



Addis Ababa University

College of Business and Economics, School of Commerce

“Modelling of Production and Inventory Control for Supply Chain Optimization, the
case of Unilever manufacturing PLC”

This thesis is submitted in partial fulfillment of the requirements for the Degree of
Master of Arts in Logistics and Supply Chain management.

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Addis Ababa, Ethiopia

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Approved by Board of Examiners

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List Of Abbreviations

- ERP – Enterprise Resource Planning.
- SAP - System Applications and Products in Data Processing (software).
- FMCG – fast moving commodity items.
- SKU – stock keeping unit.
- KPI – Key Performance Indicators.
- SLOB – slow moving and obsolete (materials/goods)
- SC – Supply Chain
- RM/PM – Raw material/Packaging Material
- CIP – Cleaning In Place (an Automated auto machine cleaning Tech usually with hot water & Caustic soda)
- CO – Change over (product changeover of moving from making “X” SKU to “Y” SKU.)
- PVA – Plan Versus Actual.
- OR – Operational reliability.
- CU/AU – Capacity Utilization/Asset Utilization.
- WIP – Work In Progress.
- MMP-code – Managing manufacturing Practice code.
- ManEx – Manufacturing Excellence.
- UMS – Unilever Manufacturing System.
- MUV – Material Usage Variance.

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Abstract

The production process as complicated as it looks on its own with the technology advantages, efficiencies, performance measures, overheads, losses, ... etc., there are multiple external factors (some external to the production facility but may be internal to the business unit) that hugely impact the competitiveness and sustainability of the overall business. In this paper, the overall discussion, interpretations, findings, conclusions as well as recommendations revolve around how a business can serve and grow its market by optimizing forecasted demand with proper management of inventory targets as well as managing production wastes and cash losses within the production process. In other words, “Service”, “Cash” and “Cost” shall be the essential measures of the whole process. Because these three if properly managed and optimized can dictate how much of the demand shall be served with the capacity a company has, what level of inventory shall be held to give healthy cash flow as well as what level of wastes is manageable in order to get a competitive and acceptable production cost, which combined dictate the profitability, competitiveness as well as existence of the company.

Keywords:

- **KPIs** – Key Performance Indicators.
- **Unconstrained Demand** – is the overall market demand for a specific period of time not considering any other constraints.
- **Constrained Demand** – this one considers the supply capacity of a manufacturing plant in addition to market demand (e.g. Production capacity, financial constraints, Inventory related issues, ...)
- **Product Change Over** – when a manufacturing facility produces different types of products on one line and makes the change from producing one product to another, which usually involves CIP and waste of product in the pipeline.
- **CIP (Cleaning in Place)** – is an automated system where a machine or storage cleans itself with built in spray ball system usually with hot water & Caustic soda without having to disassemble any machine parts or having to manually access or use cleaning materials.
- **CU (Capacity Utilization)** – a measure of performance of a manufacturing facility where capacity of the plant or what could be produced in a period of time is compared in percentage with what's actually produced.
- **SKU (Stock Keeping Unit)** – Products a manufacturing company makes and sells. It can be same materials but different sizes or same size but different materials. Eg. If Moha beverages makes Pepsi, Mirinda and 7UP in three different sizes of 300ml, 500ml and 1500ml each, We say Moha beverages makes 9 different SKUs.

Chapter 1

Introduction

1.1 Background of the study

1.1.1 Introduction

End to end supply chain has endless challenges from onboarding materials and suppliers to the processing and distribution of products and services. Supply chain being made up of Plan, Source, Make and Deliver and a disruption in one function impacts all the members of the chain. Which in turn affects the overall business and company too as supply chain is the backbone of most businesses be it manufacturing, construction, transport services, health, humanitarian, ... etc. Hence all abnormalities in any of the functions should be addressed to very seriously.

One of the challenging spaces in a manufacturing Supply chain is Make/process. And in this paper the focus shall be on how to give a high-class service to a business with the minimum possible cost, making sure cash is taken care of in the most efficient way. Because like they say, resources are limited but creativity, improvements and changes are unlimited. It's critical that in a Vuka World we're living in, companies with clear plans, agility and continuous improvement mindset thrive. One of the attempts in this paper shall be an improvement plan to reasonably optimize production with inventory. In other words, it'll be attempted to create a model that will give the highest possible optimization of "Service", "Cash" and "Cost", which are critical KPI's for a supply chain function as a whole.

To balance between the market demand, production volume and inventory levels the study should start from how much of each SKU/product is needed at a specific type of time, how much is our production capacity and how much is our allowable inventory carrying capacity. Which again should match with a second matrix of how much of the demand can be served with each SKU being visible in the market at all levels, how much raw and pack materials can be available with the realistic lead times from the suppliers with their inventory costs as well as how much of finished products/goods can be produced and carried with clear identification of fast moving and SLOB finished good items. Hence making an optimized decision to balance these six different variables and making and distributing finished goods of high quality with the minimum possible cost is the purpose of this study.

1.1.2 Background of Unit of Analysis

The study shall focus on an FMCG international company called Unilever manufacturing Plc., which produces and distributes fast moving commodity items over 192 countries Worldwide. Unilever has over 300 factories in 69 countries¹, where one of it's manufacturing sites is located in Dukem town, Ethiopia. Unilever owns more than 400 brands which include baby food, beauty products, bottled water, breakfast cereals, cleaning agents, condiments, energy drinks, healthcare and hygiene products, ice cream, instant coffee, pet food, pharmaceuticals, soft drinks, tea, and toothpaste. It is the largest producer of soap in the world¹. These products are strategically divided into five major Business groups for ease of Supply chain sourcing and distribution, which are:

Unilever is a British multinational fast-moving consumer goods company founded on 2 September 1929 following the merger of British soap maker Lever Brothers and Dutch margarine producer Margarine Unie. It is headquartered in London. Overall, the company Worldwide has an annual turn Over of 60.9 billion Euros as of 2022 annual Report². It offers a wide range of consumer products, encompassing personal care brands like Lifebuoy, Dove, Rexona, and Axe, home care brands such as Omo, Sunlight, and Domestos, beauty and well-being products like Dove, Clear, and Sunsilk, as well as nutrition and food brands like Knorr, Hellmann's, and Ben&Jerry's, and lastly, their iconic ice cream brands Magnum and Cornetto.

In Ethiopia it has established its manufacturing site and started it's production in 2016 as soaps manufacturing unit with Lifebuoy, Lux and Geisha and has grown now into four categories and makes 38 SKUs with brands of Lifebuoy soap, Knorr seasoning cube, Omo detergent powder, Sunlight soap & detergent powder, Vim, Sunsilk Shampoos and Conditioners as well as Signal tooth paste. So far 95% of the Ethiopia production serves the local market with only 5% for exports.

Unilever being in the Market for more than 100 years, it has established ways of globally optimizing demand, production, and inventory with different sorts of soft wares, strategies as well as manufacturing excellence tools. The focus of my study shall be hence on finding a best

¹ "Our approach to sustainability". Unilever. Archived from the original on 2 April 2014. Retrieved 21 March 2015

² [Statista - The Statistics Portal for Market Data, Market Research and Market Studies](#), Published by Dominique Petruzzi, Sep 26, 2023

way to improve the process of local Ethiopian context manufacturing challenges by computing a favorable model that boosts profitability and sustainable business growth with balanced service to the market keeping in mind production and overall SC cost as well as healthiest cash flow. (Global, 2014)

Of the four business groups unilever is running in Ethiopia, the hair care line comprises of 200tons of production per month which contributes to 10% of the total production volume. The highest production volumes in Ethiopia coming from Skin cleansing soaps (Lifebuoy and Lux) 1000tons per month and Knorr cubes 950tons per month. However, the hair care category contributes the highest waste due to frequent changeovers as it cannot be reworked/reprocessed unlike the other skin cleansing and home care products.

Mainly the waste comes from CIP (which is auto cleaning of a machine by itself), where all the products in pipelines and on the walls of tanks get washed away and are drained out. This happens when the production shifts from one variant to another. When for example production shifts from Sunsilk to Clear or from Sunsilk coconut flavor to Sunsilk Avocado flavor or from Shampoo to conditioner or vice versa, Full line cleaning is done in the process product residues in the mixer tanks, storage tanks as well as in the piping get washed away and drained. This is why changeover proper planning and sequencing is critical component in product waste management. (Good Manufacturing Practice, 2012)

1.2. Problem Statement

This research aims to explore the interplay among conflicting variables and key performance indicators (KPIs) within the context of Unilever Ethiopia. The focus is on three variables: “Service”, “Cash”, and “Cost” interconnected within the production perspective. Firstly, the high market demand for products necessitates comprehensive market visibility for all available SKU varieties. Secondly, continuous market serviceability requires a substantial inventory of raw and packaging materials, accounting for lead times of importing 185 diverse raw material types, as well as inventory of finished goods, which tremendously impacts inventory and cash flow targets. Lastly, meeting the full demand while ensuring all available SKUs visibility may result in the production of all SKUs within a month, causing a notable

volume of material waste due to frequent changeovers attributed to CIP (which happens during shift from producing one variant to another).

The core of the challenge lies in optimizing demand, inventory, and production run strategies to achieve an optimal market service level with minimal inventory cash holdings, alongside the lowest feasible production costs by managing waste stemming from multiple changeovers.

1.3. Objective of the Study

1.3.1. General Objective - The purpose for this qualitative case study is to investigate on how a manufacturing company optimize its overall supply chain process by exploring strategies that help to optimize and control market demand, production volume, inventory levels and raw material wastes in manufacturing processes. In the process also impacting the overall company in its profitability, sustainable business growth and better visibility of all its products in the market.

1.3.2. Specific Objective – The specific objective of this paper is to focus on one of the business groups of Unilever Ethiopia which is beauty & well-being category. This category makes “Sunsilk” and “Clear” shampoos and conditioners in 18 different SKU’s. Hence, the purpose of the research is to determine the optimal production schedule for the 18 SKUs, considering limited production capacity. This involves identifying which SKUs to produce and in what quantities to maximize profitability, by satisfying factors like inventory costs and waste generated from frequent changeovers. In other words to formulate a production run strategy model that incorporates variables such as CO waste, inventory costs, demand volatility, and market visibility of each SKU.

1.4. Research Questions

The questions that are to be addressed in this research paper revolve around the challenges in optimizing demand, production capacity, inventory as well as wastes. By doing so the following specific questions shall be addressed:

- What was the trend of market demand of Unilever products (specifically hair care category products) in the market and how much of it was served, comparison of market served versus opportunities lost in the years 2021, 2022 and 2023?
- What were the criteria selected to run the amount of each variant produced and sold?
- What discrepancies were there in terms of the category's inventory targets, what were the inventory targets, what was the PVA for the inventory, percentage of Forecast Bias, OR, CU/AU of the hair care production plant?
- How much of product waste was incurred on the plant and specifically due to frequent product changeovers over the past three years?
- And finally, what could have gone better in all the above four questions as well as how could using a model have improved all the performance measures mentioned in the aforementioned questions?

1.5. Significance of the Study

This study shall focus on the optimization of demand forecast, inventory and production waste due to multiple change overs. Hence it shall have a significant value to add on the company's decision making in terms of what to produce at a specific point in time, what inventory value is the healthiest possible cash flow without affecting the visibility of all products in market as well as having the minimum possible waste due to product change overs on the production lines.

The company already has its system of balancing demand forecast, inventory target as well as waste management. This study, however, shall try to elevate it to a higher optimization and efficiency level by trying to formulate a model that can suggest better optimized options for better decision making at different points in time, because the market in Ethiopia has a unique and unpredictable nature. Hence the study shall be very significant in suggesting the most efficient decision-making tool that best optimize the aforementioned three variables.

1.6. Scope of the study

The scope of this study shall be limited to one of the five factories Unilever has in Ethiopia, Dukem town. Which is the hair care liquids factory. The reason being that liquids plants need CIP when product changeovers are made and when the cleaning is done, whatever amount of product is left as residue on the tanks, mixers and pipelines cannot be reworked, but rather is washed away to the drainage. Hence it makes the waste level higher should there be multiple changeovers in a week or month. This is why it needs to be harmonized and optimized effectively with inventory target as well as forecasted demand numbers.

It will also be limited to three variables only as the target is to create a decision-making model that enhances the market service level, healthy cash flow as well as the best of run strategy on the production facility. For the analysis of the decision making, Multicriteria decision making models shall be used with the likes of goal programming and game theory wherever and whenever they might be applicable.

1.7. Limitations of the study

The study shall go deep down on the liquids plant only (Sunsilk and Clear) even if there might be non-reworkable wastes generated in the other three factories. In addition, these factories may be high contributors of inventory and changeover repercussions, however, from the time limitations, data size and also area of cover, it'll be better to focus on one plant and may be expand the learnings to the rest of the plants.

