Measuring Efficiency of Information Flow within Supply Chain: A Case Study on Smoked Rubber Sheet Production in Thailand

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Panutporn Ruangchoengchum*
College of Graduate Study in Management, Khon Kaen University, Thailand

Poj Dechkerd
College of Graduate Study in Management, Khon Kaen University, Thailand

ABSTRACT

Measuring the efficiency of information flow from the upstream to the downstream supply chain is a significant process of smoked rubber sheet production. The objectives of this study are to measure information flow efficiency within the supply chain in rubber smoked sheet production and provide guidelines to improve the information flow within the supply chain in the production of smoked rubber sheets. This study was conducted by using a questionnaire by nine representatives from farmers' institutions in Thailand. The efficiency of information flow was analysed by IDEF and data envelopment analysis. The results show that smoked rubber sheet production creates waste in field latex collection and storage processes. Waste occurring from information flow was analysed and the results show that small smoked rubber sheets were more efficient than medium smoked rubber sheets when measuring the efficiency of information flow within supply chains. To improve production, this study recommends reducing the production costs by adopting technology assistance in recording and distributing data. Personal development plans should be introduced through training, especially focusing on an agile process, import of raw materials, storage and export of smoked rubber sheets. Based on these findings, Researchers propose recommendations and solutions for improving information flow efficiency within the smoked rubber sheet production supply chain. These could include process improvements, technology upgrades, or changes in communication protocols. These benefits are relevant not only to the specific industry and to Thailand but also to supply chain management practices in rubber-producing countries.

Keywords: Measuring efficiency, Information flow, Supply chain, Smoked rubber sheets, Production.

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1. INTRODUCTION

The para rubber can be primarily processed into two types, namely, water rubber (concentrated latex) and dry rubber (smoked sheet, block, crepe, dried rubber and skim rubber), which is convenient for the transportation, storage and prolonging the shelf life of para rubber. Each type of rubber has a different price, and smoked sheet is the most expensive. The smoked rubber sheet brings raw latex to the filter to separate the dirt, and it undergoes rubber sheet production before being smoked until completely dry to extend the life of the rubber. Therefore, smoked sheets serve as a primary raw material for manufacturing various rubber products, including tires, footwear, industrial hoses, conveyor belts, and automotive components. These products are vital in numerous industries, such as automotive,

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construction, and manufacturing. Rubber production, including smoked sheets, is then a significant contributor to the economies of rubber-producing countries. It generates income and employment opportunities for local communities and contributes to the overall economic growth of many countries, especially in Thailand which is a rubber trading country (Office of Agricultural Economics, 2020).

In fact, rubber sheets that have not undergone the smoking process cannot be exported to foreign countries, as no one will buy raw rubber sheets due to a high risk of production failure. Rubber smoked sheet can be used as a raw material for other products, such as tires, water pipes, car parts and shoes. In 2020, the export volume of rubber smoked sheets had been increased to approximately 612,202, amounting to 20.7 billion baht (Office of Agricultural Economics 2020). Many important export markets are available, including the United States, Germany, China and Japan. Each country has a large automotive manufacturing industry with high purchasing power (Rahmat *et al*., 2017), This includes the automotive industry in Thailand. Therefore, since 2019, government agencies have paid more attention and supported farmers in expanding the production of smoked rubber sheets; especially in 2018, the production was expanded to 3.7%, resulting in Thailand producing more smoked rubber sheets (Rubber Authority of Thailand 2020). The southern region of Thailand is the major rubber cultivation area. It is one of Thailand's economic crops that can create enormous value in the country. It can be seen from the area and yield of rubber planting in the southern region in 2021 were more than those in other regions, with a plantation area of 12,071,712 rai that yields 3,223,670 tons per year. In comparison, the northeast region has 4,959,631 rai yielding 1,125,555 tons per year, the central region has 2,221,536 rai yielding 446,594 tons per year, and the northern region has 1,202,915 rai yielding 221,585 tons per year. The southern region is then the most suitable area for the growth of rubber trees in the country (Office of Agricultural Economics 2020).

