Performance Measurement of Potato Supply Chain in North Sumatra Province

Kimberly Febrina Kodrat[1], Hasan Sitorus[2], Rasmi Febriani Sihotang[3]

[1]Department of Industrial Engineering, Faculty of Engineering, Universitas Islam Sumatera Utara, Medan, Indonesia
[2]Department of Animal Husbandry, Faculty of Animal Husbandry, Universitas HKBP Nommensen, Medan, Indonesia
[3]Industrial Engineering, Institut Sains Teknologi TD Pardede, Medan, Indonesia

Corresponding Author: Kimberly Febrina Kodrat (kimberly@ft.uisu.ac.id)

ABSTRACT

This study aims to measure and analyse the performance of potato supply chain in North Sumatra Province. Data were collected from 150 respondents, namely, farmers, traders, distributors, and retailers through a questionnaire survey. The results showed that the average order cycle time was seven days, with a logistics cost of IDR 1,500.00 per kilogram. The product loss rate reached 10%, indicating that there were problems in handling and storage during distribution. Product quality was considered quite good with an average score of 3.8, while customer satisfaction was at a score of 3.7. Statistical analysis showed that logistics costs and product loss rates were negatively related to customers' satisfaction, while product quality had a positive relationship. SWOT analysis identified that infrastructure improvements, training, and implementation of information technology were needed to improve supply chain performance. Key recommendations are to improve road infrastructure, training for farmers, and product diversification. By implementing these recommendations, it is hoped that the efficiency and effectiveness of the potato supply chain in North Sumatra can be improved, which will ultimately improve farmers' welfare and product competitiveness in the market.

INTRODUCTION

Agriculture is a sector that plays an important role in Indonesian economy, as well as in North Sumatra Province [1]. One of the leading commodities produced by this province is potato. Potato is not only a staple food, but also a raw material for various processed food industries. Therefore, potato supply chain management is a crucial aspect that needs special attention [2].

The supply chain involves various stages, starting from production at the farmer's level, distribution by traders, and consumers [3]. The efficiency and effectiveness of each stage greatly determine the quality and availability of products in the market. Measuring supply chain performance becomes an important step to ensure that each component in the chain functions optimally [4]. With proper performance measurement, various obstacles and inefficiencies can be identified and fixed. In this province, potato supply chain faces various challenges because of geographical conditions, limited infrastructure, and market price fluctuations that are often uncertain. Therefore, this study aims to measure the performance of potato supply chain, with a hope to provide useful

recommendations for increasing the efficiency and productivity of potato farming sector here.

This province appears as an important player in the national potato production map; the proof was, for example in 2021, it recorded a potato harvest of 90,000 tons, placing it as one of the main potato producing centres in Indonesia [5]. Karo regency, the largest producing area in this province, plays a crucial role in supplying potato needs in this region and its surroundings. Its glittering production figures lies a complex supply chain, connecting potato farmers upstream with consumers downstream. This supply chain involves various actors, from farmers, collectors, wholesalers, retailers, and consumers [6]. The efficiency and effectiveness of the supply chain are considered the main keys to ensuring smooth distribution, minimizing waste, and, ultimately, improving the welfare of farmers and meeting consumers' needs at reasonable prices.

Table 1. Potato production in North Sumatera (2020 - 2022)

Year	Harvest area (Ha)	Production (Ton)	Productivity (Ton/Ha)
2020	7.990	128.893	16.14
2021	8.352	159.014	19.04
2022	7.635	147.230	19.27

Source: Central Statistics Agency of North Sumatra Province

Potato production over the past three years (2020-2022) has shown a fluctuating pattern and the year 2021 was the period with the highest harvest with production reaching 159,014 tons, while in 2022 there was a decrease in production to 147,230 tons [7]. This decrease was caused by several factors, including:

- pests and diseases of potato plants, such as late blight and nematodes, were one of the main constraints in increasing production.
- unpredictable rainfall patterns and extreme weather could be fatal for potato plants, especially during critical growth phases.
- conversion of agricultural land into residential, industrial, and commercial areas contributed to the decline in the area planted with potatoes.