There might as well be sub variables a multi criteria model may not give solutions to with the highly uncertain Ethiopian market nature, which could be left out of the scope of this study. However, these sub variables may not hugely impact the decision-making process.

1.8. Definition of Terms

1.8.1. Conceptual definition

- **Inventory** - Inventory is all the goods and materials that are stored by an organization at a given time to allow for variations and uncertainty in supply and demand. It includes Raw and Pack materials, Finished Goods, WIP & Spare parts, which are in Warehouse, in transit and in manufacturing process.
- **Forecasting** – the process of estimating future revenue by predicting how much of a product or service will sell in the next week, month, quarter, or year. Sales forecasts drive short-term spending decisions and impact decisions on key deals.

1.8.2. Operational definition

- **Capacity Utilization** - A long term measure which is relevant for strategic purposes and capital expenditure process. It is a measure of Unutilized Capacity losses.
- **Asset Utilization** - A measure used to understand the sweating of the assets e.g., the return on assets. It summarizes all time losses captured on a Line.³

1.9. Organization of the Study

This study comprises of five chapters. The first chapter will discuss in its introduction the background of the study, the problem statement, objectives and scope of the study, research questions, limitations of the study, significance of the study and definition of terms.

The second chapter is basically literature review which discusses theoretical literature, Empirical literature as well as Conceptual framework. In the Third chapter research methodology is discussed, which covers study description, research approach, study design and settings, sources, population, sampling procedure, Data source, data types, data collecting tools and procedures, variables and measurement of the study as well as ethical considerations.

The last two chapters shall mainly focus on data analysis, result discussions on the fourth chapter and summary findings, conclusions, recommendations and further study which's in the fifth chapter to be finally wrapped by references and appendices attached in the end.

³ [ManEx - Managing Manufacturing Performance \(MMP\) Code May 2014.pdf - All Documents \(sharepoint.com\)](#)

Chapter 2

Review of Related Literature

2.1. Theoretical Literature Review

2.1.1 The Inventory Concept

Different Scholars have defined inventory in so many different ways. (Ward & Ward, 2013) defines it as “Inventory is all the goods and materials that are stored by an organization at a given time to allow for variations and uncertainty in supply and demand. It includes Raw and Pack materials, Finished Goods, WIP & Spare parts, which are in Warehouse, in transit and in manufacturing process”.

According to (Basu and Wang 2011) Inventory plays a vital role in the success of the majority of businesses. The Generally Accepted Accounting Principles (GAAP) by the Financial Accounting Standards Board (FASB) encompass a balance statement, income statement, statement of cash flows, and retained earnings statement. Among these financial statements, inventory appears as a line item in two documents—the balance sheet and the statement of cash flows. On the balance sheet, inventory is classified as a current asset, while the statement of cash flows tracks alterations in inventory. A current asset is defined as an item that can be readily converted into cash in the short term and encompasses a corporation's cash reserves, accounts receivable, prepaid expenses, and inventory. (Manisha, 2012; Sprague & Callarman, 2010) state that: Though some sources contend inventory can be considered an immediately available cash source, others express hesitancy in describing stagnant inventory as equivalent to cash.

Again, (Basu and Wang 2011) conducted a review of inventory level changes in U.S. companies and the impact of inventory on firm performance and value over a 55-year span (1955–2005). The valuation of inventory incorporates several elements, including the procurement cost of raw materials, the expenses associated with processing and assessing the materials, the costs of transporting materials to storage and distribution locations, and the fixed costs stemming from equipment and facility depreciation. The classification of inventory as a current asset counts on factors such as the age of the inventory, its demand at the time of conversion, and the duration required to convert it into cash.

2.1.2. Definition of terms in Inventory

- **Days of inventory:** Defined by dividing average inventories (for example inventory at the start of the month and at the end of a month/2) by cost of sales per day in the same period. (Raheman et al., 2011).
- **Economic manufacturing quantity:** The economic manufacturing order quantity is the batch size of the same material that optimizes the cost of the operation. The batch size is a result of comparing the cost to change over to the product versus the cost to store it (Michalski, 2009).
- **Economic order quantity:** The economic order quantity is the amount of material to order at one time. The order size is a result of comparing the cost of the material versus the cost to finance and hold the material. The economic order quantity is a concept similar to the economic manufacturing quantity (Kannan, Grigore, Devika, & Senthilkumar, 2013).
- **Stock Keeping Unit (SKU)** – Also sometimes referred to as Trading Unit (TU), irrespective of whether that trading unit is a case or a pallet. The TU is the unit in which a particular customer places its orders. Examples: Lifebuoy 70g and Lifebuoy 150g are two different SKU's.

2.1.3 Demand Forecasting

The World's leader in ERP software, SAP on its portal with the article of "Demand forecasting for the modern supply chain" (SAP, 2023) says, Demand forecasting helps to inform core operational processes such as demand-driven material resource planning (DDMRP), inbound logistics, manufacturing, financial planning, and risk assessment.

It also defines demand forecasting as, "Demand forecasting encompasses the strategic planning and anticipation of the need for goods and materials, enabling businesses to maintain optimal profitability". In the absence of accurate demand forecasting, organizations face the potential of managing excessive and costly surplus inventory or missing out on opportunities due to an oversight in predicting customer needs, preferences, and purchasing behaviors. Professionals in demand forecasting possess specialized expertise and practical experience.

When combined with advanced supply chain technologies and predictive analytics, these skills contribute to enhancing the competitiveness and efficiency of supply chain operations to unprecedented levels."

It also discusses the why and how's of Demand forecasting in the context of, "Why is demand forecasting crucial for contemporary supply chains?" It explains that in today's rapidly evolving business landscape, companies are navigating an exceptionally dynamic environment, further amplified by the recent pandemic. With swiftly changing customer behaviors and heightened expectations, the adoption of optimized supply chain practices and interconnected cloud-based business networks is becoming increasingly prevalent, intensifying competition. Demand forecasting plays a pivotal role in supply chains by guiding essential operational processes such as demand-driven material resource planning (DDMRP), inbound logistics, manufacturing, financial planning, and risk assessment.

On the how part of the way demand forecasting function, it discusses demand forecasting and integration of both qualitative and quantitative methodologies, leveraging diverse data sources across the supply chain. It states that "Qualitative insights are derived from external channels including news reports, cultural and social media trends, as well as competitor and market research. Equally important are internally sourced data, encompassing customer feedback and preferences, significantly contributing to the accuracy of the forecasting landscape".

And for Quantitative data SAP declares that these types of data are obtained primarily from internal sources, capturing sales figures, peak shopping periods, and web and search analytics. Advanced technologies capitalize on sophisticated analytics, robust databases, and the utilization of artificial intelligence (AI) and machine learning to analyze and process intricate and extensive datasets.

According to Hans Martens, Plan & Customer Service Business School Associate (Martens, 2020) The important Performance measure variables in Demand forecasting that enable the company to be on top of its game and be agile in the market are Forecast Accuracy, Forecast Bias and PVA.

2.1.4. Definition of terms in Forecasting

- **Forecasting** – the process of estimating future revenue by predicting how much of a product or service will sell in the next week, month, quarter, or year. Sales forecasts drive short-term spending decisions and impact decisions on key deals.
- **Forecast Accuracy** - Forecast Accuracy measures how close the forecast is to the actuals. Higher accuracy enables better supply planning & stock availability.

- Formula =>
$$FA = \frac{\sum Abs(Actual\ Sales - Forecast)}{Actual\ Sales} * 100\%$$

- **Forecast Bias** - Forecast Bias is tendency for a forecast to be consistently higher or lower than the actuals. It's used to understand constant over or under forecasting behavior. (Global, 2014)

- Formula =>
$$FB = \frac{(Actual\ Sales - Forecast)}{Forecast} * 100\%$$

What does success look like, What's a Healthier Bias?

- Low bias of <+/-1% at a monthly level.
 - 3-4 polarity switches in year (Negative to Positive or vice versa).⁴
- **Takt time:** The rate at which customers purchase a product compared to the production rate. The purpose of knowing takt time in a production operation is to provide the customer the product when requested. Proper usage of takt time reduces late orders and unnecessary inventory (Lu et al., 2011).
 - **First in first out (FIFO):** FIFO is both a quality and legal compliance subject. It's a method for inventory management so that products do not expire while sitting in the WH. In this case, the procedure here is the oldest product in the warehouse leaves the warehouse first, be it Raw/Pack material to the factory lines or finished good to the customer. (Harris, 2011)
 - **PVA** - To put it simply, plan vs actual is just the active review and adjustment of financial, Sales volume, production Volume, ... forecasts based on your real-world financial results. In Our case we'll focus on PVA in terms of planned production vs. Actual production.

⁴ [Pathway Resources - What is Forecast Bias.pdf - All Documents \(sharepoint.com\)](#)

2.1.5 Wastes

The identification and understanding of different types of waste is crucial for any organization aiming to optimize its processes. By understanding each type of waste and implementing targeted measures to mitigate them, organizations can significantly enhance their operational efficiency and minimize resource waste, ultimately leading to increased productivity and cost savings.

(Johnson, 2013) stated in her book of Zero waste home formulated a great way of managing waste in manufacturing companies with her “Béa Johnson’s 5R waste principles”, which are:

- “Refuse” what you do not need.
- “Reduce” what you do need.
- “Reuse” what you consume.
- “Recycle” what you cannot refuse, reduce and reuse; or
- Transform the “Rest”.

(Matics Manufacturing Analytics Ltd, 2023) groups waste into eight categories with a relevant and targeted break down so they can be understood, measured, controlled and acted upon accordingly:

1. Defects - Defects refer to any errors or faults in the products being manufactured. These errors often result in wasted time, resources, and materials. Identifying the root cause of defects is essential for addressing and rectifying these issues. Implementing a robust data collection system can aid in pinpointing the source of defects and facilitating corrective action at the core of the problem.

2. Excess Processing - Excess processing arises from inefficient product design, poor communication, or human error, leading to unnecessary or redundant steps in the production process. This additional processing results in wasted effort, time, and resources. Addressing this type of waste often necessitates revisiting product design and refining communication channels to streamline processes.

3. Overproduction - Producing excess product components beyond immediate requirements constitutes overproduction. This leads to unnecessary inventory buildup and strains resources.

Lean manufacturing principles emphasize the avoidance of overproduction, as it can lead to wasted time, storage costs, products being expired and other associated issues.

4. *Waiting* - Downtime, whether it's due to machinery awaiting maintenance or delays in the arrival of raw materials, represents wasteful waiting. Such situations are detrimental to operational efficiency and may stem from inadequacies in planning or scheduling. Addressing this waste involves enhancing maintenance procedures and streamlining supply chain logistics.

5. *Excess Inventory* - Maintaining excessive inventory beyond demand levels can result in elevated storage costs, expiry of items and operational inefficiencies. It's imperative for organizations to regularly evaluate and adjust their inventory management procedures to minimize waste and associated expenses.

6. *Transportation* - Inefficient transportation of materials between locations contributes to waste within manufacturing processes. Optimizing transportation routes, methods, and handling processes is vital for reducing waste and enhancing overall operational efficiency.

7. *Motion* - Unnecessary motion, whether involving machine parts during operation or employees undertaking manual tasks that could be automated, represents non-value-added actions that contribute to waste. Addressing this waste entails identifying opportunities for automation and streamlining tasks to minimize wasteful motion.

8. *Non-Utilized Talent* - Failing to fully leverage employees' skills, ideas, and capabilities represents a significant waste of operational potential. Allowing employees to contribute to their maximum capacity not only enhances innovation and problem-solving but also contributes to a more efficient and effective operational environment.

2.1.6. Production Runs and Manufacturing Performance

One of the main targets in the Overall supply chain process for a manufacturing business company is to reduce the waste and remove inefficiency that our consumers will not pay for; and in the meantime, to provide better information to our customers regarding sustainability and quality; Make smarter decisions based on better information. (Unilever, 2014). In this process I shall try to discuss the subjects relating to Manufacturing performance as a whole and the

various ways of its measurements. Because so as to optimize the manufacturing process with inventory as well as demand forecast together with waste management, we need to understand and discuss how and why manufacturing performance is measured.

The various methods of measuring manufacturing Performance

The Unilever MMP code book discusses Manufacturing metrics and KPIs, demonstrates challenges and success across manufacturing operations. Manufacturing key performance indicators provide a quantitative measure of strengths and weaknesses. KPIs offer insight into how production contributes to company goals. (Deepak Agarwal, 2014)

(Jenkins, 2023) categorize the top manufacturing KPI's that measure success of a manufacturing plant into five major categories and according to them, follow up and control of these five categories can help manufacturing companies thrive in the current agile & VUCA market nature challenging most companies Worldwide.

