



**INDICATING MATERIAL UTILIZATION IMPROVEMENT POTENTIAL IN
LEATHER GOODS PRODUCTION THROUGH MIXED INTEGER LINEAR
PROGRAMMING:**

**A CASE OF ABRISH LEATHER GOODS MANUFACTURING ENTERPRISE,
HAWASSA, ETHIOPIA.**

**M.Sc. SPECIALTY IN INDUSTRIAL ENGINEERING AND LOGISTICS
MANAGEMENT**

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HAWASSA, ETHIOPIA

NOVEMBER 2023.

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A THESIS SUBMITTED TO THE
DEPARTMENT OF INDUSTRIAL ENGINEERING,
INSTITUTE OF TECHNOLOGY, SCHOOL OF GRADUATE STUDIES,
HAWASSA UNIVERSITY
HAWASSA, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN INDUSTRIAL ENGINEERING
(SPECIALIZATION: INDUSTRIAL ENGINEERING AND LOGISTICS
MANAGEMENT)

NOVEMBER 2023.

HAWASSA, ETHIOPIA.

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I hereby declare that this MSc. equivalent thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

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Acknowledgment

I would have never finished this thesis if I wasn't blessed with health, energy and consistent endurance. Therefore my prior gratitude is given for the Almighty God, for looking after me in all journeys of my life.

I would like to thank my advisor, Dr. Fentahun Moges and co-advisor, Mr. Bahredin Abdella, for their patient and tireless efforts for successful completion of this study through academic, technical as well as experience sharing assistance and supports. My friend, Ashebir Tajebe, assisted me by giving valuable resources and consulting for successful construction of this paper on more reliable foundation.

I am also very thankful to Mr. Abreham Toma, CEO of the case company, for letting me have all I need in the company and Mr. Kedir Ahmed, technical manager for his unlimited and kind assistance in gathering the relevant data.

Furthermore, I would like to thank the management committee of my Bureau, especially Mr. Gebre Gage, head of SNNPRS Science and information technology bureau for his meaningful supports in letting me walk through light track towards my goal as well as the sponsorship in covering tuition fee of this study.

I can't fully enumerate my supporters in life, but I couldn't skip calling my sister Almaz seyoun and her kind husband Mr. Samuel Sebsibe for their unconditionally stretched hands and caring hearts for my son and me.

My great and loving son, Alazar Amdework (Abi), you are my power and life sweetening flavor.

Dedication

For my life route pavers and practical teachers of humanity Mulunesh Beshiro (Enye),

Ababiya, Demeshi (Rest in Peace)

Abamuda and Hareg (Long live).

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List of Abbreviations

CSA:	Central Statistics Agency
ECE:	Economic commission for Europe
EIC:	Ethiopian Investment Commission
ESPS :	Economic and social panel survey index
EU:	European Union
GDP:	Gross domestic product
HU - IoT:	Hawassa University - Institute of Technology
ISO:	International organization for standardization
KLEMS:	Capital, labor, energy, material and service
LIDI:	Leather Industries Development Institute
LLP:	Limited liability partnership
MSMEs:	Micro, small and medium enterprise
NTQF:	National TVET qualification framework
REACH:	Registration, evaluation, authorization and restriction of chemicals
SCP:	Sustainable Consumption and Production

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Abstract

Among various inputs of leather articles production, leather is the major material dictating productivity and profitability of the company. So it should be utilized as efficiently as possible.

The utilization level of leather material is determined by the operations carried out in cutting workstation of the production line. The goal of this study was to improve material utilization in leather goods production through optimization methods in Abrish leather articles manufacturing enterprise of Hawassa town.

The current production system of the company was investigated through objective observation and interview tools applying work study techniques. The major product items were identified and their respective flow of production was analyzed to identify the causes of material wastage and also looking for opportunity doors to act improvements so as to achieve optimal material utilization.

The identified major products of the company were categorized in two classes for grouped planning and production of items with respect to their component sizes and geometric shape for economic interlocking in cutting for minimal wastage. After categorization of products, a mixed integer linear programming model was formulated for determining the optimal number of products in each group for the realization of the maximum possible profit, considering tangible constraints of the business environment.

The proposed system was analyzed to have 84.3% reduction potential of scrap generation and the achievable weekly profitability level had been calculated with the formulated model using POM-QM software. Proper implementation of the proposed system enables the company to make an estimated profit of 56,190.63 ETB per week or 2,921,912.76 ETB per annum,

Key words: Leather goods, products categorization, mixed integer linear programming.

Chapter 1: Introduction

1.1. Background

Material utilization in the manufacturing industry refers to the amount of raw material used in the production process compared to the amount of material that ends up as finished products.

Leather articles manufacturing involves multiple stages, including designing, pattern-making, component cutting, sewing, and finishing (Deskera, 2019)

The industry is facing increasing pressure to reduce waste and improve efficiency in the production process. One area of focus is the utilization of leather material. However, several factors can lead to poor leather material utilization in enterprises (Deskera, 2019)

The utilization of leather is a promising area of research that can help the industry become more sustainable. Life Cycle Assessment is an important tool that can help decision-making in the transition to a more sustainable economic model. Poor design, cutting, preparation, and stitching techniques can lead to poor leather material utilization in leather articles producing enterprises. Addressing these challenges is crucial for the industry to become more sustainable and profitable (Navarro, 2020)

To address these challenges, leather goods producing enterprises have been implementing several strategies in their production processes. Firstly, they are adopting sustainable and innovative practices to reduce waste and maximize efficiency. This includes investing in technology and innovation to improve production efficiency, diversifying product lines, targeting markets, and implementing effective marketing and branding strategies (Navarro, 2020).

Additionally they are investing in the training and development of their employees to improve their skills and expertise. This includes providing training on sustainable

practices, quality control, and product design. These efforts are crucial for the industry to become more sustainable and profitable in the coming future (Navarro, 2020)

Optimizing the leather cutting process can increase utilization by maximizing the amount of leather material that is effectively used. By implementing efficient nesting techniques, the productivity of the process with respect to the leather material can be increased, allowing for better selection and placement of parts on the materials. This means that more parts can be nested, reducing material waste and increasing utilization. This ensures that the materials are utilized to their maximum potential, resulting in cost savings and improved profitability for companies (Giuseppe, 2018)

It is asserted in the Ethiopian leather sector value chain analysis that resource endowment is a necessary but not sufficient condition to raise the competitiveness of the industry. There is evidence that some countries, among the global top ten leather product manufacturers, are not resource endowed, however their performance is based on technology and efficiency across all functional areas. The hypothesis of the Ethiopian leather sector value chain strategy is that if the country combines its resource base with efficiency, it can join the top ten global leaders of the industry (Ministry of industry, 2016).

As a result, the focus of this study was on proper planning of production by geometric shape and size based categorization of items with the aim of improving leather material utilization in the production process, thereby enhancing profitability of the business.

1.2. Statement of the problem

Abrish leather articles manufacturing enterprise is one of the manufacturing enterprises actively running in Hawassa town. The company was organized as micro and small enterprise in Haikdar sub city of the town in 2005 E.c. Currently it is operating its

production in government facilitated shed and sales its products in its own sales shops in the town as well as supplying its products for retailers around Hawassa town.

The company is producing varieties of products ranging from bags to sandals of different designs. The production of these products is not properly planned that, scraps are continuously generated causing wastes and impacting inventory management of the company. The inefficient material utilization is also observed to have multilateral effects of causing wasted resource capacity in addition to the immediate problems stated above.

As a result, the goal of this study is to improve leather material utilization in the production process through proper planning of production and material allocation approach which enhances profitability of the company.

The results of this study provide valuable insights into how manufacturers can improve material utilization in the production of leather goods, while also contributing to a more sustainable future.

1.3. Research questions

In this study the following questions are answered and proper analysis is provided through technical integration of practical scenarios with relevant knowledge and concepts of Industrial Engineering and logistics management.

- What is the organization of the production process in the factory?
- What are the potential wastes in production process?
- What is the average area of scrap material that is discarded as a waste?
- What technical modifications should be introduced for planned consumption of materials; there by enhanced productivity will be realized?
- How much productivity improvement can be achieved by implementing the new system of production?

1.4. Objectives of the study

1.4.1. General Objective

The general objective of this research is to indicate material utilization improvement potential in leather articles production through mixed integer linear programming optimization method.

1.4.2. Specific Objectives

The specific objectives of the study are:

- Examining the current production process.
- Identifying the potential wastes in leather articles production.
- Determining the average area of scrap material being discarded as a waste.
- Introducing technical alterations for planned consumption of materials to enhance business productivity.
- Determining the possible benefits that can be achieved through the implementation of the new production system

1.5. Research significance

This study is valuable to the industry practitioners as well as consumers of the products.

The possible contributions of the study are described as below;

- It contributes for the advancement of existing knowledge in leather articles manufacturing sector indicating new insights of enhancing material productivity.
- It serves as reference for interested researchers in the leather sector as well as in the fields of Industrial engineering and manufacturing technology.
- It increases competitiveness of the production sectors by indicating ways of reducing the production cost of goods.
- It helps the environment protection practices of the government and the society by reducing the wastes disposed to the environment.

1.6. Scope of the study

The focus of the study was on leather material utilization in the production of major products of the company, like bags, belts and sandals and proposing modified system of production, emphasizing on cutting operation of the production process. The current production practice had been analyzed based on the information gathered from the selected case company in Hawassa town.

The unstructured operation of the enterprise, absence of documented data especially quantitative data describing existing scenario, time and budget inadequacies were potential constraints for this work.

1.7. Research structure

This study is organized under five chapters. The first chapter provides background information on leather goods production in Ethiopia. The second section of chapter One examines the problem that motivates the researcher to conduct the study, while the third section focuses on the research questions that precede the research objectives. The second chapter reviews the research of different authors on optimization, productivity measurement and productivity improvement in general and productivity improvement of leather article production.

The third chapter describes the research approaches and methodologies employed to achieve the goals. The study area, data gathering methods, data analysis methodologies, and research framework are all described in this chapter. The fourth chapter focuses on Data analysis and discussion of the findings based on the data acquired using various methodologies.

The fifth and final chapter offers conclusion and recommendations. This chapter summarizes the findings of the thesis's analysis section and suggestions to the organization on material utilization improvement and proper planning of production.