However, the competition in the production of smoked rubber sheets is highly intensive, causing manufacturers of smoked rubber sheets to improve their production process by requesting certified standards of good practice for smoked rubber sheet production. The groups of farmers in the southern region were affected in competition because their smoked rubber sheet did not meet customer requirements. The problem was found to be caused by the information flow within the production process, that is, a problem in information flow results in information distortion and insufficient efficiency (Liu,2011). For this reason, the Institute of Rubber Smoked Sheet Rubber Farmers has found a way to adjust to continue their business (Rubber Authority of Thailand 2020), given that information flow is a communication of information.

Over the past few decades, many studies have shown that the information production flow has been developed to several aspects. Relevant studies include the following: 'Production line data validation' (Faller and Feldmüller, 2015), 'Waste reduction for efficiency improvement in production processes' (Wajanawichakon 2020), 'Material flow optimisation in a multi-echelon and multi-product supply chain' (Rajkanth *et al*. 2017), 'An investigation of supply chain performance measurement' (Saad and Patel 2006), 'Development of an integrated performance measurement framework for lean organizations' (Sangwa and Sangwan, 2018) 'The role of IT-enabled collaborative decision making in inter-organizational information integration to improve customer service performance' (Wong *et al*. 2015), 'Performance measurement in construction' (Bassioni *et al*., 2004), 'Effects of buyer-supplier relationship on social performance improvement and innovation performance improvement' (Awan 2019 and Hidayah & Kartikadevi, 2021), 'The

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relationships between supplier development, commitment, social capital accumulation and performance improvement' (Krause *et al*. 2007 and), 'Performance improvement through supply chain collaboration' (Vereecke and Muylle 2006) and 'Factors that influence interorganisational use of information and communications technology in relationship-based supply chains' (Mirkovski *et al*. 2016).

Nevertheless, research on how to improve the efficiency of information flow within the supply chain, especially in smoked rubber sheet production, is limited. In view of the concept of efficiency improvement, Harrington (1996) and Cao, Chaiwan & Chaiboonsri (2023) claimed that the factors affecting the increase or decrease of production efficiency can be divided into three categories, namely, technological factors, such as production processes and the working process of machines or tools; service system factors, such as the use of administrative techniques and promotion of labour systems; and labour factors. Stevens and Johnson (2016) stated that information flow is the movement of information among people to receive the same information, which is suitable for usage, on time and in its original form. Good information must come from good sources, and storage and data must be well controlled. Christopher (2005) claimed that a supply chain is a network of interconnected organisations through the linkages of upstream, midstream and downstream activities in processes and their different activities. Such activities create value in the form of goods and services delivered to customers' as best as possible. Moreover, the concept of efficiency improvement, Henriques *et al*. (2018) stated that data envelopment analysis (DEA), which is an estimation method that does not depend on parameters (nonparametric method) in assessing the efficiency of a production unit. The exact function that defines the performance boundary is not defined; however, the performance boundary is calculated using the 'efficient frontier'. Linear programming is a mathematical method that uses empirical data on inputs and outputs. The performance score is then calculated by comparing it with the generated performance. In using a parametric method for calculating the performance boundary function, a performance model, such as a Cobb–Douglas, comprehensive efficiency score (CES) and model production function or any other format function, should be initially defined with the desired properties. Then, econometric methods, such as corrected ordinary least squares, are used to correct maximum likelihood. Another method called the Charnes, Cooper and Rhodes (CCR) model is used to find a technical performance index or overall operational efficiency score.

The above methods can be used in improving the efficiency of information flow within the supply chain in smoked rubber sheet production to support farmer institutes producing smoked rubber sheet to develop guidelines for the development of production processes and labour, as well as gain a competitive advantage in trade. Measuring the efficiency of information flow within the supply chain, as demonstrated in a case study of smoked rubber sheet production in Thailand, can make valuable contributions to the broader literature on supply chain management and business operations, extending beyond the specific nation, industry, and business case analysed in the article. The case study focuses on a specific industry (smoked rubber sheet production) and a specific nation (Thailand), its findings and methodologies can have broader implications for supply chain management, technology adoption, sustainability, and operational efficiency, making valuable contributions to the literature that extend well beyond the confines of the specific case analysed.

