ISSN 2664-3995 (Print) & ISSN 2664-6757 (Online)
South Asian Research Journal of Business and Management
Abbreviated Key Title: South Asian Res J Bus Manag

| Volume-6 | Issue-5 | Sep-Oct- 2024 | **DOI: https://doi.org/10.36346/sarjbm.2024.v06i05.005**

Original Research Article

Linear Programming and Product Mix of Paint Manufacturing Firms in Port Harcourt

David Onwuchekwa, Ph.D[1*], Ebregbe Solomon Ekpomieme[1]

[1]Department of Management, Faculty of Management Sciences, Ignatius Ajuru University of Education, Port Harcourt, Nigeria

***Corresponding Author:** David Onwuchekwa
Department of Management, Faculty of Management Sciences, Ignatius Ajuru University of Education, Port Harcourt, Nigeria

Article History
Received: 15.08.2024
Accepted: 21.09.2024
Published: 28.09.2024

Abstract: This study examined the relationship between linear programming and product mix of paint manufacturing firms in Port Harcourt. This study adopted a correlational survey research design. The population of the study was 10 selected paint manufacturing firms in Port Harcourt as retrieved from Nigerian business directory (2024). 3 managers were selected from each firm multiplied by 10 firms gives us a total of 30 respondents. Structured questionnaire was used in data collection. The result of the Cronbach's Alpha reliability test indicates .804 which is above .70 which implies that the items are reliable. Pearson product moment correlation was used to test the hypotheses using SPSS (statistical package social sciences). The study revealed that there is a significant relationship between Ellipsoid Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt. There is a significant relationship between Graphical method Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt. There is a significant relationship between Simplex Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt. In conclusion, Linear programming is a powerful mathematical tool that can be effectively utilized by paint manufacturing firms in Port Harcourt to optimize their product mix and maximize profits. The paint manufacturing firms should conduct a thorough analysis of market demand for different types of paint products to identify profitable opportunities for product mix optimization.

Keywords: Linear Programming, Product Mix Optimization, Paint Manufacturing, Survey Research, SPSS.

BACKGROUND OF THE STUDY

Linear programming is a mathematical method used to determine the best possible outcome in a given mathematical model for a set of linear relationships. It involves optimizing a linear objective function subject to linear equality and inequality constraints. Linear programming has various applications in different fields, including economics, business, engineering, and manufacturing. One of the methods used in linear programming is the ellipsoid method. The ellipsoid method is an algorithm for solving convex optimization problems. It works by iteratively refining an ellipsoidal approximation of the feasible region until it converges to the optimal solution (Adekanmbi, 2018). Another method commonly used in linear programming is the graphical method. The graphical method involves graphically representing the constraints and objective function on a coordinate plane to find the optimal solution. By plotting the constraints and objective function, one can visually identify the feasible region and determine the optimal solution at the intersection point of the constraints. The simplex method is another widely used algorithm in linear programming. Developed by George Dantzig in 1947, the simplex method is an iterative procedure for solving linear programming problems. It starts at an extreme point of the feasible region and moves along the edges of the polyhedral set defined by the constraints until it reaches the optimal solution (Adekanmbi, 2018).

Oyedele (2016) In the context of product mix optimization for paint manufacturing firms in Port Harcourt, linear programming can be applied to determine the optimal combination of different paint products to maximize profit while

satisfying production constraints such as resource availability, demand requirements, and production capacity. By formulating a linear programming model that represents the cost structure, demand forecasts, and production constraints of paint manufacturing firms in Port Harcourt, managers can use techniques such as the ellipsoid method, graphical method, or simplex method to optimize their product mix decisions and improve overall profitability. Overall, studying linear programming methods such as ellipsoid algorithms, graphical methods, and simplex algorithms can provide valuable insights into optimizing product mix decisions for paint manufacturing firms in Port Harcourt.

Statement of the Problem

When studying the product mix of paint manufacturing firms in Port Harcourt using linear programming techniques, several challenges and issues may arise that could problematize the study. Some of these challenges include: Complexity of Production Processes: Paint manufacturing involves multiple ingredients and processes that can make it difficult to accurately model and optimize using linear programming techniques. Market Dynamics: The demand for different types of paints can fluctuate based on market trends, consumer preferences, and economic conditions, making it challenging to predict and optimize product mixes. Resource Constraints: Paint manufacturing firms may face constraints such as limited raw materials, production capacity, or budgetary restrictions that can impact their ability to optimize product mixes effectively (Oyedele, 2016).

