al., 2007) presents a different set of factors than the design of factory layouts. Frequency of order is an important consideration. Frequently ordered items should find a place near the entrance to the facility, and those ordered infrequently should find a place toward the rear of the facility. Any correlations between items are also significant (i.e., item A ordered together with item B), suggesting that placing those two items close together would reduce the cost and time of *picking* (retrieving) those items. Other considerations include the number and widths of aisles, the height of storage racks, rail or truck loading and unloading, and the need to make a physical count of stored items periodically (Stevenson et al., 2007).

3.1.1 Type of Layouts

Based on the variety and volume of the material flow (Kay, 2009), the establishment of four planning departments could take place, leading to a specific facility layout. The departments are production, fixed material location, process, and product family department.

1) The layout for a production line department (Product Layout, as visualized in figure 3) focuses on the processes for the manufacturing of the parts in a line. Material flow is sequential from one workstation to the next adjacent, usually in high volumes with low variety (Tompkins et al., 2010). Summary of advantages and limitations contained in table 6.

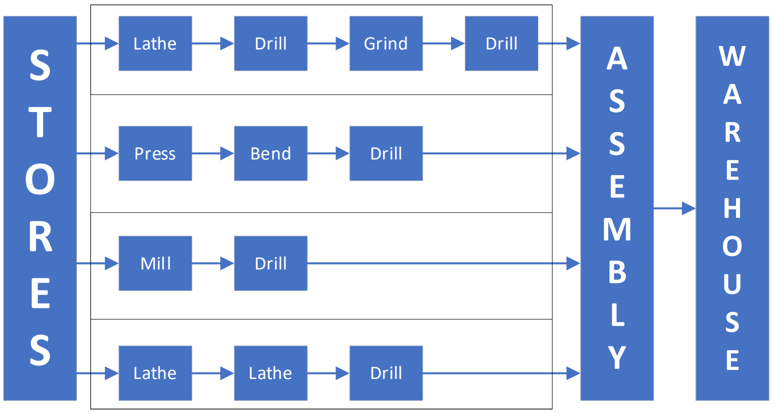

Figure 3: Product Layout (Tompkins et al., 2010)

Product Layout	
Advantages	**Limitations**
1. Smooth, simple, logical, and direct flow lines. 2. Small work-in-process inventories. 3. The total production time per unit is short. 4. Reduction of material handling requirements. 5. Less skill required from personnel. 6. Simple production control is possible. 7. The use of special-purpose equipment.	1. The machine stoppage stops the line. 2. Product design changes cause the layout to become obsolete. 3. The slowest station places the line. 4. General supervision is required. 5. Higher equipment investment.

Table 6: Product Layout - Advantages and Limitations (Tompkins et al., 2010)

2) The layout for a fixed material location department (Fixed Product Layout, as visualized in figure 4) aims at a movable workstation and a stationary material. It involves the sequential placement of workstations around the material in work (Tompkins et al., 2010). Summary of advantages and limitations contained in table 7.

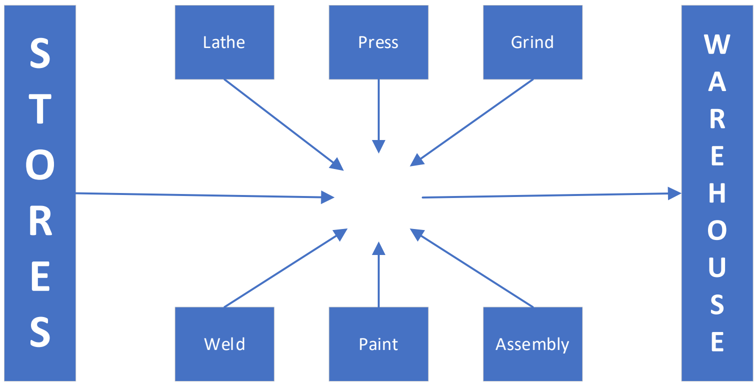

Figure 4: Fixed Product Layout (Tompkins et al., 2010)

Fixed Product Layout	
Advantages	**Limitations**
1. Reduction of material movement. 2. It is a team-centered approach, resulting in continuity of operations and an increase in responsibility. 3. It provides job enrichment opportunities. 4. Promotes pride and quality because an individual can complete the whole job. 5. Highly flexible and can accommodate changes in product design, product mix, and production volume.	1. It increases the movement of personal and equipment. 2. May result in duplicate equipment. 3. It requires higher skills from personnel. 4. General supervision required. 5. May result in increased space and greater work-in-process. 6. Scheduling production requires close control and coordination.

Table 7: Fixed Product Layout - Advantages and Limitations (Tompkins et al., 2010)

3) The layout for a product family department (Product Family Layout, as visualized in figure 5) is aimed at a grouping of parts to form product families. The base for the grouping could be shape, processing sequences, material composition, tooling requirements, control requirements, storage requirements, handling requirements. The processing equipment requires family grouping into cells. Resulting in a high degree of intradepartmental flow and a low degree of interdepartmental flow (Tompkins et al., 2010). Summary of advantages and limitations contained in table 8.

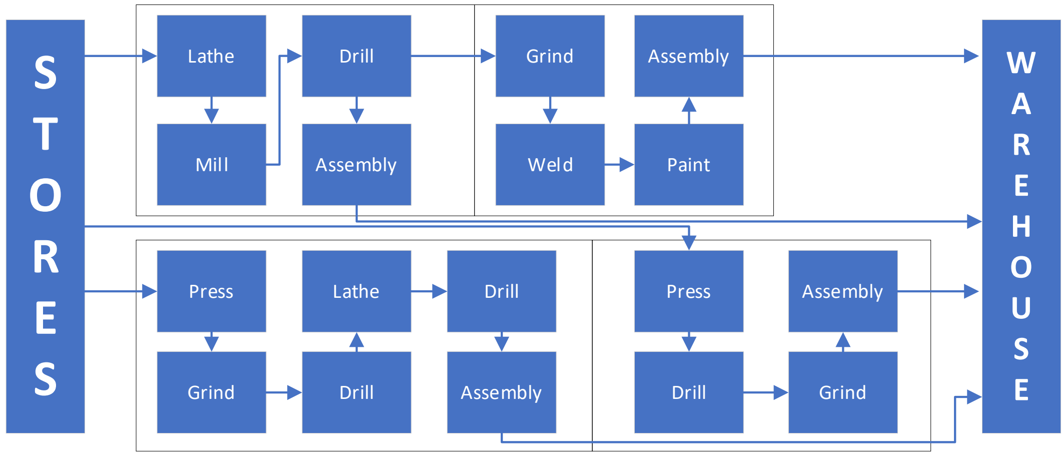

Figure 5: Product Family Layout (Tompkins et al., 2010)

Product Family Layout	
Advantages	**Limitations**
1. Higher machine utilization. 2. Smoother flow lines and shorter travel distances. 3. The team atmosphere and job enlargement benefit often result. 4. Has some advantages from product and process layout, since it is a compromise between the two. 5. The use of general-purpose equipment encouraged.	1. General supervision required. 2. Team members required to be highly skilled in all operations. 3. Critically dependent on production control, balancing the flows through the individual cells. 4. If the flow is not balanced in each cell, buffers and work-in-process storage eliminate the need for added material handling to and from the cell. 5. It had some limitations from the product and process layout since it is a compromise between the two. 6. Decreases the opportunity to use special-purpose equipment.

Table 8: Product Family Layout - Advantages and Limitations (Tompkins et al., 2010)

4) The layout for a process department (Process Layout, as visualized in figure 6) aims at grouping similar processes into departments. Usually, there is a high degree of interdepartmental flow and little intradepartmental flow (Tompkins et al., 2010). Summary of advantages and limitations contained in table 9.

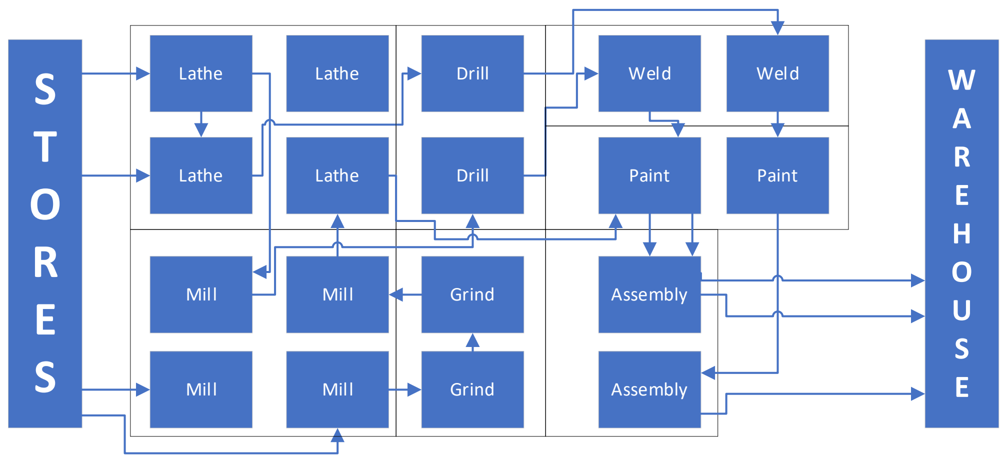

Figure 6: Process Layout (Tompkins et al., 2010)

Process Layout	
Advantages	**Limitations**
1. Increase in machine utilization. 2. Use of general-purpose equipment. 3. Highly flexible on allocating personnel and equipment. 4. Diversity of tasks for personnel. 5. Specialized supervision is possible.	1. Increase in material handling requirements. 2. More complicated production control required. 3. Increased work-in-process. 4. Longer production lines. 5. Increase in skill required to accommodate the diversity of tasks.

Table 9: Process Layout - Advantages and Limitations (Tompkins et al., 2010)

For simplification and summarizing purposes, figure 7 offers a holistic view of the correlation between volumes and variety. It puts the different layout alternatives in perspective to the well-known product-process matrix by (Hayes and Wheelwright, 1979).

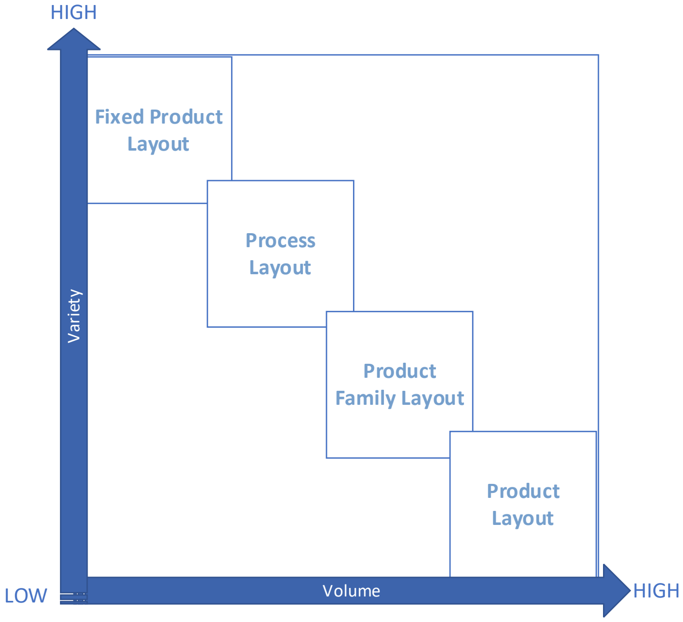

Figure 7: Product - Process Matrix Adapted for Layout (Stevenson, 2011, Tompkins et al., 2010)

3.1.2 Procedural and Algorithmic Approaches to Facility Layout

Layout procedural approaches split into construction or improvement (Tompkins et al., 2010). The first method develops a new layout from scratch, while the second seeks to achieve an improvement of an existing. Even though some of the original procedural approaches to the layout problem are old (Apple, Reed, 1961, Muther and Planning 2nd, 1973, Apple, 1977), they serve as the base for many of the layout designs done today. The summary of the three procedures contained in table 10.

Plant Layout Procedures		
Apple`s Plant Layout Procedure	**Reed`s Plant Layout Procedure**	**Muther`s Systematic Layout Planning**
1. Procure the basic data. 2. Analyze the basic data. 3. Design a productive process. 4. Plan the material flow pattern. 5. Consider the general material handling plan. 6. Calculate equipment requirements. 7. Plan individual workstations. 8. Select specific material handling equipment. 9. Coordinate groups of related operations. 10. Design activity interrelationships. 11. Design storage requirements. 12. Plan the service and auxiliary activities. 13. Determine space requirements. 14. Allocate activities to total space. 15. Consider building types. 16. Construct a master layout. 17. Evaluate, adjust, and check the layout with the appropriate persons. 18. Obtain approvals. 19. Install the layout. 20. Follow up on the implementation of the layout.	1. Analyze the product or products. 2. Determine the process required to manufacture the product. 3. Prepare layout planning charts. 4. Determine workstations. 5. Analyze storage area requirements. 6. Establish minimum aisle widths. 7. Establish office requirements. 8. Consider personnel facilities and services. 9. Survey plant services. 10. Provide for future expansion. *Step 3* is considered the most important and incorporates the following: 1) Flow process, including operations, transportation, storage, and inspections. 2) Standard times for each operation. 3) Machine selection and balance 4) Workforce selection and balance 5) Material handling requirements	1. Input data and activities. 2. The flow of materials. 3. Activity relationships 4. Relationship diagram. 5. Space requirements. 6. Space available. 7. Space relationship diagram. 8. Modify considerations. 9. Practical limitations. 10. Develop layout alternatives. 11. Evaluation. Further use of the output of the steps is in an activity relationship chart.

Table 10: Plant Layout Procedures (Ali Naqvi et al., 2016)

Procedural approaches unify both qualitative relationships such as material and personnel flow, communication, closeness, HSE, or structural as well as quantitative data (Kay, 2009, Ali Naqvi et al., 2016). They include objectives, trade-offs, and evaluation criteria (Stevenson et al., 2007). They facilitate the attainment of product or service quality, efficient use of space, and workforce. The procedural approaches aim at bottleneck utilization, minimal material handling costs, and elimination of unnecessary movement of workers. They aim at minimization of production time or customer service time go hand in hand with a design for safety. (Stevenson et al., 2007).

The SLP approach devised by Muther and broadly applied to SME (Huallpa et al., 2019, Sa'udah et al., 2015, Goyal, 2019) was applied recently to the layout design of hospitals, construction, furniture manufacturing, restaurants and food industry (Ali Naqvi et al., 2016, Le et al., 2019, Lin et al., 2015, Flessas et al., 2015, Farfan-Quintanilla et al., 2020). Further highlight made by Fahad is that some SMEs ignore the energy cost savings resulting from having an efficient layout, which is up to 25% of the total energy used by buildings (Fahad et al., 2017). Some of SLP's downsides are the need for in-depth research on existing flows, activities as well as procedures utilized in the plant. The method, however, follows a pattern of analyzing the current state of the company and researches on possibilities and selection of the best suited future state of the layout (Muther and Planning 2nd, 1973, Trein and Amaral, 2001, Tortorella and Fogliatto, 2008).

On the other hand, **simulation** (Stevenson et al., 2007) and **algorithmic approaches** (Tompkins et al., 2010) could create a layout by actually tracking the movements and interaction of the system components and aiding in optimizing such systems. The closeness ratings or material flow intensities could be the start point for the creation of an algorithm. The majority of the algorithmic and simulation approaches aim at solving the facility layout problem (FLP). The scientific literature defines the FLP as (Sagnak et al., 2019, Aiello et al., 2013, Abdinnour-Helm and Hadley, 2000) efficient organization of interrelated departments or machines satisfying the goals of the company by taking in consideration different positioning factors. The literature divides the solution techniques into exact methods, heuristic methods, metaheuristic methods, and hybrid approaches (Moslemipour et al., 2012, Hosseini-Nasab et al., 2018). From the literature and state-of-the-art review of papers on facility layout problems (Singh and Sharma, 2006, Stevenson et al., 2007, Tompkins et al., 2010), the advantages and disadvantages of the simulation are devised and visualized in table 11. They require a more significant investment of time and effort at the start but produce more information on the flow of the parts. They allow observation of the behavior of a system, individuals, layout, or a cluster of equipment. The simulation does not disturb the workers, the layout, or the equipment. It could show behavior changes in the layout due to different material handling systems, the addition of a lathe, equipment reconfiguration, or change of workforce. The advantages are that they are relatively flexible and straightforward. Simulations analyze large and complex models that may not easily lend themselves to mathematical models. Furthermore, simulation allows the study of the interactive effects of many components in a dynamic and stochastic environment, with the distinct advantage of providing the investigator with an apparent visual effect. The main disadvantage of simulation is that the development of some very complex models may be quite expensive and time-consuming. Indeed, a corporate planning model, or a large manufacturing plant with all its components, activities, and services, may take years to develop and vast computing resources (Singh and Sharma, 2006, Stevenson et al., 2007, Tompkins et al., 2010).

Layout Simulation	
Advantages	**Limitations**
1. Flexible and straightforward. 2. Produce more information on the flow. 3. Allow observation of the behavior of the system. 4. It allows the study of the interactive effects of many components in a dynamic and stochastic environment. 5. Visualization of effects, because of changes. 6. It can analyze large and complex models. 7. Try reconfiguration of current flow without stopping production.	1. Expensive and time-consuming. 2. Do not take into consideration all qualitative aspects. 3. It requires vast computing resources. 4. They are just an aid and not a perfect solution.

Table 11: Layout Simulation - Advantages and Limitations (Stephens, 2019)

The literature study showed that (Ali Naqvi et al., 2016) each of the methods possesses its assets and drawbacks as well as data and skills requirements. Table 12 contains a summary of the methods for facility layout design.

