5th Asia Pacific Conference on Industrial Engineering and Operations Management
Tokyo, Japan, September 10-12, 2024
Publisher: IEOM Society International, USA DOI: 10.46254/AP05.20240193
Published: *September* 10, 2024

Goal Programming Problem: Improving Production Systems and Maximizing Efficiency in a Shoe Manufacturing Company

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Abstract

The production of shoes is a worldwide industry that includes a wide variety of ranges, from traditional methods to advanced automation used by modern companies; these industries use approaches such as Goal Programming to streamline the production methods in order to effectively manage the company's goals. The primary focus of this study is to improve production operations at Shoe Manufacturing Company using goal programming, with the goal of increasing operational efficiency that stays competitive in the market. The research aims to enhance the company's manufacturing processes, recognize operational constraints, and suggest solutions that maximize the use of machinery and materials for ineffective production. This study performs a comprehensive analysis aimed at enhancing operational procedures, encompassing space constraints, staffing, workflow order, and disorganized materials, this study tackles the analysis evaluation in the production manufacturing company, selectively is the use of optimization using goal programming which provide beneficial and significant changes in developing the shoe manufacturing company. Through the use of goal programming model application and Matlab Simulation, the Company's shoe production improved efficiency through a revised workflow, saving 75.45 seconds per cycle. This adjustment increased production from 36 to 40 shoe components (18 to 20 pairs), emphasizing enhanced operational efficiency and quality. It proves that the study utilized the use of optimization to achieve significant results in optimizing the processes, These improvements are projected to favorably impact both the quality and quantity of manufactured shoes. Furthermore, this study suggests using other approaches such as Multiple Goal Programming, Queuing Theory, and Linear programming to give a fair approach to the competitive market; this approach lies in its ability to integrate external factors, thereby improving the effectiveness and practical implementation of the solution put forth in this study.

Keywords
Shoe manufacturing, Goal programming, Optimizing, Efficiency, Production

Introduction
The shoe industry faces relentless competition, demanding constant enhancements in productivity, efficiency, and overall performance. To keep pace with shifting consumer preferences, technological innovations, and global economic changes, manufacturers must swiftly adapt to meet diverse market demands. In this competitive landscape, enhancing operational efficiency has become critical in the shoe manufacturing process. Recent years have seen a growing interest in goal programming, a mathematical approach designed to optimize multiple, often conflicting, objectives. This method is increasingly used to balance various aspects of the manufacturing process, such as

production scheduling, inventory management, and quality control. By integrating goal programming, shoe manufacturers can achieve more consistent and efficient outcomes, helping them navigate the complexities of the modern industrial environment and secure long-term success.

This study examines how goal programming can be effectively applied in the shoe industry to enhance operational performance and strategic decision-making. By analyzing and describing the interconnected processes within this industry using available data, the study aims to provide insights into how goal programming could benefit other sectors, such as telecommunications, by improving operational efficiency and achieving excellence. Shoe manufacturing companies often leverage goal programming (GP) to optimize their operations and meet specific objectives. According to Karakutuk and Ornek (2022), GP has proven effective in streamlining operations, enhancing service quality, and optimizing production processes. For instance, GP is used to balance and simultaneously optimize multiple objectives, such as reducing production costs, improving product quality, ensuring timely delivery, and meeting design standards. This study emphasizes how mathematical modeling through goal programming helps identify optimal solutions that address conflicting goals, thereby supporting improved performance and decision-making in the shoe manufacturing industry.

1.1 Problem Statement

In the present-day constantly evolving manufacturing market has a greater significance compared to previous years. The shoe companies are dealing with intense competition as customers need changes and new innovations develop. During difficult times for decision-making, goal programming is an efficient tool that companies can utilize for balancing multiple sets of different objectives. Goal programming is an organized approach employed by manufacturing companies for setting and achieving goals across multiple metrics for performance which include manufacturing productivity, managing expenses, and product quality. This is beneficial in markets such as shoe manufacturing, wherein precise measurements, effective production, and exact delivery dates are all important for fulfilling client expectations and maintaining the competitive edge (Kumar 2023).