Therefore, the objectives of this study are to: 1) measure information flow efficiency within the supply chain in smoked rubber sheet production and 2) provide guidelines to improve the information flow within the supply chain in the production of rubber smoked sheets. In

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summary, measuring the efficiency of information flow within the supply chain in the context of smoked rubber sheet production in Thailand can lead to a wide range of benefits, including improved operations, cost savings, increased customer satisfaction, and greater resilience. These benefits are relevant not only to the specific industry and nation but also to supply chain management practices more broadly. Researchers and practitioners worldwide can leverage these insights to enhance their supply chain operations.

2. METHODOLOGY

2.1 Research design

This study uses quantitative and qualitative approaches (mixed methodology) by using case studies from samples obtained by stratified random sampling. The samples must be an institution producing smoked rubber sheet that has been certified with Good Manufacturing Practice (GMP) within the period of 2015–2019 (Thai Agricultural Standard No. 5906-2556; National Bureau of Agricultural Commodity and Food Standards, 2013) and factories producing smoked rubber sheets are registered by the Department of Agriculture. A total of nine sample groups were obtained, including five from Trang Province, three from Songkhla Province and one from Nakhon Si Thammarat Province (Figure 1). Nine sample groups are a small sample that can generate reliable results from the DEA, which determines the sample size from the research of Coelli, (1996) and Ramanathan, (2003) that brought in the DEA program to analyse a small sample which generated reliable results from the DEA. In addition, only factories producing smoked rubber sheets with positive operating results were selected. Factories of smoked rubber sheets that had negative operating results or losses were not taken into account for efficiency analysis. This is because the output variable, namely the net profit rate of the farmer institution that loses, would have a negative value. When the efficiency is analysed with DEA. using the DEAP2.1 program, the program cannot be used to analyse negative data and if the farmer institution had operating losses, it did not reflect the efficiency of operations. Therefore, those factories of smoked rubber sheets were not included in the efficiency analysis this time. The research methods are as follows.

Figure 1. Subjects in the south of Thailand

2.2 Data collection

Overall, the sample group consisted of nine smoked rubber sheet factories (factories producing smoked rubber sheets), five from Trang Province, three from Songkhla Province and one from Nakhon Si Thammarat Province. These samples were divided into two groups according to the size of the production capacity (t/year), and the performance of the two groups is compared as follows:

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1) Three factories with a production capacity of less than 1,000 ton per year are small-size factories of smoked rubber sheets.
2) Six factories with a capacity of more than 1,000 ton per year are medium-size factories of smoked rubber sheets. Then, the codes were set to 'RSF', which indicate smoked rubber sheet factories, followed by the sequence number, as shown in Table 1.

Table 1: Codes of factories that produce smoked rubber sheets with GMP certification

Code	Province
Small-sized factories of smoked rubber sheets	
RSF01	Nakhon Si Thammarat
RSF02	Songkhla
RSF03	Songkhla
Medium-sized factories of smoked rubber sheets	
RSF04	Trang
RSF05	Trang
RSF06	Trang
RSF07	Trang
RSF08	Trang
RSF09	Songkhla

3) Primary data was collected by conducting in-depth interviews with representative farmers involved in the production process and currently working at smoked rubber sheet factories. Open-ended questions on the issue of the number of labours; production time spent per day, including annual production capacity; and financial information were used to analyse the waste of information flow within the supply chain in rubber smoked sheet production.
4) Secondary data was collected from the 2013–2017 annual report (5 years' worth of historical data). This data relates to the raw material import process, production processes, production capacities, price of raw materials, the export of smoked rubber sheet, including the duration of each production activity was used as a component to measure the efficiency of information flow.

