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The analysis of " Man, Machine, Material, Method and Environment"(4M1E) on the cost of manufacturing products

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Abstract

This paper analyzes the impact of "Man, Machine, Material, Method and Environment" (4M1E) on the cost of manufacturing products. The research team aims to achieve cost reduction and competitive advantage by eliminating or optimizing non-value-added operations. The paper provides an introduction to the background and motivation of the study, research problem and objectives, and research framework. The objectives of the study include studying the proportion of "method and environment" in product cost and deducing the actual cost of the product, analyzing the cost impact index of 4M1E in product production, and promoting enterprise models for production management optimization, marketing strategy optimization, and environmental optimization to enhance enterprise competitiveness.

Keywords: 4M1E; cost analysis; Product cost optimization; Non-value-added operations

1 INTRODUCTION

1.1 Background

With the rapid advancement of the digital economy, the concept of "Man, Machines, Materials, Methods, and Environments" (4M1E) and its significance have gained widespread recognition. Many industries and enterprises have started to quantify and measure the 4M1E factors. They are increasingly concerned about the impact of these factors on quality control of their products and on safety management within the organization.

In the realm of 4M1E research, China has also made significant contributions. For instance, Zhang Yun has utilized the 4M1E model in university physics laboratory teaching, where basic experiments are designed and conducted to demonstrate the application of 4M1E in teaching physics. This serves as an example of how the concept can be practically implemented in educational settings.

Another notable study conducted by Du Wei focuses on the application of 4M1E in enterprise 6S management. The research underscores the importance of 4M1E in optimizing the management of enterprises. Through the use of real-life company examples, Du Wei provides valuable insights and program recommendations for implementing 4M1E in practice.

Overall, the research background highlights the growing recognition of the importance of 4M1E in various industries and enterprises. It showcases the efforts made in China to explore and apply the concept, both in educational and practical contexts, with the aim of improving product quality control, safety management, and overall organizational efficiency.

1.2 Motivation：

The primary motivation of this study lies in understanding the impact of variables such as "Man, Machines, Materials, Methods, and Environments" (4M1E) on product cost. The researchers aim to investigate how these variables influence the cost of manufacturing products and, consequently, how cost reduction or optimization can be achieved by eliminating or improving non-value-added operations. By delving into this relationship, the study seeks to provide insights that can give organizations a competitive advantage in terms of product cost.

The cost of manufacturing products is a critical factor that directly affects a company's profitability and competitiveness in the market. By comprehending how the different elements of 4M1E contribute to the overall cost, organizations can identify areas for improvement and take targeted actions to enhance cost efficiency. Eliminating non-value-added operations, which are activities that do not contribute to the final value of the product, can lead to significant cost savings and resource optimization.

By achieving cost reduction or optimization through the understanding and management of 4M1E variables, organizations can gain a competitive edge in the market. Lowering production costs can enable companies to offer their products at more competitive prices, attract more customers, and potentially increase market share. Moreover, optimizing operations can enhance productivity, improve product quality, and streamline processes, leading to improved customer satisfaction and loyalty.

Overall, the motivation behind this study is to explore the relationship between 4M1E variables and product cost, with the ultimate goal of enabling organizations to eliminate or optimize non-value-added operations and gain a competitive advantage in terms of product cost.

1.3 Research Contribution

1.This study applies the concept and meaning of "Man, Machines, Materials, Methods, and Environments" (4M1E) to the quality control and safety management of enterprises, providing a quantitative and research foundation for relevant fields.

2.By analyzing the impact of "4M1E" variables on product cost, the study investigates how to achieve cost reduction and competitive advantage in product cost through the elimination or optimization of non-value-added operations.

3.This research fills the research gap in the understanding of "4M1E" concept and its impact on product cost and provides theoretical and practical guidance for decision-making in related fields.

1.4 Research Problem

1.4.1 Lack of data collection on "4M1E" factors

Many companies fail to systematically collect and record data on the "Man, Machines, Materials, Methods, and Environments" (4M1E) factors. This leads to a lack of comprehensive understanding and effective management of these factors. The research problem is to investigate why most companies do not collect and utilize 4M1E data and propose solutions to drive the development in this area.

1.4.2 Underestimation of product costs

There is often a tendency to underestimate product costs. This may be due to companies neglecting the impact of 4M1E factors on costs or not fully considering various aspects related to product manufacturing and operations. The research problem is to explore why product costs are underestimated and seek solutions to accurately assess and manage product costs.

1.4.3 Ignoring the impact of Method and Environment on integrated costs

The impact of Method (production processes and techniques) and Environment (conditions and environmental factors of the production site) on integrated costs is often overlooked when studying product costs. These two factors have significant implications for costs but are frequently disregarded. The research problem is to study the influence of Method and Environment on integrated costs and explore how to better consider and manage these factors.

1.4.4 Neglecting the interplay between the five factors of 4M1E

The interplay between the five factors of 4M1E is often ignored in research. These factors are interrelated and mutually influence each other in practical applications, and neglecting their interplay can lead to misunderstandings in cost and efficiency optimization. The research problem is to delve into understanding the interplay between the five factors of 4M1E and explore how to incorporate it into cost management and efficiency optimization frameworks.

By addressing the above research problems, valuable insights can be provided to managers and decision-makers, helping them better understand and manage the impact of 4M1E factors on product costs and organizational competitiveness.

1.5 Research Objectives

1.5.1 To examine the contribution of "Method and Environment" factors to product costs and determine the actual cost of the product.

The objective of this research is to investigate the proportion of costs attributed to the "Method and Environment" factors in the production of a product. By analyzing these factors, the study aims to deduce the actual cost of the product, taking into account the specific impact of Method and Environment on cost allocation.

1.5.2 To assess the cost impact index of 4M1E variables in product manufacturing.

This research objective focuses on evaluating the cost impact index of the 4M1E variables in the production process. The study aims to quantify and analyze the relative significance of each variable's impact on production costs, providing insights into cost optimization strategies.

1.5.3 To enhance enterprise competitiveness through optimized production management models, marketing strategies, and environmental practices.

The objective of this research is to promote the development and implementation of optimized production management models, marketing strategies, and environmental practices within enterprises. By identifying and recommending effective approaches, the study aims to enhance the competitiveness of organizations in the market. This includes exploring strategies for streamlining operations, improving marketing techniques, and adopting sustainable environmental practices.

By achieving these research objectives, valuable insights and recommendations can be provided to organizations, enabling them to improve cost management, optimize production processes, refine marketing strategies, and integrate sustainable practices.

2 LITERATURE REVIEW

2.1 Introduction

With the rapid development of the digital economy, there has been a widespread recognition of the importance of the "Man, Machine, Material, Method, Environment" (4M1E) concept and its relevance in various fields. Many industries and companies have started quantifying and measuring the 4M1E factors and are increasingly focused on their impact on product quality control and internal safety management. The cost of manufacturing a product is a key factor that directly affects a company's profitability and market competitiveness. By understanding how each element of 4M1E contributes to overall costs, organizations can identify areas for improvement and take targeted actions to enhance cost-effectiveness. Eliminating non-value-added operations can result in significant cost savings and resource optimization. By understanding and managing the 4M1E variables to achieve cost reduction or optimization, organizations can gain a competitive advantage in the market. Lowering production costs allows a company to offer products at a more competitive price, attracting more customers and potentially increasing market share. Additionally, optimizing operations can improve productivity, enhance product quality, optimize processes, and thereby increase customer satisfaction and loyalty.

While some research has explored the impact of 4M1E factors on product costs and the potential for gaining a competitive advantage through the elimination or optimization of non-value-added operations, there are still gaps in the existing literature. Therefore, further research on the relationship between 4M1E variables and production efficiency, cost control strategies, environmental sustainability, technological innovation and automation, and supply chain management can provide more specific guidance and recommendations for practice. Filling these knowledge gaps can help organizations better understand and harness the potential of 4M1E to improve product cost-effectiveness and competitiveness.

In related research, some scholars have already explored the application of 4M1E factors in specific domains. For example, Jun Zhang et al. (2013) conducted an in-depth study on quality management in prefabricated construction through factor analysis using the ISM-BN method. They developed an assessment model and employed backward reasoning, sensitivity analysis, and key factor analysis methods. The study found that the construction phase had the greatest impact on building quality, and insufficient sense of responsibility among construction personnel was an important factor to be controlled. The research also suggested that combining the ISM-BN model with actual engineering projects could be used to identify key factors influencing quality.

Furthermore, Ying Wu and Pengzhen Lu (2022) conducted a comparative analysis and evaluation of construction risks in bridge projects using the 4M1E analysis method and various artificial intelligence algorithms. They proposed a bridge construction risk assessment method based on various AI algorithms and found the effectiveness of the Random Forest algorithm and other algorithms in assessing bridge construction risks.

Additionally, Mao Yihua and Xu Tuo (2011) used a structural equation model to investigate the impact of 4M1E on engineering quality. The study found that people, environment, and machines were key factors influencing engineering quality, while materials and methods had relatively smaller impacts. The research also highlighted the importance of focusing on personnel training and skill development to enhance engineering quality.

The above studies represent only a fraction of the applications of 4M1E factors in specific domains, and there are still many other areas that can be further explored. For example, in the manufacturing industry, researchers can delve into how optimizing the 4M1E factors can improve production efficiency and product quality, such as through the application of automation and intelligent manufacturing technologies. In logistics and supply chain management, researchers can investigate how optimizing people, machines, and environmental factors can enhance the efficiency and sustainability of the supply chain.

In conclusion, the 4M1E concept holds great potential for application in various domains. Through in-depth research and understanding of the relationship between 4M1E factors and costs, quality, efficiency, and safety, organizations can better leverage these factors to enhance their overall competitiveness and sustainable development capabilities.

2.2 The Research Literature Gap Area

In the field of analyzing the impact of the variables "Man, Machines, Materials, Methods, and Environments" (4M1E) on product cost and achieving competitive advantage through the elimination or optimization of non-value-added operations, there exists a research literature gap that has not been specifically addressed.