- Production Volume = *Total number of products manufactured over time*
- Production cost = How much does it cost to make a product = $\frac{\text{production cost}}{\text{no.of units produced}}$
- On-time Delivery = Are your products delivered on time? = $\frac{\text{on-time units delivered}}{\text{Total units delivered}}$
- First Time Right = Do you complete a process right the first time?

$$= \frac{\text{Total number of Good units}}{\text{Total number of units processed}}$$
- First Time Right = Do Employees contribute to Revenue? = $\frac{\text{Total Revenue}}{\text{Number of Employees}}$

When we deep dive into the Production/Manufacturing process, the Unilever MMP Code handbook best describes detailed KPI measures that help control and measure industrial manufacturing practices from all dimensions of finance, sales, Investment, Distribution, future fit strategies, ... (Deepak Agarwal, 2014).

- 1. Capacity Utilization** - Capacity utilization measures how much of a plant's total available capacity is in use. You can use this KPI to assess efficiency and as an indicator of future

growth opportunities. (Jenkins, 2023). Most companies make decisions of whether further investment/Capex/expansion projects based on how high the capacity utilization is.

- Capacity utilization = (Total capacity used during a specific time frame / total available production capacity) X 100%
- Or stated differently,
 - CU formula => $CU = \frac{\text{Loading time}}{\text{Available time}} * 100\%$

- Loading time – the time the machines were running in a week/month/year.

For example,

- *if machines are run 360 days a year and there are 5 days of bank holidays in which the lines stopped only those bank holidays, Capacity utilization is $360/(365-5)=100\%$,*
- *in the same scenario, if lines have stopped all weekends, let's say 100 days a year plus the bank holidays, the capacity utilization is $(365-5-100)/(365-5)=72.2\%$.*

- Available time – time available in a year excluding bank holidays.

- *For example, if in a specific country there are five bank holidays in a year, the available time is 360 days in a year. In a different scenario, if a specific country has 15 days of holidays by local legislation, the available time shall be taken as 350 days for the calculation.*

2. OEE (Overall Equipment effectiveness) - in simple terms is what a manufacturing line produced in an hour, or a day compared to what it is designed to produce in percentage. In technical terms it's the ratio of VOT to nominal speed of the machine: (Unilever, 2014)

$$\text{OEE formula} = \text{the ratio of VOT \& Nominal Speed} = \frac{\text{VOT}}{\text{Nominal Speed}}$$

- Where $\text{VOT (Value Operating Time)} = \frac{\text{Good Volume produced}}{\text{Available Operating time}}$

Value Operating Time (VOT): The minimum amount of time that will be consumed by the Line for a given Production Plan under ideal conditions (operating at Nominal Speed and without any loss of any kind)

OEE is generally measured from three dimensions, which are:

- **Availability:** the actual production time as a percentage of scheduled time to operate.
- **Performance:** the percentage of time your machine or plant is working at full capacity.
- **Quality:** the quality units produced as a percentage of all the units started.

3. **Asset Utilization:** is a measure of how well we're sweating our machines. A measure used to understand the usage of the assets to the fullest, in other words it's a tool to make correct decisions on the return on assets. It summarizes all time losses captured on a Line.

$$\text{AU formula} \Rightarrow \text{AU} = \frac{\text{VOT}}{\text{Total time}}$$

- Total time is the total time available in a year including bank holidays, basically 365 days/366 on leap year.

4. **Manufacturing Performance** – is a measurement of manufacturing performance losses. These losses are the sole responsibility of the manufacturing department since most of the losses are under their control.

- MP formula $\Rightarrow \text{MP} = \frac{\text{Value Operating Time (VOT)}}{\text{Operating Time (OT)}}$

There are four types of time losses a Manufacturing line can undergo: (Unilever, 2014)

- **Legal losses:** These occur when a machine or Line is unable to produce for legal/statutory/regulatory reasons. *For example: bank holidays, religious celebrations, public holidays, ...* Such losses are outside of a company's control as they result from, and can usually only be resolved under, the legal jurisdiction of the country in which the Site housing the machine or Line is located.
- **Unutilized Capacity losses:** These are losses incurred when a Line is underutilized or idle; e.g. when it is available for production. Any decision not to produce will be based on logical factors such as high costs, poor return on investment, business planning or other pre-determined considerations. Unutilized Capacity losses should be considered thoroughly in a Capacity Expenditure Proposal before any new capacity investment is approved.
- **Process Driven losses:** These occur when a Line is intentionally stopped to complete certain activities on a machine or Line, e.g., Product changeover, CIP, start up and shut down times, employee meal breaks, ... It is necessary to create standards for each of these losses and the extent of these losses should be largely consistent. For this reason, it's best to estimate Process Driven losses on machines / Lines on the basis of the mix of products.

- **Manufacturing Performance losses:** This is when a Line unexpectedly stops while it is intended to be in production under a launched Production Order. These relate to losses connected with breakdowns, speed loss, etc.

In summary, time classifications and definitions look like: (Unilever, 2014)

- Total time = 365 days * 24hrs =8760hrs per year
- Available time = Total time- legal losses
- Available Loading Time (ALT) = AT - Unutilized Capacity losses.
- Operating Time (OT) = VOT + Manufacturing Performance losses
- Loading Time (LT) = OT + Process Driven losses
- Idle Time = ALT – LT

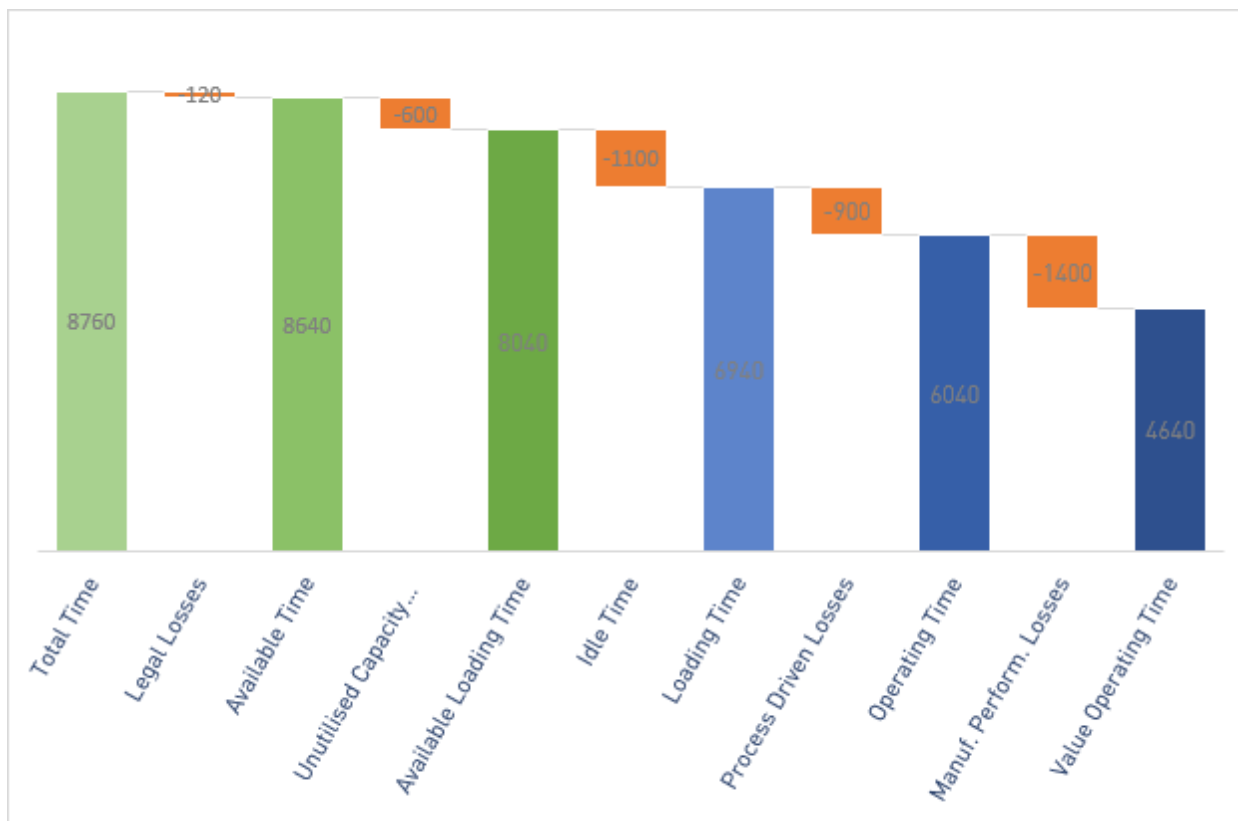


Fig 1. Illustration of time classification

2.2. Empirical Literature Review

Various scholars have conducted research on inventory optimization with a lot different factors including overheads, production runs, cost, business waste, lost sales, forecast bias, production runs, production wastes, ... in this empirical review I shall focus on researches conducted in inventory management relating with it's optimizations with production run, wastes and forecast.

Mamta sahare & saurabh chandra (2021) in their paper entitled "Role of Production Efficiency: Inventory Leanness and Financial Outcome" By building relationship between production efficiency as a mediator between inventory leanness and financial performance of a company, the scholars have demonstrated that an optimized system of production efficiency and inventory management is crucial for the sustainability of firms. Their study builds upon previous research that has examined the relationship between inventory leanness and different aspects of financial performance. However, they've tried to address the remaining a gap in the existing literature concerning the underlying mechanisms that drive the impact of inventory leanness on a firm's financial results. The objective of their research is to investigate the influence of inventory leanness on financial outcomes, specifically focusing on the mediating role of production efficiency. Using firm-level data from diverse US manufacturing sectors spanning 2000-2018 and a fixed-effect model, They've conducted empirical analysis of the acquired data. The findings from the dataset reveal that the connection between inventory leanness (IL) and financial outcomes (FO) is partially mediated by the improvement in production efficiency.

Moreover, as part of the research, with an industry-specific subsample analysis they've demonstrated that the mediation effect of production efficiency varies across different industrial sectors. As a result, this study contributes to the operations management literature by empirically confirming the mediating impact of production efficiency within the context of inventory control theory.

Feng xu (2017) explores the quest for the best inventory control policy with the aim of forecast bias, forecast accuracy as well as minimizing the overall expected costs, in which the shortage cost plays a vital role. Owing to the challenges in quantifying the indirect costs related to the loss of goodwill resulting from shortages, professionals and academics frequently assume a fixed penalty cost for inventory shortages or adopting an alternative approach by setting a

specific customer service level. Creating a suitable tool for assessing the shortage cost can empower businesses to effectively manage total costs and enhance productivity. This study suggests using probabilistic measures to evaluate the shortage cost, establishing a mathematical connection between the cost and the shortage amount. The resulting analytical approximations of the anticipated shortage cost value can be employed to determine the most effective inventory control policy.

Serhii z, (2021) “a literature Review on Models of Inventory Mgt Under Uncertainty” (2015) in the paper tried to establish relationship between inventory, costs, minimum order quantities, safety stocks as well as work in progress in production lines with their implications on cost, lost sales and business waste. According to this paper, inventory involves raw materials, work-in-progress and entirely completed goods that are in to be included in the firm’s assets that are in position or would be in position for sale. The paper focused on understanding and measuring economic order quantity for the selected items, analyzing its inventory management methods with the help of ABC analysis, economic order quantity and safety stock calculations, offering suitable suggestions for the improvement of inventory management practices and studying how effectively inventories are maintained in Reliance.

Abdullah Bah and Foday Daboh (2023) from Ipam, university of Sierra Leone in their study with the title “An Empirical Evidence of The Impact of Inventory Management on The Profitability of Manufacturing Companies” tried to examine impact of inventory management on the profitability of a manufacturing company. In this case study a research design was applied on the inventory system of a reputable manufacturing company. The secondary data employed in this study was collected from the financial statement of the company for the period 2015-2020, in the scholars have analyzed their data in the Multiple linear regression model. The result shows that Raw Material Cost and Storage Cost are having negative and insignificant relationship on the profitability of a manufacturing company. On the other hand, Inventory Conversion Period is having a positive and significant relationship on the Returns on Assets.

In this study it’s clearly shown that another big factor in the successful run of a company is returns of assets which brings into picture the importance of capacity utilization and depreciation costs in a factory which again are a result of run strategies in the factory driven by demand forecasts. The study therefore recommended that the management of manufacturing

companies need to adopt proper inventory management systems in order to control raw materials costs, reduced the working capital cycle, production run strategies and minimize storage cost such as holding costs, ordering costs among others hence increasing company profitability.

2.3. Conceptual Framework

The conceptual framework shall focus on the illustration of the expected links between the three main variables this study shall mainly emphasizes on. It will define the relevant objectives for the research process and plans out how they come together to draw coherent conclusions. It will show how the relationships and correlations of Inventory target, Production waste due to Changeovers as well as demand forecast to give an optimum amount of finished good production and storage at the lowest imaginable cost to have optimum production run, inventory level and service to the market.