Uncertainty in Input Parameters: Linear programming models rely on accurate input data such as costs, demand forecasts, and production capabilities. Uncertainty or variability in these parameters can lead to suboptimal solutions. Technological Advancements: Advances in technology and automation in paint manufacturing processes may require constant updates to linear programming models to reflect changes in production efficiency and capabilities. Overall, studying the product mix of paint manufacturing firms in Port Harcourt using linear programming techniques requires careful consideration of these challenges to ensure accurate and meaningful results.

Conceptual Framework

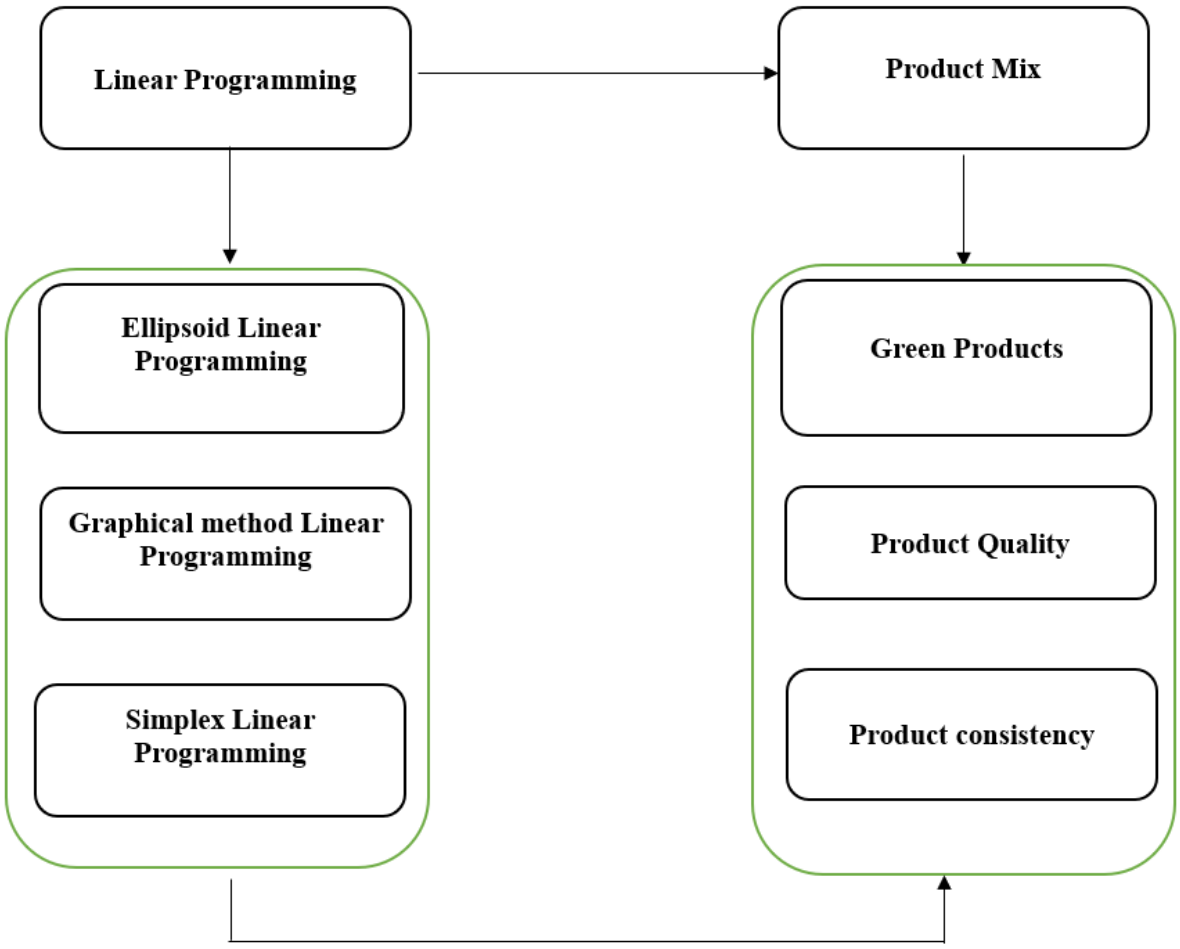

Figure 1: Conceptual framework on linear programming and product mix of paint manufacturing firms in Port Harcourt

Source: Adapted from Cascio, (2017), Kotler and Keller (2016), Blythe & Megicks, (2010)

AIMS & OBJECTIVES

The aim of this study is to determine the relationship between linear programming and product mix of paint manufacturing firms in Port Harcourt. The specific objectives are to:

1) Determine the relationship between Ellipsoid Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.
2) Determine the relationship between Graphical method Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.
3) Determine the relationship between Simplex Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.