While previous studies have recognized the importance of considering the 4M1E factors in relation to product cost and competitiveness, there remains a need for more in-depth research to fill the existing gap in the literature. The specific research gap within this field has not been clearly identified or specified.

To address this literature gap, future research could focus on several aspects. Firstly, it could delve into the quantitative analysis of the individual contributions of each 4M1E factor to product cost, providing a more detailed understanding of their relative significance. Additionally, further investigation could be conducted to explore the interplay and synergies among these variables, as their combined effect on cost optimization and competitive advantage might differ from their individual impacts.

Furthermore, the research literature gap could be addressed by examining the specific strategies and approaches that organizations can adopt to effectively eliminate or optimize non-value-added operations within the 4M1E framework. This could involve exploring case studies, conducting empirical research, or developing practical frameworks and guidelines.

Overall, the research literature gap within the field of analyzing the impact of 4M1E variables on product cost and achieving competitive advantage through the elimination or optimization of non-value-added operations presents an opportunity for future studies to contribute valuable insights and expand our understanding of this topic.

3 METHODOLOGY

The study employed various research methods, including literature review, hypothesis formulation, data analysis, correlation analysis, and regression analysis, to investigate the impact of "Man, Machine, Material, Method, and Environment" on product costs.

Firstly, through a comprehensive literature review, the researchers extensively surveyed and analyzed relevant literature in the field to understand the existing research findings and knowledge. This enabled the researchers to gain insights into the application of 4M1E in various industries and organizations and comprehend the potential effects of these factors on product costs.

Secondly, guided by the formulated hypotheses, the researchers collected product data from two companies, including labor costs, machine costs, material costs, method costs, and environmental costs. These data formed the basis of the study. The researchers performed data analysis using statistical methods, including correlation analysis and regression analysis. Correlation analysis revealed the relationships between different variables, while regression analysis established mathematical models to investigate the extent of the impact of 4M1E on product costs.

Through regression analysis, the researchers were able to determine the influence of 4M1E on product costs and assess the relative importance of each factor. These analytical findings provided valuable decision-making insights for enterprises, aiding in optimizing production management, formulating marketing strategies, and improving environmental management, thereby enhancing competitiveness and efficiency.

In conclusion, the study employed various research methods, including literature review, hypothesis formulation, data analysis, correlation analysis, and regression analysis, to comprehensively investigate the impact of 4M1E on product costs. These methods facilitated the quantification and analysis of relationships between different variables, providing theoretical and practical guidance for decision-making in enterprises.

3.1 Research Framework

Step 1: Calculation of product costs using traditional methods

In this step, the product costs are attributed to labor, machinery, and materials using traditional methods.

Step 2: Application of the 4M1E cost analysis method

The 4M1E cost analysis method, which considers Man, Machine, Material, Method, and Environment, is applied to allocate the product costs to these five factors.

Step 3: Determination of further research objectives

This step aims to achieve the following objectives:

1.Investigate the proportion of "Method and Environment" in product costs and derive the actual cost of the products.

2.Analyze the cost impact index of 4M1E in product manufacturing.

3.Enhance production management, marketing strategies, and environmental optimization to improve the competitiveness of enterprises.

Step 4: Establishment of the original product cost analysis method

This step involves developing a function for analyzing the product costs using the traditional approach.

Step 5: Development of the 4M1E product cost analysis method

This step involves developing a function for analyzing the product costs based on the 4M1E method. The function takes into account the comprehensive costs associated with Man, Machine, Material, Method, and Environment.

Step 6: Model validation and application

This step includes the validation of the model and testing its effectiveness using simulated data. Additionally, real-world examples and parameter estimation are used to derive the combined costs of the new 4M1E model. Based on the model results, adjustments to marketing strategies are made to address negative indices and strengthen positive indices.

Overall, this research framework aims to analyze product costs using both traditional methods and the 4M1E approach. It seeks to explore the impact of different factors on product costs and proposes models for optimizing production management, marketing strategies, and environmental considerations to enhance the competitiveness of enterprises.

As Figure 1.

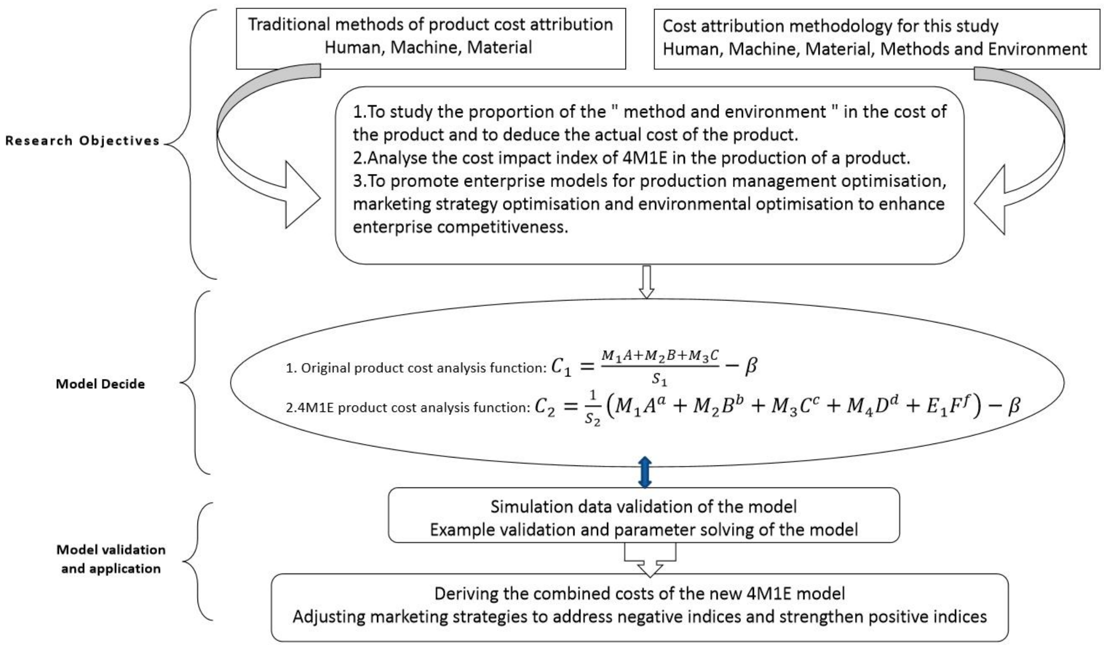

Figure 1. Research Framework

3.2 Hypotheses

H1: The product cost obtained by the 4M1E analysis method(C2) better reflects the production cost of the enterprise's products than the product cost obtained by the original statistical method(C1).

H2: There are instances where the cost of the product derived from the 4M1E cost analysis method is higher than the selling price.

H3: The gross profit margin of the enterprise is overestimated in the original product cost statistics and deviates from the expected gross profit margin of the enterprise.

H4: There is a correlation of significance between the product cost calculated by the 4M1E model for a 10% downward shift in the firm's expected gross profit margin.

H5: The product cost calculated by the 4M1E model is more conducive to the decision making of the firm's pricing strategy.

3.3 Definition of variables

C_1: Combined product cost, traditional methods of analysis (Man, Machine, Material)

r_1: Integrated product cost elasticity index, traditional analysis method

C_2: Consolidated cost of products, method of analysis for this study (4M1E)

r_2: Integrated product cost elasticity index, the method of analysis in this study(4M1E)

M_1: Labour costs in the production of products

a: Labour cost elasticity index in the production of products

A: Coefficient of elasticity of labour costs in the production of products

M_2: Costs of depreciation, maintenance, etc. of machinery in the production of products

b: Cost elasticity index for machinery depreciation, maintenance, etc. in the production of products

B: Cost elasticity coefficients for depreciation, maintenance, etc. of machinery in the production of products

M_3: Costs of direct materials, auxiliary materials, packaging, etc. in the production process of products

c: Cost elasticity index of direct materials, auxiliary materials, packaging, etc. in the production process of a product

C: Cost elasticity coefficients for direct materials, auxiliary materials, packaging, etc. in the production of products

M_4: Costs of related processes and operations in the production of a product

d: Cost elasticity indices for related processes, process operations, etc. in the production of a product

D: Cost elasticity coefficients for related processes, process operations, etc. in the production of products

E_1: Costs of providing a working environment for employees in the production process, storage of semi-finished products for turnover, etc.

f: Cost elasticity indices for the cost of providing a working environment for employees in the production process, semi-finished products for storage turnover, etc.

F: Cost elasticity coefficients for the cost of providing a working environment for employees in the production of products, semi-finished products for storage turnover, etc.

3.4 Data description and data collection

The Variable description and data sources as table 1.

Table 1. Variable Description and Data Sources

Name	Description	Data Sources
Total Costs C_1	In traditional accounting, this is obtained by adding up the costs of people, materials and cost of production.	Material Cost+Man Cost+Machine Cost+Manufacturing Cost(Others)

4M1E Cost C_2	The production cost of the new product calculated by the 4M1E model of this study.	$C_2 = C_1 + C * Co_4 * D^d + C * Co_E * F^f - \beta$
Sales Unit Price	Average sales of this product from January to August 2023	Average sales of this product from January to August 2023
Expected Gross Profit	Expected gross profit of the enterprise	Company A is 59% Company B is 48%
4M1E Profit	The discrepancy of the production cost of the new product calculated by the 4M1E model of this study and Sales Unit Price	Sales Unit Price-C_2
Cross Profit	The discrepancy of Total Costs and Sales Unit Price	Sales Unit Price-C_1
Number of Corrections β	It is not possible to calculate the cost of production of other products to "man, machine and material".	β=Manufacturing Cost(Others)

The following data for 2023 Company A's 2,292 products and Company A's 167 products are summarized: Total Costs, Material Cost, Man Cost, Machine Cost, Manufacturing Cost(Others), Sales Unit Price, Cross Profit, as Figure 2 and Figure 3.

