

Driving Productivity Enhancement in Thailand's Ready-to-Drink Tea Beverage Business through Integration of Lean, Material Flow Cost Accounting, and Internet of Things (IoT)

Chanokporn Klinsoon¹, Chavalit Ratanatamskul²

¹Technopreneurship and Innovation Management Program, Graduate School, Chulalongkorn University, Bangkok, Thailand

²Center of Excellence on Innovative Waste Treatment and Water Reuse, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand

Abstract: This research investigates the impact of integrating lean principles, Material Flow Cost Accounting (MFCA), and Internet of Things (IoT) on enhancing the productivity of small and medium-sized enterprises (SMEs) in Thailand's ready-to-drink tea beverage industry. The study employs a quantitative approach, with a sample population of 240 Thai ready-to-drink tea beverage businesses. Data collection is conducted through questionnaires, and path analysis techniques are employed for data analysis. The results demonstrate that the proposed model, which integrates lean processes, MFCA, and IoT, significantly improves the productivity of Thailand's ready-to-drink tea beverage businesses. Specifically, the variables LP (lean processes), MFCA, and IoT exhibit strong positive effects on IP (productivity). This research contributes valuable insights to the field of productivity improvement and engineering, emphasizing the practical implications of integrating lean practices, cost accounting methodologies, and IoT technologies in the context of SMEs in the ready-to-drink tea beverage sector.

Keywords: Lean Concept, Beverage SMEs, Material Flow Cost Accounting, Internet of Thing

1. Introduction

Driving a group of small and medium-sized enterprises (SMEs) is a key factor in driving the current economy. It plays an important role in the world economy because it creates jobs, develops innovation, and affects the country's competitiveness. There are many SMEs in Thailand while Mongkol, (2021) said the number of SME entrepreneurs has constantly increased, topping three million by 2021, accounting for over 99.5% of all SMEs and considerably contributing to employment, employing approximately 12 million people, or 69% of the country's population (Achanga, et al., 2006; Bulbul, 2012). However, SME entrepreneurs face three major challenges in their business operations: financial constraints, the need to increase the value of their products and services, and the drive to improve productivity. They also face competition from larger corporations, limiting their capacity to compete successfully and meet customer demands consistent with five forces model concepts that Porter (2000) said obstacles in business performance include Competitive Rivalry, Supplier Power, Buyer Power, Threat of Substitution, and Threat of New Entry.

According to The Bank of Thailand, tackling these difficulties is crucial for the survival and sustainability of SMEs (OECD, 2001). Therefore, productivity is a crucial factor for maximizing the use of

²Professor of Center of Excellence on Innovative Waste Treatment and Water Reuse, Faculty of Engineering, Chulalongkorn University. E-Mail: Chavalit.R@chula.ac.th

organizational resources to produce desired product outcomes. It is also critical to assist organizations in adapting to quick market changes and establishing long-term success (Lu & Huang, 2014) (Daskalaki & Zopiatis, 2018; Kim & Lee, 2017). Low productivity is a key concern for SMEs, manifesting as low product quality, delayed delivery, high operational costs, and non-standard services affecting customer satisfaction and confidence. This effect can lead to a decrease in customer numbers and have a negative impact on the business's long-term profitability. Not only that, but productivity issues also have a macroeconomic impact. In addition, to reducing firm earnings, they limit employment growth and impede innovations. The difficulties with productivity in SMEs have an impact on the whole national and global economy (The Office of SMEs Promotion, 2022). Consequently, productivity issues should no longer be disregarded because they influence both the family and national economies. Therefore, improving productivity in small and medium-sized enterprises (SMEs) is therefore important and requires a systematic and precise strategy to effectively increase productivity in SMEs (Chen & Wang, 2017).

Thailand is a member of the United Nations, and APEC, and a co-founder of ASEAN. Thailand has been an ally of the United States since the SETO Treaty in 1954. It is considered a leading power in Southeast Asia and a middle power on the world stage. Thailand is a middle-high income country and a newly industrialized country with the main income coming from the industrial and service sectors. Thailand's economic changes resulted in immigration to cities in the 20th century. According to year 2019 estimates, Thailand's GDP is approximately 516,662 million US dollars. This makes Thai economy the second largest in Southeast Asia and the 25th largest in the world. Therefore, education to develop the productivity of Thai SMEs is important. Because it may result in being promoted to a higher rank in the world market (Ping, Jonathan H., 2005). Currently, SMEs across industries use a variety of solutions to address production challenges and create higher efficiency, and this effort is a critical factor in business success. The solutions mentioned include productivity improvement principles (Shah & Ward, 2003; Javalgi et al., 2013), supply chain optimization, quality management systems, data analysis, financial management, project management, inventory control, customer relationship management (CRM), collaboration tools, customer feedback analysis, employee training and development, time management strategies, as well as incentive programs and employee recognition (Belamkar P., 2023).

In addition, in Thailand, the ready-to-drink tea beverage business is an interesting group of SMEs because it is a business group with a high market value and the Journal of Food and Beverage Marketing. The tea beverage industry in Thailand has grown rapidly in recent years. This is driven by increasing demand for high-quality health products. The ready-to-drink tea market in Thailand accounts for 6.4% of the non-alcoholic beverage market, which is considered to be worth more than 10,000 million baht in total. As a result, the ready-to-drink tea business in Thailand is an interesting and dynamic sector that plays an important role in driving the country's economy (Hompratum, 2023). This reflects that it is a business group with very high competition as well. So, it is crucial to enhance production productivity in order to gain a competitive edge and productivity improvement is one approach that Thailand SMEs have widely implemented to increase productivity (Narke M., 2020; Huang Z., S.2019). However, a study by the journal Small Business and Enterprise Development (2020) found that small businesses in the Thai tea beverage category are lack of managerial and technical skills. It results in a lack of productivity in these business groups as well.