Procedure	Algorithmic
Approach	
Defined as a component approach. (Bock and Hoberg, 2007)	Design constraints and target simplification into a function which is solved mathematically. (Yang and Kuo, 2003)
Data Requirements	
Both qualitative and quantitative data considered. Qualitative data takes into consideration communication between departments, equipment used, and material handling. (Padillo et al., 1997)	Usually involve only quantitative data (lead time, production rate, material routing) and are assessed with comparison to objective function values. (Yang and Peters, 1997)
Major Studies	
Apple, Reed, and Muther(Apple, 1977, Reed, 1961, Muther and Planning 2nd, 1973)	Heragu, Meller, and Gau. (Heragu, 1992, Meller and Gau, 1996)
Limitations	
The application of procedure requires experience from the designers due to the subjectivity of some decisions. (Bock and Hoberg, 2007)	Advanced mathematical modeling techniques are prerequisites for the development of algorithmic approaches. (Tompkins et al., 2010)
Comparison and evaluation of layout alternatives on multiple criteria. (Tompkins et al., 2010, Sharma and Singhal, 2017, Singh and Sharma, 2006)	Modifications are often required in the output to ensure design in practical (department shapes, utility supply, material handling systems, ergonomics concerns, work-in-process storage, space utilization). (Yang et al., 2000)

Table 12: Summary of Procedural and Algorithmic Approaches (Ali Naqvi et al., 2016)

3.1.4 Lean Principles and Facility Layout Design

The lean philosophy created and systemized by Toyota contains the following five principles (Womack and Jones, 2013).

1) Identify value: What the customer defines as value.
2) Map the value stream: Highlight bottlenecks and see non-value adding time in the production.
3) Create flow: The product flows through the system like water.
4) Pull value: Order initiates value-adding activities.
5) Go for perfection: Constant improvement and optimization of processes.

The lean philosophy has three core areas of waste

- Muda: Defects, Overproduction, Waiting, Non-utilized talent, Transportation, Inventory, Motion, Extra-processing (aka the eight wastes).
- Muri: Overload in the form of a lack of tools, experience, or stable processes.
- Mura: Uncontrolled variation.

In lean philosophy, standardization and continuous improvement are fundamental (Tarigan et al., 2018). In recent case studies, a combination of the four lean methods (takt time design, line balancing, cellular design, and one-piece flow) with the classical facility layout design in assembly plants leads to significant improvements in cost efficiency (Kovács, 2019). It is becoming visible that since lean and facility layout has similar goals combining them increases improvements (Putri and Dona, 2019, Sa'udah et al., 2015). Scientific papers on the applicability of lean principles in layout design in industry (Heinävaara, 2010, Salleh and Zain, 2012, Mejía and Ramírez, 2012, Sa'udah et al., 2015, Low et al., 2015, Tarigan et al., 2018, Kovács, 2020) are emerging. The application of lean principles in an automotive manufacturing company was proved by Salleh and Zain to be responsible for the reduction of motion of operators in a cell. Employment of the lean principles to design layout in a medium-sized machine shop (Mejía and Ramírez, 2012) led to a visible change of the working environment in regards to cleanness and neatness. Benefits for the food industry (Sa'udah et al., 2015) highlighted in the sense of travel distance reduction, capacity, and speed of material movement. The revelation of the application in the setting of factory ramp-ups (Low et al., 2015) in order to achieve higher quality output and the waste reduction took place as well. Identification and improvement of logistic processes, design of material flow paths between related departments were also researched (Hailemariam, 2010).

3.1.5 Evaluation and Performance Assessment

Evaluation and performance assessment is critical since it shows the progress toward a specific organizational goal. Performance assessment uses specific criteria predefined by the company to track closeness to reaching a goal. A pre-requirement in order to see the impact of the layout alternatives (Lin and Sharp, 1999). The majority of the scientific papers aim at layout design, but very few look into the evaluation and performance assessment. Researchers such as Gantz and Pettit, Muther and Konz, Lin, and Sharp were able to determine a few indexes and criteria which are useful for the performance assessment. Indexes and criteria contained in table 13.

Performance Assessment of Layout	
Researcher	**Indexes and Criteria**
(Gantz and Pettit, 1953)	Indirect and direct material handling, gravity utilization, automatic machine loading, production line flexibility, workstation flexibility, storage space, storage volume utilization.
(Muther and Planning 2nd, 1973)	Ease of future expansion, adaptability, storage effectiveness, space utilization, supporting service integration, safety, and housekeeping, working conditions, employee satisfaction, ease of control, appearance, promotional value, public or community relations, quality, maintenance, the fitness of organization structure, equipment utilization, security and theft, utilization of natural conditions, ability to meet capacity and compatibility with long term plans.
(Konz, 1985, Lin and Sharp, 1999)	Resource utilization ratios for materials, movement, and loss. Operation efficient ratios for manufacturing, storage, retrieval, receiving, and shipping.

Table 13: Performance Assessment of Layout (Sagnak et al., 2019)

Further study on the topic showed a new and holistic framework for evaluation of the performance of the layout incorporating tangible and intangible criteria such as cost, flow, flexibility, surrounding environment, environmental quality, time, and characteristics (Sagnak et al., 2019). In it, the fuzzy DEMATEL method used to identify and assess the causal relationship between the criteria.

3.2 Simplified Systematic Layout Planning

Muther, the original creator of the procedural SLP method, also made a simplified version. However, it was constrained to smaller sized facilities (office area up to 280m², shop, or lab up to 465m² and storage up to 930m²) (Muther and Lee, 2015).

Aim of recent research (Ali Naqvi et al., 2016) was the simplification of fundamental steps and criteria for layout selection in addition to attempted to estimate the benefits of a layout cost reduction project. The simplified procedural method contained in table 14.

SLP Simplified Approach			
Step	**Data Collection**	**Tools Used**	**Detailed Approach**
1	Determine plant capacity.	PQRST approach.	Use monthly production data for a specified period.
2	Analysis of operations.	Work and method study tools.	Identify waste using flow process chart and use manufacturers catalogs for the spatial requirement of machine.
3	Material flow.	From-to-chart.	Multiple visits to the factory.
4	Relationship between depts.	Mileage chart with grade criteria.	Include the needs for communication and logistics flow between departments.
5	Spatial requirements.	Space relationship diagram.	Identify the total area for each department, including aisles and ergonomics.
6	Layouts alternatives.	Simulate for material flow.	The characteristics of each layout are evaluated based on material flow.
7	Selected layout.	Convert block into factory layout.	Machines and transportation paths placed to transform the plant layout.

Table 14: SLP Simplified Approach (Ali Naqvi et al., 2016)

The simplification made by Ali Naqvi (Ali Naqvi et al., 2016), does not carry the constraints of Muthers Simplified SLP due to standing on the long SLP. The one devised by Ali combines lean tools (5S) as well as performance measures in the end. However, the literature study showed that the only presented scientific use was in one scientific paper and one conference paper (Ruiz et al., 2019).

The steps in the simplified SLP are seven, and each gives a specific layer of information needed for the design of the manufacturing facility layout. The author did not explain in-depth some of the steps and did not show all the diagrams and charts needed. However, their examination will take place here as well as during the application.

Step one involves following the PQRST key-model (Muther and Lee, 2015) (**P**roduct, **Q**uantity, **R**outing, **T**ime, **S**upporting Services) aimed at the determination of plant capacity. It examines the sort of products manufactured at the company, as well as the volumes expected for manufacturing. The author did not specify constraints here and used six months of data, but without clarifying if it was future forecast or historical data. Further on, the time necessary for product manufacturing, as well as route mapping, takes place in step one. The mapping of product flow routing and process sequences of the manufacturing lines takes place here as well. Finalizing part of step one is mapping the supporting services necessary for the operation of the production lines currently inside the factory.

Step two involves an analysis of operations through a material-type flow-process-chart. The chart required was not showed or examined in the paper introducing the simplified SLP method even though seen as necessary. The flow-process chart would follow the flow from the point of transition between supplier to case company to ready to ship units. Mentioned in the paper introducing the simplified SLP method was that investigation of an activity chart for individual departments inside the shop flow took place. However, none were presented in the paper or discussed to be of high importance. Step two aims at gathering and classifying the holistic data needed for the analysis and improvement of the operations (Akkoni et al., 2019) and waste identification. It serves as a visual representation of the value-adding and non-value adding activities.

Step three involves an analysis of intensity and interaction between departments in the current facility layout through a from-to-chart for each of the three scenarios. Values used for the from-to-chart would be EUR-pallet (European Pallet Association, n.d) trips between departments, due to company suggestion. The output of the from-to-chart would serve as a base for a flow diagram aimed at a visual representation of the situation.

Step four involves the creation of a relationship diagram based on sensitivity ratings. Those ratings are devised in collaboration with the company as well as from multiple factory visits. The goal of the relationship diagram is to show the necessity of the distance between specific departments and allow a grounded and informed decision to relocate a department. The relationship diagram would produce a simple pattern containing the practical constraints necessary for the design of the manufacturing facility layout.

Step five involves the analysis of current space allocation. It examines spatial requirements and gives a visualization of current department size, available space in the plant as well as the required space. In this step, the space requirements for manufacturing are not solely examined but fused with the space requirements for human-machine interaction, material flow, material handling equipment, and maintenance. The paper suggesting the simplified SLP did not explain how the calculation of the required space took place. However, the author of the original SLP explains (Muther and Lee, 2015) that it is possible to achieve the space requirements by calculations, conversion, space standards, roughed-out layout, or ration trends and projects. The roughed-out layout pointed out as the method to choose if preexisting drawings of manufacturing lines existed.

Step six involves the creation of layout alternatives based on the output from the previous five steps. This master thesis will include three layout alternatives, for each of the three forecasts, fused with the unique constraints of the case company. Step six concludes with block layout alternatives, including the preexisting manufacturing lines.

Step seven involves the evaluation of the layouts based on criteria defined by the case company. It includes the transfer from block layout to a detailed layout giving the company a better visual representation of the improved manufacturing facility layout.

3.3 Summary

Scientific literature splits the facility layout into storage (nonmanufacturing) and factory layout (manufacturing) or machine and department layout. Others define the difference as block layout (location, shape, size of planning departments), and detailed layout**.** The block layout, based on planning departments, could be split into the process department (Process Layout), fixed material location department (Fixed Product Layout), product family department (Product Family Layout), and production line department (Product Layout). Each of the corresponding layouts possesses advantages and limitations explained in detail in chapter 3.1.1.

Further on a split on methods for the design and redesign of layouts observed. The first one is a procedural approach combining both qualitative and quantitative set of tools. The second one is the algorithmic approach intended for a highly sophisticated production environment with more constraints. An emergent trend towards a combination of lean principles/tools and design of facility layout is evident. Even though there is some literature suggesting a layout evaluation using predefined criteria or indexes which could serve as input to an algorithm, the importance of a specific performance indicator is apparent. The company must define that indicator and check the progression towards those specific goals.

Further on, the scientific literature study showed that SLP is widespread in the sense of SMEs. Recently the creation of a new and simplified SLP took place. A gap In literature depicting the documented application of the method in the food and beverage industry, part of the process industry, was localized.

4. Empirical Case Study

Chapter four offers an introduction to the case company Snåsavann AS. It explains in short the history of the company and attempts to draw a holistic profile by examination of the product, process, and market characteristics. Further, in this chapter, the full documented application of the simplified systematic layout planning culminates with suggestions for three layouts. Chapter four concludes with a summary of the empirical case study.

4.1 About the Case Company

Established in 2011, Snåsavann AS got the groundwater source "Snåsa" approved as "Natural Mineral Water" by the Norwegian Food Safety Authority in 2013. Having a groundwater source with a sustainable capacity of about one billion liters a year, as well as being able to offer an award-winning and fresh Norwegian natural mineral water, is a competitive advantage for Snåsavann AS (AS). The case company has a high focus on hygiene within the manufacturing facilities in order to ensure high product quality according to food and beverage manufacturing standards. By having bottles that can be pledged and recycled, Snåsavann shows that sustainability is part of their priorities. Currently, there are 12 people employed. The turn-over of the case company in 2018 was around 736568 euro (Snåsavann AS Balance) and, in combination with having twelve employees, qualifies as an SME (refer to chapter 1.1 for the definition of SME). The company aims to fulfill its founders' vision of sharing natural mineral water with the world. (About Snåsavann AS)

4.2 Systematic Introduction to Case Company

In order to create a systematic introduction to the case company, a visualization of the current facilities disposable by Snåsavan created. Further on, in order to make the reader grasp the holistic variables and values of the case company, the product, process, and market aspects examined.

The current facilities used by Snåsavann AS, visualized in figure 8 and table 15, include the main building and two tents. The main building includes a production department, three storage departments, offices, cafeteria, restroom, wardrobes, lab, machine room, water tank room, and a processing room. Some of the areas examined above are self-explanatory, and no further explanation required. The production department contains three automated manufacturing lines, a molds stand for the first line, and an operator station. The machine room contains filters, a connection between factory and water source, engines, and air compressors. In case of emergency or electrical grid failure, they can sustain manufacturing for a while at the factory. The primary use of the lab includes frequent water sampling for tracking and product quality assurance. The processing room contains individual machines that mix oxygen and minerals to be included in production line one, further examined later in the thesis. Storage of oxygen bottles and a tank filled with purified water necessary for the production of an exclusive product takes place in the water tank room. A discussion of that product will not take place due to a third-party confidentiality agreement. In addition to that, Snåsavann owns two tents used for storage of preforms, samples, boxes, caps, and old machines. In former times tent one was utilized for manufacturing and storage. However, as time passed and demand increased, a new facility and an additional tent put into place. Tent one could still be used for manufacturing, if and only if infrastructural upgrade and acquisition of additional machines take place. Manufacturing inside tent two cannot take place, due to lack of unique hygienic walls, a pre-requisition for the food and beverage manufacturing.

Figure 8: Facilities of Snåsavann AS

Area name	Area (m²)
Storage 1 (Main)	354
Storage 2 (Secondary)	80
Storage 3 (Secondary)	80
Storage 4 (Tent 1)	150
Storage 5 (Tent 2)	600
Production	354
Machine room	35,7
Oxygen & minerals	20
Lab	20
Water tank	60,9
Offices,Cantine,WC ,Wardrobes	145,6
Total Area With Tents	**1900,2**

Table 15: Area of Facilities of Snåsavann AS

Further on, using the framework devised by Buer (Buer et al., 2018), a holistic view of the enterprise regarding the *product*, *market*, and manufacturing *process* characteristics established.

From the *product* characteristics point of view, the case company operates with both MTO and MTS products further examined in chapter 4.3.1. The MTSs are already established and available to purchase from their website. However, the MTO could be custom made regarding the form and size of bottles, the color of caps, type of labels and types of beverages such as natural mineral water, sparkling, or with flavor. Due to having so few components, product complexity is low. The case company uses only PET and glass bottles, but no aluminum cans. The accuracy of storage, orders, and generally, the product data is manually checked and contained in the Excel datasheet. Due to the low product complexity, that datasheet is a prerequisite for highly accurate product data. A high level of automation, as examined in chapter 4.3.1, further improves the level of process planning.

From the *market* characteristics point of view, there exists a difference regarding the safe storage kept by the company. The MTO items are not kept in stock since the production lead time is short enough to meet the customer demand, but for MTO, a buffer of an entire shelf exists. Since the market is dynamic and demand changes, there could be observed annual trends regarding some big customers who order during the same time of the year in addition to smaller customers purchasing products sporadically. Snåsavann AS customers are both big companies with orders of more than 400000 bottles per year and small private with orders of 24 bottles per year. The MTS products are more accessible for the company to forecast than the MTO. The reason for that is that not all customers are returning with the same product customization or quantities. From the supplier point of view, the case company does not have any procurement policy or automized inventory tracking in the form of QR tracking or an ERP system. Implementation of Dynamics 365 is taking place as this master project is coming to life, but the fruits of the investment are too early to be harvested.

From the *manufacturing process* characteristics point of view, it is essential to highlight that the shop floor layout is product-oriented due to the high level of automation in the production lines. The majority of the primary operations, further discussed in chapter 4.3.1 are blowout of preforms, filling the bottles with liquid, capping, labeling, and packing. Regarding the batch size, the company operates with it is usually based on the customer order (MTO) and or weekly demand (MTS). Planning is weekly/daily, and it is worth mentioning that due to the complexity of the apparatus and the high level of automation, the set-up time is approximately one hour for line one, twenty minutes for line two and forty-five minutes for line three. That long set up time as well as the manual operations planning are a prerequisite for low capacity and load flexibility.

The case company profile exemplified in figure 9. The conscious choice of using this particular framework was in order to introduce the reader better to the case company as well as simplify the generalization of the project findings. The framework also partially satisfies the research task one.