Chapter 2: Literature review

In this chapter some published journals and studies from different authors on the topic related to optimization, material utilization and productivity improvement in leather goods production were reviewed and presented as follows;

2.1. Basic Concepts

In this section basic concepts regarding productivity and optimization are described by reviewing books of known authors. The focus of the study is on improving leather material utilization which has inevitable influence on material productivity of the industry that, published books related with the topic are reviewed as follows.

Naresh (2005) redefined the measure of productivity in terms of Effectiveness (value to customer) or Efficiency (cost to producer). Effectiveness is the degree of accomplishment of the objectives that is: How well a set of result is accomplished? How well are the resources utilized? Effectiveness is obtaining the desired results. It may reflect output quantities, perceived quality or both. Effectiveness can also be defined as doing the right things. Efficiency occurs when a certain output is obtained with a minimum of inputs. The desired output can be increased by minimizing the down times as much as possible. But as we decrease down times the frequency of occurrence of defective products will increase due to fatigue. The production system might efficiently produce defective (ineffective) products. Efficiency can be defined as doing things right. Operational efficiency refers to a ratio of outputs to inputs (like land, capital, labor, etc.).

As it has been said so many times productivity measurement is the ratio of organizational outputs to organizational inputs. Thus productivity ratios can be Partial productivity measurement, Multi-factor productivity measurement and Total productivity measurement.

- Partial productivity measurement is used when the firm is interested in the productivity of a selected input factor. It is the ratio of output values to one class of input.

- Multi-factor Productivity Measurement is productivity measurement technique used when the firm is interested to know the productivity of a group of input factors but not all input factors.
- Total Productivity Measures deals about composite productivity when there is a desire to know about the overall productivity of all input factors. This technique will give us the productivity of an entire organization or even a nation.

The above measurement techniques can be grouped into two popular productivity measurement approaches the first uses a group-generated model and is called normative productivity measurement methodology. The second is less participative in that one model can be modified to fit any organization scheme. It is called multi-factor productivity measurement model.

Wiley (2020) defined Optimization as the act of obtaining the best result under given circumstances. In design, construction, and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is either to minimize the effort required or to maximize the desired benefit. Since the effort required or the benefit desired in any practical situation can be expressed as a function of certain decision variables, optimization can be defined as the process of finding the conditions that give the maximum or minimum value of a function.

There is no single method available for solving all optimization problems efficiently. Hence a number of optimization methods have been developed for solving different types of optimization problems. The optimum seeking methods are also known as mathematical programming techniques and are generally studied as a part of operations research. In recent years several new optimization methods that do not fall in the area of traditional mathematical programming have been and are being developed. Most of these new

methods can be labeled as metaheuristic optimization methods. All the metaheuristic optimization methods have the following features:

- They use stochastic or probabilistic ideas in various steps
- They are intuitive or trial and error based, or heuristic in nature
- They all tend to find the global optimum solution and
- They are most likely to find an optimum solution, but not necessarily all the time.

In this book it is indicated that, Mathematical programming techniques are useful in finding the minimum of a function of several variables under a prescribed set of constraints. Stochastic process techniques can be used to analyze problems described by a set of random variable having known probability distributions. The book deals with the theory and application of mathematical programming techniques suitable for the solution of engineering design problems.

Optimization, in its broadest sense, can be applied to solve any engineering problem. Some typical applications from different engineering disciplines indicate the wide scope of the subject:

- Design of material handling equipment, such as conveyors, trucks, and cranes, for minimum cost
- Shortest route taken by a salesperson visiting various cities during one tour
- Optimal production planning, controlling, and scheduling
- Analysis of statistical data and building empirical models from experimental results to obtain the most accurate representation of the physical phenomenon
- Selection of a site for an industry
- Planning of maintenance and replacement of equipment to reduce operating costs
- Inventory control

- Allocation of resources or services among several activities to maximize the benefit
- Controlling waiting and idle times and queuing in production lines to reduce the costs
- Planning the best strategy to obtain maximum profit in the presence of a competitor

2.2. Conceptual review

Ministry of industry (2016) highlighted the following issues related to the leather industry in Ethiopia.

- The sector is facing numerous challenges and it failed to meet export targets under GTP 1.
- Limited collaboration among stakeholders at various nodes of the value chain
- Rapid increase in imports of footwear and a widening trade balance
- Low capacity utilization across all the segments of the value addition segment of the leather value chain is raising Average Fixed Costs of Production
- Limited technological know-how and low labor productivity
- MSMEs in the production of footwear and leather goods are facing many challenges
- Inadequate environment management systems across the value chain
- Inadequate market development capacity in the domestic, regional and international markets
- Limited usage of e-commerce and communications systems

According to the context of this document, the causes of low productivity in Ethiopian leather industry are inadequate capacity in resource optimization, inadequate quality assurance system, inadequate technology, shortage of quality raw hides and skins, shortage of quality finished leather, inadequate access to suitable finance, and lower wages and labor mobility.

To address these issues, the context recommends implementing productivity improvement measures, developing a quality assurance system, improving technology and process

management, promoting centralized slaughtering, increasing the supply of quality hides and skins, improving access to suitable finance, and addressing labor turnover through training and skill development.

Prashant B. (2016) discussed the development of an automated leather cutting machine. The study emphasizes the importance of efficient and cost-effective cutting technologies in the mass production of leather items. The paper mentions different cutting methods used in the industry, such as manual cutting, die press techniques, and laser cutting. It also highlights the use of die cutting in collaboration with electro-mechanical technology for its flexibility, high production speed, and ability to cut complex geometries.

Automated leather cutting machines offer several advantages over manual cutting methods in the mass production of leather items. These advantages include:

- **Increased Efficiency:** Automated machines can cut leather at a much faster rate compared to manual cutting methods. This leads to higher production output and increased efficiency in the manufacturing process.
- **Precision and Accuracy:** Automated machines are programmed to cut leather with precise measurements and accuracy. This ensures consistent and uniform cuts, resulting in high-quality finished products.
- **Cost-effectiveness:** By automating the cutting process, companies can reduce labor costs and minimize material wastage. Automated machines optimize the use of leather, minimizing errors and maximizing the yield from each hide.
- **Flexibility:** Automated machines can easily adapt to cutting different shapes and sizes of leather, allowing for greater design flexibility. This is particularly beneficial in the production of customized or complex leather items.

- **Reduced Physical Strain:** Manual cutting methods can be physically demanding and tiring for workers. Automated machines eliminate the need for repetitive manual cutting, reducing the risk of injuries and improving worker safety.
- **Consistency:** Automated machines ensure consistent cutting results, eliminating variations that may occur with manual cutting. This leads to a higher level of product consistency and customer satisfaction.

The paper is summarized as automated leather cutting machines offer improved efficiency, precision, cost-effectiveness, flexibility, and consistency compared to manual cutting methods in the mass production of leather items.

Moktadir, et.al (2017) tried to show the way of finding gap of production process and operations, by implementing work study and method study and established new effective process for particular operation, to increase productivity.

This study especially shows the improvement of productivity in assembly line of leather products manufacturing industry. Line balancing is the key point to increase productivity to particular products. For reducing work content to improve productivity, lean manufacturing concept could be used for the work. The study proposed further research to be conducted by combination of lean and work study technique.

Giuseppe F. et al. (2018) conducted a study on the challenges faced by the industry in shifting to the “make to order” strategy and presents concepts for maximizing leather utilization during the cutting process. The paper highlights the benefits of the “make to order” strategy, including lower inventory levels, reduced waste, and flexible production.

Optimizing the leather cutting process can increase utilization by maximizing the amount of leather material that is effectively used. By implementing efficient nesting techniques, the productivity of the process with respect the leather material can be increased, allowing for better selection and placement of parts on the materials. This means that more parts can

be nested, reducing material waste and increasing utilization. This ensures that the materials are utilized to their maximum potential, resulting in cost savings and improved profitability for companies. Overall, optimizing the leather cutting process allows for better material utilization, reducing waste and maximizing the use of available resources.

Abdulla, et.al (2019), discussed the collection of wastage leather trimming that was used to make jewelry. The study found that it is possible to make different types of ladies' jewelry such as bracelets, necklaces, earrings and rings from leather cutting wastages. The jewelry was evaluated through a survey of 50 female students, and the results showed a level of satisfaction greater than 70% in each case, indicating a satisfactory level. The study recommends the use of leather cutting wastages for jewelry making as a cost-effective and sustainable solution for solid waste management in the leather goods industry. It also suggests further research and development in the area of design and pattern development for leather goods manufacturing.

The organization of the manufacturing process can have a significant impact on the utilization of leather material in leather articles manufacturing enterprises. A well-organized process can help minimize waste and optimize the use of raw materials, including leather. For instance, if the cutting process is not well-organized, it can lead to a significant amount of leather waste, which can increase the cost of production and reduce profitability. On the other hand, a well-organized process can help ensure that the leather is used efficiently, which can help reduce costs and improve profitability (Deskera, 2020).

The type of product being manufactured in the leather industry can have a significant impact on material utilization. A study on the life cycle assessment of the leather sector found that the type of leather product being produced can affect the amount of waste generated during production. For instance, the production of leather articles such as bags and shoes can generate more waste than the production of leather for upholstery.

The study also found that the use of recycled materials in the production of leather products can reduce the environmental impact of the industry. Therefore, it is important for manufacturers to consider the type of product they are producing and the materials they are using to ensure that they are minimizing waste and reducing their environmental impact (Navarro et al., 2020).

Amjad and Syed (2021) indicated that the industry can utilize the wastage by making small market-demand leather goods. Small leather goods manufacturers have to come forward to utilize the large amount of leather wastage produced in leather goods industries. By making quality leather products from wastage leather Self-employment can be achieved from using the proper use of leather wastage to make new goods. In this way the wastage of leather will be abated and the environment will also be eco-friendly. This study proposed further research to the development of new techniques and approaches on utilization of leather wastages as value-added materials.

The practice of production planning in the leather products manufacturing industry can have a significant impact on material utilization. Effective production planning can help manufacturers optimize their use of materials, reduce waste, and improve efficiency. By streamlining production processes, eliminating inefficiencies, and reducing waste, manufacturers can optimize production flow, and increase overall efficiency. Therefore, it is important for manufacturers to consider the impact of production planning on material utilization and to implement effective planning practices to optimize their use of materials and reduce waste (Katana, 2023).

2.3. Empirical review

Abdul M. et al. (2017) conducted a case study on the use of work study techniques to improve productivity in the leather products industry of Bangladesh. In this paper the authors provided insights and analysis on the topic.