Products Name	Product Model	Total Costs	Material Cost	Man Cost	Machine Cost	Manufacturing Cost(Others)	Sales Unit Price	Cross Profit	Expected Gross Profit
CANBUS Side Outlet Level Magnetic Scale	1MN04287	437.60	326.58	49.49	12.31	49.22	1,185.76	859.18	699.60
CANBUS Side Outlet Level Magnetic Scale	1MN05148	458.80	351.10	60.94	9.35	37.41	1,304.75	953.65	769.80
CANOPEN External Integrated Displacement Sensor	1MN02109	651.62	515.62	54.57	16.29	65.14	2,025.64	1,510.02	1,195.13
CANOPEN External Integrated Displacement Sensor	1MN01305	805.44	683.61	51.92	13.98	55.93	3,153.85	2,470.24	1,860.77
CANOPEN External Integrated Displacement Sensor	1MN05119	418.06	325.73	46.13	9.24	36.96	669.00	343.27	394.71
CANOPEN External Integrated Displacement Sensor	1MN05236	407.80	283.14	52.67	14.40	57.59	450.00	166.86	265.50
CANOPEN External Integrated Displacement Sensor	1MN05237	441.58	279.49	59.47	20.52	82.10	438.00	158.51	258.42
CANOPEN External Integrated Displacement Sensor	1MN05268	389.33	272.73	51.73	12.97	51.90	438.00	165.27	258.42
CANOPEN External Integrated Displacement Sensor	1MN05832	433.55	313.82	51.84	13.58	54.31	577.00	263.18	340.43
CANOPEN External Integrated Displacement Sensor	1MN06231	377.23	266.54	48.16	12.51	50.02	394.00	127.46	232.46
CANOPEN External Integrated Displacement Sensor	1MN08198	418.25	296.50	52.60	13.83	55.32	492.00	195.50	290.28
CANOPEN External Integrated Displacement Sensor	1MN09087	587.03	456.12	55.29	15.13	60.50	2,345.13	1,889.01	1,383.63
GJ Displacement Tape	1MN02052	296.13	192.79	48.50	10.97	43.87	1,150.44	957.65	678.76
GJ Displacement Tape	1MN04562	329.17	211.33	49.58	13.65	54.61	1,202.40	991.07	709.42
GJ Displacement Tape	1MN05814	370.95	210.95	58.61	20.28	81.12	929.20	718.26	548.23
GJ Displacement Tape	1MN06485	389.94	279.85	48.64	12.29	49.16	2,017.70	1,737.85	1,190.44
GJ Displacement Tape	1MN06486	357.74	247.66	48.67	12.29	49.13	1,699.12	1,451.46	1,002.48
GJ Displacement Tape	1MN07134	317.03	212.42	45.30	11.86	47.45	681.42	469.00	402.04
GJ Displacement Tape	1MN07555	305.00	197.16	46.87	12.20	48.78	681.42	484.26	402.03
GJ Displacement Tape	1MN08163	473.79	316.88	56.64	20.05	80.22	1,575.22	1,258.34	929.38
GJ Displacement Tape	1MN08164	419.63	262.68	56.67	20.06	80.23	1,238.94	976.27	730.97
GJ Displacement Tape	1MN08165	442.87	285.94	56.66	20.06	80.22	1,274.34	988.40	751.86
GJ Displacement Tape	1MN08307	345.72	242.37	48.52	10.97	43.87	676.99	434.62	399.42
GJ Displacement Tape	1MN08308	340.73	237.39	48.52	10.97	43.87	676.99	439.61	399.42
GJ Displacement Tape	1MN08331	298.89	195.55	48.52	10.97	43.87	676.99	481.45	399.42
GJ Displacement Tape	1MN08349	298.49	195.15	48.50	10.97	43.87	1,150.44	955.29	678.76
GJ Displacement Tape	1MN08503	395.76	291.61	45.25	11.78	47.12	1,106.19	814.58	652.65
GJ Displacement Tape	1MN08504	364.62	260.47	45.26	11.78	47.12	1,008.85	748.39	595.22
GJ Displacement Tape	1MN08505	388.99	284.84	45.25	11.78	47.12	1,061.95	777.11	626.55
GJ Displacement Tape	1MN08506	410.76	306.61	45.25	11.78	47.12	1,168.14	861.53	689.20

Figure 2. Sample data for Company A (partial data)

Products Name	Product Model	Total Costs	Material Cost	Man Cost	Machine Cost	Manufacturing Cost (Others)	Sales Unit Price	Cross Profit	Expected Gross Profit
3MPa Oil Pressure Sensor	1KN00260	64.22	33.35	10.92	9.97	9.97	57.79	-6.43	30.82
KY22 Industrial Pressure Transmitters	1KN00073	134.18	69.83	21.75	21.30	21.30	258.62	10.22	64.41
KY22 Rail Pressure Transmitter	1KA00250	63.83	32.79	12.02	9.52	9.52	46.00	4.57	30.64
KY22 Rail Pressure Transmitter	1KA00266	62.24	43.91	9.44	4.44	4.44	46.00	2.13	29.87
KY22 Rail Pressure Transmitter	1KA00276	48.97	30.32	5.13	6.76	6.76	46.00	3.25	23.51
KY22 Rail Pressure Transmitter	1KA00279	42.24	31.01	6.27	2.48	2.48	46.00	1.19	20.27
KY22 Rail Pressure Transmitter	1KA00281	51.82	33.00	5.08	6.87	6.87	46.00	3.30	24.87
KY22 Rail Pressure Transmitter	1KA00284	60.60	34.74	6.11	9.87	9.87	48.83	4.74	29.09
KY22 Rail Pressure Transmitter	1KA00300	43.98	32.95	6.03	2.50	2.50	46.00	1.20	21.11
KY22 Rail Pressure Transmitter	1KA00306	40.60	30.47	5.40	2.37	2.37	46.00	1.14	19.49
KY22 Rail Pressure Transmitter	1KA00323	41.14	31.83	5.25	2.03	2.03	46.00	0.98	19.75
KY22 Rail Pressure Transmitter	1KA00326	72.75	35.27	7.69	14.89	14.89	48.24	7.15	34.92
KY22 Rail Pressure Transmitter	1KA00361	65.63	35.51	6.28	11.92	11.92	48.74	5.72	31.50
KY22 Rail Pressure Transmitter	1KA00374	50.78	32.60	7.18	5.50	5.50	46.00	2.64	24.37
KY22 Rail Pressure Transmitter	1KA00377	51.85	30.38	4.96	8.26	8.26	46.00	3.96	24.89
KY22 Rail Pressure Transmitter	1KA00378	50.28	32.08	7.18	5.51	5.51	46.00	2.65	24.13
KY22 Rail Pressure Transmitter	1KA00381	66.51	35.11	7.29	12.05	12.05	48.74	5.79	31.92
KY22 Rail Pressure Transmitter	1KN00249	47.57	32.67	4.04	5.43	5.43	53.10	2.61	22.83
KY22 Rail Pressure Transmitter	1KN00335	50.12	27.05	5.67	8.70	8.70	53.10	4.18	24.06
KY22 Oil Pressure Transmitter	1KA00241	74.58	36.91	8.16	14.76	14.76	64.60	7.08	35.80
KY22 Oil Pressure Transmitter	1KA00365	71.34	31.60	8.50	15.62	15.62	55.75	7.50	34.24
KY22 Mining Pressure Transmitter	1KN00090	95.47	55.75	10.93	14.39	14.39	366.11	6.91	45.82
KY22 Mining Pressure Transmitter	1KN00094	101.76	57.36	17.08	13.66	13.66	345.14	6.56	48.84
KY22 Mining Pressure Transmitter	1KN00273	203.26	108.00	19.01	38.12	38.12	225.77	18.30	97.56
KY22 Mining Pressure Transmitter	1KN00339	175.38	110.69	19.57	22.56	22.56	225.77	10.83	84.18
KY22 Mining Pressure Transmitter	1KN00341	134.46	85.23	13.91	17.66	17.66	392.26	8.48	64.54
KY22 Mining Pressure Transmitter	1KN00366	180.42	93.51	19.64	33.64	33.64	225.77	16.14	86.60
KY22 Mining Pressure Transmitter	1KN00446	127.75	89.48	10.11	14.08	14.08	225.77	6.76	61.32
KY22 Gas Pressure Transmitter	1KA00231	76.26	32.60	10.08	16.79	16.79	106.19	8.06	36.61
KY22 Gas Pressure Transmitter	1KA00232	39.99	28.03	4.29	3.84	3.84	55.75	1.84	19.20

Figure 3. Sample data for Company B (partial data)

3.5 Model design

Through the parameterisation, indexation and functionalisation of 4M1E, to establish the analysis based on the cost of traditional products, the comprehensive cost index change of 4M1E products and the model of cost change in this study, to achieve the derivation of the enterprise to optimise the production management, marketing strategy optimisation, environmental optimisation model to enhance the competitiveness of enterprises.

(1) Original product cost analysis function:

$$C_1 = \frac{1}{S_1}(M_1 * A + M_2 * B + M_3 * C) - \beta \qquad \text{Eq. 1}$$

(2) 4M1E product cost analysis function:

$$C_2 = \frac{1}{S_2}(M_1 * A^a + M_2 * B^b + M_3 * C^c + M_4 * D^d + E_1 * F^f) - \beta \qquad \text{Eq. 2}$$

In the course of the investigation, the degree of influence between the factors was recorded as:

Significance of values a,b,c,d,f:

Significant positive impact: +2, Weak positive impact: +1, No effect: 0, Significant negative impact:-2, Weak negative impact: -1.