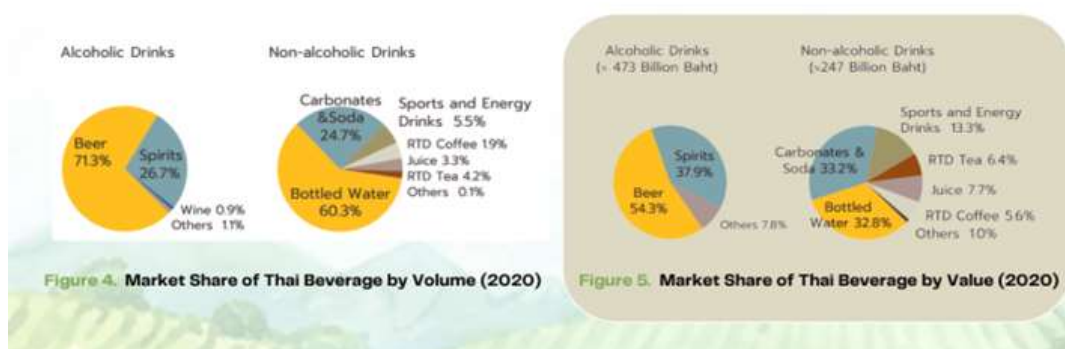


Figure 1: Market share of Thai Beverage Business by value

Ref: Hompratum (2023)

Nowadays, there are many ways for improve SMEs productivity and Lean is a principle in many industrial production systems that aims to achieve high standards of production by focusing on waste elimination throughout the manufacturing process. It applies the notion of work value to minimize costs, improve production efficiency, and ensure customer satisfaction in terms of product quality (Joseph F., et al., 2007). Some important Lean principles include: 1) Value stream mapping, a tool that visualizes material flow and process data to discover waste and improvement opportunities (Narke M., 2020). 2) 5S is a method for organizing and maintaining a clean and efficient workspace that includes processes such as sort, set in order, shine, standardize, and sustain (Oleghe O., 2017). 3) Kanban is a method of managing inventory that uses visual signals to stimulate material production or movement (Abdul Rahman N.U., 2022). 4) Standard work is a means of documenting and optimizing work processes, as well as defining the stages and equipment required for optimal execution (O'Reilly K., 2016). Numerous examples of successful Lean implementation in SMEs worldwide demonstrate its effectiveness. For example, in Mexico's automotive industry, Lean tools enabled a spectacular 50% reduction in lead times, a 35% reduction in inventory levels, and a 20% boost in total production (Rodríguez-Pérez et al., 2017). Similarly, a small Indian manufacturing company used Lean tools to reduce production time by 35%, reduce inventory levels by 25%, and increase productivity by 20% (Das, et al., 2016).

Besides, improving productivity requires other related factors as well, such as Material Flow Cost Accounting and the Internet of Things used in operation. Because it helps businesses realize the real increase in raw material waste. Businesses will be able to reduce their environmental impact and improve their processes to be more efficient. In addition, Abdel-Kader (2011) said about the Material Flow Cost Accounting (MFCA) process that the cost of raw materials, and waste (that are not products) will be separated into separate reports. While the Internet of Thing allows manufacturers to control the production process. and production equipment can operate efficiently via the internet network and can monitor and evaluate the results of improving production productivity at any time and place as well.

From the importance of the ready-to-drink tea beverage business group, which is an SME, plays an important role in driving the economy of Thailand and the problem of lack of skills and techniques that affect the lack of efficiency in increasing production productivity. And because of the importance of lean principles, Material Flow Cost Accounting (MFCA), and Internet of Thing which are popular and applied to improve productivity in the industrial sector. The actor therefore studied the results of using lean principles that affect the improvement of production efficiency in the ready-to-drink tea beverage business and it is important for SMEs in Thailand as mentioned above.

In an era where technological advancements and management strategies converge, the significance of integrating the Internet of Things (IoT), Lean processes, and Material Flow Cost Accounting (MFCA) cannot be overstated, particularly in the realm of productivity enhancement for small and medium-sized enterprises (SMEs). The IoT stands as a transformative force, offering a network of interconnected devices that facilitate unparalleled data exchange and analysis, driving operational

efficiency and enabling real-time decision-making (Gokhale, et al., 2018). This is especially pertinent in Thailand's ready-to-drink tea beverage industry, where IoT can monitor and optimize production lines and supply chains. Concurrently, Lean processes offer a systematic approach to waste minimization and value maximization, principles that are essential for streamlining operations and fostering continuous improvement (Sundar, et al., 2014) (Peter Landau, 2023). When coupled with the financial and environmental insights provided by MFCA, businesses gain a comprehensive understanding of material costs and flows, empowering them to make informed decisions that reduce expenses and environmental impact (Sulong, et al., 2015) (Burritt, R.L., 2015) (Hirotugu Kitada, et al., 2022). The concept of Improved Productivity (IP) lies at the heart of these methodologies, encapsulating the pursuit of efficiency, quality, and resource optimization (Paul Krugman, 1994) (Kaliski, Burton S., ed., 2001) (Lee et al., 2013) (Resta, et al., 2016). While existing research has delved into the individual benefits of IoT, Lean, and MFCA, there is a paucity of studies investigating their combined effect on SME productivity (Deebhijarn, 2016).