The specific work study techniques used in the leather products industry of Bangladesh included method study and work measurement. Method study involved the examination and analysis of the existing work methods to identify areas of improvement and develop more efficient methods. Work measurement, on the other hand, focused on measuring the time and work content involved in each operation to determine the standard time for completing the tasks. These techniques were applied to the production line of leather products, such as ladies bags, to improve productivity.

The findings of the case study on the impact of work study techniques on productivity in the leather products industry of Bangladesh showed that by applying method study and work measurement, productivity was improved by 12.71%. The study involved the use of questioning techniques, recording and critical analysis of information, and time study using a stopwatch. The work content in the production line was reduced, and the basic time for all operation sequences and the capacity of each workstation per day were determined. The study also highlighted the importance of work study techniques in reducing costs, improving efficiency, and achieving higher productivity in the industry.

Nadia and Abu (2018) implemented lean manufacturing tools to increase productivity in the leather products industry. The specific lean tools used in the study include tact time, bottleneck analysis, cause-effect analysis, and Pareto analysis.

The researcher uses process mapping, tact time calculating, lead time counting, bottleneck analysis, and cause-effect analysis to evaluate present process cycle efficiency and lead time in the leather products industry. Cycle time analysis is also conducted for the proposed way of bi-fold wallet production line and a Pareto chart of the bi-fold wallet production line.

The key findings of the study were that the implementation of lean tools in the wallet production line resulted in a significant improvement in productivity, with a productivity

improvement of 85.42%, a lead time reduction of 46.69%, and a non-value-added time reduction of 80.59%. The study also found that the leather products industry in Bangladesh could benefit from the implementation of lean concepts to improve productivity and reduce lead time.

Cisneros, et.al (2018), analyzed the trends on the Mexican leather footwear industry between 2007 and 2013. The productivity and competitiveness of the industry were measured using the Latin American-KLEMS Model and the Economic Commission for Europe's (ECE) Economic and Social Panel Survey (ESPS) index, respectively. The results show that the productivity of the industry is strongly correlated with the number of exporting companies and imports and exports have a strong correlation with the Total Productivity Factor (TPF). However, the competitiveness of the industry does not significantly affect the country's development.

The study found that the correlation of production value with the number of exporting companies is bigger than the correlation of the importing companies. The recommendation was that industry and institutional efforts must be directed to encourage exporting activity, mainly in companies of medium size. The study also recommended that a more diversified offer of products should be available in the Mexican domestic market, strengthened by the importation of good quality products, to increase the competitive capacity of the Leather-footwear industry.

Ivan and Anatoliy, 2019 discussed a methodology for identifying the optimal needs of resources for leather raw materials in order to increase the economic efficiency of industrial enterprises. This paper introduced an economic-mathematical model that takes into account factors such as raw materials, technological options, and technical capabilities of the enterprise. The main goal was to identify the consolidated profit from the sale of

manufactured products. The article also emphasizes the significance of strategic aims and modernization in industrial production for improving economic efficiency.

The economic-mathematical model helps in determining the ideal resource requirements for leather raw materials by considering various factors such as the types of raw materials, the different ways of treating the raw materials, and the technical capabilities of the enterprise. The model takes into account the available resources of raw materials, the yield of leather material from the raw materials, and the profitability of the enterprise. By optimizing the usage of resources and considering the different production ways, the model aims to maximize the profit from treating all kinds of raw materials. This allows for the efficient utilization of limited resources and helps in providing a competitive advantage in terms of expenses.

Nabon E. (2021) found that shoe manufacturing companies were facing material productivity problems due to various causes, including operators using personal standards or methods while cutting leather, which resulted in inefficient use of basic input materials and reduced material productivity. The study used method study as an Industrial Engineering tool to analyze and study the way of doing jobs and proposed countermeasures to fill the gaps of the existing situation. The newly proposed method achieved a noticeable quantitative result, with material improvement achieved from 4 ft² to 3.6 ft² and an equivalent material productivity increment by 12%. Other soft aspects that were expected to overcome controlling and scheduling problems were also major results obtained in this study.

The study prepared an inclusive implementation framework for the proposed countermeasures that can be applied to all kinds of footwear companies. The recommendation was for manufacturing companies, especially shoe factories, to adopt the

core concept of method study and make improvements to the rest of the point to improve productivity and compete in today's competitive market.

Muhammad, et.al (2022), discussed the use of linear programming in industrial operations research to optimize resource allocation and decision-making. The authors proposed a linear programming model for the leather industry to minimize costs and maximize profits by selecting the optimal product mix. The model is compared to traditional methods and found to increase profits by 39% with 22% less production. The research mentioned in the context has provided examples of various industries that have utilized linear programming to enhance production planning and resource allocation. Some of these industries include the housing market, clothing industry, dairy farming, textile industry, and feed mill producing business.

2.4. Summary of literature gaps

Table 1:- Summary of reviewed literatures

Author's Name	Approaches Applied
Ministry of industry (2016)	Value chain analysis to identify issues related with leather industry in Ethiopia.
Moktadir, et.al (2017)	Work study and method study to show the way of finding gap of production process and operations and established new effective process for particular operation, to increase productivity.
Nadia and Abu (2018)	Implemented lean manufacturing tools to increase productivity in the leather products industry.
Cisneros, et.al (2018)	The Latin American KLEMS model to analyze the impact of globalization on the Mexican leather footwear industry.
Abdulla, et.al (2019)	Survey study to discuss the collection of wastage leather trimming that was used to make jewelry.

Nabon (2021)	Method study as an Industrial Engineering tool to analyze and study the way of doing jobs and proposed countermeasures to fill the gaps of the existing situation.
Islam et.al (2022)	Conducted an assessment to identify the major challenges of SCP in the industry
Muhammad, et.al (2022)	Literature survey to discuss the use of linear programming in industrial operations research to optimize resource allocation and decision-making.
Navarro et al 2020	Applied a Life cycle assessment to study material utilization trends in leather articles production

As shown in the table above; different researches are conducted on productivity aspects of the leather sector. Most of the reviewed researches focused on identifying the sources of productivity problems and proposing administrative and labor productivity enhancement solutions to address the problems identified in their respective studies.

The studies which are conducted on material productivity related aspects of the sector focuses only on using the wastes generated in the production processes.

In this research, the sequence of operations was assessed to indicate possible technical interventions for planned utilization of materials to effect productivity improvement of the business. Products identification and categorizing them in distinct classes is used for production planning of items and a mixed integer linear programming model is formulated to find out the optimal numbers of each product to achieve the possible maximum profit, which is new approach that had been used in none of the reviewed studies.

Chapter 3: Materials and Methods

3.1. Description of the study area

This study was conducted at Abrish leather goods manufacturing enterprise, which is located in Addis ketema sub city of Hawassa town administration. The enterprise is engaged in manufacturing varieties of leather articles and distributes its products to end users through its own retailing shops and retailers in different towns around Hawassa and other places.

Initially the enterprise was established as MSME in enterprise development agency of Haikdar sub-city of the town, comprising five members in 2005 E.c.

Currently it is one of the model manufacturing firms of the town working in government facilitated shed with annual production of more than seven million ETB value, having 20 employees, varieties of machineries and equipment.

3.2. Research design and Methodology

In conducting this study both descriptive and explanatory methodologies through literature review and objective observation was used applying work study techniques. Based on the research questions and available resources, a case study design was followed to assess the practical situation of the current manufacturing system.

Identification and classification of wastes through a structured observation was followed as a very vital approach. Based on this preliminary observation and understanding, a classification method was developed to categorize manufacturing related factors for the purpose of cost identification.

3.3. Data collection and analysis

In the second stage of this study, existing production methods had been closely studied, through objective observation and interview, for the sake of generating the required qualitative and quantitative data applying the techniques and principles of work study.

Work study technique is a widely used method for improving productivity and reducing waste in the manufacturing industry. It involves analyzing the production process to identify areas where waste is occurring and suggesting ways to improve efficiency. In the context of this study, work study technique was used to examine material utilization through observation and interview data collection methods.

The data collected were analyzed using statistical methods and Excel solver program. The analysis was carried out to identify patterns and trends in the data and provide insights into how manufacturers can improve material utilization in the production of leather goods.

After proper identification of costs and production techniques, a conceptual framework for the development of effective material utilization strategy, maximizing productivity through planned utilization of materials had been outlined.

The following flow chart of methodological approach describes the overall process of conducting the study.