2.3 Data analysis

The primary data was then combined with the secondary data. Data was obtained from the analysis of valuable activities (VA) and non-valuable activities (NVA), including necessary non-value activities (NNVA) that affected non-efficiency processes. The data were analysed for VA and NVA, including NNVA, with IDEF maps. This data was applied in information flows within the supply chain in smoked rubber sheet production. In addition, the results were used to measure efficiency by using data from an in-depth analysis of the interviews on the number of labours; production time per day, including annual production capacity; and costs incurred.

1) The variables used in the performance level analysis were divided into two variables (input and output variables) as follows:
   1.1) The input variables of five sub-variables can be defined as **I1–I5** as follows:
      I1 is the number of labours in the institution, **I2** is the production capacity in tons per year, **I3** is the number of hours per day, **I4** is the cost of sales and administration per year, and **I5** is the cost per year.
   1.2) The amount of output factor variable (Output) of one sub-variable is defined as
      O1 as follows: **O1** is the income from the product sales per year.

All the data was analysed and synthesised by taking the data obtained from the performance measurements. These factors affect the efficiency of the process, as well as the theoretical

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data and the investigation on performance improvement. Waste occurring in the information flow was used to formulate guidelines for improving the efficiency of information flow within the supply chain in smoked rubber sheet production. In addition, this data contains results from the study of measuring the efficiency of information flow within the supply chain to synthesise and formulate guidelines for improving the efficiency of information flow within the supply chain in the production process. This data was applied in information flow within the supply chain in smoked rubber sheet production.

2) Analytical principles

2.1) Analysis of fixed production technical efficiency (CRS assumption) with an efficiency score between 0 and 1.

2.2) Analysis of technical efficiency of variable production (VRS assumption) with an efficiency score between 0 and 1.

2.3) SE analysis with an efficiency score between 0 and 1.

The efficiency score indicates the level of efficient input use. If the efficiency value is not equal to one, then it indicates that the smoked sheet factory is inefficient in using the production factors; thus, it can be reduced proportionally. Therefore, smoked rubber sheet factories should improve the efficiency rating value to 1, given that a value less than 1 implies that the factory is not fully efficient. The DEAP version 2.1 program was applied under the assumption of variable returns to scale (VRS) and constant returns to scale (CRS), and includes the results of cross-sectional data (Suebpongsakorn *et al*.2016), by solving pairs of linear equation problems to find a technical performance score. The process is described as follows.

Case of variable returns to scale (VRS)

The efficiency score can be calculated as

$Min_{\theta,\lambda}\theta$ under the limitation

$$-y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0, and$$
$$N_1' = 1\ and\ \lambda \geq 0, \qquad (1)$$

with θ = scalar

λ = size of the vector of constants (weighted value), $N \times 1$

N = number of production units

$DMU_i (i = 1 \dots N)$

x_i and y_i are vectors of inputs and outputs for DMU_i, respectively

X = matrix of factors of production size, $K \times N$

Y = matrix of output size, $M \times N$

K and M = number of inputs and outputs, respectively.

N_1' = vector with a size of 1, $N \times 1$

Case of constant returns to scale (CRS)

The efficiency score can be calculated as

$Min_{\theta,\lambda}\theta$ under the limitation

$$-y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0, and$$
$$\lambda \geq 0, \qquad (2)$$

with θ = scalar

λ = size of the vector of constants (weighted value), $N \times 1$

N = number of production units

$DMU_i (i = 1 \dots N)$

x_i and y_i are the vectors of inputs and outputs for DMU_i, respectively

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X = matrix of factors of production size, $K \times N$
Y = matrix of output size, $M \times N$
K and M = number of inputs and outputs, respectively.

Case of scale efficiency (SE)

SE can be calculated as follows:

$$SE = TE_{VRS}/TE_{CRS} \quad (3)$$

with SE = scale efficiency

TE_{VRS} = technical efficiency score under the assumption of varying productivity from Equation (1).

TE_{CRS} = technical efficiency score under the assumption of constant productivity from Equation (2).