Goal programming can be beneficial to Shoe Manufacturing Company in organizing production and lowering expenses. The company can improve production time frames, maintain high standards of quality, control assets, minimize waste through the implementation of quantitative modeling strategies. Industrial challenges including factory difficulties, shifts in demand, and costs of raw materials may be addressed by applying this strategy. Shoe Manufacturing has significant industrial expertise. Even the most well-run corporation would ultimately face production issues with performance. This research aims to identify different limitations hindering efficient shoe production, to improve process productivity, and to optimize use of machinery and materials for efficient production.

1.2 Objectives

General Objectives

The primary objective of this study is to improve the production operations at Shoe Manufacturing Company using goal programming methods, which increases its operational effectiveness and competitiveness in the marketplace.

Specific Objectives

This study aims to:

1. To identify limitations hindering efficient shoe production.
2. To process productivity.
3. To optimize the use of machinery and materials for efficient production.

2. Literature Review

The procedure of manufacturing shoes is simple and the operation process is convenient and fast, resulting in high comfort according to Hongxia (2016). According to Yong et al. (2018) highlights the groundbreaking aspect of the advanced automation technology as it can simplify manufacturing processes, decrease intricacy, and enhance the overall effectiveness of shoemaking procedures. In the world of shoe business it faces persistent and strong competition, necessitating ongoing efforts to increase production, efficiency, and overall performance. Demand for footwear is distributed over several markets as a result of shifting customer preferences, technological advancement, and global economic trends, necessitating rapid adaptation by producers. According to the study of Alkaf et al. (2021), an organization's effective and efficient performance has an impact on its service performance. Improving an organization's service performance that faces a number of challenges, including the fact that not all organizations can enhance the expertise of its members. Some organizations continue to employ old systems to carry out their business. According to Shang et al. (2018) and Bondar et al. (2024), there is an increase in the number of well-known companies operating in footwear production that are trying to push further the integration of sustainable processes and materials in the footwear industry. In this scenario, product design becomes a decisive factor in producing footwear with adequate comfort and sustainable production. Understanding consumer behavior and including them in the production process have resulted in a new paradigm of Social Manufacturing for customized production in the footwear industry.

Shoe manufacturing industry upholds a quality of work that fulfills a key strategy to attain a company goal. Hence, Improving production systems and maximizing efficiency that optimize machines' operating hours. In the study conducted by Hassan et al. (2019) the authors present a case where simulation was effectively applied to the production of footwear in manufacturing settings, where simulation modeling and analysis are frequently used to optimize the balance between high inventory and the risk of stockouts, enhance and harmonize machine usage, efficiently schedule workers, and enhance performance indicators like average and maximum queue times, as well as average and maximum queue lengths. Using the Goal programming approach to solve the Multi-Objective Possibilistic Mixed Integer Linear Programming model (MOPMILP) model maximizes the overall performance and can minimize the overall risk, this approach finds an efficient solution to the production plan (Khemiri et al. 2017).

The goal programming method aims to minimize the deviation from each goal in order to achieve optimal results while ensuring that other goals are not overlooked (Hasbiyati et al. 2023). Goal programming is a technique that has been used to formulate the model with multiple objectives (Musa. 2020). Goal-programming, as a multi-objective optimization approach, belongs to the category of methods that involve expressing preferences in advance, and shares its advantages; it is particularly advantageous for dealing with problems that have conflicting objective functions (Hussain and Kim. 2020). To meet company objectives, it is important to enhance production volume in order to fulfill customer demands, increase sales revenue, reduce production costs, and improve machine working hours through the use of Goal Programming to achieve greater manufacturing efficiency (Jong et al. 2018). In the findings of the study of Sabilla et al. (2018), emphasize that Goal Programming can be utilized to determine the most optimal route by maximizing both time and cost efficiencies; the study of Sabilla et al. 2018 indicates that scheduling has the potential to prolong the duration of work, furthermore enhancing overall execution time. Moreover, Goal Programming has been shown to successfully lower production expenses to meet the company's specific objectives. For a shoe manufacturer, goal programming can be revolutionary. This method notably increases efficiency by optimizing production systems. Using MATLAB simulation and goal programming approach, the shoe manufacturing business can address certain problems that this study found. It's important to remember that there are still certain gaps in this study, though. More specifically, there hasn't been enough research done on the systematic application of goal programming and Matlab simulation to address the particular problems encountered by manufacturing firms. There is a need for more research in this field, which remain understudied.