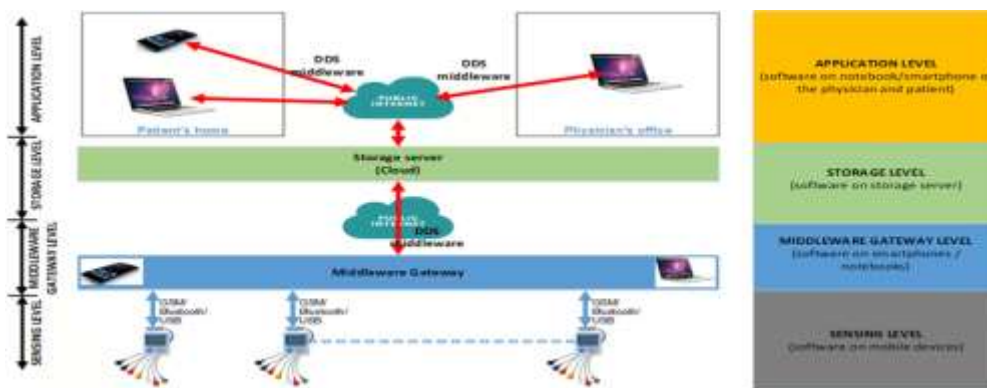


Figure 2: the Internet of Things (IoT) system architecture

Ref; Gokhale, et al., (2018)

Caitlin Walls, et al. (2024) found MFCA, when applied to emerging recycling technologies, is a practical tool that enables a clear understanding of a project's financial viability when scaled from lab to project scale. It allows for a detailed analysis of the production process and can raise awareness of possible process inefficiencies that have both an economic and environmental impact. The profitability of these recycling processes can vary significantly depending on factors such as the processing rate and capacity of machinery, as well as the output products' market value, particularly for high-value products. Other factors such as the quality of the output product, the amount of waste and the process efficiency also play an important role in determining the profitability of the process. While the result of Hirotugu Kitada, et al. (2022) found that there were several differences in the style of MFCA usage between firms that stopped using it after a short period of time and those that used it continuously. This study contributes to the literature by analyzing the diffusion of environmental management accounting from the perspective of discontinuance and by providing evidence of the relationship between the style of using MFCA and discontinuance. The improvement results have shown a positive impact reducing the waste ratio and this has meant a saving of 13% in the manufacturing cost. The improvement results have shown a positive impact reducing the waste ratio and this has meant a saving of 13% in the manufacturing cost.

Besides, the research of J Kaneku-Orbegoza, et al. (2020) found the implementation of lean manufacturing tools and an integrated framework between production planning and quality in a SME dedicated at a production of kitchen equipment. Studies of the company processes showed that the cutting and bending processes tend to create the most amount of sheet metal waste and non-value-added activities. The main objectives of the research were to standardize work, reduce waste, eliminate machine failures and develop the guidelines for a correct planning that meets quality requirements. The

improvement results have shown a positive impact reducing the waste ratio and this has meant a saving of 13% in the manufacturing cost.

While Amkwanyean, A. (2014) found Initially, there were 4 types of waste in the transportation process of empty PET drinking water bottle which was unnecessary stock, unnecessary motion, unnecessary transportation, and idle time. The improvement in the production process was done by focusing on eliminating waste using Lean manufacturing theory with line automation that conformed to just-in-time (JIT) production and the result of Supharee, B. & Ruangchoengchum, P. (2019) found Material Flow Cost Accounting (MFCA) is one technique that can reduce loss from using material in production process by analyzing loss in negative cost. Besides, Ngamwannakorn, C, et al., (2018) found the evaluation of the efficiency of the equipment control system in small factories with wireless technology through mobile applications under the concept of Internet for all things, the overall level is very high with the average level = 4.19 and SD = 0.83

While the research result of Kamolsin, J. (2022) found that consistency between the developed model and the empirical data by criteria to verify the consistency of the model and the developed empirical data are consistent with the observed data. In addition, the result of Anthony Anosike, et. al., (2023) showed that Improvements in information flow, decision-making and productivity were also found to be the most important motivations and benefits of combining LM methods with IoT and LM methods related with Iot, while Shaio Yan Huang, et. al. (2019) found that the material flow cost accounting analysis constitutes a valuable management tool, thereby facilitating the promotion of sustainable development.

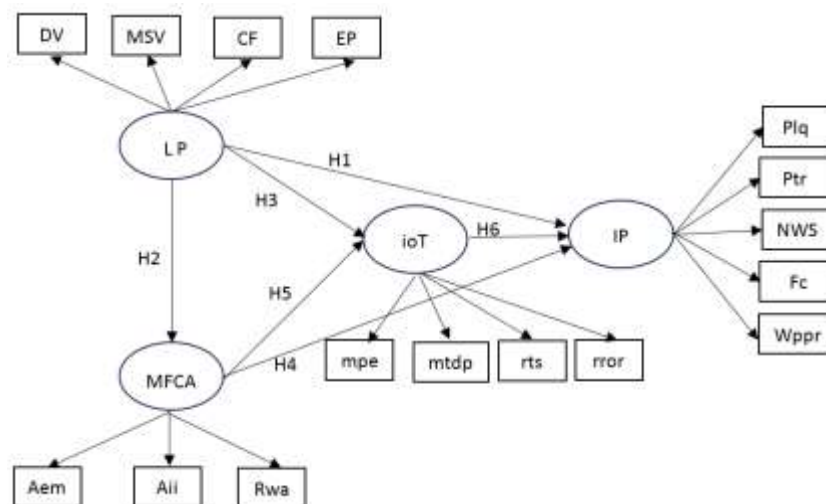
This article aims to fill this gap by examining the synergistic potential of these methodologies to revolutionize productivity in the context of Thailand's burgeoning ready-to-drink tea beverage sector.

2. Materials and Methods

2.1. Theoretical Framework

This evaluation model aims to determine the impact of integrating lean principles, Material Flow Cost Accounting (MFCA), and Internet of Things (IoT) technologies on enhancing the productivity of small and medium-sized enterprises (SMEs), specifically focusing on Thailand's ready-to-drink tea beverage industry. The research seeks to quantify the effects of these integrations and provide a systematic strategy to improve SME productivity effectively.

Figure 1
Research Model



The concept of the research model focuses on examining the impact of Lean Process (LP), Material Flow Cost Accounting (MFCA), and Internet of Things (IoT) on improving productivity in Thailand's

ready-to-drink tea beverage business¹². The model aims to understand how these three factors contribute to enhancing efficiency and competitiveness in the SME sector. It investigates the direct relationships between LP, MFCA, and IoT with improved productivity (IP), as well as the interrelationships among LP, MFCA, and IoT themselves³.