3. RESULTS

3.1 Measuring information flow efficiency within the supply chain in smoked rubber sheet production.

In-depth interviews were used to analyse the waste occurring in the information flow within the supply chain in rubber smoked sheet production using an IDEF chart, as illustrated in Figure 2. The production of smoked rubber sheets includes the taking of field rubber, DRC measurement, rubber sheet processing, sorting and quality verification and storage. In the production process, waste (NNVA) is generated in the live latex receiving facility. For instance, each day, fresh rubber producers (i.e. merchants and small farmers) wait for their raw rubber latex to be transferred, resulting in waste of time (lead times) and delays in data transmission which can lead to inefficiencies. Additionally, smoked sheet storing activities are NNVA, resulting in inventory waste (overstocking), due to inaccurate information which can lead to errors in inventory management.

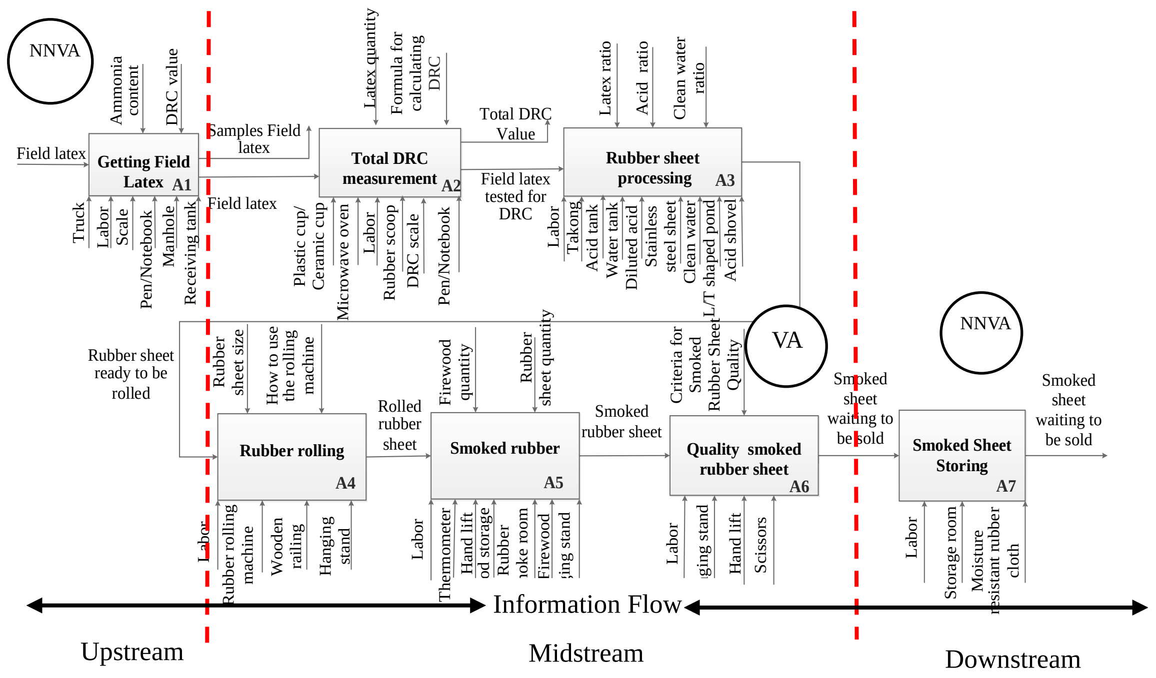

Figure 2. IDEF diagram for the waste analysis results from the information flow within the supply chain in smoked rubber sheet production.

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Measuring the efficiency of information flow within the supply chain, especially in a specific context like Smoked Rubber Sheet Production in Thailand is based on the analysis of the data from in-depth interviews with representative farmers involved in the production process and work at small-sized and medium-sized factories and the 2013–2017 annual report (5 years' worth of historical data) about labour, production capacities, production processes, prices, cost and income including the duration of each production activity resulting in the data depicted in Table 2. The data set in Table 2 (information of flow efficiency within the supply chain in smoked sheet production via the DEA method) was measured by VRS. The competition in smoked rubber sheet businesses is focused upon product quality and reputation. The production of smoked sheets requires strict quality control measures to ensure that the final product meets smoked rubber sheet production standards. Performance values were analysed under the assumption that VRS is higher than CRS. Therefore, VRS was used as a basis for analysis by DEAP version 2.1. The results are shown as follows.