Nowadays, in the popular models of average product cost analysis, people directly do not calculate the cost of the law and the environment.That is M_4=0 and E_1=0,β=0.The resulting average product costing formula is:

Original product cost analysis function as (Eq. 2):

In 4M1E Model, if we use the same set of production data, the total cost of production is equal. That is: $S_1=S_2=S$

4M1E product cost analysis function will be:

$$C_2 = C_1 + \frac{1}{S}(M_4 * D^d + E_1 * F^f) - \beta \quad \text{Eq. 3}$$

Once Total Costs is known, The contribution of Method and environmental factors to the total cost can also be obtained through expert surveys.

$$C_2 = C_1 + \frac{M_4 * D^d}{S} + \frac{E_1 * F^f}{S}) - \beta \quad \text{Eq. 4}$$

Derived after conversion to average production cost of individual products:

$$C_2 = C_1 + \frac{M_4}{C} * D^d + \frac{E_1}{C} * F^f) - \beta \quad \text{Eq. 5}$$

C is Total Costs, $\frac{M_4}{C}$ is the contribution of Method (Co_4), $\frac{E_1}{C}$ is the contribution of Environment(Co_E), β is the per Manufacturing Cost(Others).

$$C_2 = C_1 + \mathrm{Co}_4 D^d * C + \mathrm{Co}_E F^f * C) - \beta \quad \text{Eq. 6}$$

3.6 Data analysis methods

3.6.1 Panel data analysis

The study, panel data of 2,292 products of Company A and 167 products of Company B, for products Name, Product Model, Total Costs, Material Cost, Man Cost, Machine Cost, Manufacturing Cost, Sales Unit Price, Cross Profit Expected, Gross Profit, 4M1E Cost, 4M1E Profit of 2023 were created and the research methodology of analysing the panel data was used.

3.6.2 Correlation analysis

Use correlation analysis to calculating the correlation coefficients between the variables, the strength and direction of the linear relationship between them can be determined. And it is possible to calculate the correlation coefficients between different variables and determine if there is a significant correlation to support or refute these hypotheses.

3.6.3 Regression analysis

Regression analysis can be used to develop mathematical models between variables and explore the relationship between independent variables (4M1E cost) and dependent variables (product cost, gross profit, etc.). Regression analysis allows for estimating the relationship between variables, predicting the value of the dependent variable, and assessing the degree of influence of the independent variable on the dependent variable.

3.7 Data preprocessing

3.7.1 Case data: A Company

As of August 2023, Company A has 12 departments, including the Production Department(PD), General Manager's Office(GMO), New Plant Construction Office(NPCO), Chief Engineer's Office(CENO), General Office(GO), Technology Department(TD), IT Department(IT), Chief Craftsman's Office(CCO), Production Scheduling and Management Department(PSM), Quality Management Office(QMO), Finance Department(FD), and Administration Department(AD).

In this study, an expert survey was conducted using the 4M1E model on the 12 departments mentioned above, with a total of 3 people selected from each department, including department managers and employees, and the following survey data, record as Eq. 7:

$$\begin{bmatrix} M_4 \\ E_1 \end{bmatrix} + \begin{bmatrix} M_1 \\ M_2 \\ M_3 \end{bmatrix} = \begin{bmatrix} M_4M_1 & E_1M_1 \\ M_4M_2 & E_1M_2 \\ M_4M_3 & E_1M_3 \end{bmatrix} \quad \text{Eq.7}$$

Significance of values a,b,c,d,f:

Significant positive impact: +2, Weak positive impact: +1, No effect: 0, Significant negative impact:-2, Weak negative impact: -1.

Production Department(PD), General Manager's Office(GMO), New Plant Construction Office(NPCO), Chief Engineer's Office(CENO), General Office(GO), Technology Department(TD), IT Department(IT), Chief Craftsman's Office(CCO), Production Scheduling and Management Department(PSM), Quality Management Office(QMO), Finance Department(FD), and Administration Department(AD), the results as table 2.

Table 2. The results of the research

Relation	PD	GMO	NPCO	CENO	GO	TD	IT	CCO	PSM	QMO	FD	AD	Ave-rage
M_4M_1	0.67	1.33	1.00	-0.67	1.00	0.67	0.67	0.33	1.00	1.00	0.33	0.67	0.67
M_4M_2	1.33	0.67	0.67	1.33	0.33	0.67	1.33	0.67	0.33	1.00	1.00	0.67	0.83
M_4M_3	1.00	0.67	0.67	0.33	0.67	1.00	1.67	1.00	1.00	1.00	2.00	1.33	1.00
$\mathbf{Co_4}\boldsymbol{D^d}$	1.00	0.89	0.78	0.33	0.67	0.78	1.22	0.67	0.78	1.00	1.11	0.89	0.85
E_1M_1	0.33	0.33	0.67	1.00	0.00	0.67	0.67	0.00	0.00	0.33	1.00	0.67	0.47
E_1M_2	0.67	-0.67	0.00	0.67	0.33	-1.33	0.67	-1.00	1.00	1.00	1.67	-0.67	0.19
E_1M_3	0.33	0.00	0.00	0.67	1.67	-0.67	0.33	1.67	0.33	0.33	2.00	1.33	0.67
$\mathbf{Co}_{\boldsymbol{E}}\boldsymbol{F^f}$	0.44	-0.11	0.22	0.78	0.67	-0.44	0.56	0.22	0.44	1.00	1.56	0.44	1.44

Filing the 4M1E Cost with the following formula (Eq. 6):

$$C_2 = C_1 + \mathrm{Co}_4D^d * C + \mathrm{Co}_EF^f * C) - \beta$$

C_1=C, values are as Total Costs, β is Manufacturing Cost(Others), Co_4D^d=0.85, Co_EF^f=1.44

After full filled data as Figure 4.

Products Name	Product Model	Total Costs	Material Cost	Man Cost	Machine Cost	Manufacturing Cost (Others)	Sales Unit Price	Cross Profit	Expected Gross Profit	4M1E Cost	4M1E Profit
CANBUS Side Outlet Level Magnetic Scale	1MN04287	437.60	326.58	49.49	12.31	49.22	1,185.76	859.18	699.60	451.83	733.93
CANBUS Side Outlet Level Magnetic Scale	1MN05148	458.80	351.10	60.94	9.35	37.41	1,304.75	953.65	769.80	487.92	816.83
CANOPEN External Integrated Displacement Sensor	1MN02109	651.62	515.62	54.57	16.29	65.14	2,025.64	1,510.02	1,195.13	680.96	1,344.68
CANOPEN External Integrated Displacement Sensor	1MN01305	805.44	683.61	51.92	13.98	55.93	3,153.85	2,470.24	1,860.77	866.30	2,287.55
CANOPEN External Integrated Displacement Sensor	1MN05119	418.06	325.73	46.13	9.24	36.96	669.00	343.27	394.71	441.72	227.28
CANOPEN External Integrated Displacement Sensor	1MN05236	407.80	283.14	52.67	14.40	57.59	450.00	166.86	265.50	409.34	40.66
CANOPEN External Integrated Displacement Sensor	1MN05237	441.58	279.49	59.47	20.52	82.10	438.00	158.51	258.42	423.51	14.49
CANOPEN External Integrated Displacement Sensor	1MN05268	389.33	272.73	51.73	12.97	51.90	438.00	165.27	258.42	393.88	44.12
CANOPEN External Integrated Displacement Sensor	1MN05832	433.55	313.82	51.84	13.58	54.31	577.00	263.18	340.43	442.11	134.89
CANOPEN External Integrated Displacement Sensor	1MN06231	377.23	266.54	48.16	12.51	50.02	394.00	127.46	232.46	381.91	12.09
CANOPEN External Integrated Displacement Sensor	1MN08198	418.25	296.50	52.60	13.83	55.32	492.00	195.50	290.28	423.58	68.42
CANOPEN External Integrated Displacement Sensor	1MN09087	587.03	456.12	55.29	15.13	60.50	2,345.13	1,889.01	1,383.63	611.65	1,733.48
GJ Displacement Tape	1MN02052	296.13	192.79	48.50	10.97	43.87	1,150.44	957.65	678.76	295.20	855.24
GJ Displacement Tape	1MN04562	329.17	211.33	49.58	13.65	54.61	1,202.40	991.07	709.42	322.29	880.11
GJ Displacement Tape	1MN05814	370.95	210.95	58.61	20.28	81.12	929.20	718.26	548.23	343.62	585.59
GJ Displacement Tape	1MN06485	389.94	279.85	48.64	12.29	49.16	2,017.70	1,737.85	1,190.44	397.32	1,620.38
GJ Displacement Tape	1MN06486	357.74	247.66	48.67	12.29	49.13	1,699.12	1,451.46	1,002.48	360.48	1,338.63
GJ Displacement Tape	1MN07134	317.03	212.42	45.30	11.86	47.45	681.42	469.00	402.04	315.55	365.87
GJ Displacement Tape	1MN07555	305.00	197.16	46.87	12.20	48.78	681.42	484.26	402.03	300.44	380.98
GJ Displacement Tape	1MN08163	473.79	316.88	56.64	20.05	80.22	1,575.22	1,258.34	929.38	462.27	1,112.95
GJ Displacement Tape	1MN08164	419.63	262.68	56.67	20.06	80.23	1,238.94	976.27	730.97	400.25	838.69
GJ Displacement Tape	1MN08165	442.87	285.94	56.66	20.06	80.22	1,274.34	988.40	751.86	426.87	847.47
GJ Displacement Tape	1MN08307	345.72	242.37	48.52	10.97	43.87	676.99	434.62	399.42	351.98	325.01
GJ Displacement Tape	1MN08308	340.73	237.39	48.52	10.97	43.87	676.99	439.61	399.42	346.27	330.72
GJ Displacement Tape	1MN08331	298.89	195.55	48.52	10.97	43.87	676.99	481.45	399.42	298.36	378.63
GJ Displacement Tape	1MN08349	298.49	195.15	48.50	10.97	43.87	1,150.44	955.29	678.76	297.90	852.54
GJ Displacement Tape	1MN08503	395.76	291.61	45.25	11.78	47.12	1,106.19	814.58	652.65	406.03	700.16
GJ Displacement Tape	1MN08504	364.62	260.47	45.26	11.78	47.12	1,008.85	748.39	595.22	370.37	638.48
GJ Displacement Tape	1MN08505	388.99	284.84	45.25	11.78	47.12	1,061.95	777.11	626.55	398.27	663.68
GJ Displacement Tape	1MN08506	410.76	306.61	45.25	11.78	47.12	1,168.14	861.53	689.20	423.20	744.94

Figure 4. Sample data for Company A after full filled (partial data)

3.7.2 Case data: B Company

As of August 2023, Company A has 10 departments, including Production Department(PD),General Manager's Office(GMO),Chief Engineer's Office(GENO),General Office(GO), Technology Department(TD), Chief Processor's Office(CPF), Production Scheduling Management Department(PSD), Quality Management Office(QMO), Finance Department(FD), Administration Department(AD).