3. Methodology

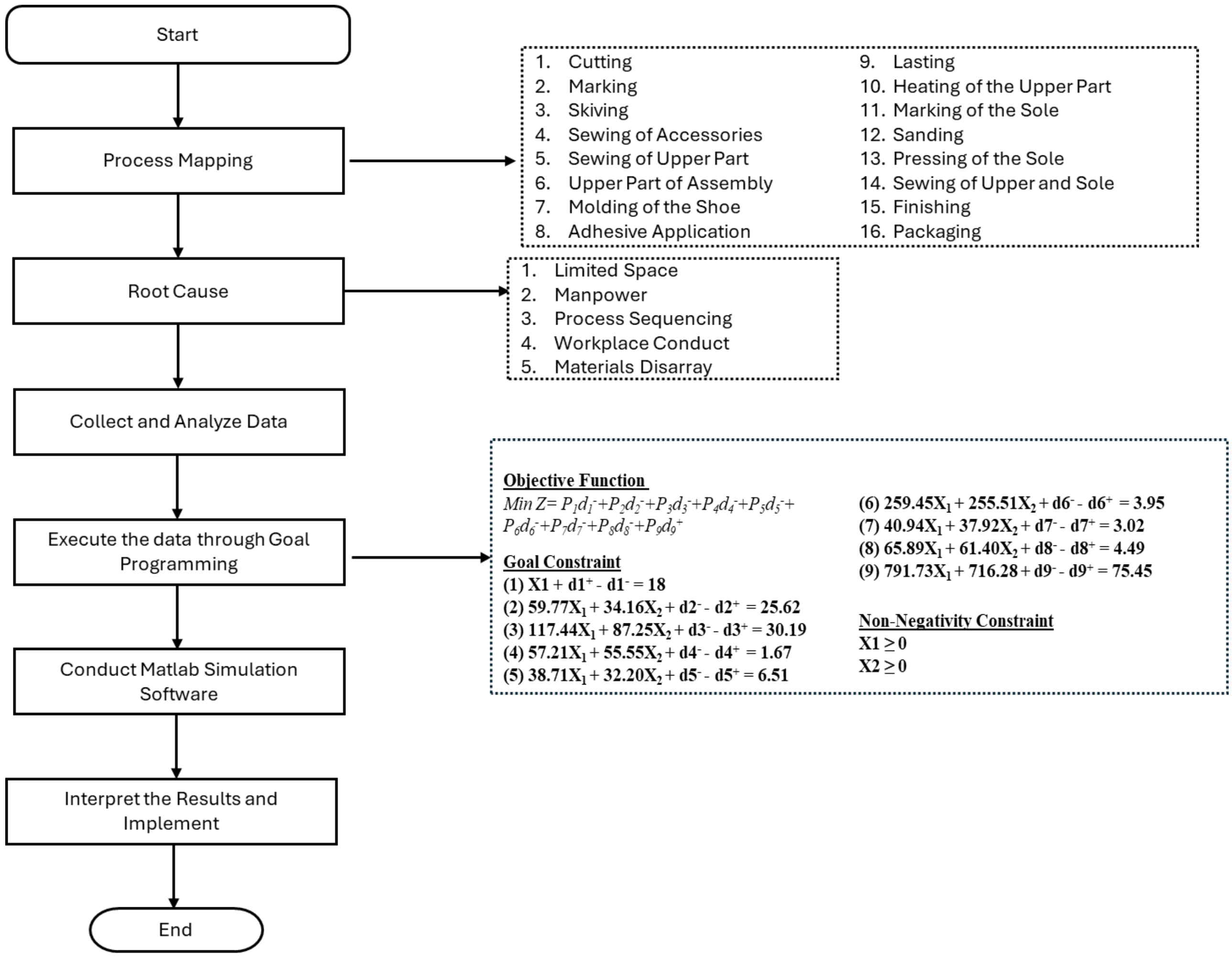

Figure 1. Case Methodology using Goal Programming in a Shoe Manufacturing Company.

Figure 1 shows the root causes of the problem for a Shoe Manufacturing Company and how it can be addressed. To augment operational effectiveness and the caliber of products, shall engage in a meticulous case methodology that systematically examines pivotal business dilemmas, delineates fundamental causes, and formulates solutions predicated on data. By concentrating on particular case studies encompassing production impediments, material wastage, or grievances from customers, the objective is to enhance procedural efficiency, curtail expenditures, and elevate customer contentment. Even though MATLAB has superb capabilities in number-crunching and scrutinizing data, its application in identifying general business process challenges within shoe manufacturing complex systems is scanty. It is when investigating particularized problems that it makes a difference to the industry. For example, examining production data with MATLAB can reveal trends that may not be readily apparent or optimize material utilization, and simulate what would happen if changes were made to shoe designs. However, determining which areas need to be improved most within a shoe manufacturer's operations tends to give far more rounded and useful insights through techniques based on business process management and qualitative data analysis. During assessment in a Flow Chart diagram, the researchers found out that Limited Space, Manpower, Process Sequencing, Workplace Conduct, and Materials Disarray contributed to the main cause of the problems encountered by the company.