Table 2. Small-size and Medium -size factory group by DEAP version 2.1

(1) Small-size factory group					**(2) Medium-size factory group**				
EFFICIENCY SUMMARY:					**EFFICIENCY SUMMARY:**				
Firm	**crste**	**vrste**	**scale**		**Firm**	**crste**	**vrste**	**scale**	
RSF01	0.997	1.000	0.997	irs	RSF04	0.979	1.000	0.979	irs
RSF02	1.000	1.000	1.000	-	RSF05	1.000	1.000	1.000	-
RSF03	1.000	1.000	1.000	-	RSF06	1.000	1.000	1.000	-
					RSF07	1.000	1.000	1.000	-
					RSF08	1.000	1.000	1.000	-
					RSF09	1.000	1.000	1.000	-
mean	0.999	1.000	0.999		mean	0.997	1.000	0.997	

Summary of Output Targets:		**Summary of Output Targets:**	
Firm output:	**O1**	**Firm output:**	**O1**
RSF01	37,684,383.830	RSF04	30,285,901.870
RSF02	25,190,423.060	RSF05	82,573,490.440
RSF03	34,450,790.530	RSF06	90,765,848.970
		RSF07	117,137,609.740
		RSF08	60,362,027.840
		RSF09	29,973,727.000

Summary of Input Targets:						**Summary of Input Targets:**					
Firm input:	**I1**	**I2**	**I3**	**I4**	**I5**	**Firm input:**	**I1**	**I2**	**I3**	**I4**	**I5**
RSF01	8.000	960.000	8.000	35,113,790.130	1,237,486.120	RSF04	4.000	1,200.000	9.000	28,471,109.520	1,341,757.960
RSF02	5.000	960.000	9.000	22,823,718.660	494,708.780	RSF05	7.000	1,200.000	7.000	78,475,670.360	3,136,182.770
RSF03	4.000	960.000	10.000	32,007,029.120	805,404.530	RSF06	5.000	1,200.000	8.000	86,324,199.070	6,018,890.780
						RSF07	6.000	1,200.000	8.000	85,723,370.490	2,593,929.840
						RSF08	5.000	1,200.000	9.000	56,193,818.600	3,709,392.720
						RSF09	4.000	1,200.000	9.000	27,555,845.510	737,229.510

Remarks: crste is technical efficiency from CRS DEA., vrste is technical efficiency from VRS DEA., scale is scale efficiency is crste/vrste, irs is increasing return to scale, I1 is the number of labours in the institution (per institution), I2 is the capacity (tons per year), I3 is the number of manufacturing hours (hours per day), I4 is the cost of sales and management (baht per year), I5 is the cost (baht per year) and O1 is the income from the product sales (baht per year).

In the analysis of input factors and revenue factor data sets within the supply chain in all nine factories from Table 3, the details are as follows.

Table 3. Input factors and revenue factor data sets

Code	**Input Factors**					**Revenue Factor**
	I1	**I2**	**I3**	**I4**	**I5**	**O1**
RSF1	8	960	8	35,113,790.13	1,237,486.12	37,684,383.83
RSF2	5	960	9	22,823,718.66	494,708.78	25,190,423.06
RSF3	4	960	10	32,007,029.12	805,404.53	34,450,790.53
RSF4	4	1,200	13	28,471,109.52	1,341,757.96	30,285,901.87
RSF5	7	1,200	7	78,475,670.36	3,136,182.77	82,573,490.44
RSF6	5	1,200	8	86,324,199.07	6,018,890.78	90,765,848.97
RSF7	6	1,200	8	85,723,370.49	2,593,929.84	95,723,370.49
RSF8	5	1,200	9	56,193,818.60	3,709,392.72	60,362,027.84
RSF9	4	1,200	9	27,555,845.51	737,229.51	29,973,727.00

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Remarks: I1 is the number of labours in the institution (per institution), I2 is the capacity (tons per year), I3 is the number of manufacturing hours (hours per day), I4 is the cost of sales and management (baht per year), I5 is the cost (baht per year) and O1 is the income from the product sales (baht per year).