- **Lean Process (LP):** Explores how lean management principles can streamline operations, reduce waste, and increase value in production.
- **Material Flow Cost Accounting (MFCA):** Looks at how accounting for material flows can help identify inefficiencies and reduce costs.
- **Internet of Things (IoT):** Studies the role of IoT in monitoring and controlling production processes to improve efficiency and adaptability.
- **Improved Productivity (IP):** Measures the outcome of implementing LP, MFCA, and IoT in terms of higher output, better quality, and increased customer satisfaction.

The model is structured to test hypotheses that posit positive influences of LP, MFCA, and IoT on IP, and also examines how LP affects MFCA and IoT, and how MFCA influences IoT. The research model is a framework for understanding the synergistic effects of these components on SME productivity.

2.2. Research Design

The research aims to investigate the impact of Lean Process (LP), Material Flow Cost Accounting (MFCA), and Internet of Things (IoT) on improving productivity in Thailand's ready-to-drink tea beverage business. The hypotheses are formulated to understand the relationships between these variables:

- **H1: Lean Process and Productivity** Lean Process (LP) is hypothesized to have a positive influence on improving productivity (IP). This suggests that implementing LP principles can lead to more efficient production processes and higher output quality.
- **H2: Lean Process and MFCA** It is posited that LP positively affects the implementation of Material Flow Cost Accounting (MFCA). This relationship indicates that lean principles can enhance the effectiveness of MFCA by reducing waste and optimizing material flow.
- **H3: Lean Process and IoT Design** The study hypothesizes that LP positively influences the design and integration of IoT in the production process, which can lead to smarter and more responsive manufacturing systems.
- **H4: MFCA and Productivity** Material Flow Cost Accounting (MFCA) is expected to positively impact productivity, suggesting that better cost allocation and waste reduction through MFCA can lead to improved production efficiency.
- **H5: MFCA and IoT Integration** The hypothesis here is that MFCA positively influences the integration of IoT technology, implying that the data and insights from MFCA can inform and optimize IoT solutions.
- **H6: IoT and Productivity** Finally, the Internet of Things (IoT) process is hypothesized to have a positive effect on improving productivity, indicating that IoT technologies can enhance operational efficiency and output.

2.3 Data Collection

These hypotheses are designed to test the interconnectedness of LP, MFCA, and IoT processes and their collective impact on productivity, aligning with the research objective of enhancing SMEs' production efficiency in the ready-to-drink tea beverage sector. The results will provide insights into how these methodologies can be synergistically applied to achieve greater productivity and competitiveness in the industry.

This study employed quantitative research, including data gathered through a survey method. The sample population is Thai ready-to-drink tea beverage business. Generally, a minimum sample size of 10 - 20 samples per 1 observed variable is used (Schumacker & Lomax, 2015; Kline, 2016). In this research has 16 observed variables. Therefore, the sample sizes equal to 240 people ($16 \times 15 = 240$). Purposive sampling method and convenience sampling method was used. Data were collected through questionnaire. The structured questionnaires used to gather data for this study were developed by following a four-stage procedure recommended by the literature (Underhill, et al., 2016).

2.4. Data Analytics

The data analysis process is divided into two main parts: the evaluation of the measurement and structural models. The measurement model aims to establish the validity and reliability of the model. Whereas the structural model evaluation includes testing hypotheses, determining the variance explained (R^2) of the independent constructs on the dependent constructs, and assessing the predictive relevance of the model as follow table 1

Table 1
Contains the measurement criteria thresholds used in this study

Criteria for Measurement	Suggestion
Factor loading: FL (Henseler, 2017)	>0.70
Composite reliability: CR (Henseler et al., 2015)	≥0.60
Average variance extracted: AVE (Rodgers & Pavlou, 2003)	>0.50
Cronbach's alpha: Ca (Henseler et al., 2015)	≥0.70
HeterotraitMonotrait ratio HTMT ratio (Henseler et al., 2015)	<0.85
Variance Inflation Factor: VIF (Kock, 2015)	<3.30
p-value	≤.05

This statistic software requires an evaluation of the psychometric features of the model, which includes discriminant validity, convergent validity and internal consistency reliability. Indicators that loaded less than 0.50 were removed. The loadings of the manifesting factors were showed in Table 2 indicate acceptable convergent validity since the values of each of the factorloadings (individual item reliabilities) are above 0.700 (Henseler, 2017). The average varianceextracted (AVE) values used to determine the convergent validity is above 0.50for the individual constructs (LP, MFCA, IoT, and IP) signifying that on average, theindicators share a minimum of half of the variance with the variables (Henseler, 2017). Thevalues for Cronbach's alpha and composite reliability of the constructs used tomeasure the internal consistency reliability of the model are above the minimum thresholds of .700 and .600 respectively. This means that the model has achieved excellent reliability as follow table 2

Table 2
Questionnaire items, Cronbach's alpha (Ca), average variance extracted (AVE), composite reliability (Cr), factor loadings and sources

Construct	Measuring items	Loading	AVE	Cr	Ca	Source
LP	1. Defining Value (DV)	0.750	0.725	0.826	0.912	Simplilearn (2023), Resta, et al., (2016), Sundar, et al. (2014).
	2. Mapping Stream Value (MSV)	0.820				
	3. Creating Flow (CF)	0.850				
	4. Establishing Pull (EP)	0.780				
MFCA	1. Anenvironmental management (Aem)	0.836	0.685	0.806	0.825	Hirotsugu Kitada, et al. (2022), Burritt, R.L. (2015), Sulong, et al. (2015)
	2. Analyzed to identify inefficiencies (Aii)	0.822				
	3. Reduce waste analysis	0.845				

Construct	Measuring items	Loading	AVE	Cr	Ca	Source
	(Rwa)					
iOT	1. Monitorproduction equipment (mpe)	0.896	0.645	0.834	0.876	Gokhale, Bhat, & Bhat (2018)
	2. Monitortemperature during production (mtdp)	0.804				
	3. Remotely turn on and off systems (rts)	0.826				
	4. Report real-time operating results (rror)	0.836				
IP	1. Production in larger quantities (Plq).	0.845	0.665	0.840	0.912	Kaliski, Burton S., ed., (2001), McKinsey & Company (2019), Lee et al., (2013), Deebhijarn (2016).
	2. Just in time (Ptr).	0.936				
	3. The number of workers is fixed (NWF).	0.864				
	4. Fixed costs (Fc).	0.856				
	5. Waste in the production process is reduced (Wppr).	0.848				