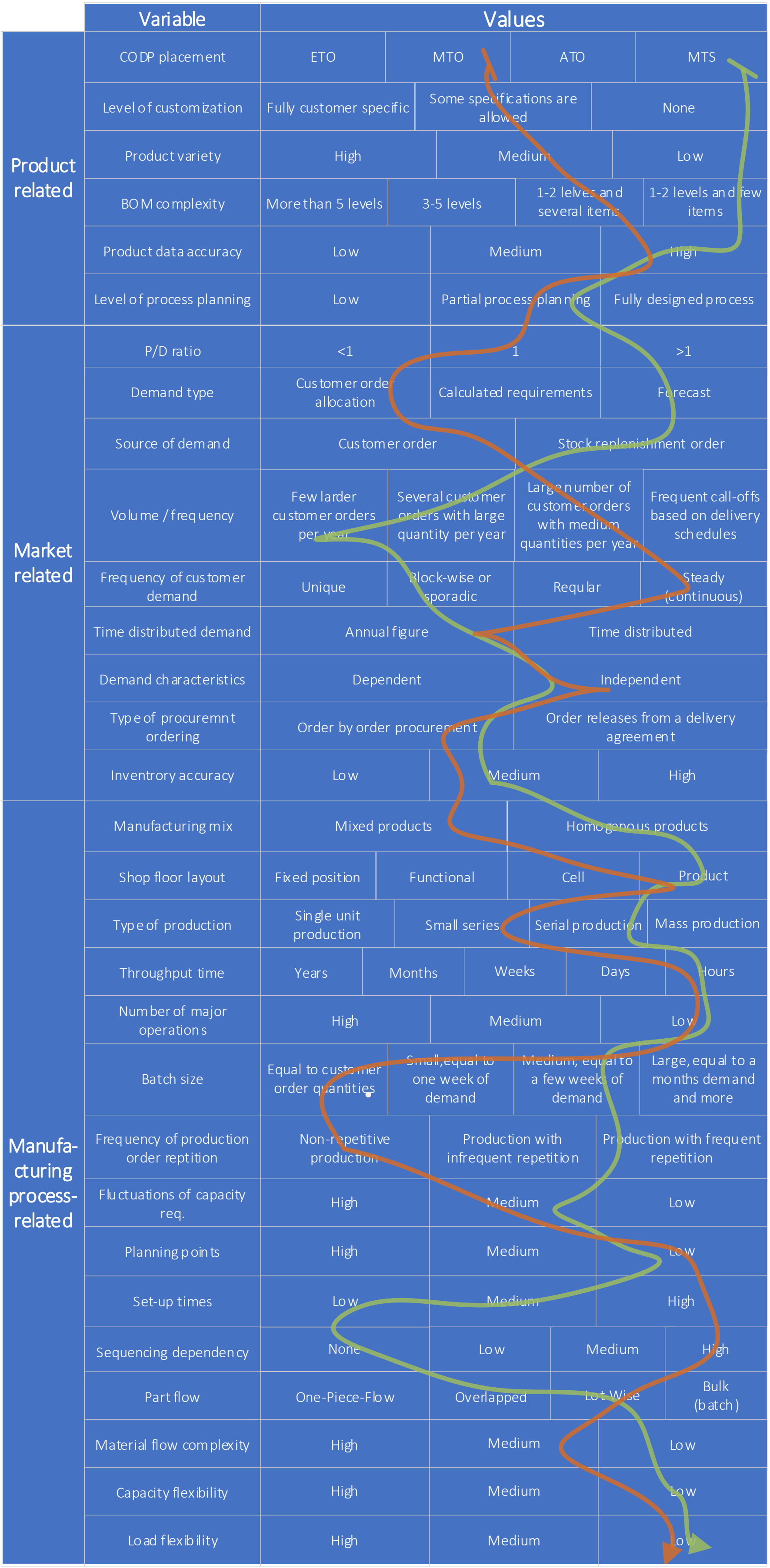

Figure 9: Strategic Fit Framework (Buer et al., 2018)

4.3 Application of Simplified SLP for Design of Manufacturing Facility Layout

Chapter 4.3 documents the application of the simplified SLP in a beverage company. It follows the steps of the procedural method and initiates the simplified SLP by gaining an overview of the plant capacity by employing the PQRST-model. Further on, an analysis of operations, material flow, and depiction of closeness sensitivity between the different departments take place. Next, the spatial requirements are examined, followed by the suggestions for layout alternatives. The application of the simplified SLP concludes with the evaluation of the new layouts. Chapter 4.3 concludes with a summary.

4.3.1 Step One: Determination of Plant Capacity

The first step of the simplified systematic layout planning involves the creation of a holistic overview of the production activities. The analysis follows the PQRST key-model (Muther and Lee, 2015) (**P**roduct, **Q**uantity, **R**outing, **T**ime, **S**upporting Services) using data collected from a one-week company visit during November 2019 and remote data collection through the phone and email during April 2020.

Product: The goods produced by the company.

The facility bottles natural mineral water and offers multiple products. The mass-produced products (or SKUs) are eleven. They all have Snåsavann label, as shown in table 16 and figure 10. Manufacturing of all the glass products takes place in line two, the 5l PET on line three and all smaller bottles in line one. In the *Routing* part of this chapter, an in-depth examination of the production takes place.

MTS products			
Bottle	**Label**	**Content**	**Caps**
0,5 liter glass	Snåsavann AS	Still	Blue
0,5 liter glass	Snåsavann AS	Sparkling	Green
0,5 liter PET	Snåsavann AS	Still	Blue
0,5 liter PET	Snåsavann AS	Still	Sport
0,5 liter PET	Snåsavann AS	Sparkling	Green
0,5 liter PET	Snåsavann AS	Sparkling & Lemon	Yellow
1 liter PET	Snåsavann AS	Still	Blue
1 liter PET	Snåsavann AS	Still	Sport
1 liter PET	Snåsavann AS	Sparkling	Green
1 liter PET	Snåsavann AS	Sparkling & Lemon	Yellow
5 liter PET	Snåsavann AS	Still	Blue with neck

* MTS are both PET and glass

Table 16: Make-To-Stock Products

Figure 10: Make-To-Stock Products (AS)

There are also custom products manufactured after an order is received. The observed product variation is in the size of bottles, the color of caps, custom labels, as well as the type of beverage. Table 17 shows the changeable product variables. Currently, there are seven molds actively used at the company, capable of producing different bottle shapes based on the customer's order.

MTO products			
Bottle	**Label**	**Content**	**Caps**
0,3l / 0,5l / 0,7l / 1l / 1,5l / 5l	Custom	Still / Sparkling / Flavored	Blue / Green / Yellow / Red / White / Sport

* Bottle forms vary due to molds

* MTO are only PET

Table 17: Make-To-Order Products

Quantity: The volume for the manufacturing of each product.

In the analysis of quantity, the creation of three different scenarios together with the case company took place. Since the original application of the simplified SLP does not state employment of what volumes should take place, this master thesis will be using the **Expected Demand Forecast**. The first forecast, shown in table 18 and figure 11, was formulated as a conservative forecast expecting a few new customers, an increase of volume and market share. The second forecast, shown in table 19 and figure 12, was formulated as a realistic forecast. The third forecast, shown in table 20 and figure 13, was formulated as an optimistic forecast emphasizing on an explosion of demand, many new customers, and substantial export. For clarification purposes, all three forecasts show a particular increase in demand. That is natural from a management perspective. Development is supposed to happen over time. The forecasts were provided by the case company in a single excel database and manually sorted out for each production line by the author of this master thesis.

Data was acquired from the company and verified by the administration as well as the chief executive officer (CEO). The chief technical officer (CTO) Roy Kolås and the staff shared data required for a comparison between the demand forecasts with the capabilities of the manufacturing lines. It was devised based on their experience that the maximum number of bottles (**aka Design Capacity**) producible on line one is 3000 bottles per hour (BPH), on line two 1200 bottles per hour and line three 480 bottles per hour. Further on, it was defined by the CTO that the time available to produce in a year is 5640 hours. Based on that data, the maximum yearly output calculated.

Working Hours per Year **x** *Bottles per Hour* **=** *Maximum Yearly Output*

Calculations showed that line one could produce 16 920 000 bottles per year (*5640hours/year x 3000BPH*), line two 6768000 bottles per year (*5640hours/year x 1200BPH*), and line three 2 707 200 bottles per year (*5640hours/year x 480BPH*). Further conversation with the CTO revealed that there is a difference between the capacity of the lines and way of operating them, due to maintenance, defects, material handling, workforce deficiency, or holidays. This master thesis defines the time a line is manufacturing as **Effective Capacity.** For line one and line two, the time of actual production is 3666 hours, and line three 282 hours.

Scenario One: A Conservative Forecast of Customer Demand.

Production Line	Concervative Expected Demand in Bottles				
	2020	2021	2022	2023	2024
Forecast Line One	2 840 000	3 875 000	4 766 250	5 242 875	5 767 163
Forecast Line Two	300 000	600 000	1 600 000	1 760 000	1 936 000
Forecast Line Three	315 000	363 750	395 313	434 844	478 328

Table 18: Conservative Expected Demand in Bottles

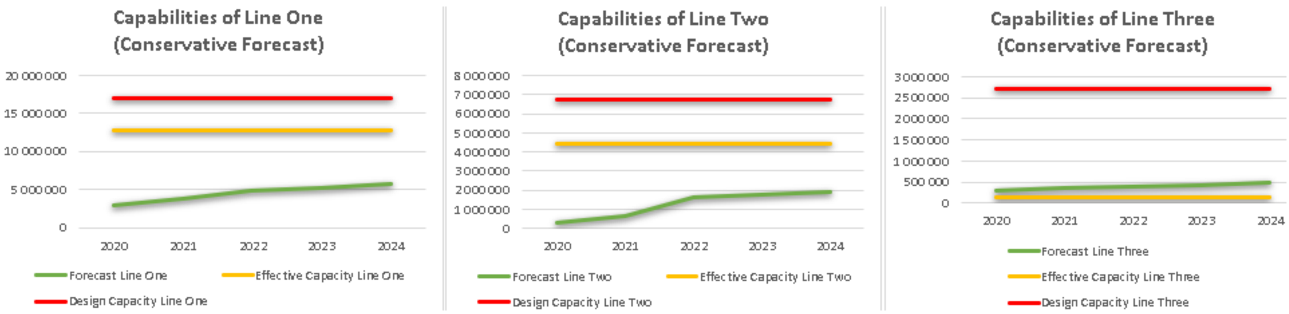

Figure 11: Capabilities of Production Lines for the Conservative Forecast in Bottles

Scenario Two: A Realistic Forecast of Customer Demand.

Production Line	Realistic Expected Demand in Bottles				
	2020	2021	2022	2023	2024
Forecast Line One	3 660 000	6 125 000	7 893 750	8 683 125	9 551 438
Forecast Line Two	700 000	2 000 000	3 500 000	3 850 000	4 235 000
Forecast Line Three	315 000	363 750	395 313	434 844	478 328

Table 19: Realistic Expected Demand in Bottles

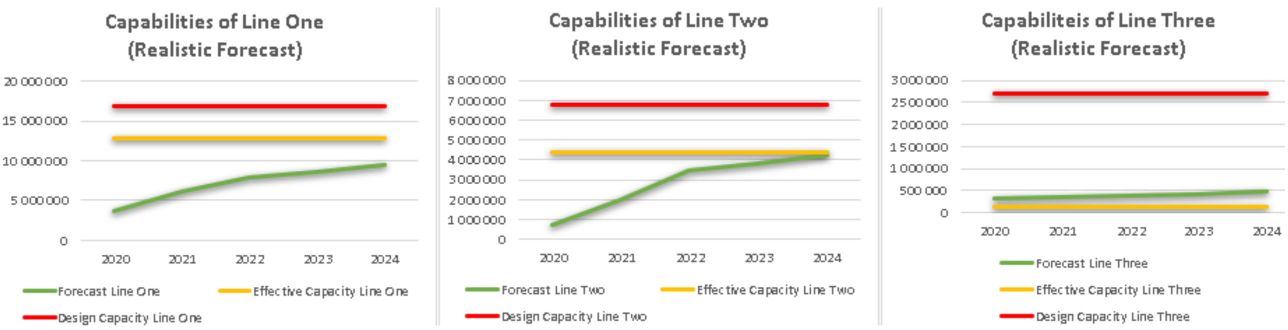

Figure 12: Capabilities of Production Lines for the Realistic Forecast in Bottles

Scenario Three: An Optimistic Forecast of Customer Demand.

Production Line	Optimistic Expected Demand in Bottles				
	2020	**2021**	**2022**	**2023**	**2024**
Forecast Line One	6 150 000	13 147 500	19 390 000	21 329 000	23 461 900
Forecast Line Two	6 500 000	16 125 000	24 150 000	26 565 000	29 221 500
Forecast Line Three	315 000	363 750	395 313	434 844	478 328

Table 20: Optimistic Expected Demand in Bottles

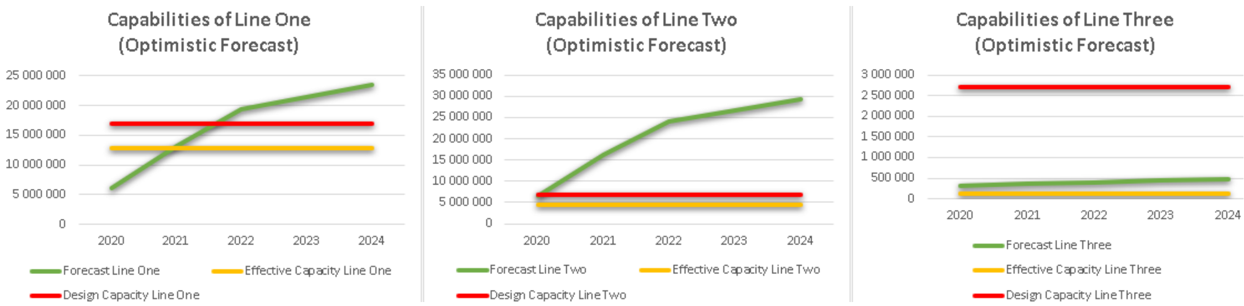

Figure 13: Capabilities of Production Lines for the Optimistic Forecast in Bottles

The sudden increase in line two is due to the nature of the product and interest from international customers. As explained in the previous chapters, line two manufactures bottled water in unique glass bottles. The design of the bottles is one of a kind, making it a premium product for luxurious restaurants, hotels, and other customers in Norway and abroad.

Routing: The process sequence shows the manufacturing of a product inside the factory.
Line One is the most complex and longest PET automated production line delivering automated process sequences, as shown in figure 14. It is capable of producing the highest variation of products in comparison with the other two. It has the least flexibility due to multiple machines synchronized, infrastructural constraints, and use regarding research and development projects. The manufacturing of some confidential products takes place on it. It takes the most space and requires the most personnel. An important observation to make is the existence of two packaging machines. One in the manufacturing department and one in storage. Besides, the sample gets taken from every batch due to health and safety precautions. That step, consciously left out of the process sequence for simplification, takes place before the packaging and is just two bottles from every batch. The path it follows is similar to the ready to deliver products but continues further to tent one. The chronological process sequence of line one contained in figure 15.

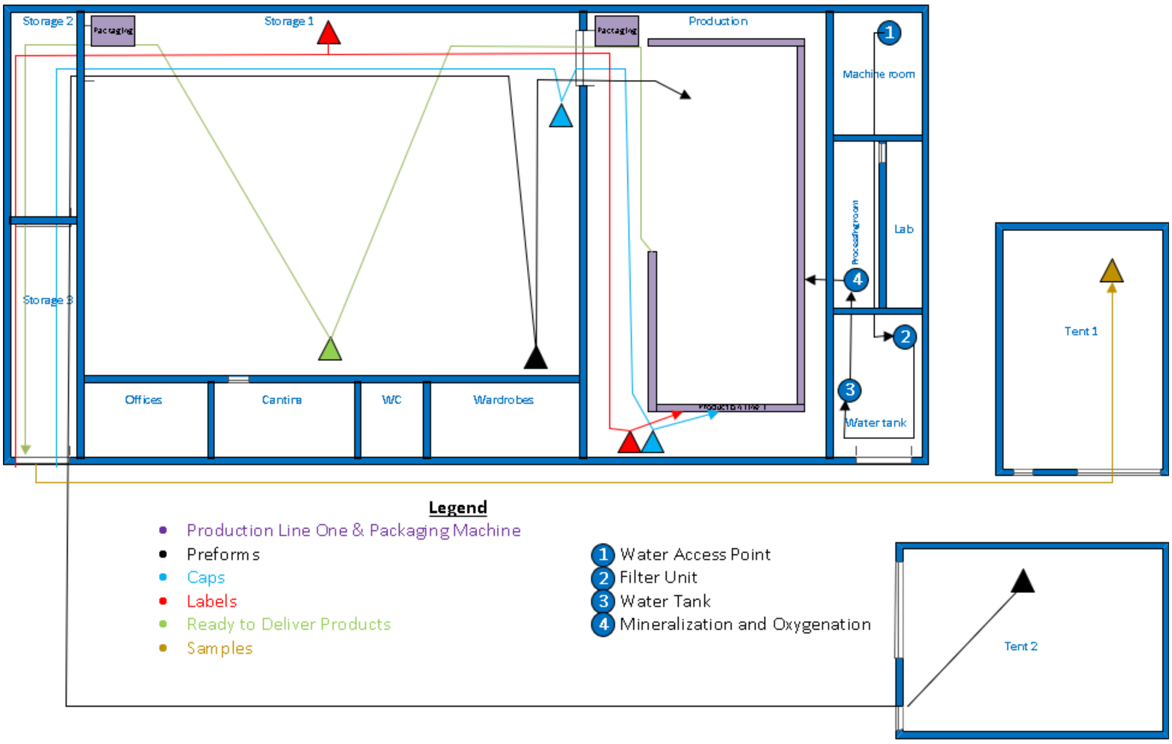

Figure 14: Material Flow of Line One

Manual	Automated								Manual	
Reload feeding machines with preforms and caps	Feeding dumping machine with preforms	Dumping preforms into blowing machine	Preform warmup and blowout of bottles	Flavor addition	Filling and carbonation	Capping	Labeling	Packing	Loading on EUR-pallet	Transfer to storage

Figure 15: Chronological Process Sequence for Line One

The routing of line two visualized in figure 16. A sample gets taken from every batch due to health and safety precautions. The path it follows is similar to the ready to deliver products but continues further to tent one. The chronological process sequence, shown in figure 17, consciously leaves out the sample taking. It is easy to spot the fewer automated processing steps, hinting at a smaller automated production. It produces glass bottles and has more flexibility due to smaller size. An important observation to make is the existence of two packaging machines. One in the manufacturing department and one in storage. The main difference in the process sequence of line two is that the supplier of the glass bottles does labeling. Due to the unique technique of blowing out the glass bottles, outsourcing of the labeling to the supplier takes place, making it not part of the chronological process sequence for line two.