Furthermore, in the analysis of data flow efficiency values within the supply chain in all nine factories from Table 4, the details are as follows;

Table 4. Results of performance measurement classified by rubber smoked sheet factory

No.	**Code**	**SE**			**Efficient**
		CRS	**VRS**	**SE**	
Small-size Factory Group					
1	RSF01	0.997	1.000	0.997	Not fully efficient
2	RSF02	1.000	1.000	1.000	Efficient
3	RSF03	1.000	1.000	1.000	Efficient
Medium-size Factory Group					
4	RSF04	0.979	1.000	0.979	Not fully efficient
5	RSF05	1.000	1.000	1.000	Efficient
6	RSF06	1.000	1.000	1.000	Efficient
7	RSF07	1.000	1.000	1.000	Efficient
8	RSF08	1.000	1.000	1.000	Efficient
9	RSF09	1.000	1.000	1.000	Efficient

Small-sized factory group

As shown in Table 4, most of the small-sized factories were efficient. The combination of these values was 1.000, which indicates that the use of the same input factors resulted in a performance average of 1.000. For example, RSF01 was efficient under CRS assumption of 0.997, VRS assumption of 1.000 and performance per size (SE) of 0.997. Therefore, the factory was not fully efficient because of the size of the production capacity at the appropriate point, as CRS and VRS values differed in the form of an increase return to scale; nevertheless, it could still generate income if the production capacity was increased.

Medium-sized factory group

On the basis of the findings in Table 4, most of the medium-size factories were efficient, given the total value of 1.000. The use of the same combination of input factors resulted in an average efficiency of 1.000. For example, RSF04 was expected to be efficient under CRS assumption of 0.979, VRS assumption of 1.000 and performance (SE) of 0.979. Therefore, the production system was not fully efficient because of the production size at the point of failure, as CRS and VRS values differed with the increasing return to scale. The medium-size factories could generate revenue by increasing capacity, developing skilled labour and using technology to distribute data quickly and accurately.

3.2 Guidelines to improve the information flow within the supply chain in the production of rubber smoked sheets.

According to the interviews about daily field rubber activities, time was not fixed for receiving fresh rubber flows each day. This finding was caused by the production process being wasted by waiting for fresh rubber and storing the smoked sheets. Most of them had smoked rubber sheets waiting for distribution. Such waste was caused by the recording of data that did not match the capacity and production, which exceeded the demand. Accurate information which can reduce delays in data transmission are essential for making informed

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decisions, streamlining order processing and inventory management. These are guidelines to improve the information flow within the supply chain in the production of smoked rubber sheets.

In addition, the performance calculations from DEAP version 2 .1 indicated that efficient small-sized factories, RSF0 2 and RFSF0 3 , had proper production capacity and sufficient labour for production. The optimum man hours were spent at the right time, with a balance of sales and cost per production of rubber smoked sheets. Conversely, RSF0 1 's rubber smoked sheets were not fully efficient due to the large production capacity.

However, improvements in the areas of labour and cost reduction, as well as to technologies and applications used in the effectiveness of data transmission can lead to improved production efficiency. Thus, the adoption of technology, such as supply chain management software and RFID tracking, can enhance the tracking and sharing of critical information, thereby improving information flow efficiency. Timely information should be reduced, and more production should be enabled while maintaining the same work time. The fully efficient medium factories, RSF0 5 , RSF0 6, RF0 7 , RSF08 and RSF0 9 , had appropriate capacity, sufficient labour for production, reasonable work hours, sales costs and balanced costs for production. The low-capacity medium-size factory is RSF04 due to low labour with high working hours. Thus, the factory should increase its labour and fix the receiving time of fresh rubber to reduce the amount of production time. As the purpose of the study was to improve information flow efficiency within the supply chain in the production process to be entirely efficient, manufacturing factors must be reviewed, particularly, developing labour skills, using technology to help in communication, monitoring data and reducing unnecessary costs. Given that most of the activities in the manufacturing process are similar, they can reference operational flaws and align policies or job targets to improve efficiency. These suggestions offer ways to improve performance, as shown in Table 5.