Consequently, the discriminant validity of the model was examined using Heterotrait-Monotrait (HTMT) ratio. According to Henseler (2017), the discriminant validity of the model can be examined using the HTMT of the constructs, where the HTMT ratio for each of the constructs should be less than 0.850 and the HTMT ratios was showed that the model is sufficiently valid since the values for each of the constructs are less than 0.850 as follow table 3

Table 3

Heterotrait-Monotrait ratio (HTMT)

Variables in Construct	LP	MFCA	ioT	IP
LP	-	.470	.360	.480
MFCA	.470	-	.410	.610
ioT	.360	.410	-	.620
IP	.480	.610	.320	-

The actor generally agree that a single statistical measurement is insufficient to justify the use of a pro- posed model, it is better to use multiple-fit indices to assess the overall fit of any proposed model (Maruyama, G.M., 1998). The commonly reported fit indices are the Chi-Square Degree of Freedom ratio, GFI, AGFI, NFI, NNFI, CFI, and RMSEA. The Chi-square value for this model is 2265. The ratio of X^2 to the degree of freedom was 2.98, which is within the recommended level of 3 (Gefen, D., et al., 2003). The other fit indices produced also indicated a good model fit as follow table 4

Table 4
Model fit indicators

Index	Value
Chi-Square/Degree of freedom (X^2/df)	2.98
GFI	0.92
AGFI	0.94
NFI	0.90
CFI	0.95
RMSEA	0.045

After the model measurement has been assessed, the variance explained (R^2) and the predictive relevance of the exogenous variables on the endogenous variables. The validity of the hypotheses and predictive relevance were tested through the calculation. The t-statistics, p-values and the (β) values were used to determine the statistical significance of the paths between LP, MFCA, IoT and IP. The result was showed in table 5.

Table 5
Direct effect

Path	Hypotheses	β	t-statistic	p-value	Results
LP→IP	H1	.869	24.642	.005	Accept
LP→MFCA	H2	.828	18.285	.018	Accept
LP→IoT	H3	.768	4.566	.040	Accept
MFCA→IP	H4	.860	20.525	.012	Accept
MFCA→IoT	H5	.752	3.685	.048	Accept
IoT→IP	H6	.864	22.566	.008	Accept

This article examines the direct effect among LP, MFCA, IoT and IP. The results of the study suggest that LP positively influence IP, which accept the H1 hypothesis ($\beta = 0.869$, $t = 24.642$, $p = .005$) and the result show that LP has strong effect on IP. IoT positively influence IP, which accept the H6 hypothesis ($\beta = 0.864$, $t = 22.566$, $p = .008$) and the result show that IoT has strong effect on IP too. MCFA positively influence IP, which accept the H4 hypothesis ($\beta = 0.860$, $t = 20.525$, $p = .012$) and the result show that MFCA has strong effect on IP. LP positively influence MFCA, which accept the H2 hypothesis ($\beta = 0.828$, $t = 18.285$, $p = .018$) and the result show that LP has strong effect on MFCA. LP positively influence IoT, which accept the H3 hypothesis ($\beta = .768$, $t = 4.566$, $p = .040$) and the result show that LP has strong effect on IoT. MFCA positively influence IoT, which accept the H5 hypothesis ($\beta = .752$, $t = 3.685$, $p = .048$) and the result show that MFCA has strong effect on IoT too.

According to the results, the regression equation for each direct relationship of variables can be expressed through a standard score equation as follows.

1. $Z_{(IP)} = .869_{LP}$
2. $Z_{(MFCA)} = .828_{LP}$
3. $Z_{(IoT)} = .768_{LP}$
4. $Z_{(IoT)} = .754_{MFCA}$
5. $Z_{(IP)} = .860_{MFCA}$
6. $Z_{(IP)} = .864_{IoT}$
7. $Z_{(IoT)} = .768_{LP} + .754_{MFCA}$
8. $Z_{(IP)} = .869_{LP} + .864_{IoT} + .860_{MFCA}$

Understanding the Impact of Lean, MFCA, and IoT on SME Productivity The data analysis reveals a significant relationship between Lean processes (LP), Material Flow Cost Accounting (MFCA), and

Internet of Things (IoT) on improving productivity in Thailand's ready-to-drink tea beverage SMEs¹. The study's objective to determine the effectiveness of integrating these concepts is supported by the positive path coefficients and statistical significance in the results.

- **Lean Processes as a Foundation:** The strong effect of LP on productivity (IP) suggests that Lean principles are fundamental in streamlining operations, reducing waste, and enhancing efficiency.
- **MFCA's Role in Cost Management:** Similarly, MFCA shows a strong influence on IP, indicating that careful tracking and management of material flows can lead to cost savings and better resource utilization.
- **IoT's Contribution to Real-Time Monitoring:** The IoT's positive impact on IP highlights the benefits of real-time data monitoring and process control, which can lead to more responsive and agile production systems.

By integrating LP, MFCA, and IoT, SMEs can achieve a holistic approach to productivity improvement. The research model demonstrates that these elements are not only interrelated but also collectively contribute to a more competitive and sustainable business environment. This integration aligns with the paper's topic, driving the design of IoT by incorporating Lean and MFCA concepts to enhance SME productivity in Thailand's beverage industry. The findings underscore the importance of adopting a multi-faceted strategy that leverages process innovation and technological advancements to thrive in a competitive market.

Forecasting productivity efficiency in the case where every factor (LP, MFCA, and IoT) increases by 1 unit at a time can be graphed as follows from the regression equation.