The same methodology was used to conduct an expert survey of the managers and two staff representatives of these ten sections, and the statistics yielded the following results:

Average value for $\mathrm{Co}_4 D^d$ is: 1.21

Average value for $\mathrm{Co}_E F^f$ is: 0.89

Filing the 4M1E Cost with the following formula (as Eq. 6):

$$C_2 = C_1 + \mathrm{Co}_4 D^d * C + \mathrm{Co}_E F^f * C) - \beta$$

C_1=C, values are as Total Costs, β is Manufacturing Cost(Others), $\mathrm{Co}_4 D^d$=1.21, $\mathrm{Co}_E F^f$=0.89

After full filled data as Figure 5.

Products Name	Product Model	Total Costs	Material Cost	Man Cost	Machine Cost	Manufacturing Cost (Others)	Sales Unit Price	Cross Profit	Expected Gross Profit	4M1E Cost	4M1E Profit
3MPa Oil Pressure Sensor	1KN00260	64.22	33.35	10.92	9.97	9.97	57.79	-6.43	30.82	57.45	0.34
KY22 Industrial Pressure Transmitters	1KN00073	134.18	69.83	21.75	21.30	21.30	258.62	10.22	64.41	119.59	139.03
KY22 Rail Pressure Transmitter	1KA00250	63.83	32.79	12.02	9.52	9.52	46.00	4.57	30.64	57.51	-11.51
KY22 Rail Pressure Transmitter	1KA00266	62.24	43.91	9.44	4.44	4.44	46.00	2.13	29.87	60.91	-14.91
KY22 Rail Pressure Transmitter	1KA00276	48.97	30.32	5.13	6.76	6.76	46.00	3.25	23.51	44.66	1.34
KY22 Rail Pressure Transmitter	1KA00279	42.24	31.01	6.27	2.48	2.48	46.00	1.19	20.27	41.87	4.13
KY22 Rail Pressure Transmitter	1KA00281	51.82	33.00	5.08	6.87	6.87	46.00	3.30	24.87	47.54	-1.54
KY22 Rail Pressure Transmitter	1KA00284	60.60	34.74	6.11	9.87	9.87	48.83	4.74	29.09	53.76	-4.93
KY22 Rail Pressure Transmitter	1KA00300	43.98	32.95	6.03	2.50	2.50	46.00	1.20	21.11	43.67	2.33
KY22 Rail Pressure Transmitter	1KA00306	40.60	30.47	5.40	2.37	2.37	46.00	1.14	19.49	40.26	5.74
KY22 Rail Pressure Transmitter	1KA00323	41.14	31.83	5.25	2.03	2.03	46.00	0.98	19.75	41.17	4.83
KY22 Rail Pressure Transmitter	1KA00326	72.75	35.27	7.69	14.89	14.89	48.24	7.15	34.92	61.49	-13.25
KY22 Rail Pressure Transmitter	1KA00361	65.63	35.51	6.28	11.92	11.92	48.74	5.72	31.50	56.99	-8.25
KY22 Rail Pressure Transmitter	1KA00374	50.78	32.60	7.18	5.50	5.50	46.00	2.64	24.37	47.82	-1.82
KY22 Rail Pressure Transmitter	1KA00377	51.85	30.38	4.96	8.26	8.26	46.00	3.96	24.89	46.19	-0.19
KY22 Rail Pressure Transmitter	1KA00378	50.28	32.08	7.18	5.51	5.51	46.00	2.65	24.13	47.28	-1.28
KY22 Rail Pressure Transmitter	1KA00381	66.51	35.11	7.29	12.05	12.05	48.74	5.79	31.92	57.78	-9.04
KY22 Rail Pressure Transmitter	1KN00249	47.57	32.67	4.04	5.43	5.43	53.10	2.61	22.83	44.52	8.58
KY22 Rail Pressure Transmitter	1KN00335	50.12	27.05	5.67	8.70	8.70	53.10	4.18	24.06	43.93	9.17
KY22 Oil Pressure Transmitter	1KA00241	74.58	36.91	8.16	14.76	14.76	64.60	7.08	35.80	63.55	1.05
KY22 Oil Pressure Transmitter	1KA00365	71.34	31.60	8.50	15.62	15.62	55.75	7.50	34.24	59.29	-3.54
KY22 Mining Pressure Transmitter	1KN00090	95.47	55.75	10.93	14.39	14.39	366.11	6.91	45.82	85.85	280.26
KY22 Mining Pressure Transmitter	1KN00094	101.76	57.36	17.08	13.66	13.66	345.14	6.56	48.84	93.19	251.95
KY22 Mining Pressure Transmitter	1KN00273	203.26	108.00	19.01	38.12	38.12	225.77	18.30	97.56	175.30	50.47
KY22 Mining Pressure Transmitter	1KN00339	175.38	110.69	19.57	22.56	22.56	225.77	10.83	84.18	161.59	64.18
KY22 Mining Pressure Transmitter	1KN00341	134.46	85.23	13.91	17.66	17.66	392.26	8.48	64.54	123.52	268.74
KY22 Mining Pressure Transmitter	1KN00366	180.42	93.51	19.64	33.64	33.64	225.77	16.14	86.60	155.81	69.96
KY22 Mining Pressure Transmitter	1KN00446	127.75	89.48	10.11	14.08	14.08	225.77	6.76	61.32	120.06	105.71
KY22 Gas Pressure Transmitter	1KA00231	76.26	32.60	10.08	16.79	16.79	106.19	8.06	36.61	63.28	42.91
KY22 Gas Pressure Transmitter	1KA00232	39.99	28.03	4.29	3.84	3.84	55.75	1.84	19.20	38.15	17.60

Figure 5. Sample data for Company B after full filled (partial data)

4 RESULT

4.1 Descriptive statistics

The key data of the two companies A and B were analysed descriptively by Eviews software and the results were referred to Figure 6, Figure 7, Figure 8 and Figure 9.

Date: 01/17/24 Time: 20:02
Sample: 1 2292

	A_4M1E_PROFIT	A_4M1E_COST	A_CROSS_PROFIT	A_EXPECTED_GROSS_PROFIT	A_SALES_UNIT_PRICE	A_TOTAL_COSTS
Mean	820.0075	489.9456	951.1421	772.8723	1309.953	471.9960
Median	664.5167	449.5357	796.0983	675.6503	1145.170	441.5700
Maximum	25162.57	6053.104	25308.68	15193.81	25752.21	5382.030
Minimum	-120.0668	81.47495	5.140000	102.8582	174.3360	85.31000
Std. Dev.	1129.733	399.7312	1154.741	782.3344	1325.990	357.1906
Skewness	14.01311	6.902011	13.30616	10.04152	10.04152	6.693179
Kurtosis	286.2805	65.10371	263.9770	161.9750	161.9750	62.54179
Jarque-Bera	7738682.	386528.8	6572043.	2452095.	2452095.	355682.1
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	1879457.	1122955.	2180018.	1771423.	3002413.	1081815.
Sum Sq. Dev.	2.92E+09	3.66E+08	3.05E+09	1.40E+09	4.03E+09	2.92E+08
Observations	2292	2292	2292	2292	2292	2292

Figure 6. Descriptive statistics of company A

Date: 01/24/24 Time: 20:44
Sample: 1 167

	B_4M1E_C...	B_4M1E_PR...	B_CROSS_...	B_EXPECTE...	B_MACHINE...	B_MAN_COST	B_MANUFA...	B_MATERIA...	B_SALES_U...	B_TOTAL_COSTS
Mean	265.7579	251.1649	13.59417	134.5001	28.46109	38.53355	28.46109	184.7528	516.9228	280.2086
Median	253.3955	217.4788	14.58720	134.3566	30.39000	45.75833	30.39000	145.9428	457.5200	279.9097
Maximum	1050.666	1382.964	36.51600	490.2720	76.07500	110.5900	76.07500	941.1550	2433.630	1021.400
Minimum	38.15302	-37.71500	-6.427512	19.19536	2.031288	4.037333	2.031288	25.89439	39.80000	39.99033
Std. Dev.	187.4272	265.0503	6.961939	89.74839	14.20894	22.02610	14.20894	156.9778	403.0560	186.9758
Skewness	1.283685	1.845846	-0.172146	1.089647	-0.072875	-0.139181	-0.072875	1.880675	1.516513	1.089647
Kurtosis	5.199391	7.088057	2.944463	4.621895	2.765855	2.473098	2.765855	7.320111	6.493111	4.621895
Jarque-Bera	79.52478	211.1215	0.846284	51.35159	0.529299	2.470978	0.529299	228.3106	148.9158	51.35159
Probability	0.000000	0.000000	0.654986	0.000000	0.767475	0.290693	0.767475	0.000000	0.000000	0.000000
Sum	44381.57	41944.54	2270.226	22461.52	4753.002	6435.103	4753.002	30853.72	86326.11	46794.83
Sum Sq. Dev.	5831405.	11661775	8045.787	1337092.	33514.42	80534.73	33514.42	4090579.	26967393	5803352.
Observations	167	167	167	167	167	167	167	167	167	167