Research Questions

The following research questions were raised to guide the study.

1) What is the relationship between Ellipsoid Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt?
2) What is the relationship between Graphical method Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt?
3) What is the relationship between Simplex Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt?

Hypotheses

The following null hypotheses were formulated and tested at a significant level of 0.01.

HO_1: There is no significant relationship between Ellipsoid Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.

HO_2: There is no significant relationship between Graphical method Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.

HO_3: There is no significant relationship between Simplex Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.

REVIEW OF RELATED LITERATURE

This section reviews various literature related to the study under investigations under the headings of conceptual review, theoretical review and empirical review.

Conceptual Review

Linear Programming

Linear programming is a mathematical method used to determine the best possible outcome in a given mathematical model for a particular set of requirements represented by linear relationships. In the context of paint manufacturing firms in Port Harcourt, linear programming can be applied to optimize various aspects of their operations such as production planning, resource allocation, inventory management, and cost minimization. In the context of paint manufacturing firms in Port Harcourt, linear programming techniques such as ellipsoid, graphical, and simplex methods can play a crucial role in enhancing decision-making processes, improving resource utilization, minimizing costs, and maximizing profits (Oyedele, 2016).

Dimensions of Linear Programming

Ellipsoid Linear Programming

Oladejo (2019) Ellipsoid Linear Programming is an optimization technique that involves using ellipsoids to define feasible regions and iteratively refine them to find the optimal solution. In the context of paint manufacturing firms in Port Harcourt, this method can be utilized to efficiently allocate resources, minimize costs, and maximize profits.

Graphical Method Linear Programming

The graphical method of linear programming involves graphically representing the constraints and objective function on a coordinate plane to identify the feasible region and optimal solution. Paint manufacturing firms in Port Harcourt can use this method to visually analyze their production constraints and make informed decisions regarding resource utilization (Akinola, 2017).

Simplex Linear Programming

Adetunji (2020) the simplex method is a widely used algorithm for solving linear programming problems by iteratively moving from one feasible solution to another along the edges of the feasible region until an optimal solution is reached. Paint manufacturing firms in Port Harcourt can leverage the simplex method to optimize their production processes and enhance operational efficiency.

Concept of Product Mix

Product mix in the context of paint manufacturing firms in Port Harcourt refers to the range of products offered by these companies, including green products, product quality, and product consistency. In conclusion, the product mix of paint manufacturing firms in Port Harcourt encompasses green products, product quality, and product consistency. By offering environmentally friendly products, maintaining high-quality standards, and ensuring consistency across their product lines, these companies can meet customer expectations and stay competitive in the market (Oyedele, 2016).

Measures of Product Mix

Green Products

Paint manufacturing firms in Port Harcourt are increasingly focusing on developing and offering environmentally friendly or "green" products. These green products are formulated using sustainable materials and production processes that have minimal impact on the environment. This includes using low-VOC (volatile organic compound) formulations, recycled materials, and eco-friendly packaging. By offering green products, paint manufacturing firms in Port Harcourt can cater to the growing demand for environmentally conscious products and demonstrate their commitment to sustainability (Akinola, 2017).

Product Quality

Akinola, (2017) Product quality is a crucial aspect of the product mix for paint manufacturing firms in Port Harcourt. High-quality paints ensure customer satisfaction, durability, and long-lasting performance. Paint manufacturing firms need to invest in research and development to continuously improve the quality of their products, including factors such as color accuracy, coverage, adhesion, and resistance to weathering and abrasion. Maintaining consistent quality across different product lines is essential for building a strong reputation and retaining customers.

Product Consistency

Consistency in product offerings is another key element of the product mix for paint manufacturing firms in Port Harcourt. Customers expect a certain level of consistency in terms of color matching, texture, finish, and performance across different batches of paint products. Paint manufacturers need to implement strict quality control measures to ensure that each batch meets the specified standards and matches the original formulation. Consistent product quality helps build trust with customers and ensures repeat business (Akinola, 2017).