Table 5. Information flow optimisation guidelines within the supply chain in rubber smoked sheet production

Optimisation Approach Type	**Information Flow Optimisation Guidelines**
Small-sized factories of smoked rubber sheets	1. Increase capacity 2. Skill development 3.Use technology to record and distribute information to all activities
Medium-sized factories of smoked rubber sheets	1. Ensure timely product delivery 2. Skill development . Use technology to help save and distribute information to all activities 4. Reduce unnecessary costs in production

4. CONCLUSIONS AND DISCUSSION

Measuring the efficiency of information flow within the supply chain, as demonstrated in a case study of Smoked Rubber Sheet Production in Thailand, can contribute to the broader literature beyond the specific nation, industry, and the business cases examined. The study's

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findings can inform discussions on supply chain resilience, which in turn offers broader contributions to the literature:

Efficient information flow refers to the waste analysis of the information flow within the supply chain in smoked rubber sheet production, and using IDEF diagrams indicates that waste occurs in non-value added but necessary activities (NNVA), particularly in receiving an order for fresh rubber and storing smoked rubber sheets. These activities in the production process had NNVA, which agrees with the research of Dechkerd and Ruangchoengchum (2019), Ruangchoengchum *et al.* (2019) who described NNVA is the waste in the production process. In addition, this result consists with the research of Larpsomboonchai and Kecharananta (2020) and Tumrongsuk *et al.* (2016), who discussed the waste in the production process caused by storing rubber smoked sheets. Thus, streamlining order processing based on accurate and timely information is vital to prevent overstocking production (Smith and Ellram, 1997).

Moreover, in measuring the efficiency of information flow within the supply chain in smoked rubber sheet production, findings indicated that one of the small-sized factories was not fully efficient, because the receiving of fresh rubber had no fixed time, skilled labour lacked experts in production, and lacked technology to provide accurate information, resulting in reduced efficiency and decreased productivity. Mokkhamakkul (2009), Thuong *et al.* (2022) and Kuo, Wu & Liu (2022) contended that the supply chain indicators can be divided into cycle time and productivity, including technology that should be used in assisting with information flow within the supply chain accurately and speedily.

Thus, the measurement of information flow efficiency involves assessing the speed, accuracy, and effectiveness of data transmission in the supply chain. This study suggests ways to improve efficiency, especially the development of labour skills. Training and practice should be consistently available to provide flexibility and expertise in work behaviours. This result coincides with Morsy (2016), who claimed that labours should always be self-improving to be able to fully work to reduce unnecessary expenses. Likewise, the research of Sinnarong and Putthakarn (2019), which proposed the use of technology to facilitate the distribution of information in the industry, such that labour can be produced according to the requirements and can be efficient according to the specified standards.

However, dividing the size of rubber smoked sheet factories into small and medium-size clearly showed the differences in the efficiency of information flow within the supply chain in rubber smoked sheet production. This is consistent with Birman *et al.* (2003), who suggested that size and area affect performance comparisons. This lead to guidelines which improved the information flow within the supply chain in the production of smoked rubber sheets. Efficient information flow within the supply chain of small-sized factories should increase capacity, whereas medium-sized factories should ensure timely product delivery. These insights suggest improving information flow efficiency within the supply chain of smoked rubber sheet production is essential for optimizing operations and ensuring timely product delivery.

Overall, the study on information flow efficiency within the smoked rubber sheet production supply chain in Thailand contributes valuable insights and methodologies that have relevance beyond its specific focus. These insights can inform and improve information flow efficiency within the supply chain practices across industries and regions, addressing global challenges such as sustainability and supply chain resilience.

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