Karo regency dominates potato production, contributing 66% of the total production in the province[8]. Other areas that are also centres of potato production include Dairi, Simalungun, and Toba Samosir. Potato from the province is distributed to various regions in Indonesia, with the main focus on the markets in Jakarta, West Java, and South Sumatra, and is exported to neighbouring countries such as Malaysia and Singapore. The provincial government and various related parties continue to strive to increase potato production and some steps have been taken:

- in case of the development of pest and disease resistant varieties, research and development of potato seeds that are more resistant to pests and diseases that commonly attack potato plants had been carried.
- application of modern cultivation technology was done through efficient irrigation, appropriate fertilization, and integrated pest control and it was expected to increase the productivity and quality of potato plants.
- the development of infrastructure such as adequate storage and post-harvest processing warehouses could help reduce crop losses and increased the economic value of potato.

In addition to its important economic aspects, potato farming in North Sumatra also had significant social impacts. Many local farmers depended on potato cultivation for their livelihoods, however, they were often faced with various challenges such as weather uncertainty, pests, and plant diseases, as well as limited access to modern agricultural technology. This condition emphasized the need to improve supply chain performance so that farmer welfare could be improved.

On the other hand, demand for potato continues to increase along with the increasing population and changes in people's consumption patterns that tend towards processed food products. All this adds to the urgency to ensure that potato supply chain is able to meet the increasing market demand, both in terms of quantity and quality.

In the context of globalization and increasingly tight market competition, measuring supply chain performance is also a strategic tool to increase the competitiveness of North Sumatran potato products in national and international markets (Silvia et al., n.d.). By utilizing information and communication technology, transparency and coordination between stakeholders in the supply chain can be improved, thereby reducing risk and inefficiency.

This study explored aspects of sustainability in potato supply chain and sustainable agriculture is not only about high production, but also about maintaining the balance of the ecosystem, wise use of natural resources, and paying attention to the social and economic aspects of farmers. Thus, the measurement of supply chain performance would include relevant sustainability indicators. All of these efforts are expected to have a long-term positive impact on the potato farming sector in North Sumatra. With better supply chain performance, it is expected to create price stability, to improve product quality, and to reduce waste of resources. Ultimately, this study aims to create an efficient, sustainable, and inclusive supply chain model that can be replicated in other areas with similar agricultural commodities.

MATERIALS & METHODS

This study uses a quantitative descriptive approach that aims to measure and analyse the performance of the potato supply chain in North Sumatra Province [9]. This approach was chosen to obtain a measurable picture of various aspects of the supply chain, as well as to identify critical factors that influenced this performance. The research was held at North Sumatra Province, which was one of the centres of potato production in Indonesia. The research subjects included all actors in the potato supply chain, namely, potato farmers, traders (collectors and wholesalers), distributors, retailers, and consumers.

Data collection techniques

The data in this study were collected through several methods [10], namely:

- questionnaires were distributed to potato farmers, traders, distributors, and retailers to collect quantitative data. The questionnaire was designed to measure various aspects of supply chain performance such as cycle time, logistics costs, product loss rates, product quality, and customer satisfaction. Interviews were conducted with key informants who had important roles in the potato supply chain. The interviews aimed to gain in-depth insights into the problems and challenges faced and potential solutions that could be implemented.
- direct field observations were conducted to see the actual conditions of the potato production, distribution, and sales processes. These observations helped to confirm the data obtained from the questionnaire and interviews.

Data analysis techniques

The collected data were analysed using the following techniques [11]:

- quantitative data were analysed descriptively to provide an overview of the performance of the potato supply chain. The analysis included the calculation of averages, percentages, and frequency distributions.
- statistical tests were used to examine the relationship and influence between variables that affected the supply chain performance. Regression and correlation analysis techniques were involved to determine the level of relationship between variables.