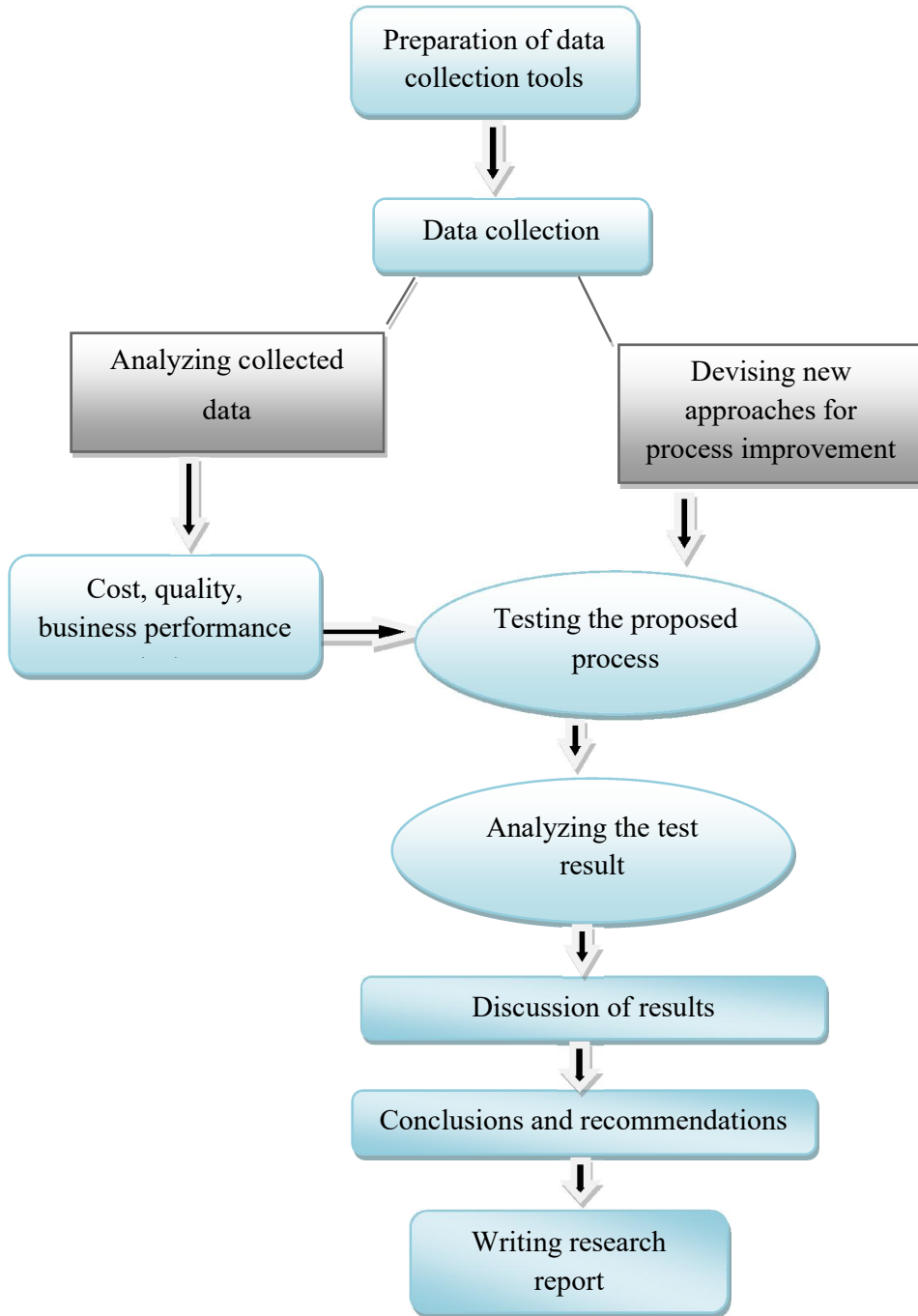


Figure 1: Flow chart of methodological approach of the study

3.3. Rationale of selection

The case company was purposively selected with respect to convenience for the intended aim.

Ideally, manufacturing firms would like to find methods for the overall productivity improvement and minimization of manufacturing costs. To analyze material utilization of leather goods manufacturing firms, the case company was selected from Hawassa town with the following considerations:

- There is continuous production throughout the year.
- Manufacturing multiple varieties of product items.
- The owners and the manager are willing for cooperation.
- Long term work experience in the sector.
- Ease of accessibility for frequent data collection with respect to the researcher.

Moreover, relevant data generation was conducted with regard to the major products of the company to examine material utilization in their course of manufacture.

3.4. Techniques used in conducting the Research

Optimization modeling technique was the major tool applied for treating the problem identified in this study. Other industrial Engineering techniques are also used in dealing with the different aspects of the case scenario. The techniques used and their application in this study is presented in the following table;

Table 2:- Description of techniques used in conducting the study

Techniques and Tools used	Application in the study
Work study	Assessing the activities carried out in each work station, the materials consumed and the level of output delivered.
Decision tree	For classification of product items in groups for integrated planning and production.
Mixed Integer linear program modeling	Finding out the optimal solution in solving the identified problem for the realization of maximum profitability of the case company.
POM-QM software	Solving the formulated model so as to find the optimal number of each product in a mix.

Chapter 4: Data analysis, Results and Discussion

This chapter presents situational analysis of the case company as well as the sequence of operations in the production system. The key sources of significant problems regarding material utilization were identified.

Moreover, depending on the nature of possible key sources of problems, the proper countermeasure that should be taken to improve material utilization of the manufacturing system had been analyzed and the corresponding material productivity level was determined accordingly.

The overall manufacturing process is investigated embracing the factors of production within four perspectives (Organization, Products and material consumption, Planning and production capacity and waste management) for convenient examination of material utilization using the principle and techniques of work study.

4.1. Data presentation and analysis

4.1.1. Description of current production system

The overall business process of the company is organized in three functional departments, namely:

- Purchasing
- Production and
- Sales

Among the above functional departments, production is the decisive section dictating material productivity of the enterprise. The production system of the company is organized to manage both the leather goods and footwear production with one process flow.

The sequence of operations executed in the company is described with the following process flow diagram.

PROCESS FLOW DIAGRAM OF THE COMPANY

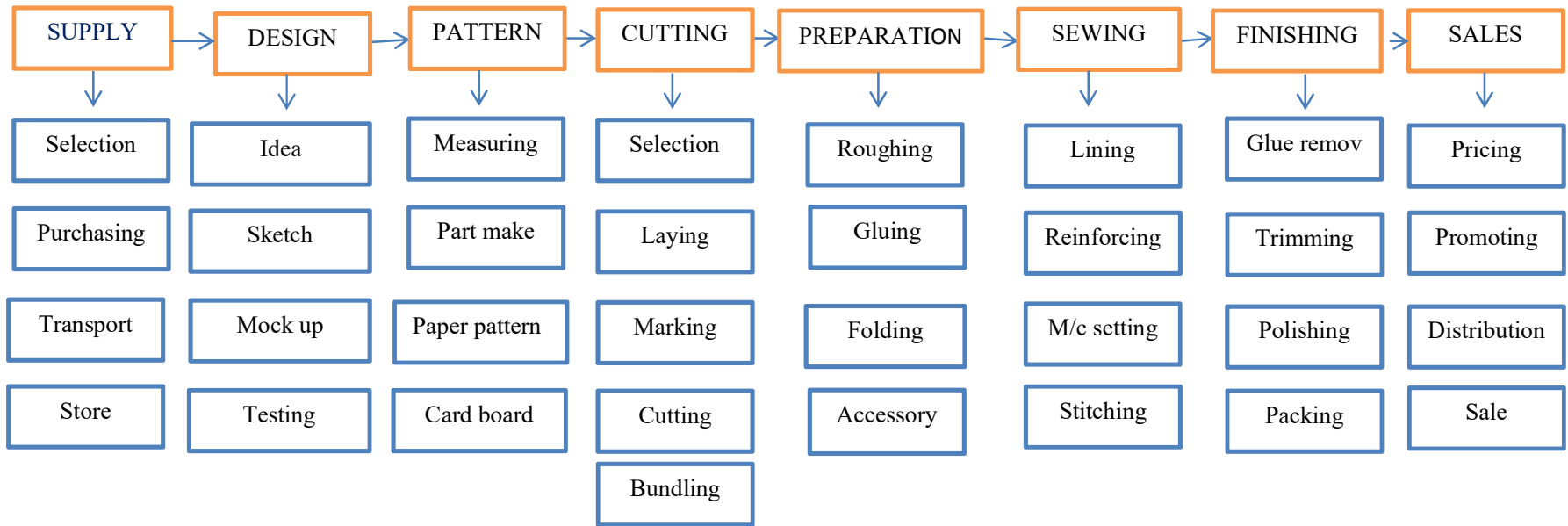


Figure 2: Flow process diagram of the company.

The above sequence of operations is carried out in the company by setting the available space of the work shop as per the following layout:

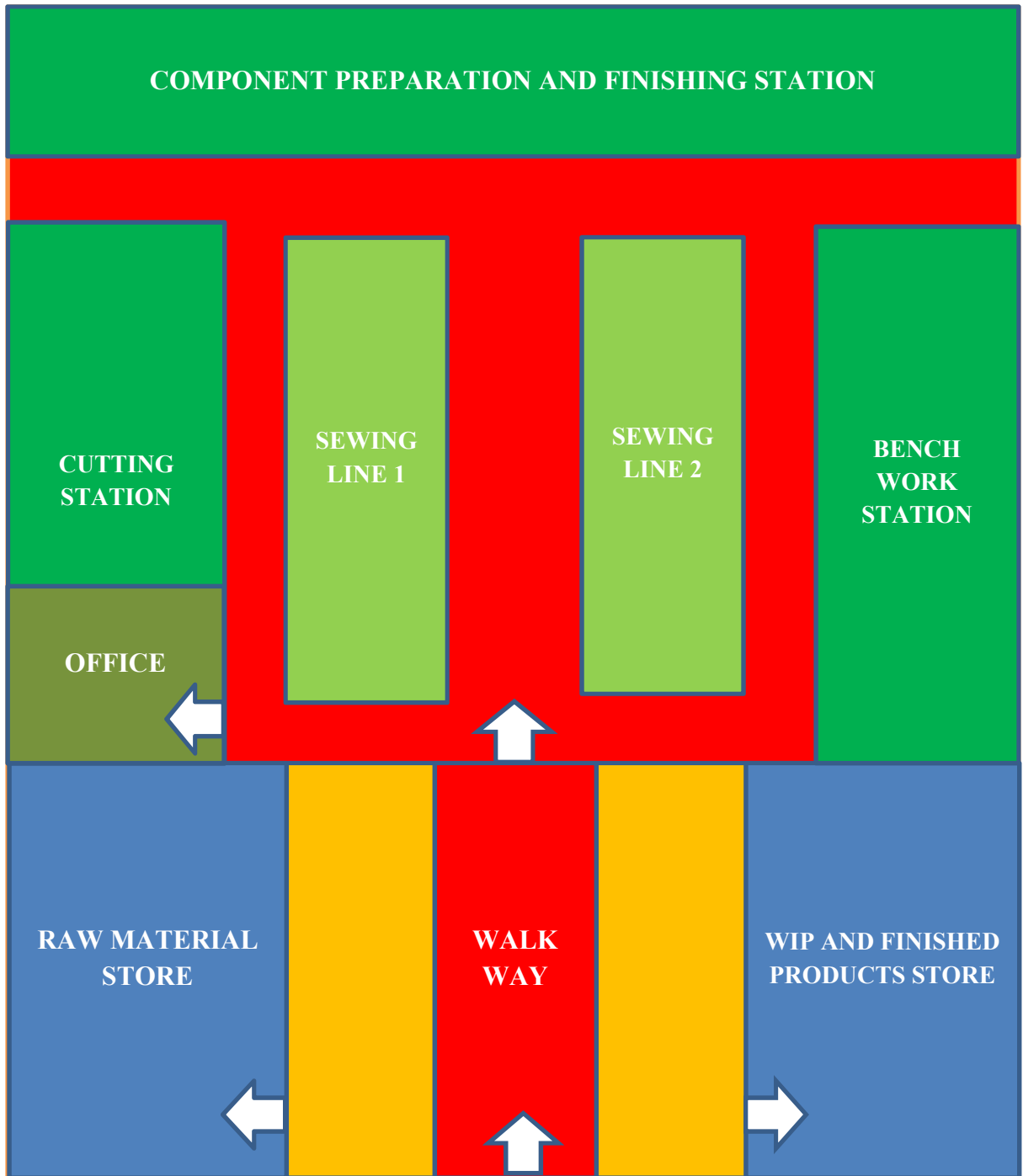


Figure 3: Current layout of the case company

As shown in figure 2 above; the main operations of the manufacturing process are designing, pattern-making, cutting, preparation, stitching and finishing. The practical execution of these operations is objectively examined and their respective situation is described as follows:

A. Designing

Designing is considered as the process of introducing new product item to the production system of the enterprise. It may also be modifying the existing product items to present it to the market as a new product. The activities carried out with regard to designing a product include:

- Preparation of visual sketches and physical features of a product
- Determining the geometric shape, size, color and texture of component parts
- Determining the material details for construction of components
- Stating technical construction and assembly styles of components
- Making sample products to test fitness and aesthetics
- Preparation of bill of materials and costing

Products of the company are manually designed using pencils, papers, cutter etc. only one item is designed at a time with due consideration of detail aspects for only that specific product.