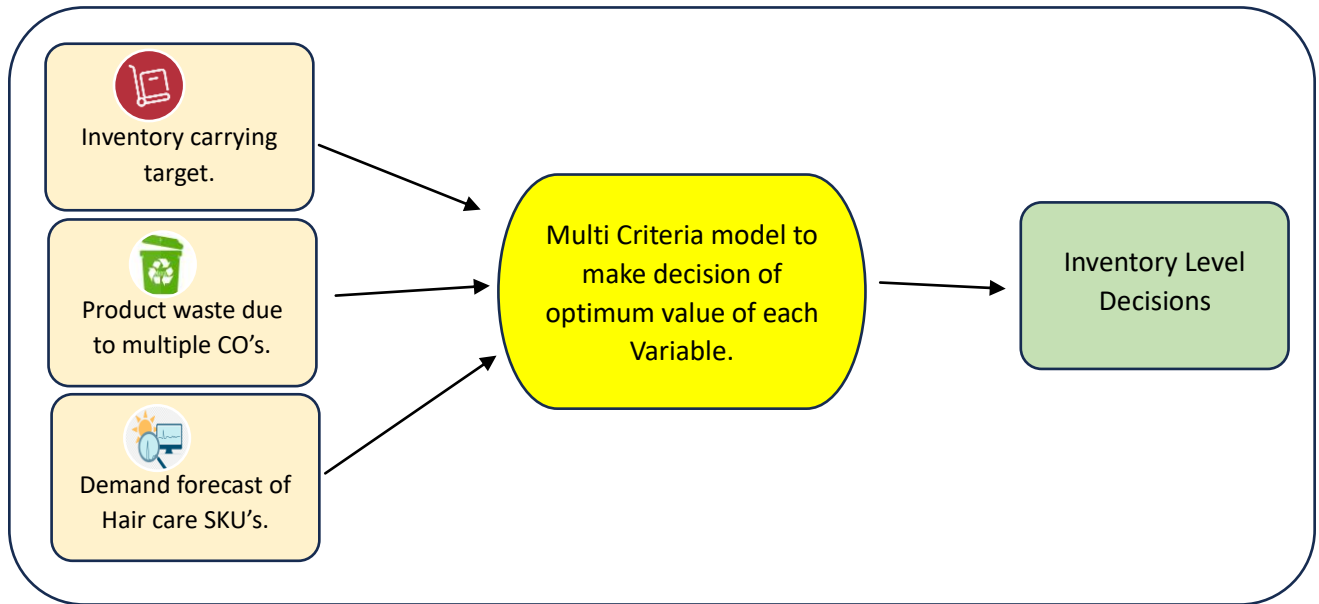


Fig. 2.2 – Conceptual Framework of the Study (Source, the Author)

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Description of the Study Area

Unilever Manufacturing Plc was established in Ethiopia in 2014 to produce and distribute its products in Ethiopia as well as export to neighbouring countries. Yet currently the export amount doesn't exceed 5%-10% of the total production amount in Ethiopia. (i.e., 90%-95% of what is produced here in Ethiopia is distributed in Ethiopia). The business has five business groups, and the supply chain has four major groups of Planning & Logistics, Sourcing/Procurement, make/manufacturing and distribution/Primary sales.

The manufacturing site as well as Warehouse & the distribution center are located at Dukem town, 40km from Addis. But the rest of the Supply chain functions are seated along with the other non-supply chain functions in Addis where the head office is. This study is focused on one of the business groups, Haircare liquids area which makes Shampoos & Conditioners two brands and 18 different variants/SKUs.

The liquid line is selected for this study because of the fact that the liquid products are the most vulnerable in terms of waste. Because, for the other products like bar soap, powder detergents and foods products if there is issue with the packaging or if the product itself has missed some parameter fluctuations or after a work in progress product is collected from the lines during Changeover, it can be taken to the upstream of the lines either immediately or at a later time to be reprocessed or mixed into a new batch in a controlled manner to be reworked/reprocessed, but for the case of liquid products in most of the mentioned cases, once it is off specification or wasted, it cannot be reworked/retrieved, which makes the problem significant.

3.2 Research design

This study shall use mainly quantitative data to understand the interrelationship between the three variables planned to optimize in the study namely: *demand forecast* (which uses data of forecast accuracy and forecast bias), *waste* records due to changeovers as well as *inventory* levels and deviations from inventory targets for the haircare lines of unilever manufacturing plc. All the

data that's to be used for all the three variables shall be of past three years on monthly basis, i.e. for the years 2021, 2022, 2023. After acquiring these data and through analysis understanding the severity of the issue on cash, cost and service performance, the study will suggest what the optimum values of the three variables shall be at a given point in time.

The research employs multicriteria decision-making models like goal programming to optimize production for a given month or quarter. This will involve determining the optimal amount of unconstrained demand to fulfill for each of the 18 SKUs, prioritizing production of mainstream SKUs for future months when capacity is limited and establishing an acceptable level of waste due to changeovers, which will then constrain the forecasted demand.

3.3 Research Approach

This research used both qualitative and quantitative methods. For the case of the qualitative data, questionnaires shall be distributed to selected and relevant employees of the company. And specifically for the quantitative approach, using the company's portals in which all manufacturing related, Planning, finance, logistics, procurement, and sales data are stored. This portal is a global hub any Unilever site employee can access, to learn and benchmark from peer sites. These platforms are partly internal and partly managed by a third-party companies such as IBM and SAP. These two are the company's main trusted 3P. Hence the data are planned to be extracted from SAP, APO (a planning excellence software), Company UMS and ManEX platforms, BuildApp digital platform that is used to fill daily factory performance data which is stored into a global hub.

3.4 Population and Sample Design

The population and sample design are: for the case of Primary data all employees (clerks, mid-level managers and senior managers) who work in the company and have works linked with forecast, inventory and production waste are included in questionnaire but secondary data restricted to data retrieved from system from the years 2021, 2022 and 2023 of only one of the four factories running in Dukem town, this is for the case of the quantitative secondary data. The haircare plant in the business group of beauty & Well-being. The data shall be taken from a

100% month by month score card of each of the three variables over the last three years: Demand forecast, Waste due to Changeover and Inventory level.

The Primary data here which serves as a support for the secondary data was collected on a questionnaire prepared and distributed to both non- management and management employees, (total 30 employees, of which 25 responded). The non-management employees include Production clerks, Planning analysts, distribution planners that work directly with demand forecast, inventory as well as production wastes.

And the mid-level and senior management employees included employees that have a say on decisions made on demand forecast, inventory as well as production wastes. These are Production manager, Planning manager, logistics manager, distribution manager, area sales and brand managers, finance business partners and financial controllers in the company.

3.5. Data Source and Type

Two types of data shall be used in this research paper: Primary data and Secondary data. As primary data we get qualitative data information from employees in different sections of the supply chain (production, Warehouse, planning, logistics, Distribution), finance, IT, Sales and marketing. there'll be a questionnaire to understand how decisions were made at some points in time and what influenced them with respect to going off or maintain the targets of the three mentioned variables.

As the source of secondary data system, generated reports shall be used to do analysis as well as find results of how the three variables behaved over the past three years. These are Data from different ERP and ManEX software the company uses like SAP, APO, Kinaxis, SAP Concur, Coupa, BuildApp, Inside Unilever, ...

3.6. Data Collection Procedure

Purposive sampling procedure shall be used through questionnaire for the primary data, and it'll be distributed to clerks, mid-level managers, and top managers to gather qualitative type of data. The procedure shall be to brief the individuals on the purpose and end goal of the

research, describe the questions in the questionnaire in detail on a one-to-one interview type set up with each individual to get accurate and reliable information. The seek from these individuals shall be on how inventory, waste and forecast deviation decisions were made or how decisions influenced score card. These selected individuals shall be employees that are directly involved in forecasting, waste management and inventory management, the reason being responses need to be from valid experience of trends of data and decisions that were being made.

For the scndary data document reviews as well as system extracted reports of KPIs and scorecards are used and analyzed accordingly. As some system generated secondary data may require access permission, required approvals were followed to get the data from employees with specific access permission. (The company usually is open and is supportive to share data for study purposes).

Sample Size (Quantitave)					
No	Digital platforms	Data type	Period (months)	duration (year)	Remark
1	SAP data	Month closing Inventory level	36	2021-2023	
2	SAP data	Waste records, MUV score	36	2021-2023	
3	APO data	Forecast accuracy	36	2021-2023	
4	APO data	Forecast Bias	36	2021-2023	
5	BuildApp	Line Performance	36	2021-2023	

Table 1 – Data sampling size, Quantitative.

Sample Size (Qualitative)			
No	Employee	No of respondents	Remarks
1	Clerks	10	
2	Mid level Managers	10	
3	Senior Managers	5	

Table 2. – Data sampling size, Qualitative.

3.7. Method of Data Analysis and Presentation

The quantitative data document reviews and system extracted reports of KPIs, and scorecards shall be analyzed using a Power-BI software on month-on-month trends of the past three years which shall be presented using graphs and trend lines. For the qualitative questionnaire gathered data the analysis was done from excel sorted data and analyzed using goal programming simplex and AHP models to reach on an optimal value for all the three variables of Inventory, Production waste and production volume. presented in graphical and tabular options. Finally with the outcomes of the three models is compared to suggest the better outcome for this particular data collected.

3.8. Validity and Reliability Test

Reliability estimates & evaluate the stability of measures, internal consistency of measurement instruments, and interrater reliability of instrument scores. Validity is the extent to which the interpretations of the results of a test are warranted, which depends on the particular use the test is intended to serve (Carole L Kimberlin, 2018).

After data is collected reliability of the data shall be measured and evaluated using Cronbach's Alpha Value. This measurement gives a decimal value between 0 and 1, where closer to zero means unreliable data and closer to 1 is a more reliable data (in other words, for the data to be concluded reliable, it should be at a score level greater than 0.7). The Cronbach's Alpha result's acquired is: 0.96 which is satisfactorily high.

The total number of variables tested for the reliability shall also be checked and confirmed.

The image shows two screenshots from SPSS. The left screenshot displays the 'Reliability Statistics' table, which includes Cronbach's Alpha (0.96) and the Number of Items (5). The right screenshot displays the 'Item-Total Statistics' table, which lists the Corrected Item-Total Correlation for five items: Item A (0.94), Item B (0.91), Item C (0.87), Item D (0.9), and Item E (0.88).

Cronbach's Alpha	Number of Items
0.96	5

	Corrected Item-Total Correlation
Item A	0.94
Item B	0.91
Item C	0.87
Item D	0.9
Item E	0.88

3.9. Ethical Considerations

Before Research questionnaires are distributed, interviews are made or Digital data is extracted, there were meetings with and approval request from the Business Integrity manager and corporate affairs manager of the company to make alignment on the types of data and information to be gathered and at the same time on the purpose and confidentiality of the study plus the type of employees to be included in the study.

All employees involved in this research were informed of the purpose of the study and why specific data are needed in the research. Also, in terms of accessing digital company data platforms, all the necessary approvals were requested and acquired from respective section managers, area owners and business group owners. So, preceding happened only when approval is granted for a specific area/platform.

Also, before data collection and distribution of questionnaire is done, all participants were briefed that they will do the participation only in willingness basis, of their roles in the research and how the data they provide is used in the research they can withdraw themselves from the study anytime. Also, clear communication of confidentiality level of the data they provide so that accurate data is provided freely.

CHAPTER FOUR

DATA PRESENTATION, RESULTS AND DISCUSSIONS

4.1 – Primary Data, analysis & Interpretation

Part One – Personal information of respondents - A total of 30 questionnaires were distributed and 28 were returned, of which 25 were fully completed and 3 were incomplete.

Gender of respondents

No	Gender	Distributed	Percentage	Completed	Completion %age
1	Male	14	47%	12	86%
2	Female	16	53%	13	81%
Total		30	1	25	83%

Table 4.1 – Gender of respondents (Source: Own Survey, Apr 2024)

As Can be seen from Table 4.1: of the questionnaires distributed, 47% were to male respondents and 53% was to female respondents. From which 86% of the male and 75% of the female respondents filled the questionnaire complete. The rate of questionnaire filled complete was 80%.

Functions of Respondents

No	Function	Distributed	Responded	completed	Completed by Category
1	Marketing/Brand	3	2	2	8.33%
2	Production	6	6	5	20.83%
3	Warehouse/Distribution	4	4	4	16.67%
4	Sales/CD	5	5	4	16.67%
5	Planning/ Logistics	8	8	7	29.17%
6	General Management	3	2	2	8.33%
Total		29	27	24	100.00%

Table 4.2 – Functions of Respondents (Source: Own Survey, Apr 2024)

As Can be seen from Table 4.2, of the 30 employees that received the questioner, the researcher has obtained data from 25 respondents of six relevant functions that actively participate in and contribute to the variables of demand forecasting, Inventory and Production wastes of Unilever manufacturing plc, Ethiopia. Of which, the highest selection of categories for data filling were:

Planning/Logistics (29.17% completed), Production (20.83% Completed) Warehouse/Distribution and Sales (16.67% each).