- strengths, weaknesses, opportunities, and threats (SWOT) analysis was applied to identify internal and external factors that affected supply chain performance. The analysis helped in formulating performance improvement strategies.

Supply chain performance indicators

Supply chain performance measurement was carried out using several main indicators, which were formulated as follows:

Order cycle time

$$\text{Order cycle time} = \frac{\sum(\text{Delivery time} - \text{booking time})}{\text{Number of orders}}$$

Logistics cost

$$\text{Logistics cost} = \frac{\sum(\text{Transportation costs} + \text{Storage costs} + \text{handling fee})}{\text{Total product volume}}$$

Product loss rate

$$\text{Product loss rate} = \frac{\text{Number of products lost or damaged}}{\text{Total products shipped}} \times 100\%$$

Product quality

Product quality was measured based on the level of consumer's satisfaction obtained from a questionnaire survey, using a Likert scale of 1-5

Customer's satisfaction level

Customer's satisfaction was measured using a Likert scale of 1-5 based on a questionnaire that measured satisfaction with various aspects of the supply chain, such as delivery speed, product condition, and customer service.

Validity and reliability

To ensure the validity and reliability of the data, tests were conducted on the questionnaire used [12]:

- validity testing aimed to ensure that the research instrument measured what had be measured; construct validity was tested using factor analysis.
- reliability testing aimed to ensure consistency of measurement results and reliability testing was carried out using the Cronbach's Alpha coefficient, with an alpha value > 0.7 which was considered reliable.

RESULT AND DISCUSSION

Table 2. Respondents' profile

Category of respondents	No. of respondents	Percentage
Farmers	60	40%
Traders	45	30%
Distributors	22	15%
Retailers	23	15%
Total	150	100%

Source: Data modified

The distributed questionnaire survey successfully collected data from 150 respondents, i.e., potato farmers (40%), traders (30%), distributors (15%), and retailers (15%). Most farmers who responded had agricultural land of less than two hectares and had been farming potato for more than ten years. The profile of the respondents was dominated by farmers with land of less than two hectares and showed that most potato farmers were classified as small farmers. This is in line with research conducted by Suharno that the majority of farmers in Indonesia was included as small-scale and faced various challenges, including access to markets and technology [13].

Table 3. Order cycle time

Cycle time (day)	No. of respondents	Percentage
5	30	20%
6	45	30%
7	50	33.3%
8	15	10%
9	6	4%
10	4	2.7%
Total	150	100%

Source: Data modified

The results of the descriptive analysis showed that the average order cycle time was seven days, with a range of five to ten days. The average logistics cost per kilogram of potatoes was IDR 1,500.00, with variations caused by shipping distance and road conditions. The average order cycle time was found to be seven days, which means that the time from ordering to shipping potato to consumers took one week. This fairly long cycle time was

caused by several factors, such as poor road conditions and the process of collecting harvests from various farmers before shipping. The average order cycle time of seven days indicated that the process from ordering to shipping potato took a long time. This can be caused by inadequate infrastructure conditions, such as damaged roads and inefficient transportation. According to Chopra & Meindl, long order cycle times could reduce supply chain efficiency and affected customer's satisfaction [14]. Therefore, improving transportation infrastructure is key to accelerating order cycle times and improving supply chain performance.

Table 4. Logistics costs

Cost components	Cost per kilogram (Rp)
Transportation cost	800
Storage Costs	500
Handling Fee	200
Total of logistics costs	1.500

Source: Data modified

The research results showed that the logistics cost per kilogram of potatoes was IDR 1,500.00. The cost was influenced by the distance between the farmer's location and the market, as well as the efficiency of the distribution process. The high logistics cost became one of the main obstacles in increasing the competitiveness potato. The high logistics cost, which was IDR 1,500.00 per kilogram, was one of the main obstacles in the potato supply chain in North Sumatra. Transportation costs contributed the largest part of logistics costs, which was in line with the research findings by Novitasari et al.; they noted that transportation costs were the main component of logistics costs in the agricultural sector [15]. The high logistics cost reduced the competitiveness of potato from North Sumatra in the market. To overcome the problem, it is necessary to increase efficiency in the distribution process, such as optimizing shipping routes and using technology for logistics management.