Figure 2
Impact of Lean, MFCA, and IoT on SME Productivity



3. Results

3.1.1. Analysis of H1

The analysis of Hypothesis 1 (H1) focuses on the relationship between Lean Process (LP) and the improvement of productivity (IP) in Thailand's ready-to-drink tea beverage business¹. The hypothesis posits that implementing lean processes positively influences the productivity of these businesses.

The statistical results supporting H1 are robust, with a beta coefficient (β) of 0.869, indicating a strong positive effect of LP on IP. The t-statistic value of 24.642 significantly exceeds the critical value, and the p-value of 0.005 is well below the conventional threshold of 0.05, leading to the acceptance of

H1. This suggests that lean processes, when applied effectively, can lead to significant improvements in productivity, which is crucial for maintaining competitiveness in the market. The analysis implies that lean principles such as waste reduction, efficient workflow, and continuous improvement are instrumental in enhancing the operational efficiency of SMEs in the ready-to-drink tea sector.

3.1.2. Analysis of H2

The analysis of Hypothesis 2 (H2) presents a compelling case for the influence of Lean processes on Material Flow Cost Accounting (MFCA) in the context of Thailand's ready-to-drink tea beverage industry. The hypothesis posits that the adoption of Lean methodologies is expected to have a positive effect on the application of MFCA. This is substantiated by a path coefficient (β) of 0.828, which indicates a strong positive relationship between the two variables. The t-statistic of 18.285 further reinforces this connection, surpassing the critical value and suggesting a statistically significant relationship. Moreover, the p-value of 0.018 lends additional credibility to the findings, falling well below the standard alpha level of 0.05. These statistical indicators collectively affirm the hypothesis, suggesting that Lean processes can significantly enhance the effectiveness of MFCA, thereby contributing to more efficient and cost-effective production practices within the industry.

3.1.3. Analysis of H3

The analysis of Hypothesis 3 (H3) examines the influence of Lean processes on the design of Internet of Things (IoT) systems within Thailand's ready-to-drink tea beverage industry. The hypothesis asserts that the principles of Lean management will have a positive impact on the conceptualization and implementation of IoT technologies. The statistical evidence supports this claim, with a path coefficient (β) of 0.768, indicating a substantial positive effect. The t-statistic of 4.566 confirms the significance of this relationship, and the p-value of 0.040, being below the standard threshold of 0.05, validates the hypothesis. This suggests that the integration of Lean methodologies is likely to enhance the effectiveness and efficiency of IoT systems, contributing to the overall productivity and competitiveness of the beverage business.

3.1.4. Analysis of H4

The analysis of Hypothesis 4 (H4) provides insightful findings on the impact of Material Flow Cost Accounting (MFCA) on productivity in Thailand's ready-to-drink tea beverage industry. The hypothesis contends that the application of MFCA has a positive influence on productivity levels. This is substantiated by a robust path coefficient (β) of 0.860, which signifies a strong positive correlation between MFCA practices and productivity improvements. The t-statistic of 20.525 further validates this relationship, indicating a high level of statistical significance. Additionally, the p-value of 0.012 reinforces the validity of the results, being well below the standard alpha level of 0.05. These statistical measures collectively support the acceptance of H4, confirming that the strategic implementation of MFCA can lead to significant enhancements in productivity for SMEs within the beverage sector.

3.1.5. Analysis of H5

The analysis of Hypothesis 5 (H5) investigates the effect of Material Flow Cost Accounting (MFCA) on the Internet of Things (IoT) processes within the ready-to-drink tea beverage industry in Thailand. The hypothesis suggests a positive influence of MFCA on the adoption and effectiveness of IoT technologies. The statistical data supports this claim, with a path coefficient (β) of 0.752, indicating a substantial positive impact. The t-statistic of 3.685 confirms the significance of this relationship, and the p-value of 0.048, being just below the standard threshold of 0.05, validates the hypothesis. This analysis implies that the meticulous tracking and management of material and cost flows through MFCA can significantly enhance IoT processes, leading to more efficient and productive operations in the industry.

3.1.6. Analysis of H6

The analysis of Hypothesis 6 (H6) explores the impact of the Internet of Things (IoT) on productivity within Thailand's ready-to-drink tea beverage industry. The hypothesis asserts that IoT processes significantly contribute to productivity enhancement. The statistical evidence supports this assertion, with a path coefficient (β) of 0.864, indicating a strong positive relationship between IoT implementation and productivity gains. The t-statistic of 22.566 provides further validation of this

significant correlation, and the p-value of 0.008 solidifies the results' reliability. These findings confirm that the integration of IoT technologies—enabling real-time monitoring and optimization of production processes—plays a crucial role in improving operational efficiency and output in the beverage sector.

4. Discussion

The research presented investigates the impact of integrating lean principles, Material Flow Cost Accounting (MFCA), and Internet of Things (IoT) on enhancing the productivity of small and medium-sized enterprises (SMEs) in Thailand's ready-to-drink tea beverage industry. The results demonstrate that the proposed model, which integrates lean processes, MFCA, and IoT, significantly improves the productivity of Thailand's ready-to-drink tea beverage businesses. Specifically, the variables LP (lean processes), MFCA, and IoT exhibit strong positive effects on IP (productivity).

The strong effect of LP on productivity suggests that Lean principles are fundamental in streamlining operations, reducing waste, and enhancing efficiency. Similarly, MFCA shows a strong influence on IP, indicating that careful tracking and management of material flows can lead to cost savings and better resource utilization. The IoT's positive impact on IP highlights the benefits of real-time data monitoring and process control, which can lead to more responsive and agile production systems.

By integrating LP, MFCA, and IoT, SMEs can achieve a holistic approach to productivity improvement. The research model demonstrates that these elements are not only interrelated but also collectively contribute to a more competitive and sustainable business environment. This integration aligns with the paper's topic, driving the design of IoT by incorporating Lean and MFCA concepts to enhance SME productivity in Thailand's beverage industry. The findings underscore the importance of adopting a multi-faceted strategy that leverages process innovation and technological advancements to thrive in a competitive market.