Educational level of Respondents

No	Function	Distributed	Percentage	Cumulative Percent
1	Master's degree and above	10	40%	
2	Bachelor's Degree	13	52%	
3	Diploma/TVET	2	8%	
4	Completed Highschool	0	0%	
Total		25	100%	0

Table 4.3 – Educational Background of respondents (Source: Own Survey, Apr 2024)

Overall summary of Table 4.3 is that most employees are on the educational level of Bachelor's or masters' degree. Only a few clerks (less than 10%) were Diploma/TVET level.

Service Year of Respondents

No	Function	Distributed	Percentage	Cumulative Percent
1	1-2 Years	6	24%	
2	3-4 Years	9	36%	
3	5-6 Years	6	24%	
4	7+ Years	4	20%	
Total		25	1	0

Table 4.4 – Service year distribution of the respondents (Source: Own Survey, Apr 2024)

In terms of service year of employees, most respondents are medium service year level (3-10 years) hence having good experience on the information they gave on the questionnaire hence more expertise based and reliable?

Part – II Functional Topics

In this Part, I'll try to tabulate and also interpret the responses of the respondents for questions on the relationships between Demand forecast, Inventory costs and production wastes.

No	Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Mean	Std Dev
14	Stretched inventory holding costs target contributes to constraining demand, lost sales and forecast bias			7	15	2	3.79	0.81

15	Selection of SKUs to produce is mainly driven by inventory levels			3	11	10	4.29	1.32
16	Selection of SKUs to produce is mainly driven by forecasted demand		5	4	7	8	3.75	0.77
17	Material wastes during production is dependent on integr'n of demand forecast and product change overs.		2	8	10	4	3.67	0.68
18	Inventory holding cost is Increased with increased changes in demand forecasting		1	7	9	7	3.92	0.94
19	Demand forecasting accuracy impacts wastes associated with multiple change overs in production lines			6	11	7	4.04	1.06
20	There is a significant amount of material loss in production due to product changeovers associated with change in demand.			7	12	6	4.13	1.15
21	Due to discrepancies in demand forecasting, there is significant loss in Inventory cost and wastes in material usage		4	3	8	9	3.92	0.94
22	There is a frequent demand trend variance that impacts the efficiency of your inventory management practices	8	9	3	4		2.13	0.89

Table 4.5 – specific questions relating variables. (Source: Own Survey, Apr 2024)

For this Part of the questionnaire, based on table 4.5 the following are the findings:

- Employees agree that stretched inventory targets contribute to demand fluctuations and lost sales. (with mean of 3.79 and std dev of 0.81).
- Also there's more agreement to the fact that Inventory level drives choice of SKU's to produce more than forecast driving SKU choice. (with mean of 4.29 vs 3.75 and std dev of 1.32 vs 1.77).
- There is a significant amount of material loss in production due to product changeovers associated with change in demand. (with mean of 4.13 and std dev of 1.15).
- Employees disagreed also on the assumption that, "There is a frequent demand trend variance that impacts the efficiency of your inventory management practices". (with mean of 2.13 and std dev of 0.89).

- Employees tend to agree more on the fact that, “There is a significant amount of material loss in production due to product changeovers associated with change in demand”. (with mean of 4.13 and std dev of 1.15).

Based on respondents’ views, this table summarizes The primary demand forecasting method(s) used in the organization.

No	Function	Frequency	Percentage
1	Moving Average	2	4%
2	DBR	17	37%
3	Trend Analysis	15	33%
4	Seasonal Analysis	12	26%
Total		45	100%

Table 4.6 – Primary demand forecasting methods (Source Own Survey, Apr 2024)

In Table 4.6, respondents’ response shows that the primary demand forecasting methods used in the organization are as DBR (with 37% of responses saying so) and Trend Analysis (with 33% of votes pointing out that). The data shows that there are some instances moving Average method, Seasonal Analysis are also considered.

No	Function	Distributed	Percentage
1	Daily		
2	Weekly	8	31%
3	Monthly	18	69%
4	Quarterly		
Total		26	100%

Table 4.7 – Frequency to Update Demand forecasts. (Source Own Survey, Apr 2024)

Data on Table 4.7. shows us that Demand forecasts are updated on weekly and monthly basis. Monthly on SnOP meeting and Weekly on WORM (Weekly Operational Review Meeting).

Also Supported by the below Table (Table 4.8) if organization consider factors beyond historical sales data in the forecasting process?

No	Function	Distributed	Percentage
1	Yes	25	100%
2	No	0	
Total		25	1

Table 4.8 organization consideration of other factors (Source Own Survey, Apr 2024)

Based on Data on Table 4.8, all the Participants agree that the organization consider factors beyond historical sales data in the forecasting process.

No	Function	Distributed	Percentage
1	Promotions	17	34%
2	Seasonality	20	41%
3	DBR	8	17%
4	Customer Feedback	0	0%
5	Other	3	7%
Total		48	100%

Table 4.9 other types of factors considered in forecasting (Source Own Survey, Apr 2024)

This above table supports the previous conclusion and summarizes which of the What other factors are considered as well as their fair distribution level of considerations by the company according to the respondents' Data.

The following table summarizes if the respondents agree to the existence of forecast bias.

No	Function	Distributed	Percentage
1	Yes	23	92%
2	No	2	8%
Total		25	100%

Table 4.10 – Forecast bias. (Source Own Survey, Apr 2024)

And the response of the respondents to the question, “Are there times significant forecast bias was observed in the sales of hair care products?” was 92% yes. Which is a confirmation that there’s deviation between forecasted volumes and actual demand which at a later stage in the secondary data analysis shall be used to correlate with inventory and production wastes.

And Table 4.11 below shows us what factors contribute to that forecast bias.

No	Function	Distributed	Percentage
1	Seasonality	15	29%
2	Forecast accuracy.	15	29%

3	Social unrest	11	22%
4	Inflation/hyper inflation	10	20%

Table 4.11 – Factors contributing to forecast bias. (Source Own Survey, Apr 2024)

According to the following two tables (Tables 4.11 and 4.12), respondents believe that the bias significantly affect the inventory costs as well as production wastes relating to product changeovers in the factory due to forecast changes the company at those times.

No	Function	Distributed	Percentage
1	Yes	25	100%
2	No		
Total		25	100%

Table 4.12 – Effect of forecast bias on inventory cost (Source Own Survey, Apr 2024)

No	Function	Distributed	Percentage
1	Yes	25	100%
2	No		
Total		25	100%

Table 4.12 – Effect of forecast bias o Production run and wastes (Source Own Survey, Apr 2024)

4.2 – Secondary Data analysis & Interpretation

This part of the data is mainly obtained from database of Unilever manufacturing Plc, Ethiopia. SnOP (sales and Operations) database, SAP records, financial data for material usage variance reports as well as production reports (which include production volumes by day as well as RM/PM usage) are used to collect the required data.

Th data are compiled at the best of my capabilities to make them more presentable & relevant to this research paper and also to reduce the number of tables and figures that are included in this thesis.

The following are the summary of the data: Three years production by month

No	Statement	SKU	Forecast vol (tons)	Inventory Target (EUR)	Produced vol (tons)	Inventory of FG	PVA	Inventory Deviation	
2021 Calendar Year	Jan 21-Apr 21	Plant Commissioning							
	May-22	Sunsilk Coconut Shampoo	15	26250	18.69	32707.5	125%	125%	
		Sunsilk Coconut Conditioner	15	26250	18.34	32095	122%	122%	
		Sunsilk Avocado Shampoo	15	26250	18.87	33022.5	126%	126%	
		Sunsilk Avocado Conditioner	15	26250	18.23	31902.5	122%	122%	
		All Sunsilk	60	105000	74.13	129727.5	124%	124%	
	Jun-22	Sunsilk Coconut Shampoo	15	26250	12.2	21350	81%	81%	
		Sunsilk Coconut Conditioner	15	26250	11.7	20475	78%	78%	
		Sunsilk Avocado Shampoo	15	26250	11.98	20965	80%	80%	
		Sunsilk Avocado Conditioner	15	26250	11.88	20790	79%	79%	
		All Sunsilk	60	105000	47.76	83580	80%	80%	
	Jul-22	Sunsilk Coconut Shampoo	20	35000	21.11	36942.5	106%	106%	
		Sunsilk Coconut Conditioner	20	35000	22.65	39637.5	113%	113%	
		Sunsilk Avocado Shampoo	20	35000	20.7	36225	104%	104%	
		Sunsilk Avocado Conditioner	20	35000	21.1	36925	106%	106%	
		All Sunsilk	80	140000	85.56	149730	107%	107%	
	Aug-22	Sunsilk Coconut Shampoo	20	35000	22.47	39322.5	112%	112%	
		Sunsilk Coconut Conditioner	20	35000	20.31	35542.5	102%	102%	
		Sunsilk Avocado Shampoo	20	35000	21.18	37065	106%	106%	
		Sunsilk Avocado Conditioner	20	35000	18.49	32357.5	92%	92%	
		All Sunsilk	80	140000	82.45	144287.5	103%	103%	
	Sep-22	Sunsilk Coconut Shampoo	25	35000	23.3	40775	93%	117%	
		Sunsilk Coconut Conditioner	25	35000	24.11	42192.5	96%	121%	
		Sunsilk Avocado Shampoo	25	35000	21	36750	84%	105%	
		Sunsilk Avocado Conditioner	25	35000	22	38500	88%	110%	
		All Sunsilk	100	140000	90.41	158217.5	90%	113%	
	Oct-22	Sunsilk Coconut Shampoo	28	35000	25.46	44555	91%	127%	
		Sunsilk Coconut Conditioner	27	35000	17.57	30747.5	65%	88%	
		Sunsilk Avocado Shampoo	28	35000	24.44	42770	87%	122%	
		Sunsilk Avocado Conditioner	27	35000	16.67	29172.5	62%	83%	
		All Sunsilk	110	140000	84.14	147245	76%	105%	
	Nov-22	Sunsilk Coconut Shampoo	30	35000	24.44	42770	81%	122%	
		Sunsilk Coconut Conditioner	25	35000	18.74	32795	75%	94%	
		Sunsilk Avocado Shampoo	30	35000	23.66	41405	79%	118%	
		Sunsilk Avocado Conditioner	25	35000	17.67	30922.5	71%	88%	
		All Sunsilk	110	140000	84.51	147892.5	76%	106%	
	Dec-22	Sunsilk Coconut Shampoo	30	35000	24.33	42577.5	81%	122%	
		Sunsilk Coconut Conditioner	25	35000	20.55	35962.5	82%	103%	
		Sunsilk Avocado Shampoo	30	35000	20.23	35402.5	67%	101%	
		Sunsilk Avocado Conditioner	25	35000	18.66	32655	75%	93%	
		All Sunsilk	110	140000	83.77	146597.5	76%	105%	
	2021 TOTAL			93897.5	1081000	632.73	1107278	92%	105%