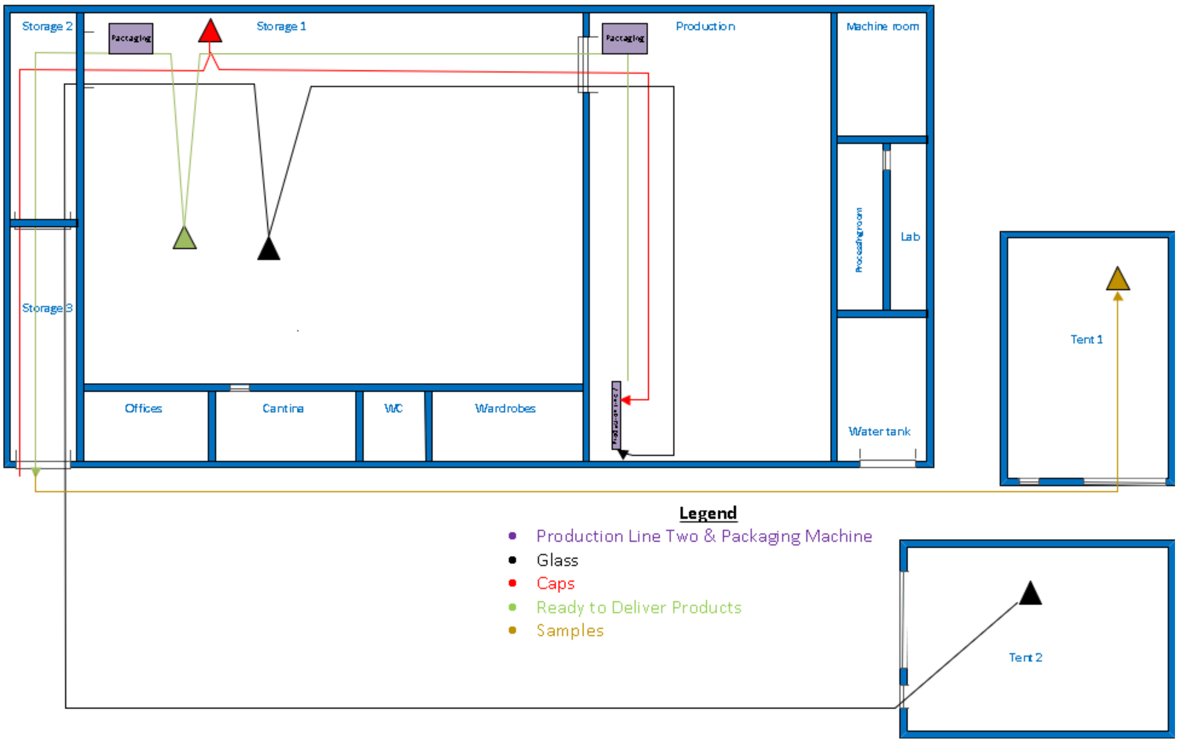

Figure 16: Material Flow of Line Two

Manual	Automated			Manual				Automated	Manual
Feeding the machine with glass bottles	Filling of bottles with water	Possibility for carbonation	Capping	Taping the box	Stabilization paper between bottles	Putting in box	Loading on EUR-pallet	Taping on EUR-pallet	Transfer to storage

Figure 17: Chronological Process Sequence for Line Two

Visualization of the routing of line three takes place in figure 18. A sample gets taken from every batch due to health and safety precautions. The path it follows is similar to the ready to deliver products but continues further to tent one. The chronological process sequence shown in figure 19 examines the automated processing steps and consciously leaves out the sample taking, happening in the end. The third line manufactures 5-liter PETs and is smaller sized compared with line one.

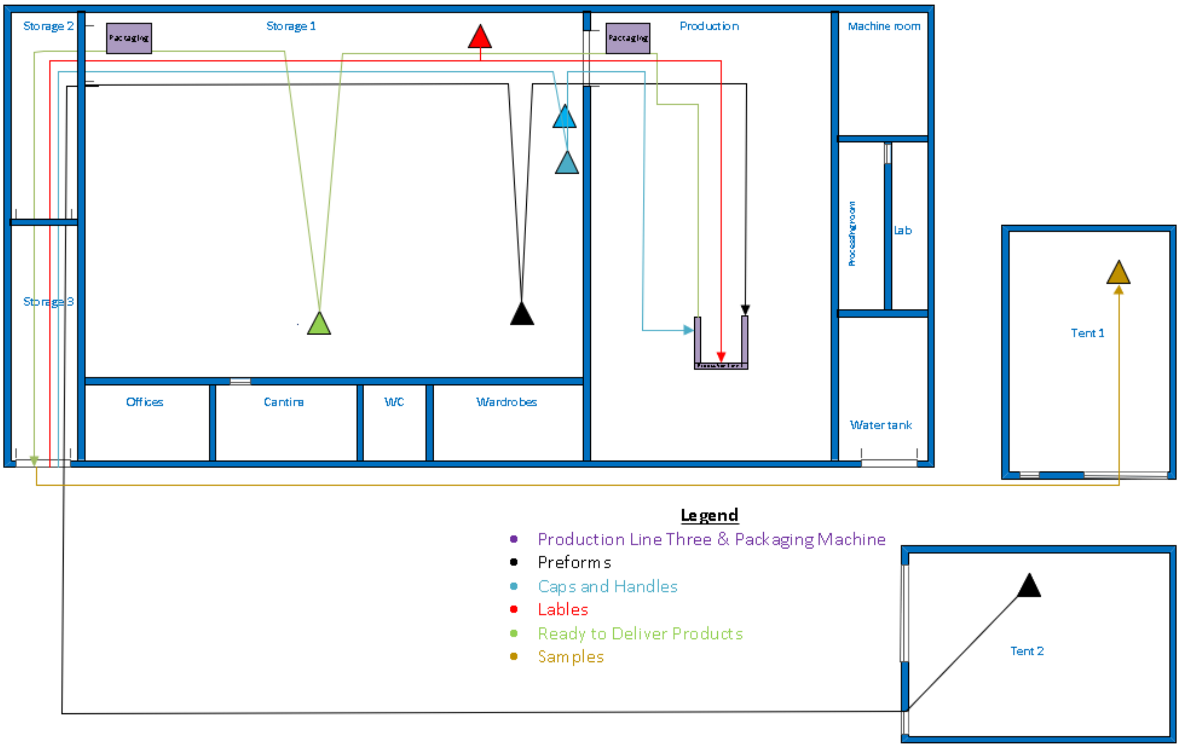

Figure 18: Material Flow of Line Three

Manual	Automated					Manual		Automated	Manual
Reload caps and elevator with preforms	Elevator feeding with preforms	Blowout of bottles	Filling	Capping	Labelling	Loading on EUR-pallet	Placing paper between rows	Packing with foil	Transfer to storage

Figure 19: Chronological Process Sequence for Line Three

For visualization purposes, figure 20 examines all production lines and storage locations at the same time in order to show the holistic picture.

Figure 20: Production Lines & Storage Locations

Supporting Services: Back-up for production.

In a manufacturing plant, the supporting services include the maintenance, toilets, receiving and shipping area, cafeteria, auxiliaries necessary for the production. In the case of Snåsavann AS, those are the supporting systems necessary for the operationality of the lines. They include the liquid cooling machine, water access point, air compressor, and back-up generator, all stationed in the machine room. Another constraint worth mentioning is the carbonation unit, stationed inside the manufacturing facility, just next to production line one. The constraints mentioned above are to be considered in the future layout, but not allowed to interfere with the redesign. High moving cost of the heavy machinery, piping, and access point to the source. Based on the conversation with the management, it would be costly to relocate that particular room elsewhere, since it would also require additional noise isolation. The case company asked if possible, to keep the location of the machine room in the future layout.

Time: Frequency of produced products.

Open conversations and emails with the case company highlighted that the time required to lead a product from raw components to a ready to deliver the product through the factory is estimated to be eight weeks. During those eight weeks, only a small fragment of that time is value-adding, since the company manufactures in huge batches and lets the ready to deliver product wait in the storage. That time includes receiving from supplier, production, picking, and packing for delivery to the customer. Further on, estimation showed that the operation time of the factory is approximately 5640 hours per year.

4.3.2 Step Two: Analysis of Operations

The simplified SLP suggests the creation of a flow-process-chart, usually aimed at gathering and classifying the holistic data needed for the analysis and improvement of the operations (Akkoni et al., 2019) and waste identification. A material-type flow-process-chart visualized in figure 21 for production line one, figure 22 for production line two, and figure 23 for production line three.