3.1 Data Collection

Operation Breakdown	Present in Seconds		Proposed in Seconds		Savings
	NT	ST	NT	ST	
Cutting	10.28	11.83	-	-	-
Marking	10.84	12.46	-	-	-
Skiving	5.49	6.32	-	-	-
Sewing of Accessories	20.11	23.11	-	-	-
Sewing of Upper Part	51.97	59.77	33.00	34.16	25.62
Upper Part Assembly	102.12	117.44	84.30	87.25	30.19
Molding of the Shoe	18.01	20.71	-	-	-
Adhesive Application on Upper Part	49.75	57.21	48.30	55.55	1.67
Lasting of the Shoe	33.66	38.71	31.11	32.20	6.51
Heating of the Upper Part	225.62	259.46	222.18	255.51	3.95
Marking of the Sole	35.60	40.94	32.97	37.92	3.02
Sanding of the Sole	6.26	7.20	-	-	-
Pressing of the Sole	15.86	18.24	-	-	-
Sewing of Upper and Sole	22.83	26.25	-	-	-
Finishing	57.29	65.89	53.39	61.40	4.49
Packaging	22.76	26.18	-	-	-
Total	688.46	791.73		716.28	75.45

Figure 2. Summary of Present and Proposed Operation Breakdown of Shoe Manufacturing *Company*

Figure 2 shows the current and proposed manner of operation breakdown for Shoe Manufacturing Corporation. The researchers calculated the Standard Time of the proposed processes and estimated the total savings.

Production Yield = Working hours in seconds / Standard CT in seconds	
Number of working hours in seconds	28,800
Standard Cycle time computed in seconds	716.28
Yield	40 pieces of shoe component or 20 pairs

Figure 3. Proposed Computation of Yield

The presented result is the proposed computed yield of products each day. Using the established eight (8) hours of work every day. The manufacturing company generates 40 shoe components per day, enough to make 20 pairs of shoes. This was calculated by translating eight hours to seconds and dividing by the usual cycle time.