Empirical Review

One such study is by Adekanmbi *et al*., (2018), titled application of linear programming in product mix optimization: a case study of a paint manufacturing company in Nigeria. This study focused on a specific paint manufacturing company in Nigeria as the population, using linear programming as the method of data analysis to optimize the product mix. The authors collected data through interviews, observations, and document analysis as instruments for data collection. The findings revealed that linear programming can effectively optimize the product mix of paint manufacturing firms, leading to increased efficiency and profitability. The study concluded that the application of linear programming techniques can significantly improve decision-making processes in the paint manufacturing industry. Recommendations included further research on different paint manufacturing firms to validate the findings.

Another relevant study is by Oyedele *et al*., (2016), titled optimization of paint production formulation using linear programming model. This study explored the use of linear programming models to optimize paint production formulations in Nigerian paint manufacturing firms. The population consisted of various paint manufacturing companies, with data collected through surveys and laboratory experiments as instruments for data collection. The method of data analysis involved applying linear programming techniques to determine the optimal formulation for paint production. The findings indicated that linear programming models can enhance the efficiency and cost-effectiveness of paint production processes. The study concluded that implementing these optimization techniques can lead to improved product quality and competitiveness in the market.

Furthermore, a study by Oladejo *et al*., (2019) titled "Application of Linear Programming Techniques in Product Mix Optimization: A Case Study of a Paint Manufacturing Company" investigated how linear programming techniques can be applied to optimize product mix decisions in a Nigerian paint manufacturing company. The population for this study was a specific paint manufacturing company, with data collected through surveys and financial records as instruments for data collection. The authors used linear programming as the method of data analysis to determine the optimal product mix for maximizing profits. The findings demonstrated that utilizing linear programming methods can lead to more informed decision-making processes regarding product mix strategies. The study concluded that implementing these techniques can result in enhanced operational efficiency and profitability for paint manufacturing firms.

Moreover, a study by Akinola *et al*., (2017) titled "Linear Programming Model for Optimal Product Mix Planning: A Case Study of a Paint Manufacturing Company" examined how linear programming models can be utilized for optimal

product mix planning in Nigerian paint manufacturing companies. The population included multiple paint manufacturing firms, with data collected through interviews, surveys, and financial reports as instruments for data collection. The researchers employed linear programming techniques to analyze the data and determine the most profitable product mix combinations. The findings highlighted that using linear programming models can help companies achieve cost savings and maximize profits through efficient resource allocation. The study concluded that integrating these optimization tools into decision-making processes can lead to improved competitiveness and sustainability within the industry.

Lastly, a study by Adetunji *et al*., (2020) titled "Enhancing Profitability Through Linear Programming: A Case Study of Paint Manufacturing Industry" investigated how linear programming methods can enhance profitability in the Nigerian paint manufacturing sector. The population comprised various paint manufacturing companies, with data collected through surveys, financial statements, and market research as instruments for data collection. Linear programming was used as the method of data analysis to identify optimal production strategies for maximizing profits. The findings indicated that implementing linear programming techniques can lead to significant improvements in operational efficiency and financial performance within the industry. The study concluded that adopting these optimization approaches is crucial for achieving sustainable growth and competitive advantage in the market.

Theoretical Review

Linear Programming Theory

Linear programming theory was propounded by George Dantzig in 1947. Dantzig, an American mathematician, developed the theory as a method for optimizing complex systems with linear relationships. Linear programming is a mathematical technique used to determine the best possible outcome in a given mathematical model for a set of linear constraints. The theory has since been widely applied in various fields such as economics, engineering, business management, and manufacturing.

Assumptions of Linear Programming Theory:

i. **Proportionality:** The relationship between variables is linear.
ii. **Additivity:** The total contribution of each variable is the sum of its individual contributions.
iii. **Certainty:** All parameters are known with certainty and do not vary.
iv. **Non-negativity:** Variables cannot have negative values.
v. **Divisibility:** Variables can take any fractional value within their feasible range.