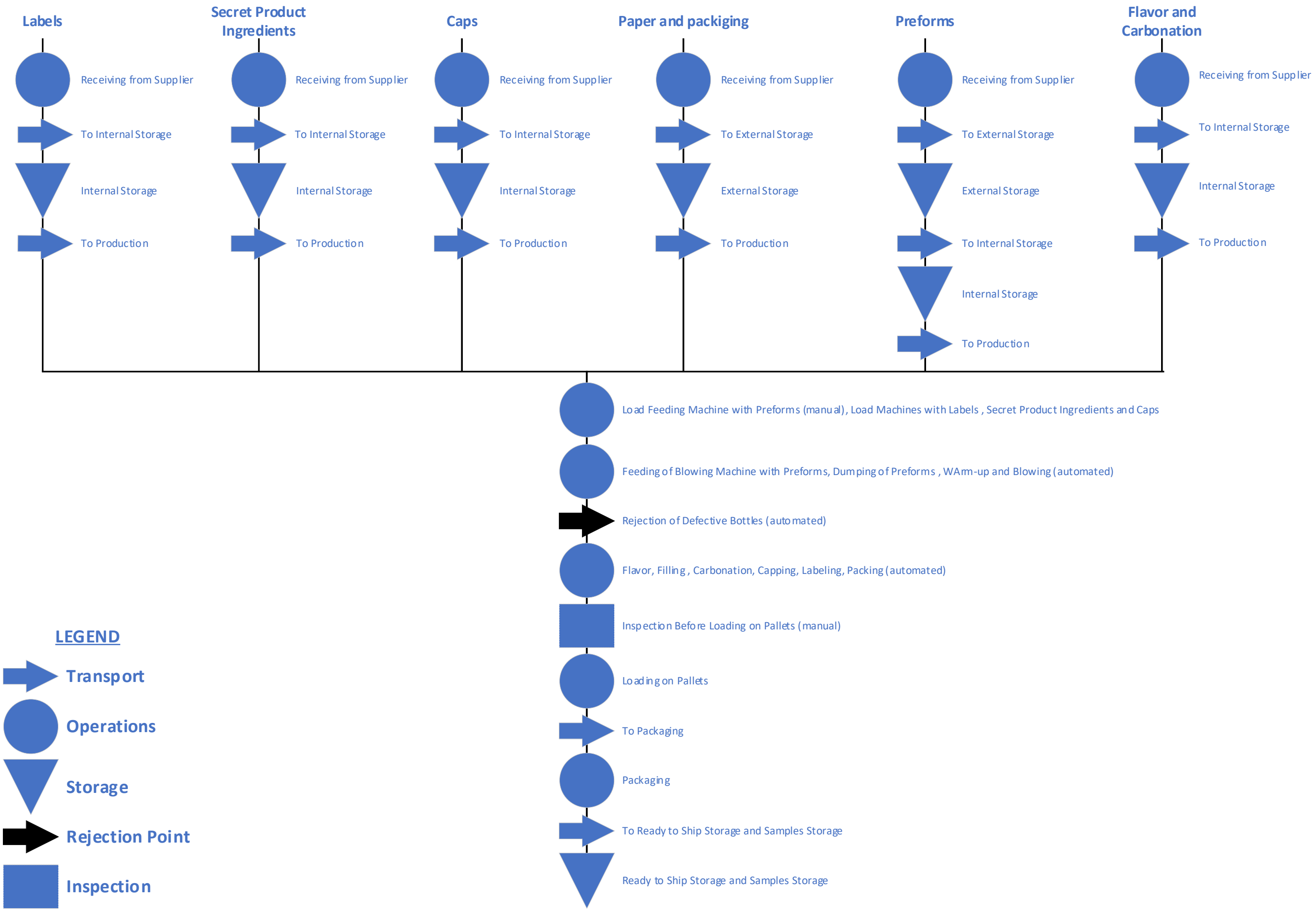

Figure 21: Flow-Process-Chart for Line One

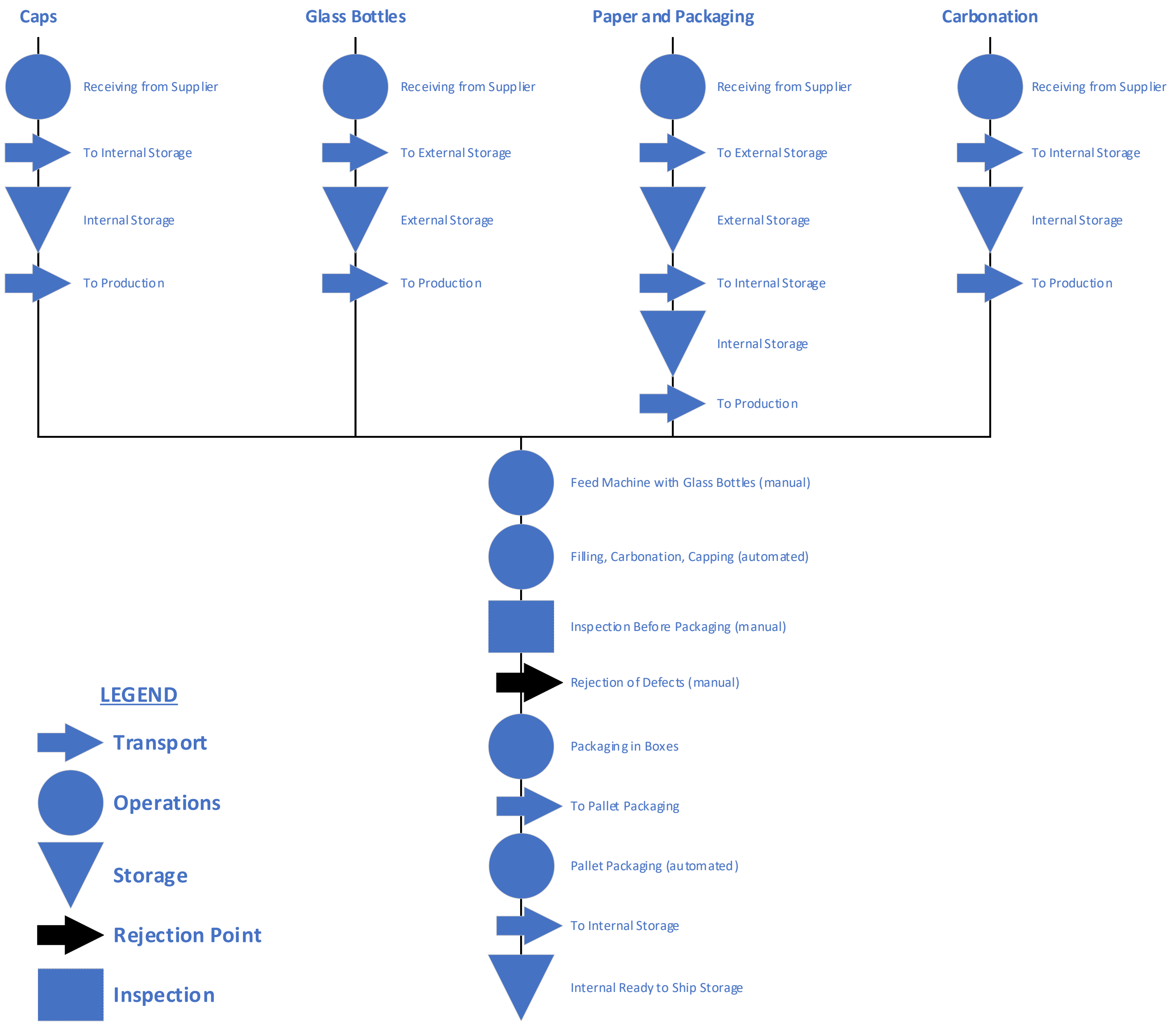

Figure 22: Flow-Process-Chart for Line Two

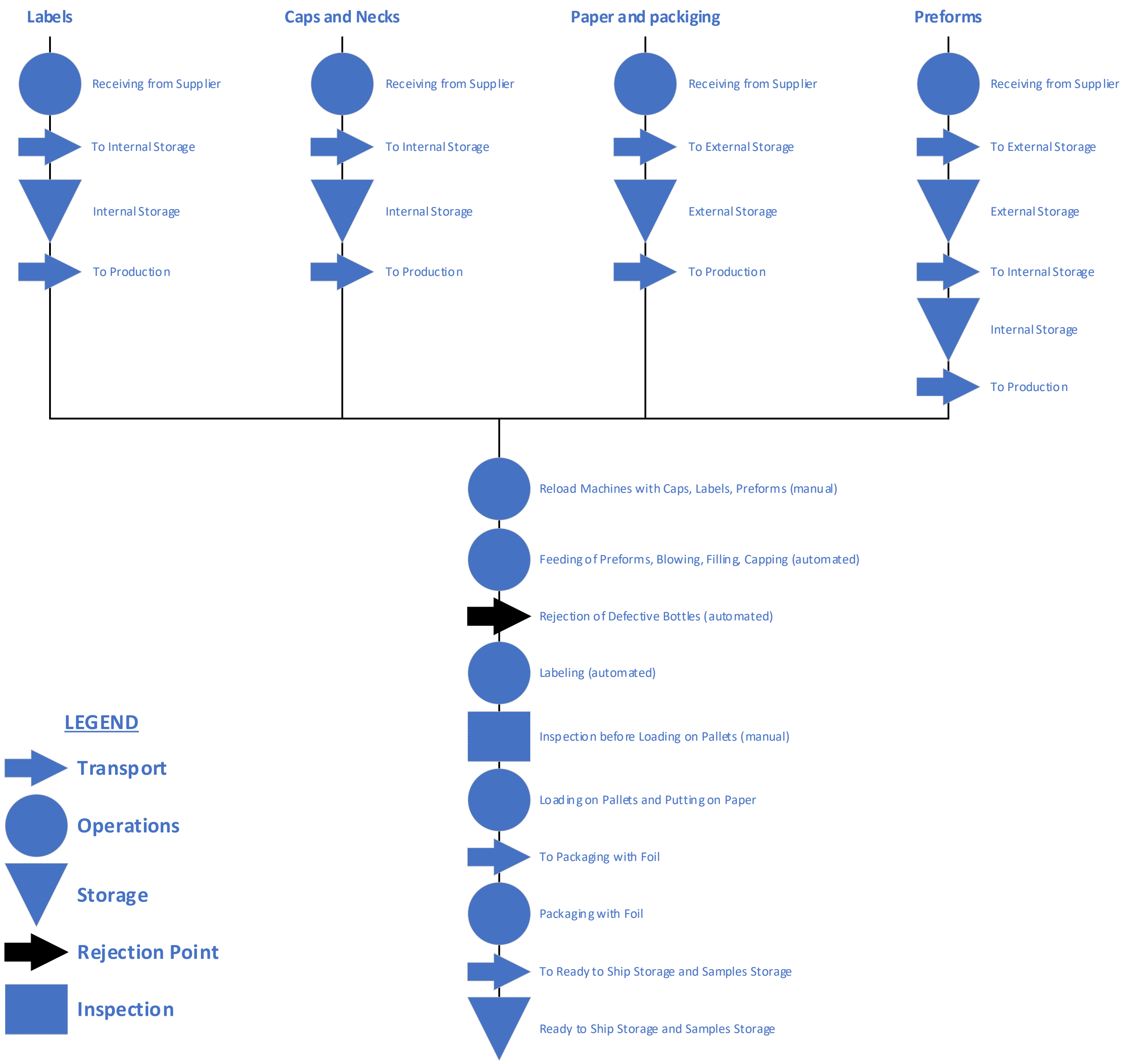

Figure 23: Flow-Process-Chart for Line Three

4.3.3 Step Three: Material Flow

This step involves the creation of a from-to-chart, figure 24, that tracks the intensity and interaction between different departments, represented as areas in the chart. The values inside the chart indicate the number of EPAL Euro pallets (aka EUR-pallet) (European Pallet Association, n.d) moving from and to the departments. Indicators in EUR-pallet were picked and not in bottles since the transportation of the manufactured products takes place in pallets, and the case company stated it would be more helpful to them presented that way. The numbers used here were calculated based on the three scenarios provided by the company. Those scenarios contain sensitive information regarding products yet to launch. Also, they contain information about a third-party agreement between the case company and some of its customers. The information used in this chart was approved and verified by the case company. However, no further disclosure of calculations will take place.

Scenario 1 - Conservative Expected Demand in EUR-pallet

FROM \ TO	A	B	C	D	E	F	G	H	Total
A						13723	372	2625	16720
B									0
C									0
D									0
E	16720								16720
F	13723								13723
G	372								372
H	2625								2625
Total	33441	0	0	0	0	13723	372	2625	

Year	2020
Production line 1	13723
Production line 2	372
Production line 3	2625

Legend	Area name	Abbreviation
A	Storage 1 (Main)	ST1
B	Storage 2 (Secondary)	ST2
C	Storage 3 (Secondary)	ST3
D	Storage 4 (Tent 1)	ST4
E	Storage 5 (Tent 2)	ST5
F	Production line 1 - mix	PL1
G	Production line 2 - glass	PL2
H	Production line 3 - 5 liter	PL3

Scenario 2 -Realistic Expected Demand in EUR-pallet

FROM \ TO	A	B	C	D	E	F	G	H	Total
A						14851	918	2625	18394
B									0
C									0
D									0
E	18394								18394
F	14851								14851
G	918								918
H	2625								2625
Total	36787	0	0	0	0	14851	918	2625	

Year	2020
Production line 1	14851
Production line 2	918
Production line 3	2625

Legend	Area name	Abbreviation
A	Storage 1 (Main)	ST1
B	Storage 2 (Secondary)	ST2
C	Storage 3 (Secondary)	ST3
D	Storage 4 (Tent 1)	ST4
E	Storage 5 (Tent 2)	ST5
F	Production line 1 - mix	PL1
G	Production line 2 - glass	PL2
H	Production line 3 - 5 liter	PL3

Scenario 3 - Optimistic Expected Demand in EUR-pallet

FROM \ TO	A	B	C	D	E	F	G	H	Total
A						16948	9053	2625	28625
B									0
C									0
D									0
E	28625								28625
F	16948								16948
G	9053								9053
H	2625								2625
Total	57250	0	0	0	0	16948	9053	2625	

Year	2020
Production line 1	16948
Production line 2	9053
Production line 3	2625

Legend	Area name	Abbreviation
A	Storage 1 (Main)	ST1
B	Storage 2 (Secondary)	ST2
C	Storage 3 (Secondary)	ST3
D	Storage 4 (Tent 1)	ST4
E	Storage 5 (Tent 2)	ST5
F	Production line 1 - mix	PL1
G	Production line 2 - glass	PL2
H	Production line 3 - 5 liter	PL3

Figure 24: From-To-Chart for Three Scenarios

Further on, the from-to-chart served for the creation of a visual drawing of the material movement as a flow diagram visualized in figure 25,26 and 27. The tents do not have a specified material flow due to an AD HOC nature of use. Further on, storage two are not used for keeping materials but are under renovation. Further investigation showed that the receiving of all raw materials takes place by the entrance of storage three and further distributed internally.

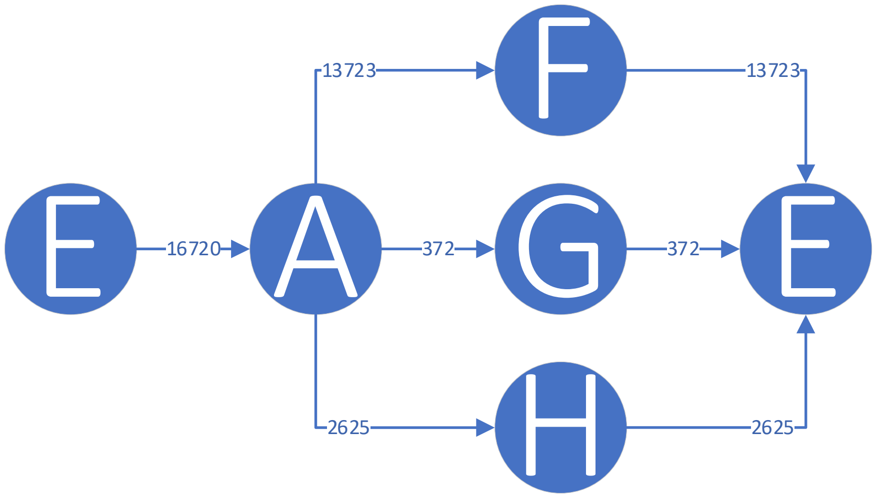

Figure 25: Flow Diagram for Conservative Scenario

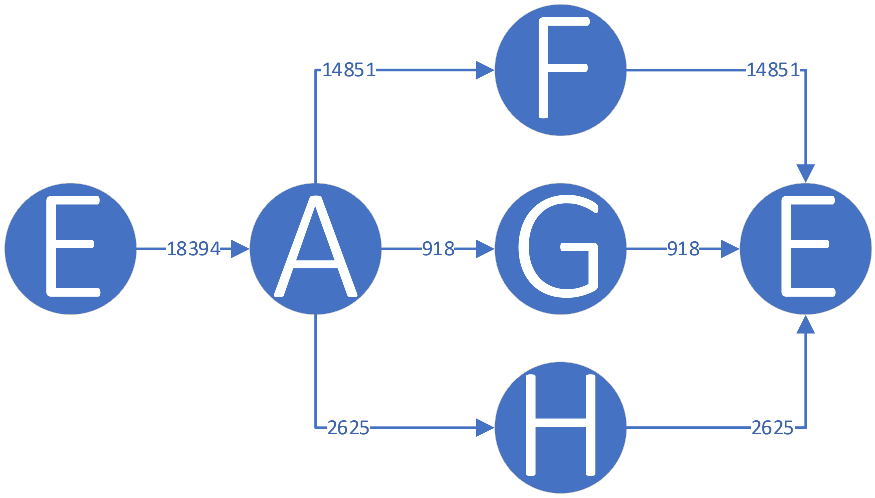

Figure 26: Flow Diagram for Realistic Scenario

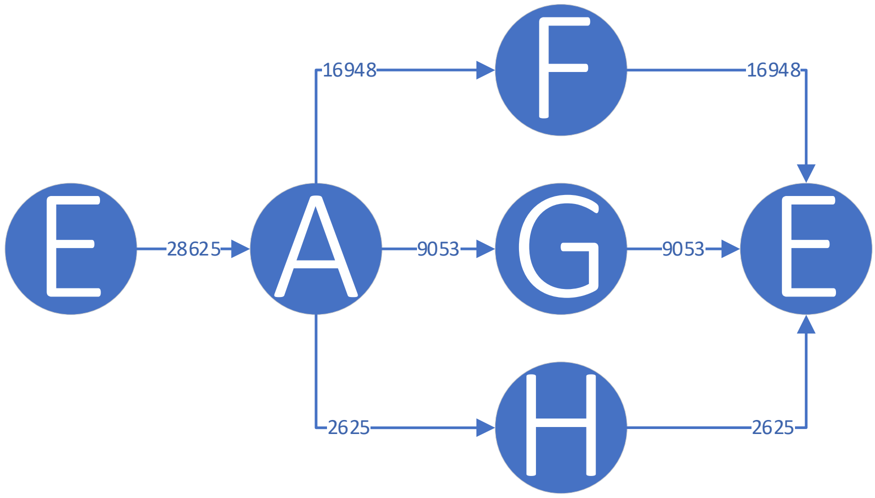

Figure 27: Flow Diagram for Optimistic Scenario

4.3.4 Step Four: Relationship Between Departments

This step involves the creation of a relationship diagram. For that case, an already established template from SINTEF (SINTEF, 2007) used in order to fill in the data. Those ratings were established in a discussion and later approved by the CTO and combine HSE, flow, material handling, vibration, and other regulations. An example of why figure 28 rate the engine room as necessary but undesired to be next to the office is the noise and heat generated.

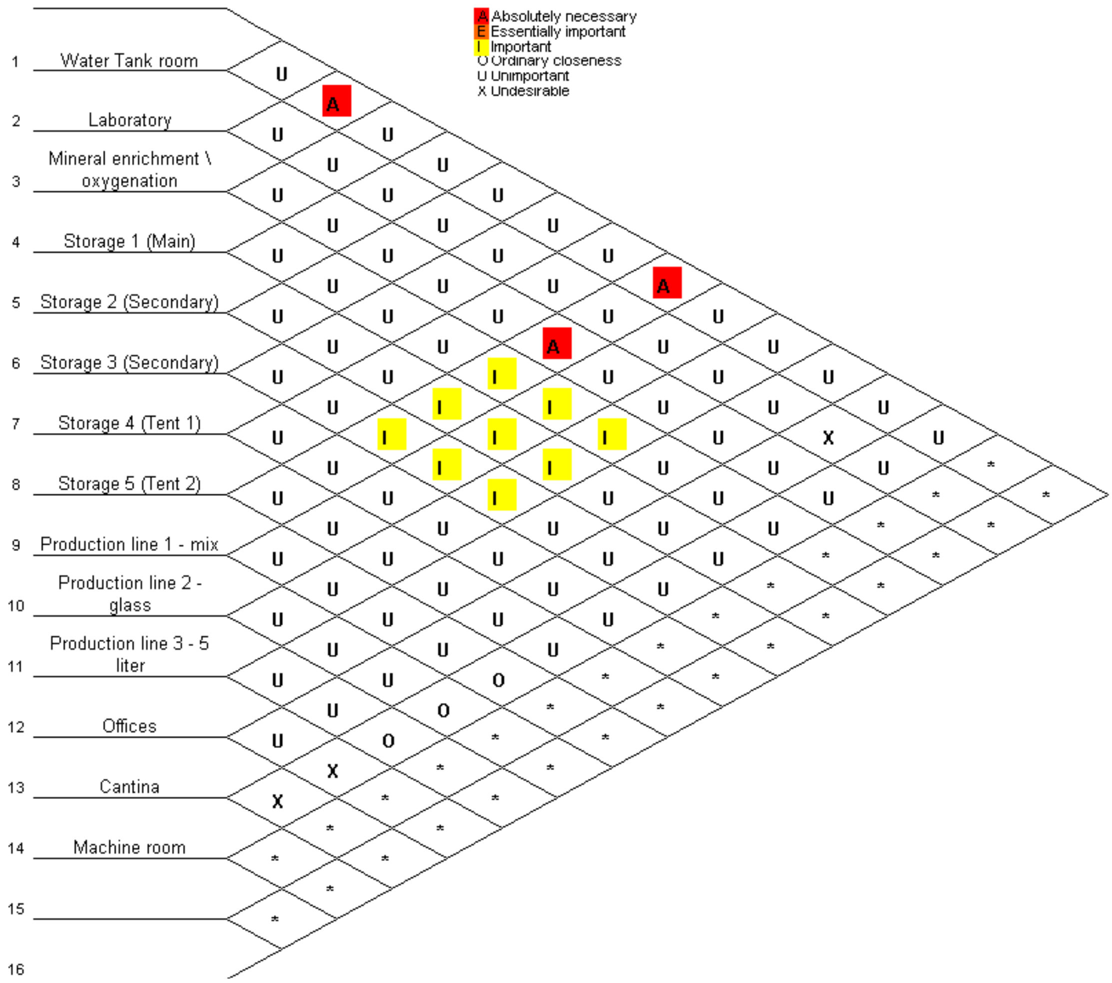

Figure 28: Sensitivity Diagram Results (SINTEF,2007)

Based on the information from the sensitivity diagram, the creation of a pattern concerning the future manufacturing facility layout takes place. The pattern, seen in figure 29, places arrows between necessary departments making it easy to see the desired future placement.

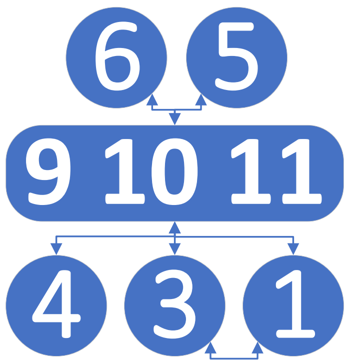

Figure 29: Pattern Based on Sensitivity Diagram

4.3.5 Step Five: Spatial Requirements

Step five examines the spatial requirements for the creation of new layouts. Summary of ***the current allocation*** of area concerning department size in table 21. Figure 30 visualizes what portion of the total area available is taken by each department.

Area name	Area (m^2)
Storage 1 (Main)	354
Storage 2 (Secondary)	80
Storage 3 (Secondary)	80
Storage 4 (Tent 1)	150
Storage 5 (Tent 2)	600
Production line 1 - PET	354
Production line 2 - glass	
Production line 3 - 5l PET	
Machine room	35,7
Oxyg. & mineral.	20
Lab	20
Water tank	60,9
Offices,Cantine,WC ,Wardrobes	145,6
Total Area With Tents	**1900,2**

Table 21: Current Area of Snåsavann AS Departments

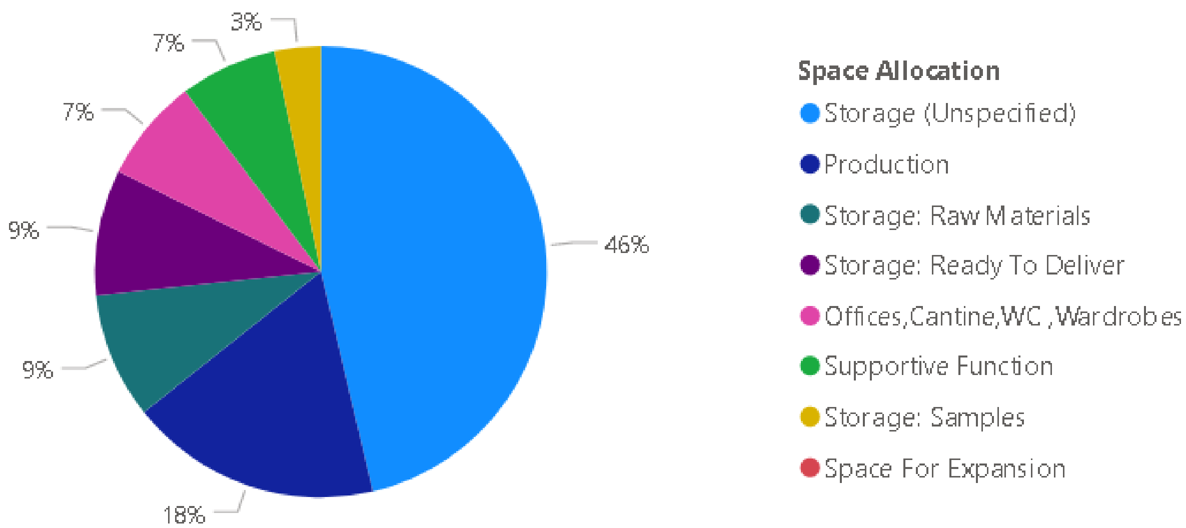

Figure 30: Current Space Allocation

Figure 30 makes the division between specified and unspecified storage easy to spot. The reason for it was due to AD HOC storage use at the case company due to the dynamic nature of the market and the need for fast changes. Further on, the workforce available focused on satisfying the customer demand and not on developing standardization of locations.

Further highlighted in this step are ***space requirements*** for the facility in order to meet the company-specific goals. From step one (figure 11,12,13), it is visible that satisfying the conservative and realistic forecast is possible with the current production lines. However, the optimistic forecast shows that current manufacturing lines cannot meet the demand. Further discussion with the case company showed that they are looking into the possibility of buying new and improved manufacturing lines.