Table 5. Level of product lost

No. of product lost/defective (kg)	Total product shipped (kg)	Level of loss (%)
10	100	10%

Source: Data modified

The average rate of product loss was 10%, meaning that out of every 100 kilograms of potatoes shipped, ten kilograms were lost or damaged. The high loss rate was caused by improper handling and inadequate storage facilities. A product loss rate of 10% indicated that there were many damaged or lost products during the distribution process. According to the supply chain management theory by. Research by Gunawan also supported such findings, stating that improvements in product handling and storage could reduce the loss rate and increased the supply chain efficiency [16].

Table 6. Product quality

Scores of product quality	No. of respondents	Percentage
1	5	3.3%
2	10	6.7%
3	30	20%
4	70	46.7%
5	35	23.3%
Total	150	100%

Source: Data modified

Product quality was measured based on a questionnaire survey with a Likert scale of 1-5. The average product quality score was 3.8, indicating that consumers were quite satisfied with the quality of the potatoes received. However, there were some complaints about the size and condition of the potato. The average product quality score of 3.8 indicated that consumers were quite satisfied with the quality of the potatoes received, although there were still complaints about the size and condition. The product quality theory by Garvi stated that product quality was influenced by various factors, including product uniformity and durability [17]. To improve product quality, stricter quality control standards were needed during the production and distribution process.

Table 7. Level of customers' satisfaction

Scores of product quality	No. of respondents	Percentage
1	5	5.3%
2	10	8%
3	30	23.3%
4	70	43.3%
5	35	20%
Total	150	100%

Source: Data modified

Table 8. Results of statistical analysis

Free variables	Regression coefficient	T-Value	P-Value
Logistics cost	-0.45	-3.25	0.001
Level of loss	-0.38	-2.78	0.006
Product quality	0.52	4.12	0.000

Source: Data modified

Customer satisfaction level was measured using a Likert scale of 1-5. The survey results showed an average value of 3.7, indicating that customers were generally satisfied with the supply chain service, although there was room for improvement especially in terms of delivery speed and product condition upon receipt. The average customer satisfaction value of 3.7 indicated that although customers were generally satisfied with the supply chain service, there were some aspects that needed improvement. Customer's satisfaction was influenced by their perception of the quality of the product and service received; therefore, improvements in delivery speed and product condition upon receipt could increase his satisfaction.

Regression analysis shows a significant relationship between logistics costs and product loss rates with customer's satisfaction. The correlation between logistics costs and customer satisfaction was negative, indicating that the higher did the logistics cost, the lower was the customer satisfied. Conversely, product quality had a positive correlation with customer's satisfaction. The results of the regression analysis showed that logistics costs and product loss rates had a negative relationship with customer's satisfaction, while product quality had a positive relationship. This finding was consistent with Christopher's research stating that efficient logistics costs and good product loss management could increase customer's satisfaction [18]. In addition, high product quality was also a key factor in maintaining and increasing customer's satisfaction.

CONCLUSION
The average of potato order cycle time is seven days, indicating a delay in delivery due to inadequate infrastructure conditions. The logistics cost per kilogram of potato reaches IDR 1,500.00 and transportation costs become the largest component of the cost, which reduces the competitiveness of potato in the market. The product loss rate of 10% indicates a problem in handling and storing products during the distribution process. The average product quality is considered quite good with a score of 3.8 on a Likert scale of 1-5, but there are still complaints about the mismatch in size and condition of the potato. Customer's satisfaction is at an average score of 3.7, indicating that although customers are generally satisfied, there is still room for improvement in terms of delivery speed and product condition. Statistical analysis shows that logistics costs and product loss rates are negatively related to customer's satisfaction, while product quality is positively related. Improvement of roads and transportation facilities speeds up order cycle time and reduces logistics costs. Providing training is needed for farmers and supply chain actors on proper handling and storage techniques. Using technology to improve logistics management and transparency in the supply chain is urgent and product diversification to meet various market segments and to reduce the risk of price fluctuations should be the focus.