B. Pattern making

Pattern making is the construction of templates for each separate component of a product with distinct geometric shape and size in conformity with the final design. Pattern making is done in the company manually right after the design is completed. The basic materials consumed in this operation are paper, card boards, pencils, cutter etc.

Once pattern is made for certain product; it is used the whole time till production of that item is ceased. Therefore; this operation is of no impact with regard to material utilization of the company.

C. Cutting

In the process of leather goods making, cutting is considered to be one of the most important operations. Cutting is the term used for cutting leather components, linings, foam and reinforcement materials using patterns for making leather goods.

The cutting operation is carried out manually in the company. The operation is planned and made for each single item at a time. In this work station, significant amount of scraps are observed being continuously generated.

D. Preparations

In bench work processes, the components are prepared with linings, zips, folding, gussets, piping, handle, etc. for subsequent process of assembling.

Some components may need immediate stitching and some may not. The prepared components, which need immediate stitching, are sent for stitching. Bench operations include; Punching, Riveting, Eyeleting, Buttoning, Zip fastening, Gluing, Lining, Gussets making, Edge folding and Handle making.

The consumable materials used in this work station are adhesives, zippers, linings, buttons, rivets, eyelets etc.

E. Stitching

In the process of leather goods manufacturing, sewing is the most important operation, which decides the quality of the end products. Sewing the products is carried out in flat bed sewing machine or cylinder bed sewing machine as the case may be.

Stitching thread should have good tensile strength, abrasive resistance to moisture, heat and ability to withstand oils, solvents and adhesives. A correct thread for specific use is essential to achieve efficient production. Commonly used threads are cotton, nylon, nylon cotton, and polyester cotton. Before stitching of the products, the stitches are tested on a piece of leather. If necessary, suitable adjustments are made for perfect stitching.

The thread used in the company is polyester thread. Other materials consumed in this operation are oils and needles that are considered as miscellaneous in cost estimation.

F. Finishing

Finishing is the final process in the manufacture of leather goods. After stitching, the articles are checked carefully. Excess thread is removed by burning with a thread burner. Excess adhesive is removed with a piece of crepe rubber sheet. The whole product is cleaned both inside and outside with a clean piece of cloth. Before the articles are sent for packing, quality control is observed for perfection in assembling, stitching accuracy and smooth functioning of fittings. The material used in this operation is polishing oil.

In accomplishing the above production operations the enterprise is using the following machineries, tools and equipment.

Table 3:- Machineries, tools and equipment of the company.

S/No	Machine/ tool/equipment	Type	Function	Number
1.	Sewing machine	Flat bed, Electrical	For stitching simple items	4
2.	Sewing machine	Cylinder bed, Electrical	For components stitching and attaching.	1

3.	Sewing machine	Post bed, Electrical	For sewing foot wear	1
4.	Skiving machine	Electrical	For reducing thickness of folded parts.	1
5.	Tables	For cutting leather, fabric and foams.	For proper laying of patterns on cut materials, for making patterns	2
6.	Tables	For bench work, Wooden	For bench work activities.	4
7.	Cutter	Manual, snapel	For cutting leather	10
8.	Hammer	Rubber head	For effectively attaching folded parts, assembled components etc.	6
9.	Hand needle	Metallic	For hand stitching	20
10.	Puncher	Revolving, 5 tubes	Making holes to attach accessories.	6
11.	Scissors	Metallic, 10	Cutting patterns, linings and fabrics.	10
12.	Brushes	Number 6, wooden handle	Applying adhesives and polishing end products	10
13.	Marble stone	Normal and fit to bench size	For smooth and effective attachment of parts.	6
14.	Shoe lasts	Different sizes	Molding foot wears	12

15.	Lasting machine	Manual, fitted on table	Fitting sole to the upper part of foot wears.	1
16.	Roughing machine	Electrical motor driven,	Roughing foot wear parts for effective functioning of adhesives.	2

4.1.2. Product types and material consumption

The major products of the enterprise are;

- Laptop cases (Back pack)
- Ladies' Shoulder bags
- Belts
- Men's and women's wallets.
- Men's', women's and children's sandals

The basic process of operations is almost the same for all of the above products, with few additional activities with regard to sole preparation and attaching in the case of sandal production.

Data had been collected with regard to current material consumption of the first two large sized products. The cost of products is calculated with an average consumption of each material, indicating contribution of each material with respect to total material cost of the product as follows:-

A. Laptop case

Table 4:- Current material consumption for laptop case production

S/No	Item	Unit	Amount consumed	Unit Cost (ETB)	Total cost (ETB)	Contribution (%)
1.	Leather	Ft ²	9.5	88	836	84.32
2.	Zipper	Meter	1	6	6	0.61
3.	Zip runner	Pcs	1	5	5	0.50
4.	Foam	Meter	1/8	270	33.75	3.40
5.	Lining fabric	>>	1/2	40	20	2.02
6.	Elastic band	Pcs	1	12	12	1.21
7.	Threads	Cone	1/150	400	2.67	0.27
8.	Adhesive	Galloon	1/50	1800	36	3.63
9.	Hook/ Best	Pcs	1	20	20	2.02
10.	Rings	>>	4	5	20	2.02
Total					991.42	

B. Shoulder bag

Table 5:- Current material consumption for Shoulder bag production.

S/No	Item	Unit	Amount consumed	Unit Cost (ETB)	Total cost (ETB)	Contribution (%)
1.	Leather	Ft ²	7.25	88	638	83.36
2.	Lining fabric	Meter	1	40	40	5.23
3.	Pu- foam	>>	1/8	270	33.75	4.41

4.	Threads	Cone	1/250	400	1.6	0.16
5.	Rings	Pcs	4	5	20	1.96
6.	Adhesive	Galloon	1/75	1800	24	2.35
7.	Rope	Meter	1	8	8	0.78
Total					765.35	

As can be seen from the above tables, leather is the major material contributing up to 84% of total material cost of products. Therefore improving the production system for its optimal utilization can inevitably improve profitability and business sustainability of the company.

The above products are made in different design and styles. Design alterations are made depending on various factors and conditions. The initiation factors for the introduction of new design to the production system of the company include;

- Obsolesce of existing design
- Seasonal events, public festivals, holydays etc.
- Specified request from customers
- Products with strange designs (copy) from various sources

4.1.3. Planning and production capacity

The company manufactures products and distributes to retailers and sells to customers through its own show rooms. In addition to this, customers order products with their own designs and the exchange is carried out accordingly.

From the information described above, the production strategy of the company is understood to be a hybrid of make to stock and make to order.

Relevant documents had been reviewed to gather data regarding the current planning practice of the company. There is no documented file to be considered as annual as well as any other term plan of the company. An interview had been conducted with the technical manager, and it is found that the company is producing articles being dictated by seasonal demands of customers and market information obtained from sales men.

4.1.4. Wastes and waste management practice

Continuous generation of scraps is observed in the production system. The scraps being generated in the course of production are collected for future production of other articles.

Interview had been conducted regarding waste management practice of the company. It is indicated that scraps generated from the production of large sized component items are used for producing items with smaller components.

Despite this ideal assumption, large amount of scrap material is observed being accumulated in work stations and in store. The continuous generation of scraps makes the management very difficult hindering the company from generating wealth as per the preconceived assumption. The amount of scrap materials currently available in the company reveals underutilization level of material. This indicates the necessity of process improvement for improved material productivity. The area of scraps currently generated in the company is measured by randomly taking 10 sample scraps from each of the 3 batches and working out the average. The samples are taken from different positions (top, middle and bottom) of each batch.

Table 6:- Description of average size of scrap

Sample	Area of sample scraps in each batch (ft ²)		
	Batch 1	Batch 2	Batch 3
1	0.045	0.095	0.073
2	0.105	0.090	0.109
3	0.079	0.169	0.101
4	0.128	0.106	0.139
5	0.168	0.145	0.151
6	0.079	0.101	0.117
7	0.179	0.119	0.267
8	0.079	0.172	0.151
9	0.337	0.141	0.101
10	0.151	0.139	0.149
Average	0.135	0.128	0.136
Total average			0.133

4.2. System improvement for optimal material utilization

Based on the description presented in previous section, the manufacturing operation that is significantly impacting material utilization of the enterprise is cutting, leather being the material.

The system improvement devised as a solution for the identified problem focuses on effective planning of available materials for the production of known and planned product items and using them accordingly, rather than using scraps for additional and unplanned generation of

revenues. For this to be done the types of products being made in the factory are needed to be categorized in two or more families so that integrated design and manufacture of product varieties can be applied.

4.2.1. Categorization of products

In this case scenario the available workstations for cutting is 2 (two) that the products can be categorized in to two families. The rationale of classifying product items was established based on the technical principle of cutting leather materials.

4.2.1.1. Cutting techniques

Cutting is done either by hand cutting or by machine cutting in the hydraulic clicking press. Cutting straps is done in the strap cutting machine while reinforcement boards are cut in the hand shearing machine.

Hand cutting: Hand cutting is done using either cardboard patterns or metal templates. Hand cutting is done on an inclined wooden table fitted with a plastic mat, galvanized zinc sheet or Teflon sheet on its top. A sharp blade knife is used for hand cutting. The cutting knife is used to cut the leathers and other materials like linings, foam, reinforcements, etc. used in leather goods making.