From this report other fit indices also indicate good model fit, showing that the model in this research is consistent with the empirical data. (Kamolsin, J, 2022). In addition, the finding shows the constructive basis for managers to apply lean processes and MFCA and IoT to improve the productivity of Thailand's ready-to-drink tea beverage business (Caitlin Walls, et al., 2024; J Kaneku-Orbegozo, et al., 2020). such as LP has strong effect on IP (Amkwanyean, A., 2014). Besides, the actor found MFCA has strong effect on IP (Supharee, B. & Ruangchoengchum, P., 2019). While IoT has strong effect on IP too (Ngamwannakorn, C, et al., 2018). And finally, LP positively influence IoT (Anthony Anosike, et. al., 2021), and MFCA positively influence IoT too (Shaio Yan Huang, et. al., 2019).

5. Conclusion

The study aimed to examine the impact of integrating lean principles, Material Flow Cost Accounting (MFCA), and Internet of Things (IoT) on the productivity of SMEs in Thailand's ready-to-drink tea beverage industry. The results showed that lean processes, MFCA, and IoT had strong positive effects on productivity, and that these elements were interrelated and synergistic. The findings suggested that SMEs can benefit from adopting a holistic approach to productivity improvement that leverages process innovation and technological advancements.

Nowadays, under intense competition in the ready-to-drink tea beverage business, it was found that improving production productivity is an important factor that leads the business to success over competitors. Therefore, business operators need to use management tools to improve production productivity by Lean process and other whereas LP, MFCA, IoT are integrated innovation both process innovation and technology innovation. This can be further explained as follows. LM influences IoT because it allows designing IoT from evaluating LM data. LM also influences MFCA. Data obtained from LM can be used to assess and improve MFCA process methods, which ultimately results from LM, and MFCA can also be used as a database for improving and developing IoT as well. All of these can significantly improve the production efficiency of Thailand's ready-to-drink tea beverage business at statistics at the .05 level.

Reference

1. Abdel-Kader. (2011). Hybrid discrete PSO with GA operators for efficient QoS-multicast routing. *Ain Shams Engineering Journal* 2 (1), 21-31. [\(Journal Article\)](#)

2. Abdul Rahman, N. U. (2022). The importance of a global mindset to the Malaysian food industry SMEs. *Voice of Academia*, 18(2), 140-150. **(Journal Article)**
3. Achanga, et al. (2006). Critical success factors for lean implementation within SMEs. *Journal of Manufacturing Technology Management*, 17(4), 460-471. **(Journal Article)**
4. Amkwanyean, A. (2014). Increasing Efficiency in the Production Process of PET-bottled Drinking Water Using Lean Manufacturing Theory. Master of Business Administration Degree. Faculty of Business Administration Rajamangala University of Technology Thanyaburi.
5. Anthony Anosike, et. al. (2021). Lean manufacturing and internet of things – A synergetic or antagonist relationship? *Computers in Industry*. 129(2021). n.p. **(Journal Article)**
6. Bulbul, T. (2012). Developing a Scale for Innovation Management at Schools: A Study of Validity and Reliability. *Educational Sciences: Theory and Practice*, 12(1), 168-175. **(Journal Article)**
7. Burritt, R.L. (2015). Material Flow Cost Accounting: A Review and Agenda for Future Research. *Journal of Cleaner Production*, 108, 1378-1389. **(Journal Article)**
8. Caitlin Walls, et al. (2023). Recycling of Metallized Plastic as a Case Study for a Continuous Sustainability Improvement Process. *Sustainability*, 2023(15), 1-23. **(Journal Article)**
9. Chen, A., & Wang, Y. (2017). The role of interest in physical education: A review of research evidence. *Journal of Teaching in Physical Education*, 36(3), 313–322. **(Journal Article)**
10. Das, et al. (2016). Interventions for adolescent mental health: An overview of systematic reviews. *Journal of Adolescent Health*, 59(4), S49–S60. **(Journal Article)**
11. Deebhijarn, S. (2016). The Marketing Mix Strategy Model to Influencing the Decision to Purchase Ready-to-Drink (RTD) Green Teas among University Students in Bangkok Metropolitan Region, Thailand. *International Journal of Sciences: Basic and Applied Research (IJSBAR)* *International Journal of Sciences: Basic and Applied Research*, 29(1), 90-103. **(Journal Article)**
12. Gefen, D., et al. (2003). Trust and TAM in Online Shopping: An Integrated Model. *MIS Quarterly*, 27(1), 51-90. **(Journal Article)**
13. Gokhale, et al. (2018). A Study on Inventory Management and Its Impact on Profitability in Foundry Industry at Belagavi, Karnataka. *International Journal of Engineering Management and Economics* 7(9):29-31. **(Journal Article)**
14. Henseler, et al. (2015). A New Criterion for Assessing Discriminant Validity in Variance-Based Structural Equation Modeling. *Journal of the Academy of Marketing Science*, 43, 115-135. **(Journal Article)**
15. Henseler. (2017). “A new criterion for assessing discriminant validity invariance-based structural equation modeling”, *Journal of the Academy of Marketing Science*, 43(1), 1-21. **(Journal Article)**
16. Hirotsugu Kitada, et al. (2022). Management practice of material flow cost accounting and its discontinuance. *Cleaner Environmental Systems*, 2022(6), Article 100089. <https://doi.org/10.1016/j.cesys.2022.100089> **(Online Journal Article)**
17. Hompratum, S. (2023). Factors positively affecting customer loyalty of Ito En ready to drink tea customers in Sukhumvit area, Bangkok, Thailand. **(Book)**
18. Javalgi, et al. (2013). “Marketing research, market orientation and customer relationship management; a framework and implications for service providers”, *Journal of Service Marketing*, 20(1), 12-24. **(Journal Article)**
19. J Kaneku-Orbegozo, et al. (2020). Applying Lean Manufacturing Principles to reduce waste and improve process in a manufacturer: A research study in Peru. *OP Conference Series Materials Science and Engineering* 689(1):012020. **(Journal Article)**
20. Joseph F., et al. (2007). *Research Methods for business*. West Sussex: Wiley & Sons Ltd.
21. Kaliski, Burton S., ed. (2001). *Encyclopedia of business and finance* *Encyclopedia of business and finance*. Macmillan Reference USA, Detroit. **(Book)**