Critiques of Linear Programming Theory:

i. **Linearity Assumption:** In reality, many relationships are not strictly linear.
ii. **Simplistic Model:** Linear programming may oversimplify complex real-world problems.
iii. **Limited Scope:** The theory may not be suitable for problems with non-linear relationships or discrete decision variables.
iv. **Sensitivity to Data Errors:** Small errors in input data can lead to significant changes in output solutions.
v. **Computational Complexity:** Solving large-scale linear programming problems can be computationally intensive.

Relevance to the Study of Linear Programming and Product Mix of Paint Manufacturing Firms in Port Harcourt: In the context of paint manufacturing firms in Port Harcourt, linear programming can be applied to optimize production processes, resource allocation, and product mix decisions. By formulating a linear programming model based on factors such as raw material availability, production capacity, market demand, and cost constraints, firms can determine the most efficient product mix that maximizes profits or minimizes costs.

Linear programming can help paint manufacturing firms in Port Harcourt: Optimize production schedules to meet customer demand efficiently, allocate resources such as labor, raw materials, and equipment effectively, Determine the optimal pricing strategy based on cost structures and market conditions, Identify opportunities for cost reduction and profit maximization through sensitivity analysis. Overall, the application of linear programming theory can enhance decision-making processes within paint manufacturing firms in Port Harcourt by providing quantitative tools for optimizing operations and improving overall performance.

METHODOLOGY

This study adopted a correlational survey research design. The population of the study was 10 selected paint manufacturing firms in Port Harcourt as retrieved from Nigerian business directory (2024). The population of the study include Berger Paints Nigeria Plc, Portland Paints & Products Nigeria Plc, DN Meyer Plc, Chemstar Paints Industry Nigeria Limited, Eagle Paints Nigeria Limited, Dulux Paints, President Paints Nigeria Limited, Crown Paints Nigeria Plc, Finecoat Paints and Prestige Paints Limited. 3 managers were selected from each firm multiplied by 10 firms gives us a total of 30 respondents. Structured questionnaire was used in data collection. The reliability of empirical measurement is indicated by the internal consistency, one of the most commonly used indicators of internal consistency is Cronbach's alpha coefficient.

Questionnaire item statements with Cronbach's alpha reliability coefficient below the 0.70 threshold were eliminated. The test-re-test method was used. 5 copies of the questionnaire instrument were issue and some later same copies were issue through electronic media. The results were used in computation using Cronbach's alpha test of reliability.

Table 1: Reliability Statistics

Cronbach's Alpha	N of Items
.804	6

Source: Researcher Computation via SPSS Version 25

The result of the Cronbach's Alpha reliability test indicates .804 which is above .70 which implies that the items are reliable. Pearson product moment correlation was used to test the hypotheses using SPSS (statistical package social sciences).

Data Analysis

HO_1: There is no significant relationship between Ellipsoid Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.

Table 2: Correlations on Ellipsoid Linear Programming and Product Mix

		Ellipsoid Linear Programming	Product Mix
Ellipsoid Linear Programming	Pearson Correlation	1	.656**
	Sig. (2-tailed)		.000
	N	30	30
Product Mix	Pearson Correlation	.656**	1
	Sig. (2-tailed)	.000	
	N	30	30
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 2 Correlations on Ellipsoid Linear Programming and Product Mix revealed there is a significant relationship between Ellipsoid Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt where R. .656 = .000 leading to acceptance of alternate hypothesis: There is a significant relationship between Ellipsoid Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.

HO_2: There is no significant relationship between Graphical method Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.

Table 3: Correlations on Graphical method Linear Programming and Product Mix

		Graphical method Linear Programming	Product Mix
Graphical method Linear Programming	Pearson Correlation	1	.711**
	Sig. (2-tailed)		.000
	N	30	30
Product Mix	Pearson Correlation	.711**	1
	Sig. (2-tailed)	.000	
	N	30	30
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 3 Correlations on Graphical method Linear Programming and Product Mix revealed there is a significant relationship between Graphical method Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt where R. .711 = .000 leading to acceptance of alternate hypothesis: There is a significant relationship between Graphical method Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.

HO_3: There is no significant relationship between Simplex Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.

Table 4: Correlations on Simplex Linear Programming and Product Mix

		Simplex Linear Programming	Product Mix
Simplex Linear Programming	Pearson Correlation	1	.762**
	Sig. (2-tailed)		.000
	N	30	30
Product Mix	Pearson Correlation	.762**	1
	Sig. (2-tailed)	.000	
	N	30	30
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 4 Correlations on Simplex Linear Programming and Product Mix revealed there is a significant relationship between Simplex Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt where R. .762 = .000 leading to acceptance of alternate hypothesis: There is a significant relationship between Simplex Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.