Since the new manufacturing lines and sizes are not known up to the point of writing this thesis, a decision taken to focus on the assumption that as much space for future extension would be necessary for the new lines in the optimistic layout. All estimated space requirements take into consideration that the production lines must be able to operate simultaneously without interference, contain the space needed for maintenance, material handling, human-machine interaction as well as comply with health and safety regulations.

In the original application of the simplified SLP the author did not explain how to calculate the required area. Since the simplified SLP roots in the original SLP, an informed decision for the case of Snåsavann AS taken and a space relationship diagram devised. As explained in the original SLP, an examination of the space requirement is possible and recommended using a space relationship diagram, since a plan of the area already exists, equipment is high investment and size of machines is already defined. The space relationship diagram shown in figure 31 is of the output of steps three and four. It creates a visual representation of the space required, based on the sensitivity and material flow. It represents a roughed-out layout and visualizes the basic idea of the departments in the new layout.

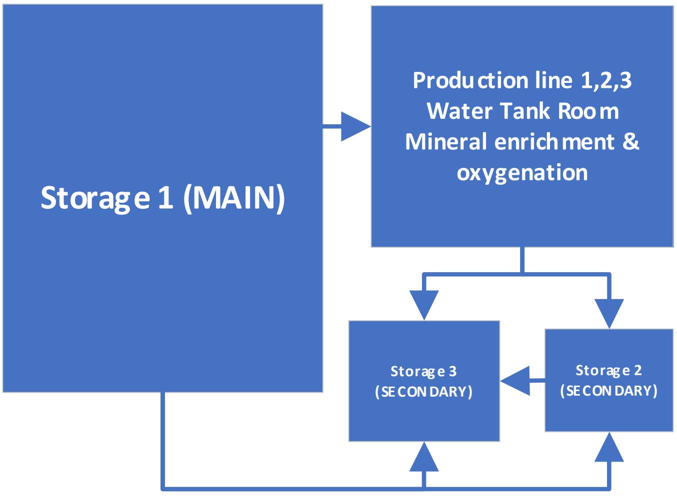

Figure 31: Space Relationship Diagram

From the space relationship diagram in figure 31 is visible that the pattern observed suggests that the primary storage should be the most prominent department and have a connection to the other two secondary storages. The pattern points out that all flows end up in storage 3, which is understandable, considering it is the only entrance and exit of the building for both raw materials and ready to deliver products. It also visualizes that the connection between storages and production must be available and uninterrupted. The higher the demand, the bigger the size of the storage facilities and production facility. That conclusion is logical yet unpractical since the principles of lean aim at the reduction of storage space and flow creation. Besides, based on the one week visit at the case company, it is known that the storage facilities they have are not full, and improvement regarding the layout of the storage facility exists. The layout of a storage facility will not be looked at in detail since its size is a part of the holistic manufacturing strategy not evaluated or analyzed in this master thesis. Even though the storage facility layout has its methods and procedures of calculation, it would be valuable for the case company to get an idea of the storage space requirements. The methods are outside of the scope of this master thesis; however, in order to make a valid assumption of the capabilities of the current factory, a simple calculation will take place.

Storage is crucial regarding the ability to meet the desired service level and satisfy the customer. Based on the forecasted yearly demand, the calculation of one-week safety stock for the MTS products took place. The amount converted into pallets and then shelf space as well as square meters. At Snåsavann AS, a single shelf can carry 33 pallets and has 13m² of area. Its common practice for them to keep a single shelf as safe storage and refill it every 18th day. Tables 22,23, and 24 show an increase in safety storage requirements if the production does not change. The solution for that challenge could be proper scheduling in order to cut the need for such a considerable safety stock.

Conservative Forecast	SUM of EUR-pallets to buffer				
MTS product &Year	**2020**	**2021**	**2022**	**2023**	**2024**
5l	2625	3031	3294	3624	3986
0.5l	741	1111	1278	1406	1546
1l	83	185	213	234	258
Total Pallets to Buffer	**3449**	**4328**	**4785**	**5264**	**5790**
One Week Buffer	66	83	92	101	111
Space Required (m²)	26	33	36	40	44
Number of shelves	2	3	3	3	3

Table 22: Safety Stock in Shelves for Conservative Scenario

Realistic Forecast	SUM of EUR-pallets to buffer				
MTS product &Year	**2020**	**2021**	**2022**	**2023**	**2024**
5l	2625	3031	3294	3624	3986
0.5l	1019	2014	2316	2548	2802
1l	102	648	745	820	902
Total Pallets to Buffer	**3745**	**5693**	**6356**	**6991**	**7690**
One Week Buffer	72	109	122	134	147
Space Required (m²)	28	43	48	53	58
Number of shelves	2	3	4	4	4

Table 23: Safety Stock in Shelves for Realistic Scenario

Optimistic Forecast	SUM of EUR-pallets				
MTS product &Year	**2020**	**2021**	**2022**	**2023**	**2024**
5l	2625	3031	3294	3624	3986
0.5l	1944	4144	4972	5469	6016
1l	648	1458	1750	1925	2118
Total Pallets to Buffer	**5218**	**8633**	**10016**	**11018**	**12120**
One Week Buffer	100	166	192	211	232
Space Required (m²)	39	65	76	83	92
Number of shelves	3	5	6	6	7

Table 24: Safety Stock in Shelves for Optimistic Scenario

Since tables 22,23 and 24 only give a very rough estimation of the safety stock, their inclusion into consideration for the layouts will not take place. The tables mentioned above offer an estimation of the safety storage for the MTS products only. Placement and number of shelves available inside the buildings owned by Snåsavann AS will not be calculated due to not being part of the manufacturing facility layout procedure.

4.3.6 Step Six: Layout Alternatives

Step six involves the creation of three different manufacturing facility layouts corresponding to the three different scenarios. The creation of the layouts uses the information from all previous steps as well as keeping in mind the fundamental lean principles explained in chapter 3.1.4. The step builds upon the demand forecasts, examines the sensitivity diagram, considers constraints such as noise, hygiene, safety, infrastructure, ergonomics, and existing buildings. It does not constrain based on walls and existing piping or cables. It takes into consideration the bearing beams of the factor. It takes into account that only the office area has floor heating and that the connection to the water source preexists in the machine room. Step six concludes with three block layouts, shown in figures 32, 33, and 34, combined with existing manufacturing lines.

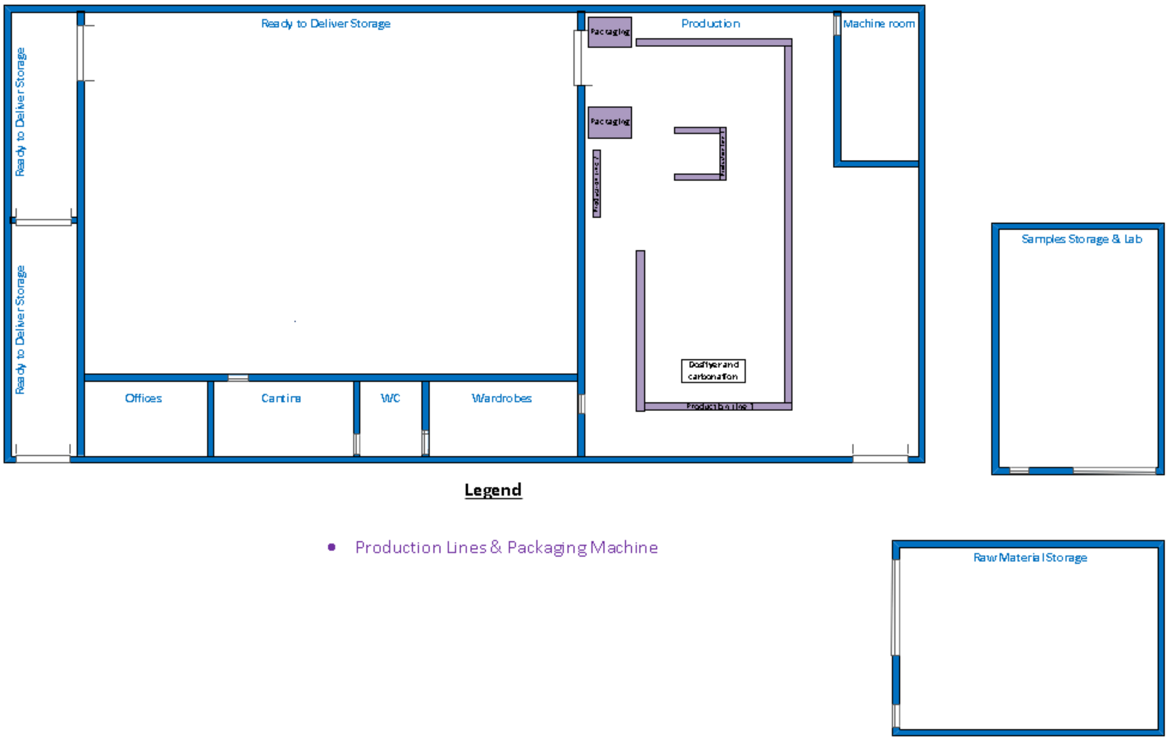

Figure 32: Layout Alternative One for Conservative Customer Demand

Figure 33: Layout Alternative Two for Realistic Customer Demand

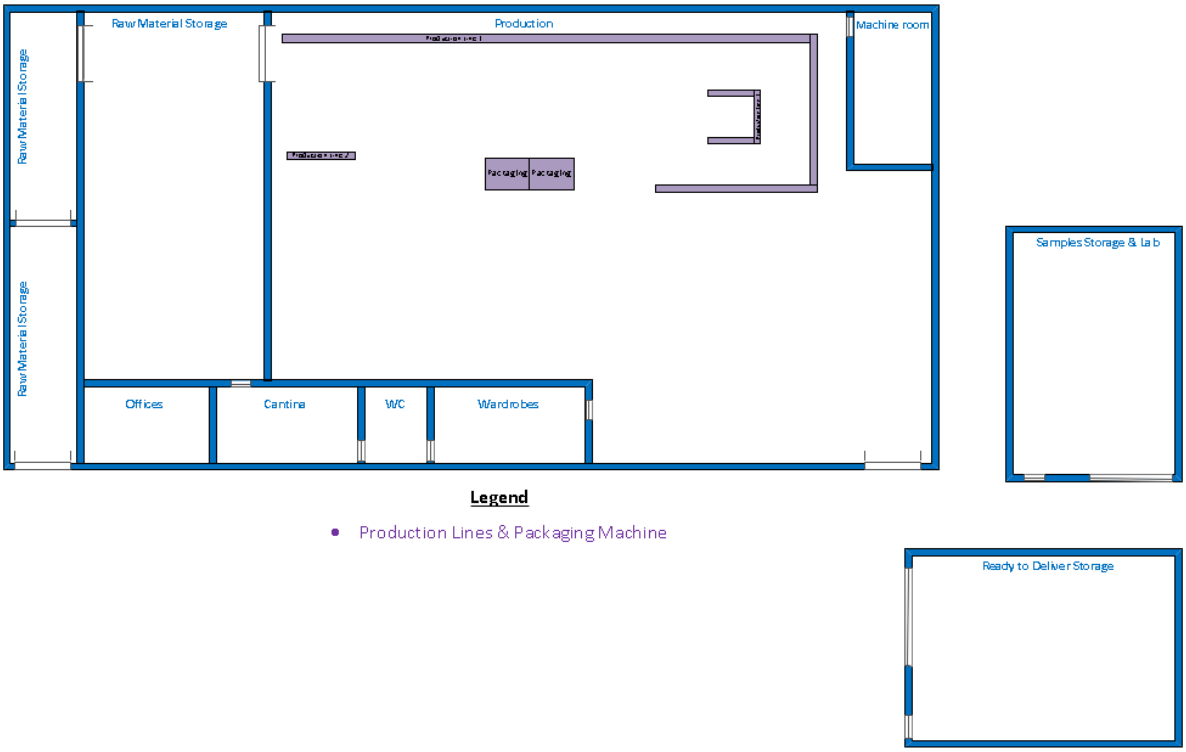

Figure 34: Layout Alternative Three for Optimistic Customer Demand

4.3.7 Step Seven: Layout Evaluation

Step seven involves the criteria evaluation of layouts. The criteria visualized in table 25, were developed with the case company and examine the performance of the current and the new layouts. Some of the performance criteria can be measured, but others are complicated and represent long-term improvements.

Priority	Criteria	Reason for choosing it	Measure
High for Optimistic	Space for Expansion	The company wishes to analyze if more lines could be placed within the same factory since the costs of a new building are high.	Space for Expansion /Total Space (%)
Medium for all	Holistic Flow	The company wishes to analyze the holistic flow and standardize the storage locations.	Discussion
High for Conservative	MUDA Reduction	Time costs money, so all non-value adding time is to be eliminated.	Walking distance (meters)
High for all	Meet Demand	How much can the layout facilitate the increase in demand?	Forecasted demand not over design capacity
Medium for all	Process Steps Reduction	Reduce the steps and free up worker time.	Number of Steps (before vs. after)
Medium for all	Lead Time Reduction	Lead time would benefit from a logical flow. Likely, the new layout would further improve the lead time.	Discussion
High for all	Standardization of Locations	Have a clear plan of what is happening where.	Departmentalization

Table 25: Layout Evaluation Criteria

Since the documented application of the simplified SLP took place in a switchgear factory, the evaluation and performance part is not applicable for a food and beverage company, due to different set of characteristics such as higher hygiene standards or perishability rate. The material flow, lead time, production rate, and cost reduction per panel used as evaluation criteria in the original application are relevant for the case company. However, they do not align with the desired measuring criteria. The newly developed evaluation criteria had relevance to the company's actual needs. The layout evaluation criteria heavily emphasize the satisfaction of forecasted demand, the establishment of flow, process steps reduction, and space for additional production lines. Since the new layout alternatives follow three different sets of data for the expected demand, they align with different prioritization of the performance criteria. For instance, the space for expansion is highly desired for the optimistic scenario, while the MUDA reduction desired for the conservative. Based on the discussions with the case company, it was agreed upon that the conservative scenario should focus on improvement with as little investment as possible, while the optimistic was to prepare the current factory for new production lines. Evaluation of the current and new layouts took place aligned with the performance criteria mentioned above.

Figure 35: Current Facility Layout

Figure 35 shows what the current layout provides regarding the storage location and material flows. Storage 3 is the only access to the building. The single point of entry and exit from the facility contributes to the crossing of the material flow and dispositions to backtracking. Figure 36 visualizes how the space allocation in the current layout. In it, the raw material partition combines Preforms, Labels, Caps, Necks, and the partition Supportive Function includes the lab and machine room.

Further, there is no free space for new manufacturing lines and the expansion of production. The workforce is required to walk from storage 3 to tent 2 and tent 1 in order to deliver samples or pick raw materials. Estimation devised that the walking distance is 190 meters in total. Further, due to the dynamic market and limited workforce, some operations and placement of materials done in the AD HOC manner. There is no standardization regarding what is stored where. It is visible from figure 32 that the holistic flow is disturbed, and additional yet avoidable process steps take place.

Regarding the ability to meet the forecasted demand, the current production lines are capable of facilitating realistic and conservative scenarios. However, the optimistic scenario shows that line one and two will not be able to satisfy the demand. Based on the challenges mentioned earlier, the lead time is prolonged, and non-value-adding activities evident.

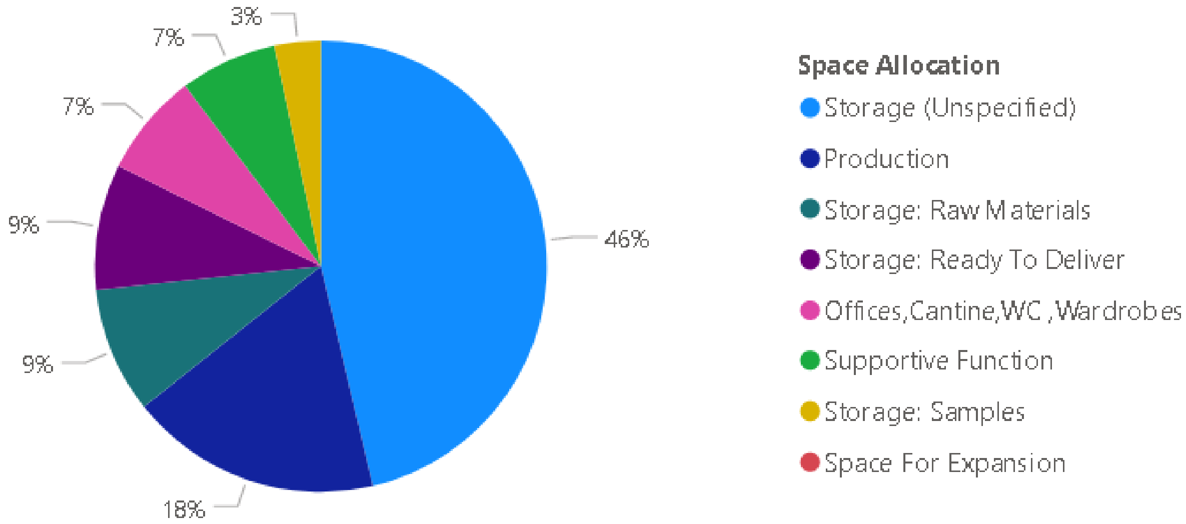

Figure 36: Current Space Allocation

Further on, the process steps examined in this thesis highlight multiple transportations and storage locations of the same raw material. The lean philosophy sees that as waste and that knowledge employed for the creation of the new layouts.

Layout Alternative One for Conservative Customer Demand figure 37 focuses on the conservative customer demand forecast. It serves as an improvement to the old layout aiming at using as little resources as possible in order to reduce the non-value-adding activities and improve the overall performance of the plant. The space a department is using out of the total area visualized in figure 38.