22. Kamolsin, J. (2022). Causal Factors Affecting Industrial Business Effectiveness in Digital Industry Promotion and Innovation Zone, Thailand. Doctor of Philosophy Business Administration degree. Faculty of Business Administration. Naresuan University. **(Book)**
23. Kim, D.-H., Lee, H. and Kwak, J. (2017) Standards as a driving force that influences emerging technological trajectories in the converging world of the Internet and things: An investigation of the M2M/IoT patent network. *Research Policy*, 46(7), pp. 1234-1254. **(Journal Article)**
24. Kline, R.B. (2016). *Principles and Practice of Structural Equation Modeling* (4th ed.). New York, NY: The Guilford Press. **(Book)**
25. Kock. (2015). Common method bias in PLS-SEM: A full collinearity assessment approach. *International Journal of e-Collaboration* 11(4):1-10. **(Journal Article)**
26. Lee, et al. (2013). Improving productivity of the SMEs in Singapore—Case studies. 2013 IEEE International Conference on Industrial Engineering and Engineering Management. **(Research Report)**
27. Lu & Huang. (2014). A Comparative Study of Chinese and American Think Tank Websites Based on Link Analysis. *Information Theory and Practice*, 129-133. **(Journal Article)**
28. Maruyama, G.M. (1998). *Basics of structural equation modeling*. Basics of structural equation modeling. Sage Publications, Inc. **(Book)**
29. McKinsey & Company. (2019). Our top ten insights of 2019. Retrieved March 3rd, 2024 from <https://www.mckinsey.com/about-us/new-at-mckinsey-blog/top-ten-insights-of-2019>. **(Web page)**
30. Mongkol, K. (2021). The influence of dynamic capabilities on performance of small and medium firms: The case of Thai SMEs. *International Journal of Entrepreneurship*, 25(7), 1-11. **(Journal Article)**
31. Narke M. (2020). Value Stream Mapping: Effective Lean Tool for SMEs. *Materials Today Proceedings* 24(2):1263-1272. **(Journal Article)**
32. Ngamwannakorn, C, et al., (2018). Development of a small plant-based device control system with wireless technology through mobile applications on the Internet of Things concept. Research report. Yala Province: Yala Rajabhat University. **(Research Report)**
33. OECD. (2001). Competencies for the knowledge economy. In: OECD Paris. **(Book)**
34. Oleghe, O. (2017). O. Oleghe, Container placement and migration in edge computing: concept and scheduling models, in IEEE Access. Digital Object Identifier 10.1109/ACCESS.2017.DoiNumber. **(Online Journal Article)**
35. O'Reilly, K. (2016). From toilet insecurity to toilet security: creating safe sanitation for women and girls. *Wiley Interdisciplinary Reviews: Water* 3 (1), 19-24. **(Journal Article)**
36. Paul Krugman. (1994). Competitiveness: A Dangerous Obsession. *Foreign Affairs*, 73(2), 28-44. **(Journal Article)**
37. Peter Landau, (2023). What Is Lean Manufacturing? Retrieved March 3rd, 2024 from <https://www.projectmanager.com/blog/what-is-lean-manufacturing>. **(Web page)**
38. Ping & Jonathan, H. (2005). *Middle Power Statecraft: Indonesia, Malaysia, and the Asia Pacific*. Ashgate. **(Book)**
39. Porter, M.E. (2000). Technology and competitive advantage. *Journal of business strategy*, 5(3), 60-78. **(Journal Article)**
40. Resta, et al. (2016). Lean manufacturing and sustainability: an integrated view. *Advances in Production Management Systems. Initiatives for a Sustainable World: IFIP WG 5.7 International Conference, APMS 2016, Iguassu Falls, Brazil, September 3-7, 2016, Revised Selected Papers*. **(Conference)**
41. Rodgers & Pavlou. (2003). Predicting E-Services Adoption: A Perceived Risk Facets Perspective. *International Journal of Human-Computer Studies* 59(4):451-474. **(Journal Article)**
42. Rodríguez-Pérez, et al. (2017). Coping strategies and quality of life in caregivers of dependent elderly relatives. *Health Qual Life Outcomes*. 2017 Apr 14;15(1):71. doi: 10.1186/s12955-017-0634-8. **(Journal Article)**

43. Shah, R., & Ward, P. T. (2003). Lean manufacturing: context, practice bundles, and performance. *Journal of operations management*, 21(2), 129-149.**(Journal Article)**
44. Shaio Yan Huang, et. al. (2019). The Application of Material Flow Cost Accounting in Waste Reduction. 11(5), 1 – 27.**(Journal Article)**
45. Schumacker, R. E., & Lomax, R. G. (2015). *A Beginner's Guide to Structural Equation Modeling* (4th ed.). New York, NY: Routledge.**(Book)**
46. Sulong, et al. (2015). Material Flow Cost Accounting (MFCA) enablers and barriers: the case of a Malaysian small and medium-sized enterprise (SME). *Journal of Cleaner Production*, 108, 1365-1374.**(Journal Article)**
47. Sundar, et al. (2014). A review on lean manufacturing implementation techniques. *Procedia Engineering*, 97, 1875-1885.**(Journal Article)**
48. Supharee, B. & Ruangchoengchum, P. (2019). Loss Reduction from Negative Cost Material Flow Cost in the Powdered Beverage Production Process with the Application of Material Flow Cost Accounting Technique. *Sisaket Rajabhat University Journal*, 13(3); 1-15.**(Journal Article)**
49. Underhill, et al. (2016). Fragment Length of Circulating Tumor DNA. *PLOS Genetics* | DOI:10.1371/journal.pgen.1006162**(Journal Article)**