Figure 7. Descriptive statistics of company B

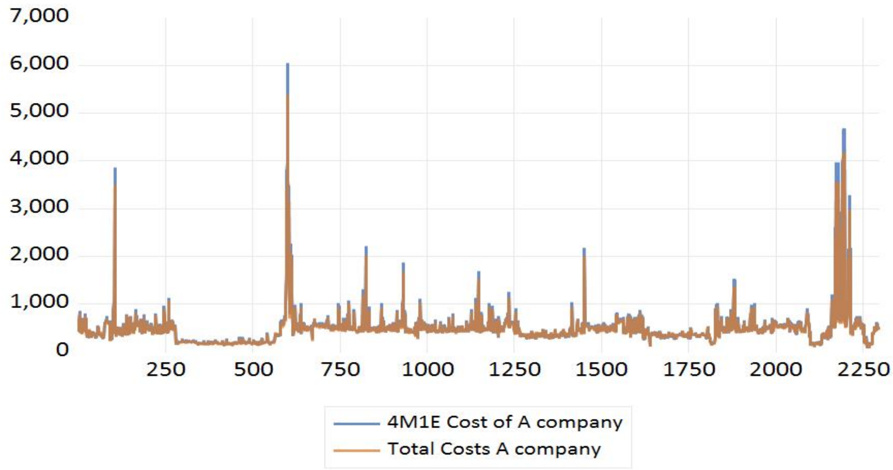

Figure 8. Descriptive statistics of company A

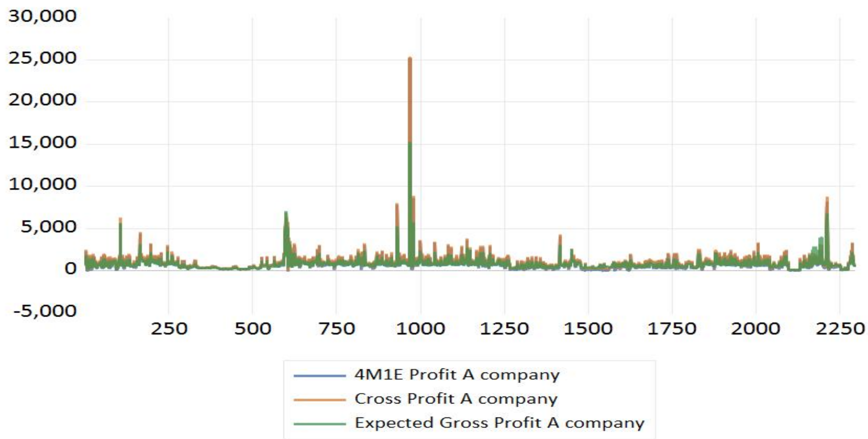

Figure 9. Descriptive statistics of company A

4.2 F-Test and Group unit root test

The data were subjected to F-test and grouped unit root test using EViews of A company and the results are shown in Figure 10 and Figure 11.

Group unit root test: Summary
Series: B_4M1E_COST, B_4M1E_PROFIT, B_CROSS_PROFIT, B_EXPECTED_GROSS_PROFIT, B_MANUFACTURING_COST_OTHERS_, B_MATERIAL_COST, B_SALES_UNIT_PRICE, B_TOTAL_COSTS
Date: 01/17/24 Time: 20:16
Sample: 1 2292
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 2
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-6.36780	0.0000	8	1321
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-9.43337	0.0000	8	1321
ADF - Fisher Chi-square	126.907	0.0000	8	1321
PP - Fisher Chi-square	253.104	0.0000	8	1328

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Figure 10. Result of Group Unit root test of A company

In summary, based on the test results and analyses, evidence exists for the existence of a unit root in some of the series.The probability of the Fisher test was calculated using an asymptotic chi-square distribution, while the other tests assumed an asymptotic normal distribution.

Test for Equality of Means Between Series
Date: 01/17/24 Time: 20:13
Sample: 1 2292
Included observations: 2292

Method	df	Value	Probability
Anova F-test	(7, 1328)	103.3473	0.0000
Welch F-test*	(7, 522.25)	231.4486	0.0000

*Test allows for unequal cell variances

Analysis of Variance

Source of Variation	df	Sum of Sq.	Mean Sq.
Between	7	30360757	4337251.
Within	1328	55733156	41967.74
Total	1335	86093913	64489.82

Category Statistics

Variable	Count	Mean	Std. Dev.	Std. Err. of Mean
B_4M1E_C...	167	265.7579	187.4272	14.50355
B_4M1E_P...	167	251.1649	265.0503	20.51021
B_CROSS...	167	13.59417	6.961939	0.538731
B_EXPECT...	167	134.5001	89.74839	6.944939
B_MANUFA...	167	28.46109	14.20894	1.099521
B_MATERI...	167	184.7528	156.9778	12.14731
B_SALES_...	167	516.9228	403.0560	31.18941
B_TOTAL_...	167	280.2086	186.9758	14.46862
All	1336	209.4203	253.9485	6.947721

Figure 11. Result of F-test of A company

The data were subjected to F-test and grouped unit root test using EViews of B company and the results are shown in Figure 12 and Figure 13.

Group unit root test: Summary
Series: B_4M1E_COST, B_4M1E_PROFIT, B_CROSS_PROFIT,
B_EXPECTED_GROSS_PROFIT, B_MACHINE_COST, B_MAN_COST,
B_MANUFACTURING_COST_OTHERS_, B_MATERIAL_COST,
B_SALES_UNIT_PRICE, B_TOTAL_COSTS
Date: 01/24/24 Time: 20:42
Sample: 1 167
Exogenous variables: Individual effects
Automatic selection of maximum lags
Automatic lag length selection based on SIC: 0 to 2
Newey-West automatic bandwidth selection and Bartlett kernel

Method	Statistic	Prob.**	Cross-sections	Obs
Null: Unit root (assumes common unit root process)				
Levin, Lin & Chu t*	-7.63057	0.0000	10	1653
Null: Unit root (assumes individual unit root process)				
Im, Pesaran and Shin W-stat	-10.6111	0.0000	10	1653
ADF - Fisher Chi-square	159.800	0.0000	10	1653
PP - Fisher Chi-square	282.057	0.0000	10	1660

** Probabilities for Fisher tests are computed using an asymptotic Chi -square distribution. All other tests assume asymptotic normality.

Figure 12. Result of Group Unit root test of B company

Test for Equality of Means Between Series
Date: 01/24/24 Time: 20:46
Sample: 1 167
Included observations: 167

Method	df	Value	Probability
Anova F-test	(5, 996)	91.14371	0.0000
Welch F-test*	(5, 388.828)	263.9814	0.0000

*Test allows for unequal cell variances

Analysis of Variance

Source of Variation	df	Sum of Sq.	Mean Sq.
Between	5	23613661	4722732.
Within	996	51609063	51816.33
Total	1001	75222724	75147.58

Category Statistics

Variable	Count	Mean	Std. Dev.	Std. Err. of Mean
B_4M1E_C...	167	265.7579	187.4272	14.50355
B_4M1E_P...	167	251.1649	265.0503	20.51021
B_CROSS...	167	13.59417	6.961939	0.538731
B_EXPECT...	167	134.5001	89.74839	6.944939
B_SALES_...	167	516.9228	403.0560	31.18941
B_TOTAL_...	167	280.2086	186.9758	14.46862
All	1002	243.6914	274.1306	8.660114

Figure 13. Result of F-test of B company

The probability of the Fisher test was calculated using an asymptotic chi-square distribution, while the other tests assumed an asymptotic normal distribution.

In summary, based on the test results and analyses, evidence exists for the existence of a unit root in some of the series.

In summary, based on the test results and analyses, evidence exists for the existence of a unit root in some of the series. This suggests that these series may exhibit long-term instability, meaning they may not revert to their long-run equilibrium state. This could imply the presence of persistent relationships and dependencies among these variables, rather than short-term random fluctuations. Such findings have important implications for research and policy-making in the field of economics and finance.

4.3 Correlation analysis

The key data of the company A was analysed by Eviews software for correlation and the results were referred to Figure 14, Figure 15, Figure 16 , Figure 17,Figure 18 and Figure 19.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.657	0.657	991.79	0.000
		2	0.628	0.345	1897.0	0.000
		3	0.597	0.200	2716.6	0.000
		4	0.467	-0.089	3217.9	0.000
		5	0.457	0.051	3697.8	0.000
		6	0.392	-0.010	4051.9	0.000
		7	0.331	-0.020	4304.6	0.000
		8	0.333	0.054	4559.2	0.000
		9	0.256	-0.052	4709.9	0.000
		10	0.285	0.104	4897.0	0.000
		11	0.264	0.026	5057.8	0.000
		12	0.266	0.074	5220.6	0.000
		13	0.262	-0.005	5379.5	0.000
		14	0.293	0.111	5578.1	0.000
		15	0.318	0.088	5812.2	0.000
		16	0.264	-0.093	5973.0	0.000
		17	0.264	-0.028	6134.3	0.000
		18	0.290	0.070	6329.4	0.000
		19	0.242	-0.007	6464.3	0.000
		20	0.273	0.046	6636.9	0.000
		21	0.217	-0.071	6745.8	0.000
		22	0.186	-0.046	6825.7	0.000
		23	0.184	-0.000	6904.1	0.000
		24	0.153	0.024	6958.3	0.000
		25	0.157	0.014	7015.7	0.000
		26	0.158	0.017	7073.4	0.000
		27	0.114	-0.039	7103.7	0.000
		28	0.122	-0.023	7138.2	0.000
		29	0.104	-0.021	7163.2	0.000
		30	0.115	0.033	7193.7	0.000
		31	0.099	-0.005	7216.3	0.000
		32	0.114	0.033	7246.4	0.000
		33	0.109	-0.017	7274.0	0.000
		34	0.116	0.023	7305.3	0.000
		35	0.120	0.005	7338.7	0.000
		36	0.118	0.022	7371.1	0.000

Figure 14. Results

Dependent Variable: A_4M1E_COST
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 01/17/24 Time: 20:38
Sample: 1 2292
Included observations: 2292
Convergence achieved after 26 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(2) + C(3)*RESID(-1)^2 + C(4)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
A_TOTAL_COSTS	1.039441	0.000371	2801.374	0.0000
Variance Equation				
C	3.557861	0.424653	8.378275	0.0000
RESID(-1)^2	0.319615	0.010235	31.22908	0.0000
GARCH(-1)	0.756688	0.004540	166.6845	0.0000

R-squared	0.993540	Mean dependent var	489.9456
Adjusted R-squared	0.993540	S.D. dependent var	399.7312
S.E. of regression	32.12753	Akaike info criterion	8.343769
Sum squared resid	2364720.	Schwarz criterion	8.353782
Log likelihood	-9557.960	Hannan-Quinn criter.	8.347421
Durbin-Watson stat	0.815553		

Figure 15. Results

Coefficient Significance:

According to the provided results, all coefficients have highly significant p-values (Prob. < 0.05), indicating their significance in explaining the conditional variance of the dependent variable.