REFERENCES

1. Sari FWAW, Bangun RHB. Analisis peranan sektor pertanian, kehutanan dan perikanan pada perekonomian Kabupaten Deli Serdang. Agroland: Jurnal Ilmu-Ilmu Pertanian. 2019; 26(3): 198–211.
2. Dasipah E. Rantai Pasok Pertanian: Mengoptimalkan Tata Niaga dari Ladang ke Meja. Mega Press Nusantara; 2024.
3. Buana D, Wijayani WW, Nabila KM, Zahra A, Anugrah R, Prayudha A, Astiani S. Analisis jaringan rantai pasok (supply chain) kopi robusta: (studi kasus: PT. Bogor Kopi Indonesia). Jurnal Teknologi dan Manajemen Industri Terapan. 2024; 3(2): 181–189.
4. Syamil A, Subawa S, Budaya I, Munizu M, Darmayanti NL, Fahmi MA, Wanda SS, Murwani IA, Utami FN, Dulame IM. Manajemen Rantai Pasok. PT. Sonpedia Publishing Indonesia; 2023.
5. Admin. Tingkatkan Produksi Kentang Sumut: Edy Rahmayadi Dorong Pengembangan Bibit. Pemerintah Provinsi Sumatera Utara; 2021. https://sumutprov.go.id/artikel/artikel/tingkatkan-produksi-kentang-sumut--edy-rahmayadi-dorong-pengembangan-bibit.
6. Apurwanti ED, Rahayu ES, Irianto H. Analisis efisiensi rantai pasok bawang merah di Kabupaten Bantul. Jurnal Pangan. 2020; 29(1): 1–12.
7. Badan Pusat Statistik. Produksi Tanaman Sayuran dan Buah–Buahan Semusim Menurut Jenis Tanaman di Provinsi Sumatera Utara 2020–2021; (n.d.). https://Sumut.Bps.Go.Id/. https://sumut.bps.go.id/statictable/2022/03/08/2569/produksi-tanaman-sayuran-dan-buah-buahan-semusim-menurut-jenis-tanaman-di-provinsi-sumatera-utara-2020-2021.html
8. Hutapea S. Analisis Agribisnis Kentang di Kabupaten Karo. 2001.
9. Sudaryana B, Agusiady HRR. Metodologi Penelitian Kuantitatif. Deepublish; 2022.
10. Hartono JM. Metoda Pengumpulan Dan Teknik Analisis Data. Penerbit Andi; 2018.
11. Retnawati H. Teknik pengambilan sampel. 2017: 1–7.
12. Siregar S. Metode Penelitian Kuantitatif: Dilengkapi dengan Perbandingan Perhitungan Manual & SPSS. 2015.
13. Suharno T. Tantangan dan peluang petani kecil di Indonesia. Jurnal Agribisnis Indonesia. 2018; 6(1): 45–54.
14. Chopra S, Meindl P. Strategy, planning, and operation. Supply Chain Management. 2001; 15(5): 71–85.
15. Novitasari A, Sutopo W, Purwanto WW. Analisis biaya logistik produk pertanian di Jawa Tengah. Jurnal Teknologi dan Manajemen Industri. 2019; 8(2): 120–130.
16. Gunawan R. Manajemen Rantai Pasok Produk Pertanian. Universitas Indonesia; 2017.
17. Garvin D. Competing on the eight dimensions of quality. Harv. Bus. Rev. 1987: 101–109.
18. Christopher M. Logistics and Supply Chain Management. Pearson UK; 2016.

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