Table 1. Present Priority Goals

Priority	Description
P1	The primary goal of the shoe manufacturing company is to improve the production of 36 pieces of shoes or 18 pairs in a day for Product 1 and Product 2
P2	The secondary goal of the company is to minimize overtime in the Sewing of Upper part department.
P3	The tertiary goal of the company is reduce to idle time in the Upper Part of Assembly department to avoid delays
P4	The fourth goal of the shoe company is to enhance productivity in Adhesive Application on Upper Part to reduce delays
P5	The fifth goal of the shoe manufacturing company is to improve the time efficiency in Lasting of the Shoe department.
P6	The sixth goal of the shoe manufacturing company is to utilize the productivity in Heating of the Upper Part department.
P7	The seventh goal of the shoe manufacturing company is to boost productivity in Marking of the Sole Department
P8	The eighth goal of the shoe company is to furnish and polish all the ready-made materials and check in Finishing department
P9	The final goal of the shoe manufacturing company is to combine workstations that will enhance the production, to process optimization of machinery and materials.

Deviational Variables
The shoe manufacturing company is unconcerned with $d1^+$, $d1^-$, $d2^+$, $d2^-$, $d3^+$, $d3^-$, $d4^+$, and $d4^-$

$d1^+$ = Overachievement of the Product 1 and Product 2 target quota per day
$d1^-$ = Underachievement of the Product 1 and Product 2 target quota per day
$d2^+$ = Overtime in sewing of upper part department (overutilization)
$d2^-$ = Idle time in sewing of upper part department (underutilization)
$d3^+$ = Overtime in upper part of assembly department (overutilization)
$d3^-$ = Idle time in upper part of assembly department (underutilization)
$d4^+$ = Overtime in adhesive application on upper part department (overutilization)
$d4^-$ = Idle time in adhesive application on upper part department (underutilization)
$d5^+$ = Overtime in lasting of the shoe department (overutilization)
$d5^-$ = Idle time in lasting of the shoe department (underutilization)
$d6^+$ = Overtime in heating of the upper part department (overutilization)
$d6^-$ = Idle time in heating of the upper part department (underutilization)
$d7^+$ = Overtime in marking of the sole department (overutilization)
$d7^-$ = Idle time in marking of the sole department (underutilization)
$d8^+$ = Overtime in finishing department (overutilization)
$d8^-$ = Idle time in finishing department (underutilization)
$d9^+$ = Overachievement of the production process
$d9^-$ = Underachievement of the production process

Goal Programming Problem Model

Decision Variables

X1= 1st Product or Black Shoes
X2= 2nd Product or Leather Shoes

Objective Function

$Min\ Z= P_1d_1^- + P_2d_2^- + P_3d_3^- + P_4d_4^- + P_5d_5^- + P_6d_6^- + P_7d_7^- + P_8d_8^- + P_9d_9^+$

Goal Constraint

(1) $X1 + d1^+ - d1^- = 18$
(2) $59.77X_1 + 34.16X_2 + d2^- - d2^+ = 25.62$
(3) $117.44X_1 + 87.25X_2 + d3^- - d3^+ = 30.19$
(4) $57.21X_1 + 55.55X_2 + d4^- - d4^+ = 1.67$
(5) $38.71X_1 + 32.20X_2 + d5^- - d5^+ = 6.51$
(6) $259.45X_1 + 255.51X_2 + d6^- - d6^+ = 3.95$
(7) $40.94X_1 + 37.92X_2 + d7^- - d7^+ = 3.02$
(8) $65.89X_1 + 61.40X_2 + d8^- - d8^+ = 4.49$
(9) $791.73X_1 + 716.28 + d9^- - d9^+ = 75.45$