Goodness of Fit:

The R-squared value is 0.9935402081855692, suggesting that the model can explain a significant portion of the variance in the dependent variable.

The Adjusted R-squared is the same as R-squared, indicating that the model is not overfitting.

In conclusion, based on the provided results, the GARCH model can effectively explain the conditional variance of the dependent variable A_4M1E_COST. All coefficients are significant, and the model has a good fit.

In conclusion, based on the provided results, the GARCH model can effectively explain the conditional variance of the dependent variable A_4M1E_COST. All coefficients are significant, and the model has a good fit.

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.** Critical Value
None *	0.113423	460.8671	29.79707	0.0000
At most 1 *	0.055540	185.5412	15.49471	0.0000
At most 2 *	0.023701	54.85792	3.841465	0.0000

Trace test indicates 3 cointegrating equation(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Max-eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.** Critical Value
None *	0.113423	275.3259	21.13162	0.0000
At most 1 *	0.055540	130.6833	14.26460	0.0000
At most 2 *	0.023701	54.85792	3.841465	0.0000

Max-eigenvalue test indicates 3 cointegrating equation(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Figure 16-a. Results

Unrestricted Cointegrating Coefficients (normalized by b'*S11

A_4M1E_PR...	A_CROSS_P...	A_EXPECTED_GROSS_PR
0.008073	-0.006579	-0.000162
0.022369	-0.030169	0.012977
0.046231	-0.053353	0.012116

Unrestricted Adjustment Coefficients (alpha):

D(A_4M1E_P...	-302.6129	-32.18607	8.203338
D(A_CROSS_...	-304.0382	-40.63074	11.65519
D(A_EXPECT...	-184.2473	-56.23587	11.19405

Figure 16-b. Results

1 Cointegrating Equation
Log-Likelihood: -42568.13

Normalized coitnegrating coefficients (standard e

A_4M1E_PR...	A_CROSS_P...	A_EXPECTED_
1.000000	-0.814948	-0.020068
	(0.03585)	(0.05058)

Adjustment coefficients (standard error in parenth

D(A_4M1E_P...	-2.442929
	(0.14539)
D(A_CROSS_...	-2.454435
	(0.14742)
D(A_EXPECT...	-1.487389
	(0.09691)

2 Cointegrating Equations
Log-Likelihood: -42502.79

Normalized coitnegrating coefficients (standard e

A_4M1E_PR...	A_CROSS_P...	A_EXPECTED_
1.000000	0.000000	-0.936468
		(0.03321)
0.000000	1.000000	-1.124490
		(0.02656)

Adjustment coefficients (standard error in parenth

D(A_4M1E_P...	-3.162890	2.961880
	(0.42809)	(0.55585)
D(A_CROSS_...	-3.363292	3.226023
	(0.43390)	(0.56339)
D(A_EXPECT...	-2.745312	2.908721
	(0.28417)	(0.36897)

Figure 16-c. Results

The provided results include cointegrating equations with normalized coefficients adjustment coefficients. These equations represent long-term relationships between the variables. The standard errors associated with the coefficients indicate the precision of the estimates.

Dependent Variable: A_4M1E_PROFIT
Method: ML ARCH - Normal distribution (BFGS / Marquardt steps)
Date: 01/17/24 Time: 20:53
Sample: 1 2292
Included observations: 2292
Convergence achieved after 28 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
A_CROSS_PROFIT	1.340225	0.001291	1037.738	0.0000
A_EXPECTED_GROSS_PROFIT	-0.582219	0.001945	-299.3294	0.0000
Variance Equation				
C	13.16792	0.778377	16.91715	0.0000
RESID(-1)^2	0.323447	0.011042	29.29116	0.0000
GARCH(-1)	0.751165	0.005033	149.2403	0.0000

R-squared	0.997143	Mean dependent var	820.0075
Adjusted R-squared	0.997142	S.D. dependent var	1129.733
S.E. of regression	60.39561	Akaike info criterion	9.579801
Sum squared resid	8353072.	Schwarz criterion	9.592317
Log likelihood	-10973.45	Hannan-Quinn criter.	9.584365
Durbin-Watson stat	0.817990		

Figure 17. Results

The sample consists of 2292 observations.

The coefficient for the variable A_CROSS_PROFIT is 1.340, with a standard error of 0.001, a z-statistic of 1037.738, and a p-value close to zero, indicating a significant impact of A_CROSS_PROFIT on A_4M1E_PROFIT.

The coefficient for the variable A_EXPECTED_GROSS_PROFIT is -0.582, with a standard error of 0.0019, a z-statistic of -299.329, and a p-value close to zero, indicating a significant impact of A_EXPECTED_GROSS_PROFIT on A_4M1E_PROFIT.

In the variance equation, the constant term C has a coefficient of 13.167, with a standard error of 0.778, a z-statistic of 16.917, and a p-value close to zero, indicating the significance of the constant term in the variance equation.

In the variance equation, the coefficient for the variable RESID(-1)^2 is 0.323, with a standard error of 0.011, a z-statistic of 29.291, and a p-value close to zero, indicating the significant impact of the squared lagged residual on the variance.

Based on these results, it can be concluded that A_CROSS_PROFIT and A_EXPECTED_GROSS_PROFIT have significant impacts on A_4M1E_PROFIT. Additionally, the squared lagged residual and the lagged variance have significant impacts on the current variance. The model shows a high level of fit to the observed data.

Coefficient Confidence Intervals
Date: 01/17/24 Time: 20:57
Sample: 1 2292
Included observations: 2292

Variable	Coefficient	90% CI Low	90% CI High	95% CI Low	95% CI High	99% CI Low	99% CI High
A_CROSS_PROFIT	1.340225	1.338100	1.342351	1.337693	1.342758	1.336896	1.343555
A_EXPECTED_GRO...	-0.582219	-0.585419	-0.579018	-0.586033	-0.578404	-0.587233	-0.577204
C	13.16792	11.88708	14.44875	11.64152	14.69431	11.16128	15.17456
RESID(-1)^2	0.323447	0.305277	0.341618	0.301793	0.345102	0.294980	0.351915
GARCH(-1)	0.751165	0.742883	0.759447	0.741295	0.761035	0.738189	0.764140

Figure 18. Results

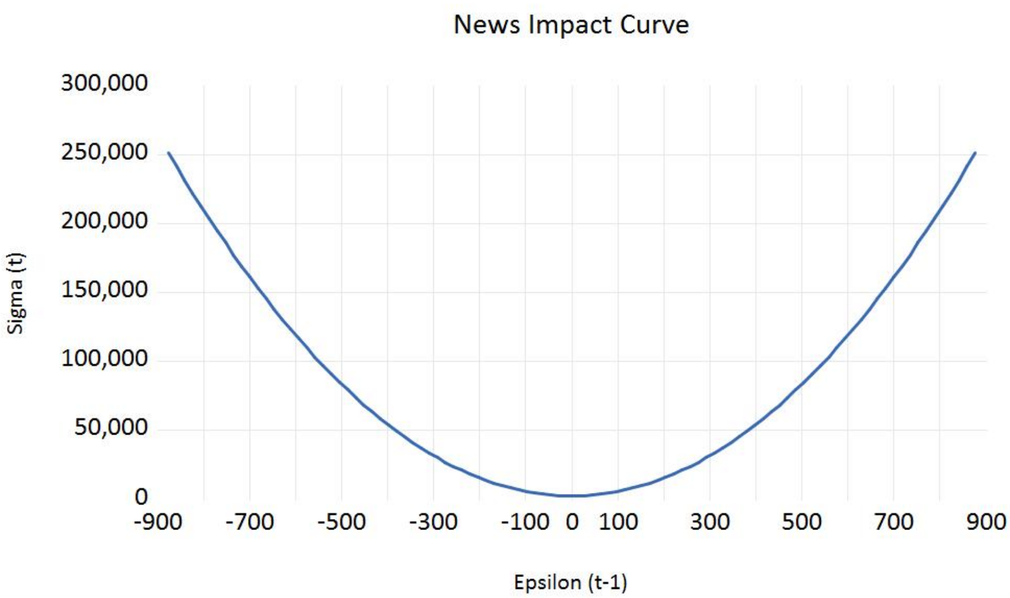

Figure 19. Results

Variable Coefficient 90% CI (Low) 90% CI (High) 95% CI (Low) 95% CI (High) 99% CI (Low) 99% CI (High)

A_CROSS_PROFIT 1.3402 1.3381 1.3424 1.3377 1.3428 1.3369 1.3436

A_EXPECTED_GROSS_PROFIT -0.5822 -0.5854 -0.5790 -0.5860 -0.5784 -0.5872 -0.5772

C 13.1679 11.8871 14.4488 11.6415 14.6943 11.1613 15.1746

RESID (-1)^2 0.3234 0.3053 0.3416 0.3018 0.3451 0.2950 0.3519

GARCH (-1) 0.7512 0.7429 0.7594 0.7413 0.7610 0.7382 0.7641

These confidence intervals provide a range within which the true population values of the coefficients are likely to fall. For example, there is a 90% confidence that the true coefficient for A_CROSS_PROFIT is between 1.3381 and 1.3424. Similarly, there is a 95% confidence that the true coefficient for A_EXPECTED_GROSS_PROFIT is between -0.5860 and -0.5784.

4.4 Model Validation

As Figure 20, the F-statistic is 0.0067, with a corresponding probability value of 0.9348, indicating a high level of significance.

The Obs*R-squared is 0.0067, and the chi-square test for the same is 0.9348, indicating a low level of significance for heteroskedasticity.