Machine cutting: machine cutting is done in the case of bulk production. The leathers are placed one by one on the Teflon board of the hydraulic clicking press and then components are cut with the dies. Press cutting ensures speed of operation, accuracy and uniformity and least wastage.

In the process of cutting, the cutter plays a vital role because the economy of production depends upon his skill in placing patterns, maximizing the cutting value and minimizing wastages.

The following points are technically advised for hand cutting of leather material;

- The best part of the leather is used for cutting the greater proportion of large parts.
- Start to cut smaller parts after large parts are completed.
- Place several patterns on to the leather at the same time to reduce waste.
- Always plan two or three cuts ahead. Never cut without knowing where the next pattern will be placed.
- Always start cutting at the butt part of the leather and proceed along the backbone to the outward direction as much as the quality and substance of leather is suitable
- If you are cutting skin leather, start also at the butt and continue towards each side from the backbone to the shank until you reach the neck.
- If you find defects near the backbone, start cutting as close as possible to the defected portion and proceed towards the direction from the backbone to shank.
- Use the pattern as a knife-guide. Keep the blade edge against the pattern at all times
- Your cutting movement with the knife should be as continuous as possible. Shorter cuts and several stops will give you irregular edges as the stop points
- Arrange your straight edge patterns in such a way that straight lines fit against straight lines to have a minimum amount of waste.
- To minimize waste of curved edge patterns use the possibilities of similar curved patterns
- Always keep a note of how many pieces are cut to make complete sets. Do not leave one pattern to last as good quality leather may be used for an unimportant piece.
- Work out small and large patterns together. Mix pattern shapes to get the best combination.

- Always remember that you should reach the maximum quantity of parts at a consistent quality.

(Leather industry development institute, Leather garments and goods manufacturing technology directorate, Manual of leather garments and goods production operation)

4.2.1.2. Categorization of company products

Considering the above technical points as a baseline principle, the rationale of classifying the product items of the case scenario was established as follows; considering size differences of component parts i.e. Suitability for integrating them in production planning and Geometric compatibility of components for interlocking as parameters of classification.

Since cutting of large size components is done first and goes on to smaller components, the first two large sized products were selected and set as fathers of their families to serve as reference in categorizing the remaining items. In our case, laptop case and shoulder bag are set as fathers of the two families.

After selecting the two products, other products were categorized under them with respect to compatibility of their shapes for interlocking so that maximum utilization of material can be achieved. The laptop case product is constructed with straight edged components whereas shoulder bag is constructed with more of curved edged components. Therefore items with curved components were organized under shoulder bag family and items with lesser curvature (more straight edge) were categorized under laptop case family.

Products of relatively similar sizes were categorized in different classes for exhaustive utilization of material by nesting patterns in accordance with their sizes. Their categorization was done with respect to their relative possession of straight and curved components.

The approach followed for classifying products in their corresponding families is described with the following decision tree.

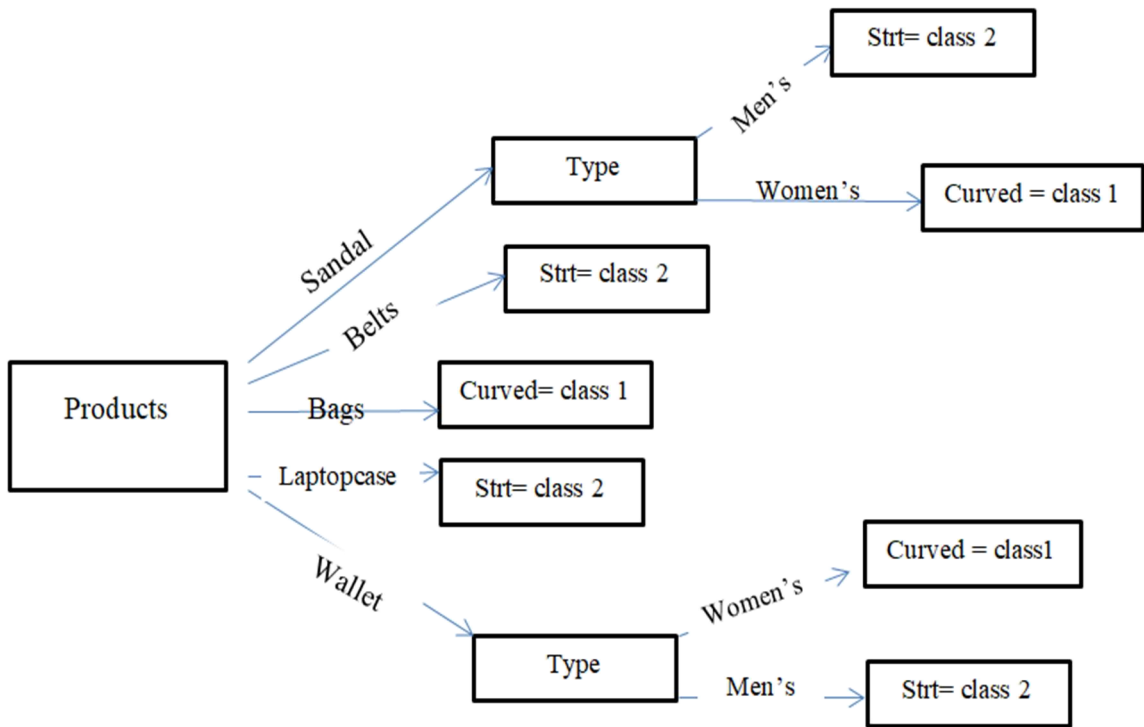


Figure 4: Decision tree for products' categorization

As per the above decision tree diagram; the products are categorized as;

- Family 1:- shoulder bag, women's wallet and women's sandal
- Family 2:- Laptop case, belt, men's wallet and men's sandal

4.2.2. Modeling the new system

4.2.2.1. Description of the model

- **Objective function**

An objective function is a mathematical relationship that describes the objective of the firm in terms of the decision variables. In this study the objective function was set to achieve the maximum possible amount of profit by making optimum number of product items.

- **Decision variable**

Decision variables are mathematical symbols that represent levels of activity by the firm. In this study, the decision variable was the number of different product items produced.

- **Constraints**

A constraint is a relationship that represents a restriction on decision making. The constraints identified in this study are;

- The amount of leather that can be allocated for each category of products
- The minimum and maximum number of each product that can be made in each week.

4.2.2.2. Planning period

In formulating the model to determine the optimal number of products in a mix, the following points were taken in to consideration;

- weekly planning of production
- weekly purchasing of raw materials
- The amount of material that can be purchased in each week
- Customer demands for each type of product/ orders received
- The maximum number of products that can be sold in the planning period.
- Available working hours in that respective term. i.e. week

- Categorization of product items in two families and assigning distinct cutting station dedicated for preparation of components for each of the product family. i.e. cutting station1 will be assigned for Shoulder bag, Women's wallet and Women's sandal. Cutting station 2 will be assigned for Laptop case, belts, Men's wallet and Men's sandal. The planning term was set to be weekly with the following considerations:
- Raw material is supplied from central market, Addis Ababa.
- For letting dynamism to respond to frequently fluctuating market prices.
- Time requirements for logistic process from order placing to material receiving
- Letting responsiveness through design alterations according to customer requirements and market conditions.
- To make a system timely adjustable whenever correction is acted in the production process.

4.2.2.3. Model formulation

A model was formulated to support decision making in planning production for the integrated product items in conformity with the identified constraints. The possible optimization models that can be used for resource allocation are cargo loading dynamic programming and mixed integer linear programming.

Cargo loading dynamic programming is a mathematical optimization technique that can be used to solve problems with single constraint and objective.

Mixed integer linear programming is a mathematical optimization technique that can be used to solve problems with multiple constraints and objectives. It is particularly useful for finding the optimal number of products in a mix for the aim of achieving efficient utilization of raw material. By using mixed integer linear programming, we can determine the optimal combination of products that can be produced using the available raw materials

while minimizing waste and maximizing efficiency. Thus, the problem was seen to be properly treated with a mixed integer linear program modeling.

The objective was to realize the possible maximum profit with a minimum of satisfying the identified demands of customers and the maximum expected demand for the items were also taken to consideration.

For family 1 products

Let W be the amount of leather in square feet allocated for family 1 in the planning period.

- $X_1, X_2,$ and X_3 be the number of shoulder bag, women’s wallet and sandal respectively produced in that planning term
- R_1, R_2 and R_3 be the profits per unit of items produced
- W_1, W_2 and W_3 be the amount of leather consumed per unit of items produced
- N_1, N_2 and N_3 be the minimum number of products demanded in the planning term
- M_1, M_2 and M_3 are the maximum number of products that can be made in a week.
- The available working hours is found to be 45 hours per week.

The sequence of production is carried out in such a way that, products with larger component size are done first and goes on to products with smaller sized components.

In addition to material consumption of products described in previous section, labor costs, administrative costs, depreciation cost of fixed assets etc. were included in estimating cost per unit of the products.

The ILP representing the case scenario can be formulated as;

$$\text{Maximize } Z = R_1 X_1 + R_2 X_2 + R_3 X_3$$

Subject to

$$W_1 X_1 + W_2 X_2 + W_3 X_3 \leq W \quad \text{--- Capacity constraint}$$

$$N_1 \leq X_1 \leq M_1 \quad \text{--- Demand constraint for product 1}$$

$$N_2 \leq X_2 \leq M_2 \quad \text{--- Demand constraint for product 2}$$

$$N_3 \leq X_3 \leq M_3 \text{ --- Demand constraint for product 3}$$

$$X_1, X_2, X_3, M_1, M_2, M_3, N_1, N_2 \text{ and } N_3 \geq 0 \text{ and integer.}$$

For family 2 products

Let Y be the amount of leather in square feet allocated for family 2 in the planning period.

- X_4, X_5, X_6 and X_7 be the number of laptop case, belts, men's wallet, and men's sandal respectively produced in that planning term
- R_4, R_5, R_6 and R_7 be the profits per unit of items produced
- W_4, W_5, W_6 and W_7 be the amount of leather consumed per unit of items produced
- N_4, N_5, N_6 and N_7 be the minimum number of products demanded in the planning term
- M_4, M_5, M_6 and M_7 are the maximum number of products that can be made in the planning term.

The sequence of production is carried out in such a way that, products with larger component size are done first and goes on to products with smaller sized components.