No	Statement	SKU	Forecast vol (tons)	Inventory Target (EUR)	Produced vol (tons)	Inventory of FG	PVA	Inventory Deviation	Remark
2022 Calendar Year	Jan-22	Sunsilk Coconut Shampoo	45	65625	39.80	69650	88%	106%	
		Sunsilk Coconut Conditioner	45	65625	40.50	70875	90%	108%	
		Sunsilk Avocado Shampoo	35	65625	38.00	66500	109%	101%	
		Sunsilk Avocado Conditioner	35	65625	38.00	66500	109%	101%	
		All Sunsilk	160	262500	156.30	273525	99%	104%	
	Feb-22	Sunsilk Coconut Shampoo	40	65625	42.30	74025	106%	113%	
		Sunsilk Coconut Conditioner	40	65625	44.20	77350	111%	118%	
		Sunsilk Avocado Shampoo	48	65625	51.00	89250	106%	136%	
		Sunsilk Avocado Conditioner	48	65625	50.55	88462.5	105%	135%	
	All Sunsilk	176	262500	188.05	329087.5	107%	125%		
	Mar-22	Sunsilk Coconut Shampoo	42	65625	43.50	76125	104%	116%	
		Sunsilk Coconut Conditioner	42	65625	42.05	73587.5	100%	112%	
		Sunsilk Avocado Shampoo	38	65625	36.60	64050	96%	98%	
		Sunsilk Avocado Conditioner	38	65625	38.20	66850	101%	102%	
		All Sunsilk	160	262500	160.35	280612.5	100%	107%	
	Apr-22	Sunsilk Coconut Shampoo	55	65625	48.50	84875	88%	129%	
		Sunsilk Coconut Conditioner	45	65625	42.30	74025	94%	113%	
		Sunsilk Avocado Shampoo	55	65625	48.34	84595	88%	129%	
		Sunsilk Avocado Conditioner	45	65625	41.80	73150	93%	111%	
		All Sunsilk	200	262500	180.94	316645	91%	121%	
	May-22	Sunsilk Coconut Shampoo	55	65625	46.60	81550	85%	124%	
		Sunsilk Coconut Conditioner	50	65625	41.00	71750	82%	109%	
		Sunsilk Avocado Shampoo	50	65625	43.30	75775	87%	115%	
		Sunsilk Avocado Conditioner	49	65625	40.43	70752.5	83%	108%	
		All Sunsilk	204	262500	171.33	299827.5	84%	114%	
	Jun-22	Sunsilk Coconut Shampoo	46	65625	41.55	32333.333	90%	49%	
		Sunsilk Coconut Conditioner	44	65625	40.32	28200	92%	43%	
		Sunsilk Avocado Shampoo	46	65625	42.06	32226.667	91%	49%	
		Sunsilk Avocado Conditioner	44	65625	40.67	27866.667	92%	42%	
		All Sunsilk	180	262500	164.60	120626.67	91%	46%	
	Jul-22	Sunsilk Coconut Shampoo	36	65625	37.80	66150	105%	101%	
		Sunsilk Coconut Conditioner	34	65625	38.34	67095	113%	102%	
		Sunsilk Avocado Shampoo	36	65625	38.11	66692.5	106%	102%	
		Sunsilk Avocado Conditioner	34	65625	38.22	66885	112%	102%	
		All Sunsilk	140	262500	152.47	266822.5	109%	102%	
	Aug-22	Sunsilk Coconut Shampoo	32	65625	34.20	59850	107%	91%	
		Sunsilk Coconut Conditioner	26	65625	30.91	54092.5	119%	82%	
		Sunsilk Avocado Shampoo	36	65625	36.00	63000	100%	96%	
		Sunsilk Avocado Conditioner	32	65625	32.30	56525	101%	86%	
		All Sunsilk	126	262500	133.41	233467.5	107%	89%	
	Sep-22	Sunsilk Coconut Shampoo	56	65625	48.80	85400	87%	130%	
		Sunsilk Coconut Conditioner	45	65625	38.56	67480	86%	103%	
		Sunsilk Avocado Shampoo	56	65625	46.40	81200	83%	124%	
		Sunsilk Avocado Conditioner	45	65625	39.10	68425	87%	104%	
		All Sunsilk	202	262500	172.86	302505	86%	115%	
	Oct-22	Sunsilk Coconut Shampoo	48	65625	44.40	77700	93%	118%	
		Sunsilk Coconut Conditioner	48	65625	40.90	71575	85%	109%	
		Sunsilk Avocado Shampoo	36	65625	35.55	62212.5	99%	95%	
Sunsilk Avocado Conditioner		36	65625	35.80	62650	99%	95%		
All Sunsilk		168	262500	156.65	274137.5	94%	104%		
Nov-22	Sunsilk Coconut Shampoo	52	65625	50.55	88462.5	97%	135%		
	Sunsilk Coconut Conditioner	38	65625	38.24	66920	101%	102%		
	Sunsilk Avocado Shampoo	52	65625	51.00	89250	98%	136%		
	Sunsilk Avocado Conditioner	38	65625	39.11	68442.5	103%	104%		
	All Sunsilk	180	262500	178.90	313075	100%	119%		
Dec-22	Sunsilk Coconut Shampoo	50	65625	44.11	54875.625	88%	84%		
	Sunsilk Coconut Conditioner	45	65625	44.52	60972.917	99%	93%		
	Sunsilk Avocado Shampoo	50	65625	49.78	54875.625	100%	84%		
	Sunsilk Avocado Conditioner	45	65625	44.88	60972.917	100%	93%		
	All Sunsilk	190	262500	183.29	231697.08	97%	88%		
2021 TOTAL			1906	2887500	1820.25	2928954	97%	101%	

No	Statement	SKU	Forecast vol (tons)	Inventory Target (EUR)	Produced vol (tons)	Inventory of FG	PVA	Inventory Deviation	Remark
2023 Calendar Year	Jan-23	Sunsilk Coconut Shampoo	25	35000	23.49	41107.017	94%	117%	
		Sunsilk Coconut Conditioner	35	35000	33.98	59459.694	97%	170%	
		Sunsilk Avocado Shampoo	20	35000	17.72	31013.441	89%	89%	
		Sunsilk Avocado Conditioner	10	35000	11.49	20100.024	115%	57%	
		All Sunsilk	90	140000	86.67	151680.18	99%	108%	
	Feb-23	Sunsilk Coconut Shampoo	40	35000	34.78	60857.202	87%	174%	
		Sunsilk Coconut Conditioner	20	35000	19.56	34230.595	98%	98%	
		Sunsilk Avocado Shampoo	15	35000	15.93	27869.352	106%	80%	
		Sunsilk Avocado Conditioner	15	35000	14.15	24763.715	94%	71%	
		All Sunsilk	90	140000	84.41	147720.86	96%	106%	
	Mar-23	Sunsilk Coconut Shampoo	30	35000	30.08	52638.81	100%	150%	
		Sunsilk Coconut Conditioner	20	35000	17.57	30743.997	88%	88%	
		Sunsilk Avocado Shampoo	15	35000	12.62	22093.743	84%	63%	
		Sunsilk Avocado Conditioner	10	35000	10.78	18857.244	108%	54%	
		All Sunsilk	75	140000	71.05	124333.79	95%	89%	
	Apr-23	Sunsilk Coconut Shampoo	30	35000	28.15	49269.612	94%	141%	
		Sunsilk Coconut Conditioner	20	35000	18.73	32769.03	94%	94%	
		Sunsilk Avocado Shampoo	30	35000	30.32	53062.548	101%	152%	
		Sunsilk Avocado Conditioner	25	35000	24.58	43012.032	98%	123%	
		All Sunsilk	105	140000	101.78	178113.22	97%	127%	
	May-23	Sunsilk Coconut Shampoo	15	35000	15.28	26738.187	102%	76%	
		Sunsilk Coconut Conditioner	15	35000	14.05	24589.53	94%	70%	
		Sunsilk Avocado Shampoo	1	35000	1.23	2153.004	123%	6%	
		Sunsilk Avocado Conditioner	1	35000	0.77	1347.57	77%	4%	
		All Sunsilk	32	140000	31.33	54828.291	99%	39%	
	Jun-23	Sunsilk Coconut Shampoo	40	35000	39.21	68625.207	98%	196%	
		Sunsilk Coconut Conditioner	30	35000	24.72	43261.544	82%	124%	
		Sunsilk Avocado Shampoo	40	35000	18.08	31635.366	45%	90%	
		Sunsilk Avocado Conditioner	30	35000	15.67	27414.933	52%	78%	
		All Sunsilk	140	140000	97.68	170937.05	69%	122%	
	Jul-23	Sunsilk Coconut Shampoo	40	35000	10.17	17800.188	25%	51%	
		Sunsilk Coconut Conditioner	30	35000	15.30	26768.011	51%	76%	
		Sunsilk Avocado Shampoo	40	35000	10.46	18308.115	26%	52%	
		Sunsilk Avocado Conditioner	30	35000	10.30	18025.56	34%	52%	
		All Sunsilk	140	140000	46.23	80901.874	34%	58%	
	Aug-23	Sunsilk Coconut Shampoo	40	35000	36.21	63375.67	91%	181%	
		Sunsilk Coconut Conditioner	30	35000	20.61	36069.025	69%	103%	
		Sunsilk Avocado Shampoo	40	35000	21.98	38458.413	55%	110%	
		Sunsilk Avocado Conditioner	30	35000	15.60	27291.915	52%	78%	
		All Sunsilk	140	140000	94.40	165195.02	67%	118%	
	Sep-23	Sunsilk Coconut Shampoo	40	35000	35.66	62406.792	89%	178%	
		Sunsilk Coconut Conditioner	30	35000	24.35	42618.573	81%	122%	
		Sunsilk Avocado Shampoo	40	35000	19.81	34675.494	50%	99%	
		Sunsilk Avocado Conditioner	30	35000	13.15	23017.365	44%	66%	
		All Sunsilk	140	140000	92.98	162718.22	66%	116%	
	Oct-23	Sunsilk Coconut Shampoo	35	35000	36.71	64233.813	105%	184%	
		Sunsilk Coconut Conditioner	25	35000	22.22	38891.16	89%	111%	
		Sunsilk Avocado Shampoo	30	35000	28.29	49503.93	94%	141%	
Sunsilk Avocado Conditioner		20	35000	17.98	31465.035	90%	90%		
All Sunsilk		110	140000	105.20	184093.94	94%	131%		
Nov-23	Sunsilk Coconut Shampoo	40	35000	36.87	64529.472	92%	184%		
	Sunsilk Coconut Conditioner	30	35000	27.92	48860.28	93%	140%		
	Sunsilk Avocado Shampoo	35	35000	29.45	51535.638	84%	147%		
	Sunsilk Avocado Conditioner	25	35000	21.63	37847.88	87%	108%		
	All Sunsilk	130	140000	115.87	202773.27	89%	145%		
Dec-23	Sunsilk Coconut Shampoo	30	35000	9.83	17203.851	33%	49%		
	Sunsilk Coconut Conditioner	25	35000	7.96	13928.46	32%	40%		
	Sunsilk Avocado Shampoo	25	35000	10.06	17600.415	40%	50%		
	Sunsilk Avocado Conditioner	20	35000	9.50	16623.243	47%	47%		
	All Sunsilk	100	140000	37.35	65355.969	38%	47%		
2023 TOTAL			1162	1540000	849.0734	1485878	78%	96%	

Table 4.13 – Summary of forecast & production volume and inventory (2021-2023)

Extracting some useful summary of data from the above bulk data:

Let's consider only summary of 2023 data for interpretation to see the trend of shampoo and conditioner volumes.

SKU	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Sunsilk Coconut Shampoo	23.5	34.8	30.1	28.2	15.3	39.2	10.2	36.2	35.7	36.7	36.9	9.8	336.4
Sunsilk Coconut Conditioner	34.0	19.6	17.6	18.7	14.1	24.7	15.3	20.6	24.4	22.2	27.9	8.0	247.0
Sunsilk Avocado Shampoo	17.7	15.9	12.6	30.3	1.2	18.1	10.5	22.0	19.8	28.3	29.4	10.1	215.9
Sunsilk Avocado Conditioner	11.5	14.2	10.8	24.6	0.8	15.7	10.3	15.6	13.2	18.0	21.6	9.5	165.6
All Sunsilk	86.7	84.4	71.0	101.8	31.3	97.7	46.2	94.4	93.0	105.2	115.9	37.3	964.9

Table 4.14 – Summary of forecast & production volume and inventory (2021-2023)

From the above table we can conclude that:

- There is more sale of shampoo than conditioner.
- There is fluctuation in monthly volumes due to different factors which led to exceeding the inventory target which dictates us to produce only 74 tons a month. However annual total was 1161 tons with monthly average of 80.4 tons.

Next comparing annual material wastes associated only with product change over in the factory, we see the following trends.

No	Month	No of Changeovers	Product waste due to CIP	Remark
	May-22	14	0.77%	
	Jun-22	16	0.87%	
	Jul-22	15	0.82%	
	Aug-22	17	0.90%	
	Sep-22	23	1.27%	
	Oct-22	11	0.62%	
	Nov-22	14	0.76%	
	Dec-22	15	0.83%	
	2021 TOTAL	125	0.85%	

Table 4.15 2021 changeover vs material waste percentage

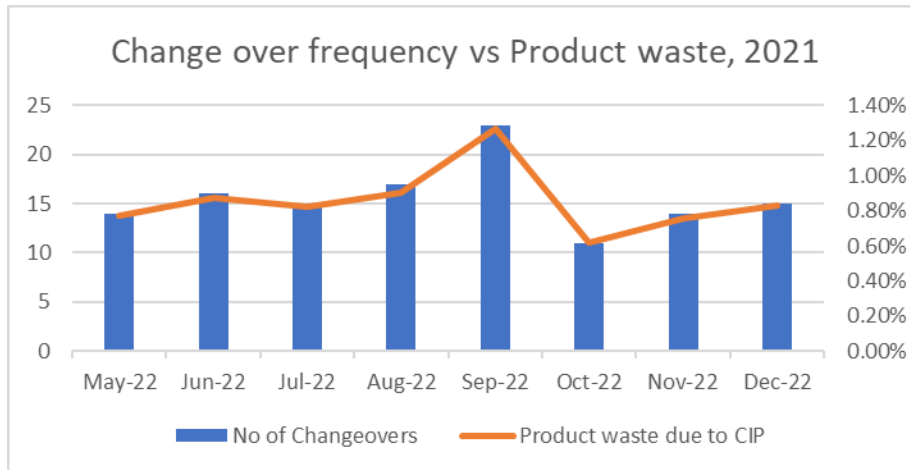


Fig 4.1 graphical presentation of 2021 changeover vs material waste

Both tables and graph show that in 2021, with increased number of change overs more wastes and cash loss was incurred. We see that there has been increased number of change overs even though volume was small, this was mainly because it was a startup year and it was a young market for sales.