DISCUSSION OF FINDINGS

Table 2 Correlations on Ellipsoid Linear Programming and Product Mix revealed there is a significant relationship between Ellipsoid Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt where R. .656 = .000 leading to acceptance of alternate hypothesis: There is a significant relationship between Ellipsoid Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt. Table 3: Correlations on Graphical method Linear Programming and Product Mix revealed there is a significant relationship between Graphical method Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt where R. .711 = .000 leading to acceptance of alternate hypothesis: There is a significant relationship between Graphical method Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt. Table 4: Correlations on Simplex Linear Programming and Product Mix revealed there is a significant relationship between Simplex Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt where R. .762 = .000 leading to acceptance of alternate hypothesis: There is a significant relationship between Simplex Linear Programming and Product Mix of paint manufacturing firms in Port Harcourt.

Similarly**,** Furthermore, a study by Oladejo *et al*., (2019) titled "Application of Linear Programming Techniques in Product Mix Optimization: A Case Study of a Paint Manufacturing Company" investigated how linear programming techniques can be applied to optimize product mix decisions in a Nigerian paint manufacturing company. The population for this study was a specific paint manufacturing company, with data collected through surveys and financial records as instruments for data collection. The authors used linear programming as the method of data analysis to determine the optimal product mix for maximizing profits. The findings demonstrated that utilizing linear programming methods can lead to more informed decision-making processes regarding product mix strategies. The study concluded that implementing these techniques can result in enhanced operational efficiency and profitability for paint manufacturing firms.

Also, Moreover, a study by Akinola *et al*., (2017) titled "Linear Programming Model for Optimal Product Mix Planning: A Case Study of a Paint Manufacturing Company" examined how linear programming models can be utilized for optimal product mix planning in Nigerian paint manufacturing companies. The population included multiple paint manufacturing firms, with data collected through interviews, surveys, and financial reports as instruments for data collection. The researchers employed linear programming techniques to analyze the data and determine the most profitable product mix combinations. The findings highlighted that using linear programming models can help companies achieve cost savings and maximize profits through efficient resource allocation. The study concluded that integrating these optimization tools into decision-making processes can lead to improved competitiveness and sustainability within the industry.

CONCLUSION

In conclusion, Linear programming is a powerful mathematical tool that can be effectively utilized by paint manufacturing firms in Port Harcourt to optimize their product mix and maximize profits. By formulating the problem as a linear programming model, firms can determine the optimal combination of different paint products to produce based on factors such as demand, production costs, and resource constraints. Through the use of linear programming techniques, firms can make informed decisions regarding pricing strategies, production levels, and inventory management to enhance their competitiveness in the market.

RECOMMENDATIONS

The following recommendations were drawn from the findings of the study for paint manufacturing firms:

1. Conduct a thorough analysis of market demand for different types of paint products to identify profitable opportunities for product mix optimization.
2. Utilize linear programming software tools to develop and solve mathematical models that represent the firm's production processes and constraints accurately.
3. Regularly review and update the linear programming model to reflect changes in market conditions, input costs, and other relevant factors affecting product mix decisions.
4. Collaborate with suppliers and distributors to streamline supply chain operations and ensure timely delivery of raw materials and finished products.

REFERENCES

- Adekanmbi, J. (2018). Application of Linear Programming in Product Mix Optimization: A Case Study of a Paint Manufacturing Company in Nigeria. *International Journal of Engineering Research & Technology*, *6*(3), 22-53.
- Adetunji, O. (2020). Enhancing Profitability Through Linear Programming: A Case Study of Paint Manufacturing Industry. *Journal of Management Sciences*, *3*(7), 15-44.
- Akinola, M. (2017). Linear Programming Model for Optimal Product Mix Planning: A Case Study of a Paint Manufacturing Company. *Operations Research Perspectives journal*, *3*(7), 24-59.
- Oladejo, F. (2019). Application of Linear Programming Techniques in Product Mix Optimization: A Case Study of a Paint Manufacturing Company. *Journal of Business & Economic Studies*, *5*(8), 22–49.
- Oyedele, L. (2016). Optimization of Paint Production Formulation Using Linear Programming Model. *Journal of Industrial Engineering & Management*, *7*(9), 22–59.