The ILP representing the case scenario can be formulated as;

$$\text{Maximize } Z = R_4X_4 + R_5X_5 + R_6X_6 + R_7X_7$$

Subject to

$$W_4 X_4 + W_5X_5 + W_6X_6 + W_7X_7 \leq Y \text{ --- Capacity constraint}$$

$$N_4 \leq X_4 \leq M_4 \text{ --- Demand constraint for product 4.}$$

$$N_5 \leq X_5 \leq M_5 \text{ --- Demand constraint for product 5.}$$

$$N_6 \leq X_6 \leq M_6 \text{ --- Demand constraint for product 6.}$$

$$N_7 \leq X_7 \leq M_7 \text{ --- Demand constraint for product 7.}$$

$$X_4, X_5, X_6, X_7, M_4, M_5, M_6, M_7, N_4, N_5, N_6 \text{ and } N_7 \geq 0 \text{ and integer.}$$

According to the data obtained from observation the hourly production rate, production cost, current selling price and profit per unit of item for each product is described in the table below;

Table 7:- The hourly production, price and profit per unit of products

Product	Production per hour	Cost per unit	Price per unit	Profit per unit (R_i)
Shoulder bag	1.5	880.10	1200	319.90
Women's wallet	6	159.85	210	50.15
Women's sandal	3	275.82	320	44.18
Lap top case	1.5	1,140.13	1350	209.87
Belts	8	279.62	330	50.38
Men's wallet	5	160.00	220	60
Men's sandal	3	398.29	450	51.71

The maximum amount of leather that the company can purchase is 1000 ft² per week

To allocate this amount of leather material for the two families of products, the material consumption of the products to be made first in each category was taken to account. The rationale for such consideration is that large sized products are potential limiting agents dictating material utilization in their respective families.

The maximum amount of material that can be allocated for each product was determined by either maximum weekly demand or the maximum possible production that can be made in the available working hours of the week.

The largest item in size among products in family 1 category is shoulder bag with 7.25 ft² material consumption per unit.

The largest item in size among products in the second category is laptop case with 9.5 ft² material consumption per unit.

The maximum production/week = working hours in a week* production per hour.

Based on this simple calculation the maximum number of products that can be made in the available working hours is described in the following table;

Table 8:- The maximum possible production in working hours of a week

Item	Maximum possible Production per week (pcs)
Shoulder bag	67.5
Women's wallet	270
Women's sandal	135
Lap top case	67.5
Belts	360
Men's wallet	225
Men's sandal	135

The minimum and maximum weekly demands as well as the material consumption per unit of item for major product items is described in the following table;

Table 9:- Material consumption, minimum and maximum weekly demands of products

Product	Leather consumption in ft²	Minimum demand per week (N_i)	Maximum demand per week (M_i)
Shoulder bag	7.25	10	30
Women's wallet	1	25	40
Women's sandal	0.75	93	138
Laptop case	9.5	10	40
Belts	2	60	210
Men's wallet	1	30	42
Men's sandal	1	70	180

The lower and upper bounds of the number of each product to define constraints of the production system is determined as:

- Minimum number of each product is the minimum weekly demand and
- Maximum number of each product made per week is the minimum of the maximum weekly demand and the maximum production in the available working hours of a week. i.e Min (maximum weekly demand, maximum production).

Table 10:- Description for upper bound of production limits

Item	Maximum demand per week	Maximum Production per week	Upper bound of production
Shoulder bag	30	67	30
Women's wallet	40	270	40
Women's sandal	138	135	135
Lap top case	40	67	40
Belts	210	360	210
Men's wallet	42	225	42
Men's sandal	180	135	135

The maximum amount of material allocation for each family is found by proportional division of the available material in terms of the material requirement for the upper bound production limit of large sized product of the family. Based on this rationale the maximum amount of material that can be allocated for family 1 is:

$(30 \times 7.25) / [(30 \times 7.25 + 40 \times 9.5)]$ of 1000 ft² i.e. 364 ft² and 636 ft² for family 2 products.

Using the figures in the table above, the formulated model, for optimal product mix planning, is contextualized with the case scenario as:

For family 1

The model was contextualized as;

$$\text{Maximize } Z = 319.90X_1 + 50.15X_2 + 44.18X_3$$

Subject to

$$7.25 X_1 + X_2 + 0.75X_3 \leq 364$$

$$10 \leq X_1 \leq 30$$

$$25 \leq X_2 \leq 40$$

$$93 \leq X_3 \leq 135$$

X_1, X_2 and X_3 are integers.

For family 2

The model was contextualized as;

$$\text{Maximize } Z = 209.87X_4 + 50.38X_5 + 60X_6 + 51.71X_7$$

Subject to

$$9.5 X_4 + 2X_5 + X_6 + X_7 \leq 636$$

$$10 \leq X_4 \leq 40$$

$$60 \leq X_5 \leq 210$$

$$30 \leq X_6 \leq 42$$

$$70 \leq X_7 \leq 135$$

X_4, X_5, X_6 and X_7 are integers.

The model was formulated with the following assumptions;

- The material requirement is constantly and smoothly supplied
- Constant weekly demand of products and price of material.
- Uninterrupted access of utilities and infrastructures
- Constant and proper operation of company resources.

4.2.3. Determining optimal number of products

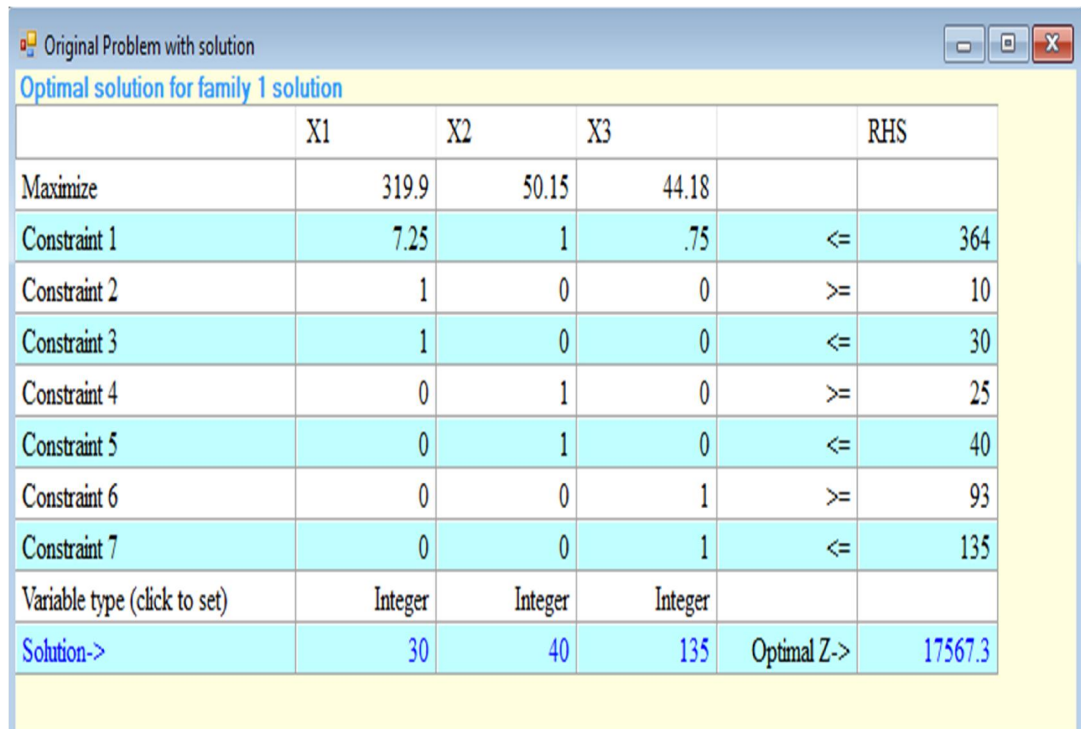
The optimal number of products to be made for maximum profitability of the case company was computed by solving the model using POM-QM software.

POM-QM software is an application program that is used for what-if analysis. It is applicable to find an optimal (maximum or minimum) value for an optimization mathematical model subject to constraints, or limits on various factors of the system under consideration.

The program works with decision variables or simply variables that are used in computing the formulas in the objective and constraint functions. It adjusts the values of the decision variables to satisfy the limits on constraints and produce the result that is required for the objective function.

The optimal solution determining the product mix and the profit level that can be achieved with the improved system is presented in the following section.

For family 1 products



	X1	X2	X3		RHS
Maximize	319.9	50.15	44.18		
Constraint 1	7.25	1	.75	<=	364
Constraint 2	1	0	0	>=	10
Constraint 3	1	0	0	<=	30
Constraint 4	0	1	0	>=	25
Constraint 5	0	1	0	<=	40
Constraint 6	0	0	1	>=	93
Constraint 7	0	0	1	<=	135
Variable type (click to set)	Integer	Integer	Integer		
Solution->	30	40	135	Optimal Z->	17567.3

Figure 5:- Optimal solution for family 1.

For family 2 products

	X4	X5	X6	X7		RHS
Maximize	209.87	50.38	60	50.71		
Constraint 1	9.5	2	1	1	<=	636
Constraint 2	1	0	0	0	>=	10
Constraint 3	1	0	0	0	<=	40
Constraint 4	0	1	0	0	>=	60
Constraint 5	0	1	0	0	<=	210
Constraint 6	0	0	1	0	>=	30
Constraint 7	0	0	1	0	<=	42
Constraint 8	0	0	0	1	>=	70
Constraint 9	0	0	0	1	<=	135
Variable type (click to set)	Integer	Integer	Integer	Integer		
Solution->	10	182	42	135	Opt...	20633....

Figure 6:- Optimal solution for family 2 products

The optimal solution of the two models was summarized as:

Total material consumption per week in ft^2 - - - 994.75

Total profit per week in ETB - - - 38,201.01

Total profit per annum in ETB - - - 1,986,452.52

4.3. Discussion of Results

In the AS-IS system, products are individually planned, designed, manufactured and pushed to the market. Scraps are continuously generated in the course of production, collected and stored for future making of smaller products. Even though scraps are assumed to be used for further processing, the issues of ‘when to use?’ and ‘how to use them for optimal profit generation?’ are not technically considered, that multiple sacks of scraps are observed in store creating unnecessary inventory, taking space, imparting difficulty of material management along with the great impact of raising production costs. Moreover, inventory of obsolete products, idle machineries and equipment, idle labor force are also observed and considered as potential wastes of the company.