Non-Negativity Constraint

$X1 \geq 0$
$X2 \geq 0$

4. Results and Discussion

The time and motion study at a shoe production factory provided useful insights into the efficiency of the shoe-making process. The initial analysis found 16 items within the production cycle, which were documented in (see Figure 5), with both normal and standard timeframes for each operation resulting in a manufacturing yield of 36 shoe components or 18 pairs of shoes (see Figure 6). Strategic improvements have been introduced to the proposed flowchart (refer to Figure 2) to address the identified sources of delay. The comparison of the current and proposed flows revealed a 75.45-second time savings (see Figure 2). This enhanced workflow not only expedited the manufacturing process, but also resulted in a significant boost in production yield, increasing from 36 to 40 shoe components or from 18 to 20 pairs of shoes (see Figure 6 and Figure 3). The detailed analysis and subsequent adjustments highlight the importance of conducting a thorough time and motion assessment in improving operational efficiency. By identifying and addressing impediments, particularly those connected to delays, the proposed modifications not only save time but also contribute to a more productive and resource-efficient shoe production process. The proposed flowchart is expected to have a favorable impact on both the quality and quantity of final shoe components, coinciding with Shoe Manufacturing Company's overall goal of continuous improvement in production processes.

4.1 Graphical Results

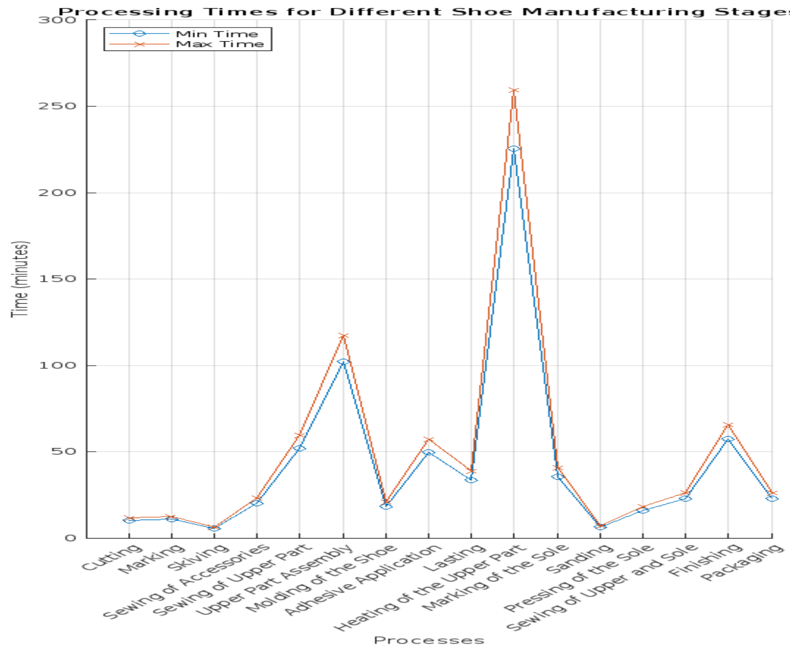

Figure 4. Goal Programming Analysis Results Using MATLAB Software

Figure 4. shows the Goal Programming Analysis results using MATLAB Software to visualize each process in shoe manufacturing and their corresponding time.

Element No	Therbligs Symbol	Elements	Present	
			Normal Time	Standard Time
1	◡	Cutting	10.28	11.83
2	0	Marking	10.84	12.46
3	8	Skiving	5.49	6.32
4	#	Sewing of Accessories	20.11	23.11
5	#	Sewing of Upper Part	51.97	59.77
6	#	Upper Part Assembly	102.12	117.44
7	8	Molding of the Shoe	18.01	20.71
8	U	Adhesive Application	49.75	57.21
9	#	Lasting	33.66	38.71
10	∩	Heating of the Upper Part	225.62	259.46
11	0	Marking of the Sole	35.60	40.94
12	II	Sanding	6.26	7.20
15	0	Finishing	57.29	65.89
16	◡	Packaging	22.76	26.18
		Total Cycle Time	**688.46**	**791.73**

Figure 5. Summary of Present Time and Motion Study of Shoe Manufacturing Company in Marikina

Figure 5 represents the summary of the process flow diagram of the company. It consists of 16 processes with a total time of 791.73 seconds to produce the product.