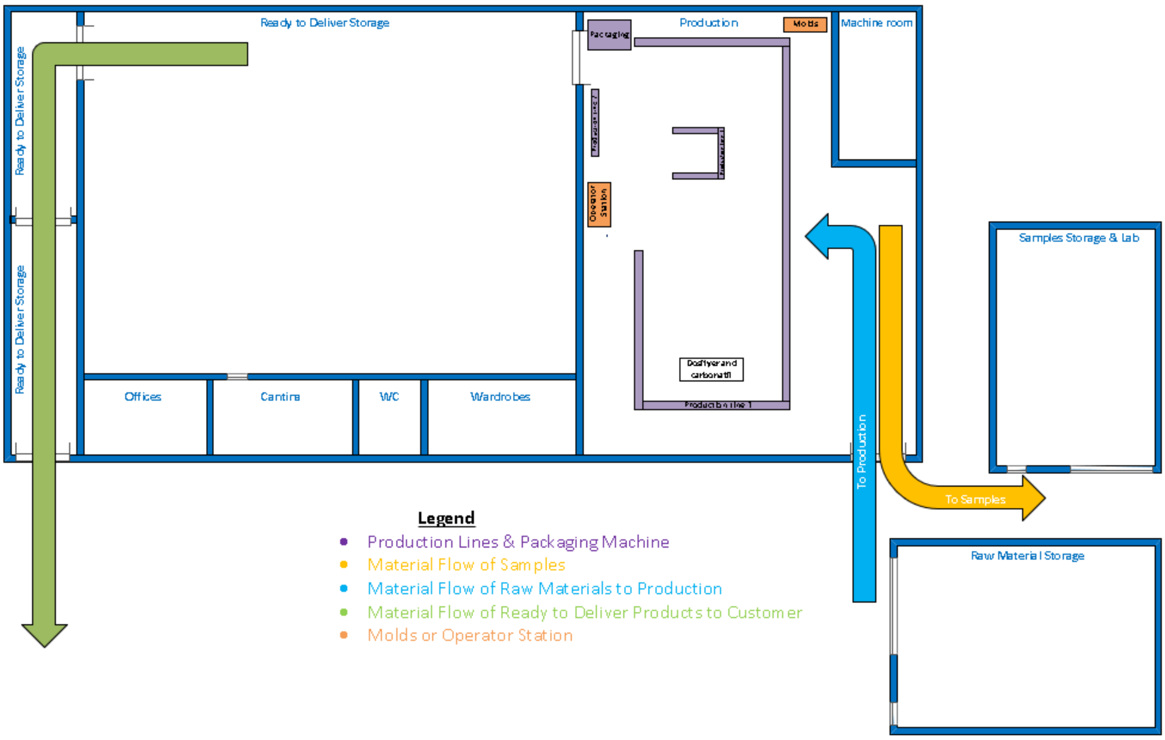

Figure 37: Layout Alternative One for Conservative Customer Demand with Material Flows

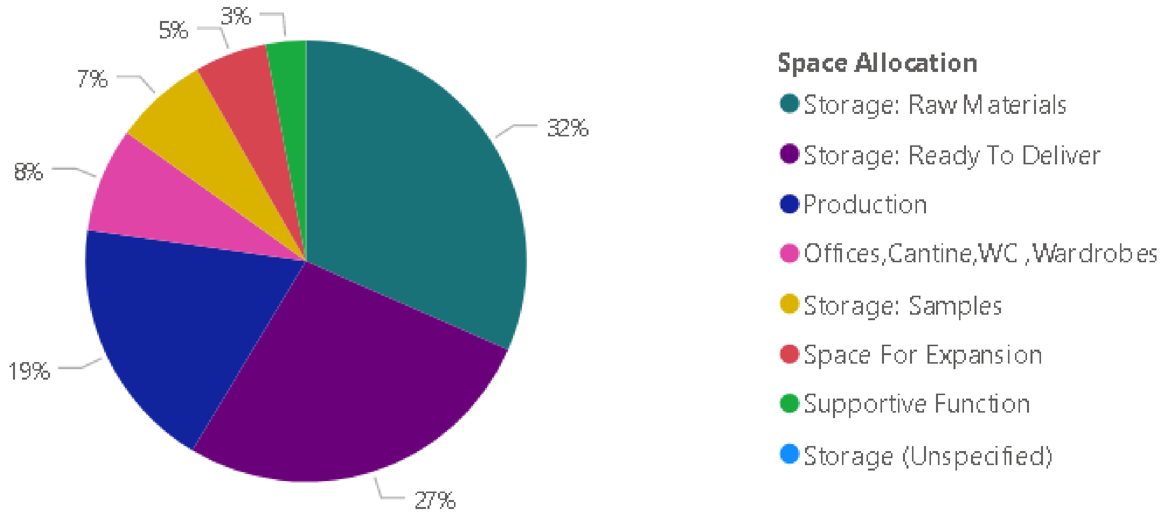

Figure 38: Space Allocation for Conservative Scenario

Since the existing manufacturing lines are capable of satisfying the conservative increase of demand, the focus moved to establish flow. In this layout, the second possible port opened, and walls removed in order to create a single point of entry and exit for the flow. By doing that, the walking distance outside of the factory reduced to an estimate of 70 meters. Holistically speaking, the raw material is fed to the production on one side while ready to deliver products are stored and awaiting delivery to customers on the other. That, combined with the standardization of storage locations predispose to the creating of an easy to follow flow correlated with the process of product manufacturing. In the first layout alternative, the lab is moved to tent one and departments rearranged and combined in order to align with the holistic flow. The oxygenation and water tank fused with the production department and molds stored in the machine room. Besides, even though only two bottles are taken for samples and stored in tent one, it is highly relevant to set up a storage system in order to use the space entirely. The reallocation of space allows freeing up to 101 square meters for expansion of the production. The improvements above further contribute to lead time reduction and removes steps from the process sequence. Line one and three loose need for two storage locations and one additional transportation of preforms. Line two loses the need for two storage locations and one additional transportation of paper and packaging (put the reference to figure). This layout would involve the least amount of investment. Due to COVID19 limitations and the scope of work, estimation of that amount will not take place. However, it is visible from the figures that the reuse of old infrastructure takes place.

Layout Alternative Two for Realistic Customer Demand figure 39 focuses on the realistic customer demand forecast. It further builds upon the improvement suggested in layout one. However, it encourages relocation of the manufacturing lines and emphasizing freeing up space for new lines. That is not because of the inability to satisfy the customer demand but in order to allow the case company to take in other contracts requiring new lines. It follows the logic of placing the raw materials as close to the production line as possible. It also reduces the walking distance outside of the factory to 70 meters and satisfies all other performance criteria. The new space allocation visualized in figure 40.

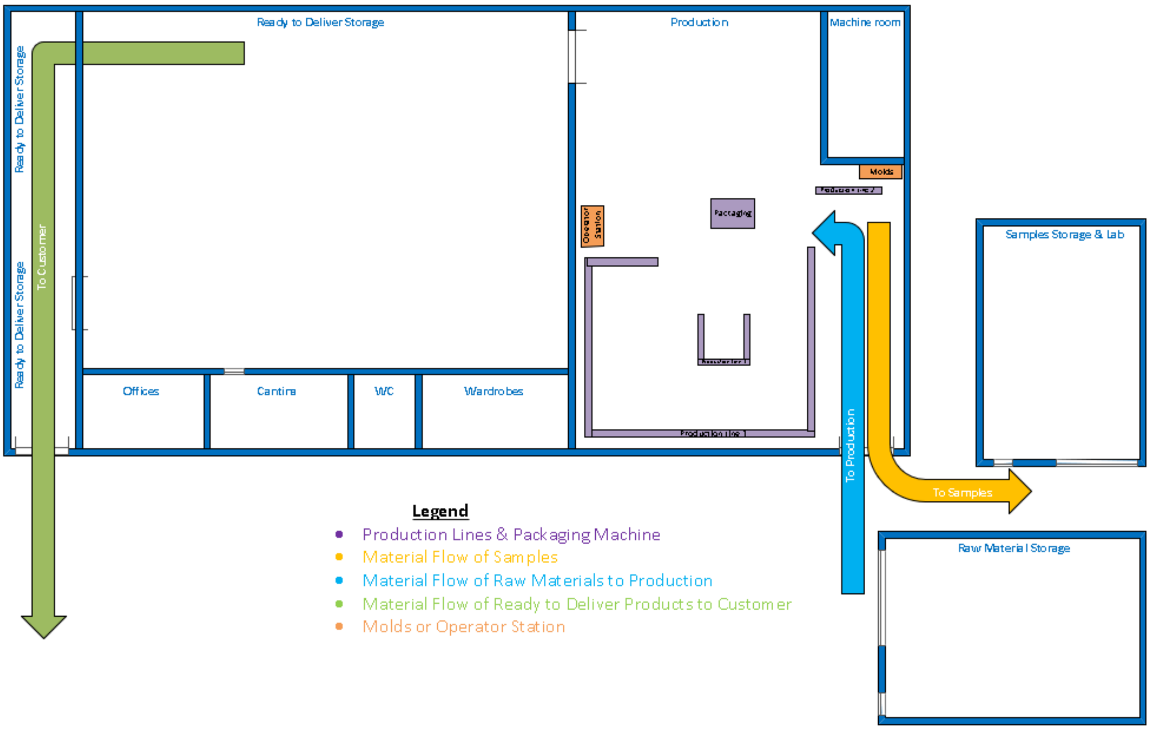

Figure 39: Layout Alternative Two for Realistic Customer Demand with Material Flows

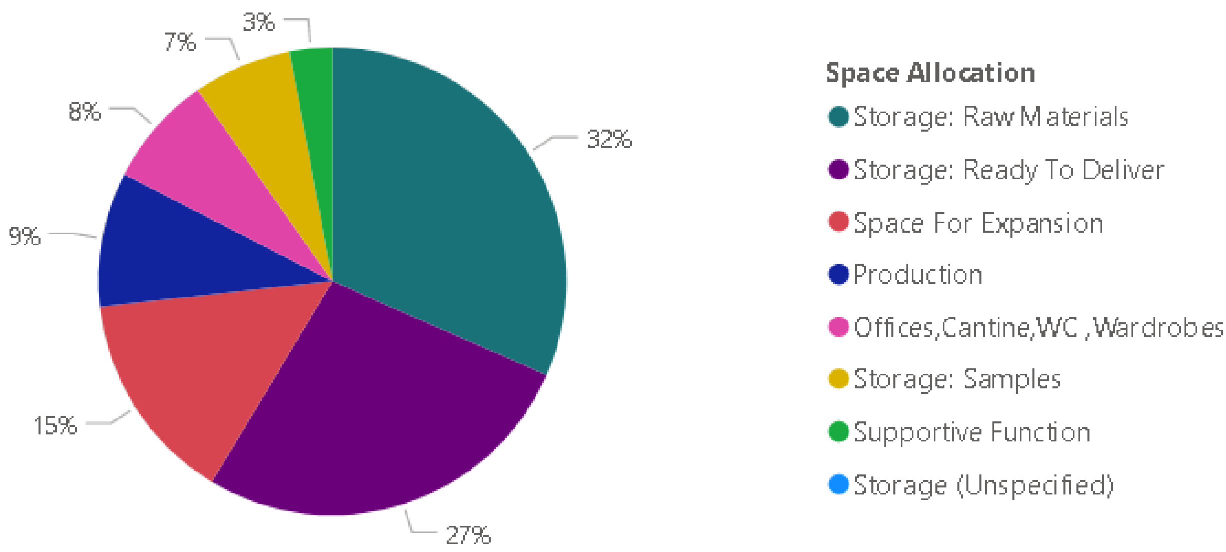

Figure 40: Space Allocation for Realistic Scenario

Layout Alternative Three for Optimistic Customer Demand on figure 41 focuses primarily on the space for expansion performance indicators. It takes into consideration all other improvements examined in layout alternatives one and two. It suggests freeing up to 336 square meters of space for future expansion of the production lines by improving the grouping of the departments. Even though the manufacturing lines are unable to meet the Optimistic scenario, the available space for expansion in figure 42 allows the company to place more production lines inside the existing facility without compromising the holistic flow.

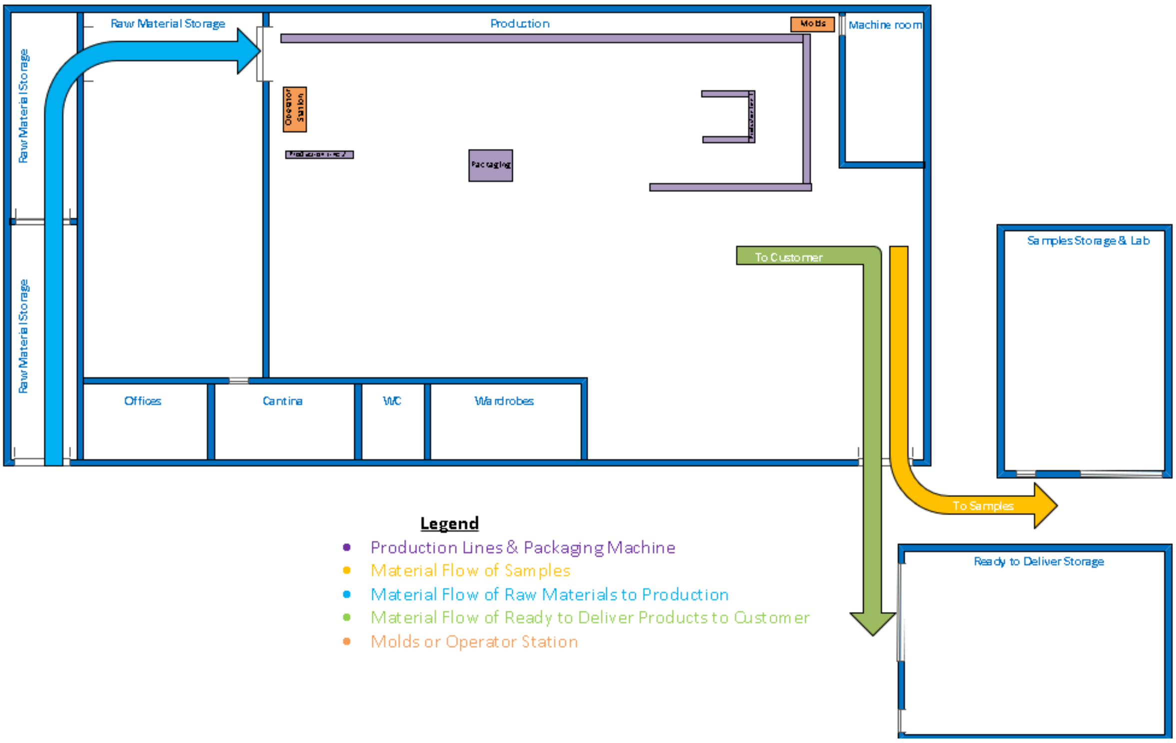

Figure 41: Layout Alternative Three for Optimistic Customer Demand with Material Flows

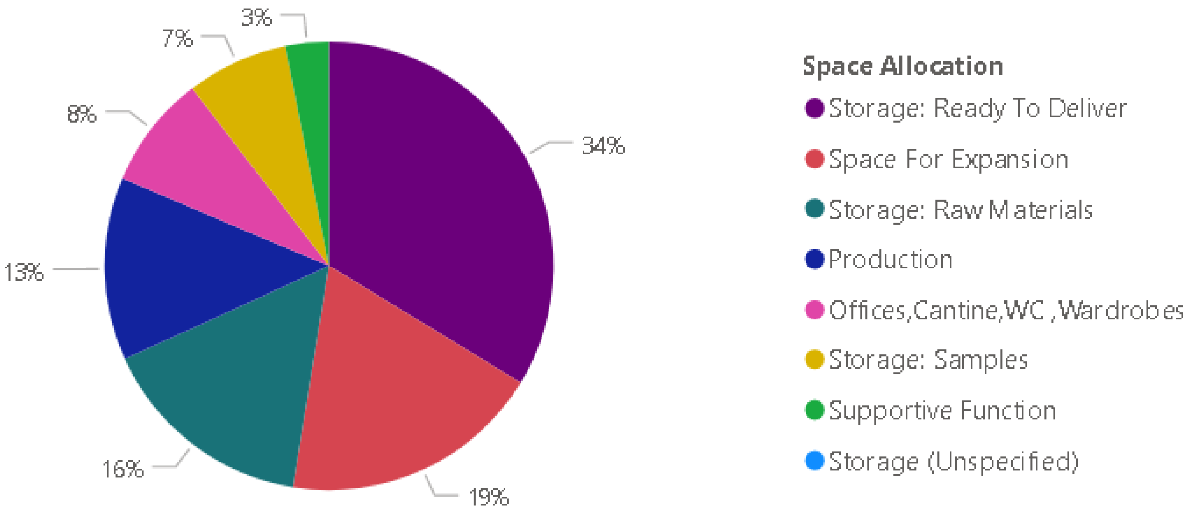

Figure 42: Space Allocation for Optimistic Scenario

For simplification purposes, the way the old and new layouts are performing based on the company defined performance assessment criteria found in tables 26 and 27. The holistic flow criteria are essential to the overall operations, since it creates a value-adding stream of activities, reduces backflow, and supports the company in reaching their production quota. Since the time spent in non-value adding activities is time lost, the MUDA reduction initiative is vital. For simplicity, the company decided to use walking distance and consideration of it taken in all layouts. The process step reduction is the elimination of the need to transport and store both in internal and then external storage for the raw components required for the manufacturing of bottled water.

The lead time reduction is a long-term effect supported by an efficient layout, standardization of storage, reduction of process steps, and MUDA. Measuring it on this stage would be highly inaccurate and unscientific. The standardization of storage and holistic flow would reduce variation in the daily operations and complement the lead time reduction. Table 29 compares the space utilization of the new and old layout.