Integrated planning and production of items, categorizing them in families with respect to their relative shape and size, will transform the production planning of the company, enabling feasible determination of the optimal number of product items with due consideration of tangible constraints; thereby the maximum possible profit is realized.

Comparison of material utilization of the improved system against the existing one is done by examining area of scraps generated in workstations. The improved system enables the company to exhaustively utilize the materials at a time and arrive at the final state of wastes. Therefore, the relative difference between areas of scrap and the smallest component of the smallest product is the achievable improvement in material utilization.

Material that is smaller in area than the smallest component of an article is scrap for that specific product manufacturing, since it can't be further used. Thus, area difference of the scrap and smallest component of women's sandal in family 1 and area difference of the scrap and smallest component of men's sandal in family 2 is the achievable improvement in material utilization of the company.

The area of the components was measured using a 1ft x 1ft grid and described in the table below:

Table 11:- Description of material utilization improvement

Family	Smallest product	Area in ft ²			Improvement (%)
		Smallest part	Scrap (Average)	Difference	
1.	Women's sandal	0.0278	0.133	0.105	79.07
2.	Men's sandal	0.0139	0.133	0.119	89.54
Average		0.02085	0.133	0.112	84.30

As shown in the table above, the improved system enables the company to reduce the current scrap generation by 84.3%, thereby improving material utilization of the enterprise. Producing optimal number of products as per the proposed categorization of items enables the company to make a profit of 38,201.01ETB per week or 1,986,452.52 ETB per annum. This profit is calculated estimating cost of products as per the AS-IS material consumption (citrus paribus).

Furthermore, the 84.3% reduction in scrap generation improves the current material utilization of the company, thereby reducing cost of leather material. To quantify the cost reduction of the improved system, the proportion of scrap generated per unit of each product was found by measuring the exact area of components using a feet square grid as follows:

Table 12:- Description for scrap generated per unit products

Product	AS IS consumption	Measured area	Scrap/unit (ft²)	Scrap (%)
Shoulder bag	7.25	5.125	2.125	29.31
Women's wallet	1	0.6	0.4	40
Women's sandal	0.75	0.5	0.25	33.33
Lap top case	9.5	6.25	3.25	34.21
Belts	2	1.5	0.5	25
Men's wallet	1	0.625	0.375	37.5
Men's sandal	1	0.725	0.275	27.5

The total amount of scrap and the cost reduction potential of the proposed system were determined as per the optimal solution found in previous section:

Table 13:- Description of estimated reduction in leather material cost

Products	Optimal number	Scrap/unit	Total scrap	Saved material
Shoulder bag	30	2.125	63.75	53.74
Women's wallet	40	0.4	16	13.49
Women's sandal	135	0.25	33.75	0
Lap top case	36	3.25	117	98.63
Belts	60	0.5	30	25.29
Men's wallet	42	0.375	15.75	13.28
Men's sandal	132	0.275	36.3	0
Total(ft ²)			312.55	204.43
Proportion relative to total material consumption (%)			31.42	20.55

As described in the table above, 204.43 ft² of leather can be saved per week. The monetary value of this material was estimated to be 17,989.62 ETB, which is the possible reduction in cost of leather material.

The possible outcome of the proposed system can be described as a combined benefit of the cost reduction and optimal solution of the previously formulated model. Therefore, implementing the proposed system, with the existing company set up and material purchasing capacity, a profit of 56,190.63 ETB per week or 2,921,912.76 ETB per annum can be generated, creating conducive work environment with improved material management and more effective utilization of resources.

Chapter 5: Conclusion, Recommendations and Suggestion for future works

This chapter deals with conclusion and recommendations of the study. In the first section conclusion on the study and the major findings are presented and finally possible recommendations as well as topics for future studies are suggested.

5.1. Conclusion

The company uses varieties of materials as an input, for the manufacturing of its products. Among the various materials, leather is the major one contributing for up to 84% of the production cost.

The production system of the case company had been investigated in the course of conducting this study. Continuous generation of scraps was observed, causing wastes. Among various work stations of the production system, cutting is the major site consuming the major material and creating majority of the scraps. The existing production system was analyzed and a system has been devised to tackle the identified problems, with respect to leather material utilization, ensuring better profitability of the company.

The utilization of leather material can be considerably improved by implementing size and shape based production planning and making of product items. For effective application of this system, products of the firm should be categorized in families, in terms of their shape and size, so that they can be compatibly interlocked during cutting of product components. The proposed system, with proper determination of optimum number of products in a mix, can significantly enhance profitability of leather articles manufacturing companies and considerably increase utilization of other resources.

5.2. Recommendations

As per findings of the study and concept of industrial engineering as well as techniques of leather goods manufacturing, the following recommendations are forwarded to the company;

- As a business company, it is mandatory to have a well-organized and properly planned system of production.
- Material utilization should be consistently monitored and a system should be devised and implemented for continuous improvement of the business and profitability of the company.
- Rather than planning and making items individually, technical categorization of products should be made so that they can be compatibly planned and made together for efficient utilization of materials and other company resources.
- While cutting components of products a ratio of (6:8:27) should be maintained for shoulder bag, women's wallet and women's sandal. Likewise a ratio of (6:10:7:22) should be maintained while cutting components of laptop case, belt, men's wallet and men's sandal products.
- The model should be updated as per seasonal costs of materials and changes in other factors of the business environment, so that the optimum number of products can be reviewed as per the updated solutions.
- The optimal production planning should be followed while purchasing materials and the quality parameters should be reasonably examined so that company profitability can be realized as planned.
- Working time should be added and labor productivity improvement solutions should be devised for more effective utilization of resources and the available capacity.

5.3. Suggestion for Future works

Although an effort was made to conduct this research as extensively as feasible, time and other constraints may have prevented the consideration of other concerns. In general, the goal of this study is to show how to enhance profitability of leather goods manufacturing company by improving material utilization. I suggest future studies to be conducted on the following topics:

- Design optimization of leather goods products for efficient material utilization.
- Improving inventory management of firms for smooth and efficient production.
- Integrated system of sales record, demand forecasting and material requirement planning for optimal production of articles.
- The effect of material utilization improvement on resource productivity of the industry.

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Annexes

Annex 1: Checklist for data collection

The overall manufacturing process is investigated embracing the factors of production within four perspectives for convenient examination of material utilization of the case company using the principle and techniques of work study.

Data collection is conducted on the following focus areas to examine the AS-IS production practice of the case company. Objective observation and interview is implemented in collecting the relevant data.

1. Organization

- 1.1. Organization of the current production process . . . the process flow and the workshop layout (Observation + interview).
- 1.2. Types of machineries, tools and equipment used in major functions of the production system (their effects on material utilization)
- 1.3. Labor and category of expertise in each workstations. (Knowledge, skill and behavioral requirements; capacity building programs etc.)
- 1.4. Characterization of work stations in terms of their material utilization . . . what type of materials is consumed at each distinct workstation. (examining the cost contributions of workstations) (Observation + interview).

2. Products and material consumption

- 2.1. Identifying product varieties. ... Analyzing the sequence of operations in their productions along with material utilizations. (Observation + interview).
- 2.2. How often is new design of products introduced to the company? – (Interview)
- 2.3. Driving factors (inspirations) for new product developments. (Interview)
- 2.4. Average material consumption per products --- Analyzing current material productivity level for each product type.

3. Planning and production capacity

3.1. Production planning practice of the enterprise

3.2. Demand forecasting practice of the enterprise

3.3. Average annual production of the enterprise – product type and amount of production ... Data of the current year - Taking General data and then special focus will be given for sample product items.

3.4. Costing and pricing in the enterprise.(consideration of wastes in cost estimation and product pricing)

4. Waste management

4.1. Prioritizing work stations in terms of waste generation; identifying the types of wastes.

4.2. The real cause of wastes in each work station.(observation + interview)

4.3. The waste management practice of the enterprise. (Ways, costs and revenues)

Annex 2: Terminology

- Leather goods: are products made up of leather material excluding footwear and leather garments.
- Footwear: leather products made for covering and protecting human foot. Like shoe, sandals etc.
- Skin: upper covering of small animals having an area of less than 6 feet square.
- Hide: upper covering of big animals having an area of greater than 6 feet square.
- Pattern: a template representing the geometric shape and size of a product component.
- Cutting value: The proportion of usable area of a leather which is free of defects.
- Table rank: Leather materials having a cutting value of greater than 50%.
- Scars: Leather materials having a cutting value of less than 50%.
- Value chain: is a sequence of target-oriented combinations of production factors (From input to the market for specific product/services) that create a marketable product or service to the final consumption.
- Ante mortem defects: leather defects created while the animal is alive.
- Post mortem defects: defects created after the death of the animal, in slaughtering, tanning and so on.
- Tanning: a process of converting skin/hide in to finished leather.
- Measuring tape: a tool for measuring the dimension of a fabric.
- Puncher: a tool for making holes on leather materials.
- Cutting: cropping out the product component as per the pattern template.
- Take back program: collecting used leather products to use them as raw material for making new one.

Annex 3:- Scraps in working stations



Annex 4: Sacks of leather and scraps in store



Annex 5: Data collection



Annex 6: Obsolete products



Annex 7: Partial view of workshop arrangements



Annex 8: Sampling for scraps



Annex 9: Feet square grid for scrap area measurement

$5\frac{1}{2} + \frac{1}{8} + 12 + 2 + \frac{3}{4} + 2 + \frac{1}{2} + \frac{2}{5} = 22 + 1 + \frac{1}{8} + \frac{3}{4} + \frac{2}{5} = 23 + \frac{1+3+4}{8} + \frac{1}{5} = 24 + \frac{1}{12} + \frac{1}{5}$

Color	sample 1	sample 2	sample 3	Average
Tan	$6\frac{1}{2}$	$11\frac{1}{3}$	$15\frac{1}{2}$	
White	$13\frac{3}{4}$	$12\frac{11}{12}$	$24\frac{19}{60}$	
Black	$10\frac{7}{12}$	$15\frac{4}{5}$	$14\frac{1}{2}$	

$10 + \frac{1}{3} + \frac{1}{4} = \frac{40}{12} + \frac{4}{12} + \frac{3}{12} = \frac{47}{12}$

Total Average
 $\frac{293}{12}$

$5\frac{3}{4} + 3 + \frac{4}{5} + \frac{3}{5} + 9 + \frac{3}{2} + \frac{4}{5} + \frac{2}{6} = 17\frac{4}{5}$

Annex 10: Measuring areas of scrap and component



Annex 11: Sample products