Production Yield = Working hours in seconds / Standard CT in seconds	
Number of working hours in seconds	28,800
Standard Cycle time computed in seconds	791.73
Yield	36 shoe components 18 or pairs of shoes.

Figure 6 Computation of Yield of Present Operation

The calculated monthly product yield is shown above. Using the established eight (8) hours of work every day. The company generates 36 shoe components per day, enough to make 18 pairs of shoes. This was calculated by translating eight (8) hours to seconds and dividing by the usual cycle time.

5. Conclusion and Recommendation

The intent of the research is the exploration of the deployment of goal programming aimed at streamlining the operations within a shoe production enterprise, precisely at Shoe Manufacturing Company. Goal programming stands as a multi-objective decision-making methodology empowering entities to attain varied objectives concurrently. Pertinent to shoe manufacture, this might encompass elevating production volumes, curtailing expenses, and satisfying consumer demand concurrently with adherence to quality norms. The case investigation centered on a Shoe Manufacturing Company presumptively delves into the enactment of goal programming within the firm's operational framework, scrutinizing the hurdles, advantages, and subsequent results linked to such a methodology. Possible analysis within the study may encompass data concerning production capacities, material consumptions, workforce expenditures, and market demand to pinpoint enhancement zones and formulate a goal programming schema consistent with the corporation's aims. Furthermore, the implementation of goal programming can facilitate alignment of production strategies with overall business objectives, ultimately leading to improved performance metrics and competitiveness in the market. These proposed enhancements demonstrate the significance of embracing advanced decision-making tools in today's complex business environment.

The optimization of goal programming in shoe manufacturing embodies substantial promise for refining production processes and amplifying efficiency. Concurrent consideration of multiple objectives, accompanied by incorporation of uncertainty factors, enables managers to formulate more informed and strategic decisions that harmonize with the company's overarching objectives. The capability to balance conflicting objectives and constraints systematically and quantitatively provides a structured approach to decision-making that can fortify operational performance and profitability. Furthermore, the adaptability of goal programming facilitates adjustments in response to altering market conditions or business priorities. By harnessing this advanced decision-making tool, Shoe manufacturing companies can remain competitive and agile in the fast-paced environment of the shoe manufacturing industry. The assimilation of goal programming into the production process possesses the potential to catalyze substantial improvements in efficiency, quality, and overall business performance.

5.1 Proposed Improvements

This study explores optimal decision-making strategies for manufacturing enterprises. The investigation of the application of innovative optimization techniques to enhance the overall performance in a leading shoe manufacturing company. By leveraging synergies between process optimization and cost management, the researchers aim to identify innovative solutions that can drive business growth and improve customer satisfaction. This study seeks to contribute to the development of best practices in goal programming for manufacturing industries, with a focus on maximizing efficiency and profitability. Goal programming for shoe manufacturing encounters difficulties due to lack of accurate and up-to-date data regarding production costs, material availability, and market demands. Absence of clarity hinders ability to set realistic and achievable goals that align with strategic objectives. This lack of clarity is particularly challenging in the fast-paced shoe manufacturing industry, where trends and consumer preferences change rapidly. Moreover, complexity of balancing competing objectives, such as minimizing costs while maintaining product quality, adds another layer of difficulty to the goal programming process. To overcome these challenges, robust data collection and analysis systems, and strategic partnerships with suppliers and distributors ensure timely and accurate information for decision-making purposes. Proactive approach to goal programming, considering these factors, is essential for long-term success in the shoe manufacturing industry. The proposed enhancements to goal programming for shoe manufacturing have the potential to significantly refine the operational efficacy and optimize decision-making processes. By integrating multiple objectives such as cost optimization, quality control, and production volume management into the decision-support model, strategic planning can be augmented to accommodate conflicting goals and facilitate more informed decision-making. The incorporation of uncertainty factors via interval numbers enables a more resilient and adaptable approach to decision-making, particularly in the dynamic and unpredictable Shoe Manufacturing Industry.