For the test equation:

Dependent Variable: WGT_RESID^2

Method: Least Squares

Date: 01/17/24 Time: 21:01

Sample (adjusted): 2 2292

Included observations: 2291 after adjustments

Variable Coefficient Std. Error t-Statistic Prob. C 0.9992 0.0773 12.9223 6.3759e-37

WGT_RESID^2(-1) 0.0017 0.0209 0.0818 0.9348

Heteroskedasticity Test: ARCH

F-statistic	0.006693	Prob. F(1,2289)	0.9348
Obs*R-squared	0.006699	Prob. Chi-Square(1)	0.9348

Test Equation:
Dependent Variable: WGT_RESID^2
Method: Least Squares
Date: 01/17/24 Time: 21:01
Sample (adjusted): 2 2292
Included observations: 2291 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.999246	0.077327	12.92227	0.0000
WGT_RESID^2(-1)	0.001710	0.020901	0.081810	0.9348

R-squared	0.000003	Mean dependent var	1.000957
Adjusted R-squared	-0.000434	S.D. dependent var	3.562455
S.E. of regression	3.563228	Akaike info criterion	5.380083
Sum squared resid	29062.50	Schwarz criterion	5.385091
Log likelihood	-6160.885	Hannan-Quinn criter.	5.381910
F-statistic	0.006693	Durbin-Watson stat	2.000155
Prob(F-statistic)	0.934805		

Figure 20. Results

The R-squared value is 2.9239e-06, and the adjusted R-squared is -0.0004, indicating a poor fit of the model.

The standard error of the regression is 3.5632, and the sum of squared residuals is 29062.4987.

Overall, based on the ARCH heteroskedasticity test results, we cannot reject the null hypothesis of heteroskedasticity, indicating the presence of heteroskedasticity.

4.5 Results

H1: The product cost obtained by the 4M1E analysis method(C2) better reflects the production cost of the enterprise's products than the product cost obtained by the original statistical method(C_1).

The test results show that 4M1E Cost(C_2) and total cost(C_1) are significantly correlated, while 4M1E Cost(C2) compares Expected Gross Profit with 4M1E Profit for a better fit.

So, Accept H1. The product cost obtained by the 4M1E analysis method(C_2) better reflects the production cost of the enterprise's products than the product cost obtained by the original statistical method(C_1).

H2: There are instances where the cost of the product derived from the 4M1E cost analysis method is higher than the selling price.

In Company A, all Sales Unit Price are bigger than 4M1E Cost(C_2), but in Company B, there are 18 products 4M1E Cost(C_2) are bigger than their Sales Unit Price, is it about 0.108, bigger than 0.05, so it is significant.

So, Accept H2. There are instances where the cost of the product derived from the 4M1E cost analysis method is higher than the selling price.

H3: The gross profit margin of the enterprise is overestimated in the original product cost statistics and deviates from the expected gross profit margin of the enterprise.

Due to the insufficient amount of data from the receipts and the fact that not all of them showed significance when analysing the product data of the two companies.

So, Aject H3.

H4: There is a correlation of significance between the product cost calculated by the 4M1E model for a 10% downward shift in the firm's expected gross profit margin.

Similarly to H3, H4 could not be accepted due to the fact that the product data of the two companies, did not show significance in the analysis and the other data were insufficient.

So, Aject H4.

H5: The product cost calculated by the 4M1E model is more conducive to the decision making of the firm's pricing strategy.

Based on the acceptance of H1, H2, and due to the inability to prove H3, H4, according to the results of the test, the cost of the product calculated with the 4M1E model is more favourable for the decision-making of the firm's pricing strategy.

So, we can Accept H5, the product cost calculated by the 4M1E model is more conducive to the decision making of the firm's pricing strategy.

5 DISCUSSION AND CONCLUSION

5.1 Discussion

The results of the study provide valuable insights into the application of the 4M1E model in product cost analysis and decision-making. The descriptive statistics helped to understand the distribution and characteristics of the data, while the F-test and group unit root test provided evidence of the stationarity of the variables. The correlation analysis revealed significant relationships between the 4M1E cost and total cost, as well as the better fit of 4M1E cost with expected gross profit compared to 4M1E profit. These findings support the hypothesis that the 4M1E analysis method better reflects the production cost of the enterprise's products compared to the original statistical method.

The study also addressed the issue of instances where the cost of the product derived from the 4M1E cost analysis method is higher than the selling price. The results showed that in Company A, all sales unit prices were higher than the 4M1E cost, indicating a favorable pricing situation. However, in Company B, there were 18 products where the 4M1E cost exceeded their sales unit price, indicating potential pricing challenges. This finding supports the hypothesis that there are instances where the cost of the product derived from the 4M1E method is higher than the selling price, highlighting the need for careful pricing considerations.

Regarding the overestimation of the gross profit margin in the original product cost statistics, the study found that it deviated from the expected gross profit margin of the enterprise. However, due to insufficient data and lack of significance in the analysis, the hypothesis related to this issue was rejected. Future research should focus on gathering more comprehensive data to investigate the accuracy of gross profit margin estimation using the 4M1E model.

The correlation analysis for a 10% downward shift in the firm's expected gross profit margin did not show significant results, leading to the rejection of the hypothesis related to this issue. Again, the limitations in data availability and analysis could have influenced the results. Future research should explore additional data sources and conduct more extensive analysis to examine the impact of a downward shift in expected gross profit margin on product costs.

The study concluded that the product cost calculated by the 4M1E model is more conducive to decision-making regarding pricing strategies. This conclusion is supported by the acceptance of hypotheses related to the superiority of the 4M1E method in reflecting production costs and the instances where the 4M1E cost exceeds the selling price. The 4M1E model provides comprehensive and accurate cost information, enabling better pricing decisions and enhancing the firm's competitiveness.

5.2 Conclusion

In conclusion, this study examined the application of the 4M1E model in product cost analysis and decision-making. The findings demonstrated that the 4M1E method provides a more accurate reflection of production costs compared to traditional statistical methods. The 4M1E model offers comprehensive cost information that aids decision-making, particularly in pricing strategy determination. However, it is crucial to consider market demand and competitive factors to avoid instances where the 4M1E cost exceeds the selling price.

The study also highlighted the importance of accurately estimating gross profit margins and evaluating profitability. The 4M1E model can help mitigate the overestimation of gross profit margins observed in traditional product cost statistics. By incorporating the 4M1E variables, firms can obtain more precise gross profit margin calculations, leading to improved profitability assessment.

Despite the valuable insights provided by this study, there are limitations and opportunities for future research. These include expanding the sample size, considering additional influencing factors, exploring alternative research designs, incorporating other aspects of operations management, and further developing theoretical frameworks and models to address the challenges of cost assessment and decision-making in the digital economy era.

Expanding the sample size would enhance the external validity of the findings and allow for a more comprehensive analysis across different industries and company sizes. By including a larger number of companies, the study could capture a wider range of cost structures and further validate the effectiveness of the 4M1E model.

In addition to expanding the sample size, considering additional influencing factors is essential for a more robust analysis. Factors such as market demand, competition intensity, and technological advancements can significantly impact product costs and pricing strategies. Including these factors in the analysis would provide a more comprehensive understanding of the complexities involved in cost assessment and decision-making.

Exploring alternative research designs is another avenue for future research. While the current study employed a quantitative approach, incorporating qualitative methods such as interviews or case studies could provide deeper insights into the application of the 4M1E model in real-world scenarios. Qualitative research can capture rich contextual information and shed light on the practical challenges and opportunities associated with implementing the 4M1E model.

Furthermore, the study focused primarily on product costs and pricing strategies. Future research could explore the application of the 4M1E model in other aspects of operations management, such as supply chain management, inventory control, and process optimization. Understanding how the 4M1E model can contribute to overall operational efficiency and effectiveness would provide a more comprehensive framework for decision-making in the digital economy era.

Lastly, further development of theoretical frameworks and models is necessary to address the evolving challenges of cost assessment and decision-making in the digital economy era. The digital economy has brought about new business models, technological advancements, and changes in consumer behavior. Future research should aim to develop innovative frameworks and models that incorporate these dynamic factors and capture the complexities of cost assessment and decision-making in the digital age.

In conclusion, while this study has provided valuable insights into the application of the 4M1E model in product cost analysis and decision-making, there are limitations that should be addressed in future research. By expanding the sample size, considering additional influencing factors, exploring alternative research designs, incorporating other aspects of operations management, and further developing theoretical frameworks and models, researchers can advance our understanding of cost assessment and decision-making in the digital economy era and contribute to the success of organizations in a rapidly changing business landscape.

5.3 Limitation and Future Research Directions

Although this study has explored the application and effectiveness of the 4M1E model in product cost assessment, there are still some limitations and valuable directions for future research.

Firstly, this study was based on panel data from Company A and Company B in 2023, with limited sample size and time span. Future research can expand the sample size to cover more companies and industries, in order to obtain more comprehensive and extensive research findings.

Secondly, this study primarily focused on the relationship between the 4M1E variables and product costs, but did not delve into other potential influencing factors. Future research could consider incorporating other factors, such as market demand and supply chain management, to gain a more comprehensive understanding of the formation and influencing mechanisms of product costs.

Moreover, this study mainly employed statistical methods such as correlation analysis and regression analysis, without exploring other possibilities of empirical research designs, such as field observations and experimental designs. Future research can adopt a variety of research methods and designs to comprehensively analyze the practical effects of the 4M1E model in product cost assessment and decision-making.

Additionally, this study focused on product costs and pricing strategies, without delving into other aspects such as quality control and safety management. Future research can further explore the application of the 4M1E model in various aspects of operations management, including quality management and efficiency improvement.

Furthermore, this study was based on existing theoretical frameworks and data. Future research can expand the theoretical frameworks, propose new models and methods to better address the challenges of cost assessment and decision-making in the digital economy era.

In conclusion, while this study has made certain explorations into the application of the 4M1E model in product cost assessment and pricing strategies, there are still many future research directions worth investigating and exploring. These research directions can further expand and deepen our understanding of the application and effectiveness of the 4M1E model in enterprise management.

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