No	Month	No of Changeovers	Product waste due to CIP	Remark
	Feb-22	16	0.88%	
	Mar-22	19	1.05%	
	Apr-22	14	0.76%	
	May-22	11	0.61%	
	Jun-22	9	0.51%	
	Jul-22	7	0.39%	
	Aug-22	7	0.38%	
	Sep-22	8	0.44%	
	Oct-22	7	0.37%	
	Nov-22	9	0.50%	
	Dec-22	11	0.61%	
2022 TOTAL				
		118	0.59%	

Table 4.16 2022 changeover vs material waste percentage

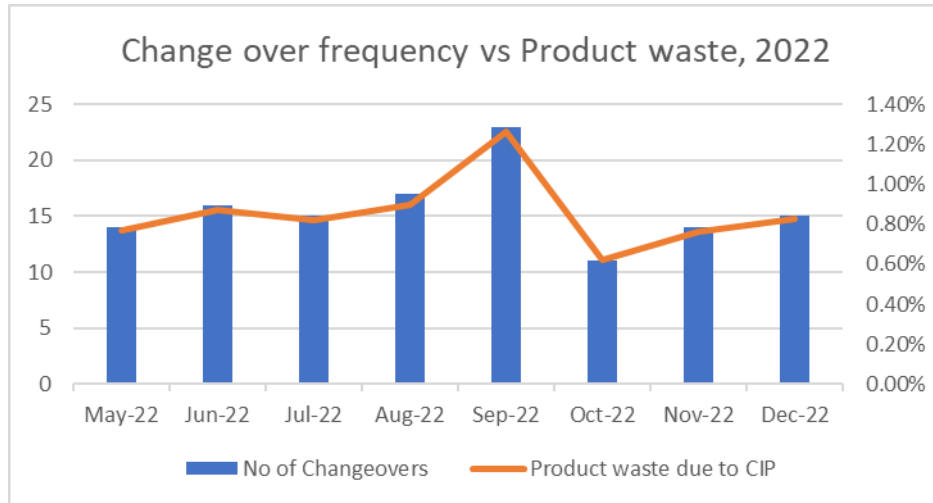


Fig 4.2 graphical presentation of 2022 changeover vs material waste

However, in 2022, even though the volumes have significantly increased, the rate of change over to increased volume has significantly improved. Contribution to this are maturity of market, forecast accuracy as well as bias, ... etc.

No	Month	No of Changeovers	Product waste due to CIP	Remark
	Feb-23	7	0.40%	
	Mar-23	8	0.45%	
	Apr-23	5	0.29%	
	May-23	5	0.28%	
	Jun-23	6	0.35%	
	Jul-23	6	0.36%	
	Aug-23	4	0.23%	
	Sep-23	5	0.30%	
	Oct-23	6	0.35%	
	Nov-23	7	0.38%	
	Dec-23	7	0.39%	
2023 TOTAL				
		66	0.34%	

Table 4.17 2023changeover vs material waste percentage

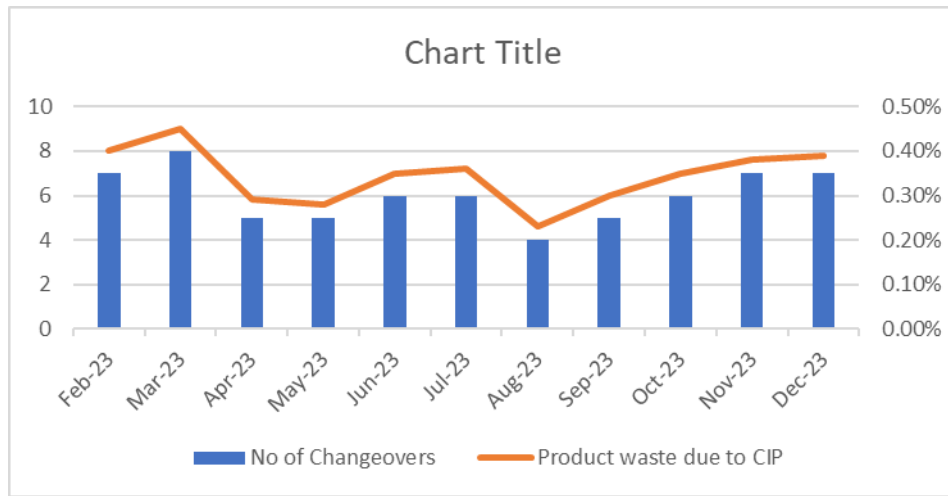


Fig 4.3 graphical presentation of 2023 changeover vs material waste

In 2023, the number of changeovers has almost perfected, however there was a significant reduction in forecasted volumes, inventory targets due to a lot of external factors including forex challenges, raw material availability and social unrest.

Summary of the data of the last three years' waste and changeover related data can be seen in the below table

No	Year	Monthly average No of Changeovers	Product waste due to CIP
1	2021G.C.	13.89	0.85%
2	2022G.C.	9.83	0.59%
3	2023G.C.	5.5	0.34%

Table 4.18: 2021 – 2023 comparison of changeover vs material waste percentage

4.3 Data Analysis Using linear programming Models

Goal Programming & Simplex methods

The Primary finding I want to use as a main variable in this analysis is the 2023 annual forecasted volume, which is 1162tons distributed into months as 98.3 tons every month against

inventory holding limit allocated to Sunsilk of 140K Euro per month which translates into two weeks safety stock of 37ton (meaning monthly production can go only to 74 tons).

Without having to consider any constraint the best-case scenario is:

The maximum volume for the two combined is 98 tons, so we need to find a combination of shampoo and conditioner that adds up to 98 tons.

One possible combination is to produce 98 tons of shampoo and 0 tons of conditioner. This would meet the demand for volume of 98 tons plus capacity wise achievable as 4 tons per day shampoo in 26 days means 104 tons capacity.

another possible combination is to produce 0 tons of shampoo and 98 tons of conditioner. This would be impossible because capacity wise for conditioner alone with 2.5 tons per day production, maximum achievable volume is 65 tons.

There are many other possible combinations that would meet the demand for both products and use up the maximum volume of 98 tons, but inventory targets, Turn over targets, waste targets, profit margin, ... can be missed. The best combination will depend on the fore mentioned specific variables of the constraints.

The constraints with their associated values are as below:

- Turn Over generated Per ton of Production.
 - Shampoo = 3200 Euro
 - Conditioner = 3700 Euro
- Profit margin.
 - Shampoo = 27%
 - Conditioner = 35%
- Production Capacity of the manufacturing Plant, the plant Can make:
 - 4tons of Shampoo in a one shift (8hrs) per day run.
 - 2.5 tons of Conditioners in a one shift (8hrs) per day run.

- Demand volumes should double to run two shifts per day, otherwise labor cost doubles and profitability will be affected.
- Shampoos sell alone sometimes, but conditioners do not sell alone, meaning the amount of conditioners produced cannot exceed the amount of shampoos produced.
- All four variants (Avocado Shampoo, Avocado Conditioner, Coconut Shampoo and Coconut conditioner) should be produced each month. And as the safety stocks should be two weeks cover, all the four should be produced every two weeks, meaning we need to have at least four product changeovers in the production lines every two weeks (eight in a month).
 - Wastes due to CIP per changeover – 75kg for shampoo.
 - Wastes due to CIP per changeover – 105kg for Conditioner.

(meaning eight change overs cause 300kg of shampoo waste and 420kg of Conditioner waste per month), which cashes to $300\text{kg} \times 3.2\text{Euro} + 420\text{kg} \times 3.7\text{Euro} = 2554\text{Euro}$.

The below table summarizes the waste amounts with increased number of changeovers.

No of Change overs a week	No of Change overs a month	Waste incurred (%age volume)	Waste incurred (Euro)	Percentage increase in inventory	Max Inventory level (tons)
2	8	0.35%	2554	0.00%	74
3	12	0.53%	3831	5.00%	77.7
4	16	0.70%	5108	10.00%	81.4
5	20	0.88%	6385	15.00%	85.1
6	24	1.05%	7662	20.00%	88.8

Table 4.19. Source: Researcher’s Secondary data (SAP hub, Unilever manufacturing Plc)

According to the table, the more change overs we make the more stock of each variant of product and better inventory capacity. Because when we have more SKUs available at a time, the more volumes can be sold and less risk of having to hold as inventory, but also more changeovers mean more material waste due to CIP (Cleaning in Place). Hence goal programming model shall be used here to suggest possible optimization Options between the variables.

Model I

(Relationship between Forecasted volume, Inventory target and production waste)

The Objective function Z in the first model is to maximize Inventory and get close to the average monthly volume forecast for the year 2023 with its associated turnover of 331200 Euro (\$3200 per ton of production and the turnover for conditioners \$3700 per ton of Production). The first constraint is the monthly inventory target which dictates monthly production of 74 tons only. The second constraint is the amount of product waste we generate due to changeovers and the money loss due to it. If we make minimum of 8 changeovers we lose 2554 Euro but our inventory target grows by 25% however if we do more changeovers, say 16 per month (5108 Euro loss) we can minimize the inventory level to 10% as more SKUs get to be produced during a month.

The first step is to convert the problem into a standard form. This means that we need to express the objective function and the constraints in terms of the decision variables. The decision variables in this problem are:

$$\text{Maximize } Z = €3200x_1 + €3700x_2$$

which represent the production volumes of products shampoo and conditioner, respectively. Fact: we can get more turnover by producing and selling more volumes of conditioners than shampoo.

Subject to:

The first constraint is the monthly inventory target, which is given by:

$$I = x_1 + x_2 \leq 74.$$

The second constraint is the amount of product waste, which is given by PW:

8 to 16 changeovers production waste goes €2550 < PW < €5110 in a month.

which can increase the turnover by 10% according to Table 4.15 from 74 tons to 81.4 tons without having to affect the inventory cash target.

Hence the purpose is to formulate a model and solve it in such a way that how we get an optimum value of production volume that could get close to the forecasted monthly volume of 96 tons while we miss reasonably on inventory levels and production wastes.

The next step is to solve the problem using the simplex method. The simplex method is an algorithm that can be used to solve linear programming problems. The basic idea of the simplex method is to start with an initial solution that satisfies the constraints and then to improve the solution iteratively until the optimal solution is found.

The solution found is:

The first constraint ensures that the total production volume does not fall far behind the monthly targeted forecast volume of 98tons. The second constraint ensures that the production waste does not exceed 2550Euros. The third constraint ensures that the inventory does not exceed 74 tons.

To solve the given problem using the simplex method, we first need to convert it into a standard linear programming problem. We can do this by introducing slack variables for the constraints. The slack variables represent the amount by which the constraints are not met.

The standard form of the problem is:

$$\text{Maximize } Z = 3200x_1 + 3700x_2$$

Subject to:

- $x_1 + x_2 + s_1 = 74$
- $2554x_3 + 5108x_4 + s_2 = 2550$
- $-x_1 - x_2 + s_3 = 0$
- $x_1, x_2, x_3, x_4, s_1, s_2, s_3 \geq 0$

We can now use the simplex method to solve this problem. The simplex method will iteratively improve the solution until it finds the optimal solution. The optimal solution is:

- $x_1 = 40$ tons
- $x_2 = 34$ tons

- $x_3 = 1$
- $x_4 = 0$
- $s_1 = 0$
- $s_2 = 0$
- $s_3 = 0$

Goal programming algorithm

The goal programming algorithm is a method for solving multiple objective linear programming problems. The goal programming algorithm starts with a set of goals and then iteratively minimizes the deviations from the goals.

To solve the given problem using the goal programming algorithm, we first need to define our goals. Our goals are to:

- Maximize inventory
- Minimize production waste
- Get close to the forecasted monthly volume of 96 tons

We can then formulate the goal programming model as follows:

$$\text{Minimize } Z' = d_1 + d_2 + d_3$$

Subject to:

- $x_1 + x_2 + d_1 = 74$
- $2554x_3 + 5108x_4 + d_2 = 2550$
- $x_1 + x_2 - d_3 = 96$
- $x_1, x_2, x_3, x_4, d_1, d_2, d_3 \geq 0$

We can now use the goal programming algorithm to solve this problem. The goal programming algorithm will iteratively minimize the deviations from the goals. The optimal solution is:

- $x_1 = 40$ tons
- $x_2 = 34$ tons
- $x_3 = 1$
- $x_4 = 0$
- $d_1 = 0$
- $d_2 = 0$
- $d_3 = 0$

Comparison of the two methods

The simplex method and the goal programming algorithm are both methods for solving linear programming problems. The simplex method is a more general method that can be used to solve any linear programming problem. The goal programming algorithm is a specialized method that is designed to solve multiple objective linear programming problems.

In this case, the simplex method and the goal programming algorithm both find the same optimal solution. However, the goal programming algorithm provides more information about the trade-offs between the different objectives.