Space Allocation	Current	Conservative	Realistic	Optimistic
Storage: Ready To Deliver	9 %	27 %	27 %	32 %
Storage: Preforms,Labels,Caps,Necks	9 %	32 %	32 %	15 %
Storage: Samples	3 %	7 %	7 %	7 %
Production	19 %	19 %	9 %	12 %
Offices,Cantine,WC ,Wardrobes	8 %	8 %	8 %	8 %
Supportive Function: LAB & Machine room	7 %	3 %	3 %	3 %
Space For Expansion	0 %	5 %	15 %	18 %
Storage (Unspecified)	48 %	0 %	0 %	0 %

Table 26: Space Allocation Comparison

Layout	Walking Distance Reduction	Space for Expansion (m^2)	Standardization of Locations	Holistic Flow	Process Steps Reduction	Forecasted Demand Not Above Design Capacity	Lead Time Reduction
Current	190m	0	No	No	No	Yes	No
Conservative	70m	101	Yes	Yes	Yes	Yes	Yes
Realistic	70m	278	Yes	Yes	Yes	Yes	Yes
Optimistic	70m	336	Yes	Yes	Yes	No	Yes

Table 27: Evaluation and Performance Assessment

4.4 Summary

Chapter four contains the complete scientific documented application of the simplified SLP in a beverage company. The chapter starts with an introduction to the origin of the company. It continues with a systematic introduction to Snåsavann AS following a framework aimed at painting a picture of the current state of operations. The visualization resulting from the framework highlights the holistic variables and values of the case company. Further on, the documented application of the simplified SLP takes place in chronological order. Step one determines the current plant capacity using the PQRTS-model. In it three different datasets used in order to end up with three different layouts answering three different demand forecast: conservative, realistic, optimistic increase of demand. Step two initiates an analysis of operations and employees a material-type flow-process-chart in order to map the process steps. Step three involves the creation of a from-to-chart that tracks the intensity of interaction between different departments. Results from it are visible in a flow diagram for each of the three scenarios. Step four involves the creation of a sensitivity relationship diagram culminating with a pattern visualizing the importance of closeness between departments. Step five examines the spatial requirements for the creation of new layouts. It shows the current space allocation as well as an estimated required space in the form of a space relationship diagram. In this step, a calculation of the safety stock for the MTS products takes place. Step six combines the output of all previous steps and takes into consideration the critical constraints. It suggests three different block layouts combined with the preexisting manufacturing lines. Step seven completes the documented application of the simplified SLP by comparing the old and new layouts with performance assessment criteria co-developed with the case company.

5. Discussion

Chapter five follows the satisfaction of the research tasks structured to help reach the overall objective of assessing and documenting the applicability of the simplifies SLP. Further, the chapter covers a discussion of the limitations and weaknesses of both layout and research related aspects.

5.1 Applicability of the Simplified SLP for Snåsavann AS and F&B Industry

RT1: Map the case company.

The research task one (RT1) was examined and satisfied in chapter 4.2. By employing a systematic framework aimed at mapping the product, market, and manufacturing process-related characteristics. Further on, chapter 4.3.1 and 4.3.4 offers additional in-depth information regarding the case company, giving the reader a better understanding of Snåsavann AS.

RT2: Develop a new layout design for each scenario using the simplified SLP.

Research task two (RT2) involves the application of all steps of the simplified SLP, in-depth examined in chapter 4.3, and combines specific hygienic constraints for the food and beverage industry as well as existing constraints such as bearing beams and existing ports. Each of the three scenarios (conservative, realistic, and optimistic) led to a new layout design correlated with company defined performance criteria. The new layouts are in-depth, examined in chapter 4.3.7. They all aim at the satisfaction of forecasted demand. However, the main difference is that the conservative serves as an upgrade to the current layout with an emphasis on the reduction of non-value-adding activities and performance improvement. The realistic allows for the introduction of new lines, and the optimistic focus on freeing up as much space for future expansion within the current facility as possible.

RT3: Discuss the applicability of the simplified SLP for Snåsavann AS. Create reasonable generalization for the SMEs in the food and beverage industry.

Research task three (RT3) was satisfied in chapter four in which the full step-by-step application of the simplified SLP took place. The results of the method are validated and affirmed by the case company.

Further, the simplified SLP was examined and explained in more detail in this master thesis than in the novel work presented by its creator. The procedural method does not require a layout designer for its application and can be put into use by the SME on their own. Examination of all the prerequisite data, steps, and necessary minor modifications take place in this master thesis. That makes it easy to see that custom modification to specific areas that better suit the companies needs is acceptable and does not compromise the integrity of the method and its output. Based on the feedback from the company, it is their opinion that simplified SLP offers what they need: simple to follow procedure for the design of a manufacturing facility layout in an everchanging and dynamic market.

Based on the output from the research tasks, the reasonable generalizations for SMEs in the food and beverage industry summarized in table 28.

	Generalization
1	SMEs could use the simplified SLP to make a quick evaluation of their capabilities and check if the current manufacturing layout satisfies future demand forecasts. Instead of having an AD HOC approach towards new manufacturing lines or adding new products to their portfolio, a holistic approach realized, and a decision based on facts taken.
2	Simplified SLP offers a simple process chart showing MUDA.
3	Simplified SLP could show how well the space utilization is and what departments could be fused, terminated, or established.
4	Simplified SLP does not require expensive investment or add danger to exposing sensitive info to third party participants.
5	Simplified SLP highlights how well a line is operating compared to the forecasted demand making it easy to see if the line can meet the demand, or there is a lack of workforce or work hours.
6	No advanced skills are needed to apply the simplified SLP since all steps are explained in detail here.
7	The framework simplifies the reality for both the reader and designer. It underlines that the MTS and MTO have different characteristics, and MTS should have a clearer path through the factory due to a more significant volume. Nothing should stand on its flow. Due to the high level of automation, the flexibility is low, set-up time high, and part flow in batches. That further highlights the importance of having a holistic perspective on the placement of lines. The framework was an asset for applying the simplified SLP; however, it is possible to exclude it. As argued above, it gave the author of this master thesis a better understanding of the case company.
8	Application of the simplified SLP requires communication with someone who has been working long enough to know the specifics of the factory and machines. Lack of documentation regarding the machines and their capabilities could make the application difficult. Further understanding of the infrastructure, pipes, walls, and bearing beams must be at hand. No special skills are required, but an understanding of the building, area, source. The rushing of assumptions and solutions based on the first steps must not take place. Application of all steps of the simplified SLP must take place with as good precision and accuracy as possible in order to get sound output.

Table 28: Generalizations for SMEs

Findings devised from this master thesis are that the procedural method used to analyze and improve the manufacturing facility layout at Snåsavann AS offered the case company a holistic view of their operations. It highlighted how the material flow, placement of machines, and space allocation affect the overall factory performance. It helped them understand the tradeoff between efficiency and variants as well as giving a grounded and easily presentable holistic view of the operations. Prerequisites for a reduced lead time were also examined and explained to them.

During the application of the simplified SLP, some minor modifications took place. The summary of all of them devised in table 29. They do not change the simplified method but modify the input to it as well as the exclusion of some sub-steps, not explained by the author of the simplified SLP as crucial due to reasons unknown.

Step	Explained in Paper	Deviation for Applicable at Snåsavann AS
1	PQRST and lead time reduction mentioned but not explained in-depth. Six-month data mentioned, but not specified if historical or the future forecast.	Use of three scenarios of demand forecast for future layouts.
2	The process chart and activity chart used but not presented or examined as important.	Picked the material type flow-process chart, since it covers the need for this step.
3	Use of a from-to-chart and a flow diagram.	No deviation and full application of step.
4	Relationship diagram and mileage chart.	No deviation and full application of step.
5	Space requirements and availability.	Use of roughed-out layout and simple safety stock calculation.
6	Practical constraints for alternatives.	Block layout for all alternatives combined with current machine lines.
7	Evaluation of the four layout alternatives.	Use evaluation and performance assessment criteria defined by the case company. Compare old and new layouts with the criteria.

Table 29: Deviation from the Simplified SLP

The new layouts would further facilitate lead time reduction due to establishing a logical and value-adding flow. The alternatives presented establish a holistic movement of material from each production line, standardization of storage, and better allocation of space. Those improvements contribute to lead time reduction.

Further, it is the author of this master thesis conviction that the application of the simplified SLP could be made in a month, making it cost-efficient for the SMEs.

5.2 Limitation and Weaknesses

The limitations and weaknesses of this master thesis exist in two domains: layout creation and research process-related. ***Layout creation*** wise the available data for the creation of the layouts was a factor since only one week of observation, and data gathering took place in 2019. Due to the COVID19 additional details were gathered remotely, and all activities regarding library availability, company availability, supervisor availability, and access to office majorly influenced the outcome of this work. Due to that, the preliminary plan, which included a second company visit in April, was dropped, and dense improvisations for the completion of the master thesis within the timeframe took place. Further on, this master thesis only evaluates the application of the simplified SLP to a single SME in the F&B industry.

Another weakness of this master thesis was the lack of previous experience with the design of the manufacturing facility layout, both from a practical and academic point of view. NTNU does not offer subjects on methods of design of manufacturing facility layout, so the knowledge and skills necessary to accomplish this master thesis were acquired as the project developed.

Further, the creation of the evaluation and performance assessment criteria were developed together with the case company. The performance evaluation criteria draw inspiration from scientific literature, the knowledge earned during the BSc in Production Engineering, having a yellow belt in lean six sigma, and during the MSc in Global Manufacturing Manager. The case company noted that the chosen criteria reflect their needs. However, what other SMEs in the F&B industry use as evaluation and performance assessment criteria is unknown by the author.

Another weakness to examine is that MUDA reduction is barely touched in the master thesis, since it is a wide area, and due to time limitation and traveling restrictions simplification to walking distance outside the factory took place. Even if its something simple, it is still a valid nonvalue adding activity.

An additional limitation of this master thesis is the estimations based on the experience of the personnel and not an actual measurement. The level of certainty, precision, method, and formula used to devise the forecasts provided by the company is unknown.

Another weakness of this master thesis is that the framework employed could have been used more in order to highlight an area of improvement regarding taking the storage decisions. The eight weeks of storage for the MTS products is too much. The framework sheds light on that challenge and allows the designer to see that the company could improve that aspect and does not have to fast-forward building a new storage building. It allows seeing the improvement potential regarding supply chain management, scheduling, OEE analysis, and process planning.

Another point worthy of mentioning is the walls between former storage departments 1,2, and 3. Removal of them could take place in order to create a better storage solution. Further storage of raw materials required for the manufacturing could be further optimized. For instance, the heavies components such as the glass bottles located closer to the manufacturing department. Regarding the ready to deliver storage, the more daily dispatching of a product is, the closer it should be to the exit. The closeness of safety storage to the exit could simplify picking into the trucks. Storage of the molds could either be inside the machine room or outside close to it. Placement of the operator station could be close to the engine room as well in order not to take up the strategic place. Due to time limitations measuring both areas required for the molds and the operator station did not take place, however during the presentation of the finding to the case company, that suggestion welcomed. Also, the location of the molds could have been inside the engine room. However, time was not enough to check if there is some special storage requirement for them. It is also worth mentioning that the location of the operator station is unknown, if optimal. Placement of it took place as close to the production lines as possible. However, there might be other factors not known to the author of this master thesis regarding ergonomics and optimal placement of operator station in a factory.

Another detail worth mentioning is the cost analysis. Each layout adds different features and require different changes to the interior of the factory. Even though the cost analysis of a layout improvement is not part of the simplified SLP, it would have been valuable for the case company to visualize the cost of improvement versus potential gains.

Research Process Related limitations were present as well. Working from home because of the pandemic offered additional resistance and reduction of productivity. Power and internet outage, hardware failure of the improvised workstation as well as an overload of the university's VPN services added additional strain to the performance. The forced digital data-gathering and unavailability to print out the project contributed to the challenge. Further on, having virtual meetings with the supervisors and case company was not as productive as the physical ones. The isolation from human contact puts much mental strain as well. Besides, a multicase study could have been useful, affirming the knowledge generated here and reinforcing the generalizations

However, it is the author's conviction that completion of the master thesis within the timeframe and with the available resources show the ability to tackle challenges, perseverance, and flexibility aimed at delivering a scientific contribution to literature and assisting the local industry in a time of dire need.

6. Conclusion

This master thesis examines an area of importance for an SME. As being an entity with limited capabilities, the optimal use of their resources would make the difference between being competitive and not being able to handle the dynamic nature of the market. Chapter six reviews the research objective, tasks, and a summary of the main results. Further, it examines the contribution to literature and industry. It ends with suggestions for further research.

6.1 Review of Research Objective, Tasks, and Summary of Main Results

The satisfaction of the research tasks helped reach the overall objective of assessing and documenting the applicability of the simplifies SLP to Snåsavann AS. Mapping of the case company as research task one (RT1) done in chapter 4.2 using a framework and further in-depth examination during the actual application of the simplified SLP in chapter 4.3.1, and 4.3.4 helped gain a holistic view of the current state of the enterprise. Further, research task two (RT2) clashed the current capabilities of the factory with three future demand scenarios (conservative, realistic, and optimistic), resulting in three different layout designs examined in chapter 4.3.7. The three different layout suggestions were compared with the current layout using company pre-defined performance assessment criteria examined in chapter 4.3.7. As discussed, those criteria could be changed based on the needs of the SME. The main difference between the suggested layouts, besides the forecasted demand, is that the conservative serves as an upgrade to the current layout with an emphasis on the reduction of non-value-adding activities and performance improvement. The realistic frees up space allowing the introduction of new lines and the optimistic focus on freeing up as much space for future expansion within the current facility as possible while retaining the upgrades from the other layout suggestions. Lastly, research task three (RT3) culminated in the generalization of findings for SMEs regarding the application of the simplified SLP. RT3 highlighted that the simplified SLP did not require special skills by the one applying it, but an understanding of the holistic picture gained by following the procedural method.

Further, feedback from the company, attached as an appendix, highlights that the method is well explained and understood. They feel confident in applying it on their own if the change of their portfolio occurs in the future.

6.2 Contribution to Literature and Industry

This master thesis contributes to the literature in a novel way. It contributes to filling the gap regarding the application of the simplified systematic layout planning to an SME in the F&B industry. Compared to the original work (Ali Naqvi et al., 2016), it offers are more detailed approach and step-by-step analysis and improvement of the manufacturing facility layout of Snåsavann AS. It also utilizes a framework to map the company improving the generalizability of the findings of this master thesis for similar SMEs in the F&B industry. Further on, the master thesis offers a detailed and systematic approach towards the case company, offering them a holistic view of their current operations. That approach could be replicated by other similar companies to achieve the same results. The process and theory behind the analysis and improvement of the manufacturing facility layout for an SME are described in detail step-by-step, offering similar companies a guide to follow on the pursuit of designing a new layout. The easy to follow steps and simple explanation, affirmed by the case company, reinforce the hypothesis of self-applicability of the simplified SLP. The case company affirmed that they could use the master thesis as a guide to applying the method themselves. The explanation and diagrams were easy to understand and replicate, making this master thesis highly applicable and resource-saving for similar SMEs due to the reduction of the need to hire a consultant. Also, slight adjustments regarding the performance criteria could take place if other SMEs wish to achieve different goals.

6.3 Further Work

Future work could be a multiple case study of simplified SLP at other SMEs or even in other industries. Alternatively, a comparison between the results of the simplified SLP with a simulation-based method could take place. Further work might also focus on the creation of a single Excel tool connected to Power Bi, which companies can use in a plug&play manner. For example, input to steps and pre-defined performance and evaluation criteria happen in Excel. That Excel database further connected to PowerBi for visualization purposes.

Another possibility is to test how well an SME applies the simplified SLP on their own and scientifically document their progression or areas of challenge to map other weaknesses of the procedural method. That will also help map if some SMEs have unique challenges with the method.

The research done in this master thesis could support the future expansion plans of Snåsavann AS by giving a holistic and scientific perspective of the current state and improvement potential of the enterprise. It is up to them to decide which layout alternative/future demand forecast correlates with the current demand. It would be helpful to them and literature on the topic of simplified SLP if documentation during the application of the suggested layouts takes place in order to map possible challenges and areas unmapped by the procedural method.

Further, it would be highly beneficial for them if an MSc student writes a thesis regarding the storage facility layout taking this master thesis as supportive material. Also, it would be highly appropriate if a connection established between the soon to be implemented enterprise resource planning system with some of the technology or tools Industry 4.0 umbrella provides (for example, augmented operator or smart maintenance of machines).

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Appendix: Feedback From Case Company

SNÅSA

Feedback on Master Thesis

The master thesis written by Velin Aleksandrov Georgiev offers a valuable oversight of the operations, and current capabilities of Snåsavann AS. Hidden areas of improvement are examined in the thesis. They will be taken into consideration for future expansion. Further, the framework applied before the application of the simplified SLP gave a structured simplification of reality, helpful for keeping in mind the different characteristics and variables of the products offered in the portfolio.

The way the simplified systematic layout planning is explained in this master thesis is easy to understand and follow. Application of it correlated with how strategic planning is happening at Snåsavann AS and will help improve the current facilities. Every step of the simplified SLP contains the explanation of application with easy to understand figures. We feel the method is straight forward and we can apply it on our own. We do not see the need for specialized skills in order to apply the method.

Further, the data used in the simplified SLP does not compromise the contracts we have with our customers and suppliers regarding confidentiality.

Snåsavann AS is pleased with the results and the collaboration with the student taking the Global Manufacturing Management (GMM) Msc program at NTNU. His work helps see the facilities from a holistic point of view as well as seeing actual areas of improvement. Because of that, we would like to continue collaborating with GMM in the future.

Chief Operating Officer (COO)

Coo

Signature

29.05.2020
Snåsa,Norway

NTNU

Norwegian University of
Science and Technology