5. 2 Practical Implications of the study

The significance of goal programming in enhancing manufacturing efficiency in the shoe industry is underscored by a recent analysis. Key findings demonstrate that the integration of multi-objective optimization techniques simplifies production workflows, reduces resource waste, and generates substantial cost savings. By systematically prioritizing goals, ranging from production output to quality control, manufacturers can align their operational capabilities with strategic objectives, leading to improved performance metrics. However, the current research landscape highlights a need for further investigation into the applicability of goal programming in dynamic environments, particularly as market demands change. Future research should focus on developing adaptive models that can respond to real-time data and shifting consumer preferences, ensuring sustainable manufacturing practices. Concurrently, empirical studies examining the long-term effects of goal programming on workforce dynamics and supplier relationships can provide valuable insights for practitioners seeking to optimize their operations.

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Biographies

Mae Ann Bodiongan is an Industrial Engineering student from the Technological Institute of the Philippines in Quezon City residing in Cainta, Rizal. An active participant of ORIENTS in the year 2021 to 2022, Inhinyera in the year 2022 to 2023 and the Society of Scholars QC. She is also proficient in using Microsoft Word, Microsoft PowerPoint, Microsoft Excel, Autocad, Minitab, Matlab, Lindo, ProModel, and Adobe Photoshop.

Chustin Luwis A. Gutlay is a fourth-year industrial engineering student at the Technological Institute of the Philippines in Quezon City. He graduated from senior high school in Cainta Rizal, where he took information and communication technologies. He is passionate about achieving his dream to make up for the sacrifices of his sister, aunt, and father. He is dedicated to accomplishing the given task and has an attitude of learning more about different things.

Gabriel Jerome R. Sabangan is a third-year industrial engineering student at the Technological Institute of the Philippines in Quezon City. He is an aspiring Industrial Engineer with high aspirations. His curiosity for leadership is what drives him to pursue his academic path. Although he faced a challenging period in his academic journey, losing sight of his passion and motivation, the unending encouragement of his loved ones inspired him to get back on his feet and start on a new journey.

Daniel Johns N. Tagibao is a third-year industrial engineering student at the Technological Institute of the Philippines in Quezon City. He graduated from senior high school at the same institution with high honors. He is a creative and dedicated individual with a passion for writing that knows no bounds. With a keen eye for detail and a flair for storytelling, His commitment to his craft shines through in every word he pens, making him a true wordsmith.

Jonna Mae R. Valdeviezo is a third-year industrial Engineering from the Technological Institute of the Philippines - Quezon City, she graduated senior high school from the same Institution. She is academically inclined and aims to provide quality results in the field of academics. Can work under pressure and is able to handle challenging situations using critical thinking and problem-solving with professionalism. She is also a highly motivated and driven individual who is always looking for ways to improve her skills and knowledge. She is optimistic, adventurous and enjoys learning new things. As part of my development, She is willing to be trained, acquire knowledge and discover new skills.

Maricar M. Navarro. holds the esteemed titles of ASEAN Engineer (AE) and Professional Industrial Engineer (PIE), accredited by the ASEAN Federation of Engineering Organizations (AFEO) and Philippine Institute of Industrial Engineers (PIIE). She currently serves as a Professor in both Undergraduate and Graduate School Program of Technological Institute of the Philippines, bringing over 17 years of combined experience in industry, academia, and research. Her expertise spans optimization of production processes, facility layout design, warehouse operations, and service delivery. Dr. Navarro's current research interests focus on financial optimization and decision-making in operations research. She earned both her master's and Ph.D. in Industrial Engineering from MAPUA University. As an active associate member of the National Research Council of the Philippines (NRCP) and member of PIIE, Dr. Navarro contributes significantly to advancing research initiatives and professional standards in Industrial engineering and related fields. Her dedication and expertise make her a pivotal figure in both academic circles and national research endeavors.