This solution satisfies all of the constraints and maximizes the objective function but the volume forecasted of 98 tons. The total production volume is 74 tons, which is close to the average monthly volume forecast (about 25% less) for the year 2023. The production waste is 2500 euros, which is within the acceptable range. The inventory is 37 tons (for two weeks safety stock), which is below on target.

Now if we consider the second scenario of accepting more changeovers (16 instead of 8 in a month) and production wastes (0.7% instead of 0.35%) to get more volumes, hence turnover, then recalculating the program we get:

Simplex method

The optimal solution to the problem with the revised constraints is:

- $x_1 = 45.7$ tons
- $x_2 = 35.7$ tons
- $x_3 = 0$
- $x_4 = 1$
- $s_1 = 0$
- $s_2 = 0$

Goal programming algorithm

The optimal solution to the problem with the revised constraints is:

- $x_1 = 45.7$ tons
- $x_2 = 35.7$ tons
- $x_3 = 0$
- $x_4 = 1$
- $d_1 = 0$
- $d_2 = 0$
- $d_3 = 0$

Interpretation

The optimal solution is to produce 45.7 tons of shampoo and 35.7 tons of conditioner. This solution meets both constraints and minimizes the total deviation from the goals.

Note: The optimal solution is the same for both the simplex method and the goal programming algorithm. This is because the problem is a linear programming problem with a single objective.

Model II

The objective function, Z , represents the total Turnover to be made from Shampoos and Conditioners, which is \$330000 given that the turnover of Shampoos is \$3200 per ton of production and the turnover for conditioners \$3700 per ton of Production. The first constraint is profit margin of each, which is 27% profit margin for shampoos and 35% profit margin for Conditioners. The second constraint is daily Production capacity, PC. The plant can Produce only 4 tons of shampoo or 2 tons of conditioner in a one shift per day production. Assuming there are 26 days of Production

$$\text{Maximize } Z = \text{€}3200x_1 + \text{€}3700x_2$$

(we can get more turnover by producing and selling more volumes of conditioners than shampoo)

Subject to:

$$\text{Maximize Production Volume, PC} = (4x_1 + 2x_2) * 26 \text{days}$$

$$\text{while maximizing profit, P} = (\text{€}3200x_1) * 27\% + (\text{€}3700x_2) * 35\%$$

Hence the purpose is to formulate a model and solve it in such a way that how many days of shampoo production and how many days of Conditioner production should there be to get Optimum monthly Production volumes for both Shampoos and conditioners, maximum profit and minimum inventory that meets the set targets.

The following is a goal programming model that can be used to solve this problem:

$$\text{Maximize: } \text{€}Z = \text{€}3200x_1 + \text{€}3700x_2$$

$$\text{Subject to: } \text{€}3200x_1 + \text{€}3700x_2 = \text{€}33000$$

$$4x_1 + 2x_2 \Rightarrow \text{Max } 26 \text{days}$$

$$x_1 \text{ and } x_2 \text{ both non-negative}$$

The first constraint ensures that the total turnover does not exceed \$330000. The second constraint ensures that the total production volume does not exceed 26 days. The third and fourth constraints ensure that the production of shampoo and conditioner are non-negative.

This model can be solved using the goal programming algorithm. The goal programming algorithm is a heuristic algorithm that is used to solve goal programming problems. The algorithm starts by initializing the goal levels. The goal levels are the desired values for the goals. In this case, the goal levels are $Z = \text{€}330000$ and $\text{PC} = 26 \text{days}$.

The algorithm then iterates through the following steps:

1. Solve the linear programming problem with the current goal levels.
2. Calculate the deviational variables. The deviational variables are the differences between the actual values of the goals and the goal levels.
3. Update the goal levels. The goal levels are updated to reflect the deviational variables.
4. Repeat steps 2 and 3 until the goal levels converge.

The goal programming algorithm will converge to a solution that satisfies the goals as closely as possible. In this case, the solution will be a production schedule that maximizes the turnover and meets the production capacity constraints:

The following is a possible solution to the problem:

$x_1 = 10$ days production which is 41 tons

$x_2 = 16$ days production which is 33 tons

This solution satisfies the constraints and achieves the goal levels. The total turnover is \$253300, which is less than the goal level of \$330000\$ but meeting the other targets of inventory and waste.

Model III

In the other hand if we use linear programming to solve the problem with the same variables, i.e. -

- Demand Forecast – 98 tons
 - Turnover with this demand - €330000
 - Profit with this demand - €102300
- Finished good stock holding Inventory target – 74 tons
 - Turnover with this demand - €255300

- Profit with this demand - €79143
- Change over frequency
 - 16 needed with this demand, hence Production waste – €5110
 - 8 needed with Inventory target , hence Production waste - €2550

We get that

$$\text{Maximize Profit (P)} = 102300 (98) + 79143 (74) - 5110 (16) - 2550 (8)$$

$$P = 1109392$$

- Constraints:
- Demand constraint: $98x + 74y \geq 98$
 - Inventory target constraint: $98x + 74y \geq 74$
 - Change over constraint: $16x + 8y \geq 16$

- Variables:
- x: Volume produced at €102300/ton
 - y: Volume produced at €79143/ton

Solving Using Linear Programming:

Using a linear programming solver, we obtain the following optimal solution:

- $x = 25$ tons

- $y = 53$ tons

Volume Produced:

Therefore, the total volume that needs to be produced is:

$$\text{Total volume} = x + y = 25 + 53 = 78 \text{ ton}$$

4.4 - Interpretations of the models and the results

In table 4.20 we see which is distribution of shampoo to conditioner that can work and we also see the best combination highlighted in green as well as the turn over generated in each combination. Also:

- We clearly see that the highest turnovers are achieved with the lowest shampoo production and highest conditioner production, but that cannot satisfy other constraints like:
 - The plant can produce twice more shampoo in a day than conditioner, hence turnover can be achieved with more volumes.
 - Shampoos are consumed alone by some consumers, but conditioner in most cases is consumed with Shampoos, so it's not realistic to produce and sell twice as much conditioner than Shampoos throughout the year. Hence, it's better producing more shampoo than conditioner than the vice versa.
 - Hence considering the fact that there are only 26 days to produce and meeting a target of 74 tons per month combined volume, the Optimal volume of production for one shift per day production run is 41 tons of shampoo and 33 tons of conditioner.

Shampoo volume	Conditioner volume	Total Volume	Shampoo TO per ton	Conditioner TO per ton	Total Turn over
37	37	74	3200	3700	255300
36	38	74	3200	3700	255800
35	39	74	3200	3700	256300
34	40	74	3200	3700	256800
33	41	74	3200	3700	257300
32	42	74	3200	3700	257800
31	43	74	3200	3700	258300
30	44	74	3200	3700	258800
29	45	74	3200	3700	259300
28	46	74	3200	3700	259800
27	47	74	3200	3700	260300
26	48	74	3200	3700	260800
25	49	74	3200	3700	261300

38	36	74	3200	3700	254800
39	35	74	3200	3700	254300
40	34	74	3200	3700	253800
41	33	74	3200	3700	253300
42	32	74	3200	3700	252800
43	31	74	3200	3700	252300
44	30	74	3200	3700	251800
45	29	74	3200	3700	251300
46	28	74	3200	3700	250800
47	27	74	3200	3700	250300
48	26	74	3200	3700	249800
49	25	74	3200	3700	249300

Table 4.20 – Turn over comparison of different combination of shampoo and conditioner
(source: Company SAP data)

However, as indicated in table 4.21, if we compromise on Production wastes and do more changeovers in a month than 8 changeovers, i.e. let’s say four changeovers in a week can give us all the four SKU’s which means the safety stock can be reached in about ten days, which gives us the opportunity of sustain inventory level in terms of cash while delivering 10% more volume in a month. The next constraint now will be Production capacity because there is a limit of 4tons per day of shampoo and 2.5tons per day of conditioners unless we want to increase number of shifts per day from one to two (i.e. 16hrs of production per day instead of 8hrs).

Next table shows the max volumes we get in a month by combining different days of productions of the two products. The pre-requisite here is that we can’t produce more conditioners than shampoo and we can’t also do more than double shampoos than conditioners.

Shampoo production days	Conditioner production days	Available production days	Shampoo Produccible per month	Conditioner producible per month	Total max producible per month
8	18	26	32	45	77
9	17	26	36	42.5	78.5
10	16	26	40	40	80
11	15	26	44	37.5	81.5
12	14	26	48	35	83
13	13	26	52	32.5	84.5
14	12	26	56	30	86

15	11	26	60	27.5	87.5
16	10	26	64	25	89
17	9	26	68	22.5	90.5
18	8	26	72	20	92
19	7	26	76	17.5	93.5
20	6	26	80	15	95

Table 4.21 – Achievable monthly production volume with different combination of days of production for shampoo and conditioner in a month.

(source: analysis based on secondary data from Company SAP Portal)

4.5 Comparison of the results of the goal programming Algorithm and Simplex method

For this specific case we have found out that the simplex method gives us a better optimized solution than the goal programming algorithm because by keeping the turnover target and a small variation from the waste target, it gave us a possible combination of produceable shampoo and conditioner volume that totals to 81.6tons a month where as the goal programming algorithm gave us a combined produceable volume of 74 tons only.

Chapter five

Summary of findings Conclusions and Recommendations

5.1 Conclusions

Overall, the research has addressed both its general and specific objectives of optimization of demand forecast, inventory levels and production wastes as well as in responding to its pre stated problem statement, where at this stage suggestions are available and recommendations can be made.

The below are the main findings of this research paper and consequent conclusions and recommendations:

- Current production capacity is 4 tons of Shampoo or 2.5 tons of Conditioner in a day, which on 26 days per month means max 104tons (if shampoos only are produced) and minimum 65 tons of Production (if conditioners only are produced), both are unrealistic scenarios because:
 - Shampoo production volume can't exceed double of conditioner production volume as the usually go together.
 - i.e.: $X_1 < 2X_2$
 - Conditioner production volume cannot exceed shampoo production volume as either shampoo alone or shampoo prior to conditioner is hair care practice in Ethiopia (people wash their hair with shampoo only or shampoo and conditioner together, not conditioner alone).
 - i.e.: $X_2 \leq X_1$
- From point of view that the inventory target shouldn't be impacted and other constraints well considered, the best volumes to produce in a month are 40 tons of shampoo and 34 tons of conditioner to make the minimum wastes, better profit margin and better monthly turnover.
- If we have to play around the constraints where we should lose on one to serve the market with more than 74 tons of product, an easier win is to have more change overs to

have better volumes but incurring production wastes. It's less expensive than losing out on inventory targets as it has less impact on cash flow of the company as well as staying competitive in the market by serving the forecasted demand. As we have figured out in the goal programming model, by losing out on waste target.

- We found from the model that by increasing changeover frequency from 8 times a month to 16, we can produce 81.4tons (with a distribution of 45.7 tons shampoo Production and 35.7 tons of conditioner production) and we are still within target for Inventory cash holding. (incurring 2500Euros more of cash loss due to production waste, we can serve the market by 10% more volume)
- This can be summarized as

Additional volumes earned	7.4 tons
Additional Turnover earned	25530 Euro
Additional Profit earned	7659 Euro

5.2. Recommendations

In a scenario where volume exponentially grows, there are decisions that can be made whether we should:

- As the plant is currently running with one shift (8 hours per day) there is an opportunity to increase shift pattern to produce either 16hrs or 24hrs a day if the volumes are convincingly high that labor cost, cost per ton of the product and hence profit margin get altered of the product all have positive projection.
- Increase capacity of the manufacturing plant to be able to improve the number of units produced per minute per hour, which affects depreciation cost and hence cost per ton as well as profitability of the product as this means buying a new filler and labeler machine (the current machine is a low-speed machine that can produce only 18 bottles per minute).
- Increase our inventory level where again cash flow can be impacted with consideration of for example, if 10% increase in inventory level increase can give me let's say double turnover and 30% more profit. (But this 10% increase is in all Raw & Pack materials as well as finished goods.

- Or maintain all the above constraints and serve the market with less supply than forecasted demand.

5.3 Other points to Consider.

here is that there are other factors that influence meeting the forecasted demand including the company's choice to focus on high sales volumes (A SKUs like Lifebuoy, Knorr and Omo as they sell roughly 800 tons each, every month) that when there's foreign currency issues focus can go to these brands.

Demand forecast accuracy is another factor as it has been pointed out by respondents during primary data collection that forecast accuracy greatly impacts inventory level of Finished goods as well as material wastes in the production facility.

Sales strategy changes and shifts due to Social unrest is another factor that disrupts demand forecast and results in inventory fluctuations as well as production run strategies that influence the acceptable production wastes caused by product changeover

Hence this research is a point out on what opportunities of delivering more of the forecasted volumes are available with most of the KPI's still met, there are a thousand more options available out there, hence all decisions shall depend on how much demand can grow and it's gap from the current supply. The same Linear programming, goal programming or other modelling tools can be used to determine the best strategy and make the right decision to make the business more profitable, sustainable and growing.

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