Print ISSN: 1738-3110 / Online ISSN 2093-7717
JDS website: http://www.accesson.kr/jds
http://doi.org/10.15722/jds.23.01.202501.33

Designing a Supply Chain Network for Rubber Exports: A Case Study in Northeast Thailand*

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Received: January 15, 2024. Revised: November 29, 2024. Accepted: December 05, 2024

Abstract

Purpose: This research is to determine the optimal location of rubber processing plants in North East Thailand, and aim to design a supply chain network from the central rubber market, processing plants, and export to customs checkpoints, train stations, and ports in Thailand. **Research design and Methodology:** This research integrates center of gravity and location-allocation problem analysis using a Distribution science Geographic Information system (GIS), to find the most suitable factory location and leading to the design of a supply chain network that has the shortest duration and distance. **Results:** The scenario analysis, if entrepreneurs invest in building only 1 factory in upper North East Thailand, the factory in Sakon Nakhon province will be selected. If entrepreneurs invest in constructing 2 factories in the upper northeastern region, the factory in Bueng Kan Province and the factory in Loei Province will be selected. If entrepreneurs choose to invest in the construction of only 1 factory in the lower northeast region, Buriram Province will be chosen. In addition, entrepreneurs must consider land costs when deciding on the most appropriate factory location. **Conclusion:** This research may help entrepreneurs design the supply chain network, considering the distance related to transport costs and land costs in North East Thailand.

Keywords: Distribution science, Supply Chain Network, Logistics Network Design, Geographic Information System, Location Allocation Analysis, Rubber Exports

JEL Classification Code : M16, R42, R41

1. Introduction

Rubber currently plays a vital role in the global economy as one of the key commodity groups, with the increasing demand among consumers as a raw material. The major consumer markets include China, India, Japan, and the United States. The global market recognizes the importance of rubber, with consumer behavior worldwide significantly contributing to the high demand in the industry. Rubber is a crucial component in manufacturing automotive tires, medical products, and various household items, making it essential across diverse sectors. Amid this rapid demand surge, the rubber industry continues to be crucial in both domestic and international contexts. This growth has led to the development of strategies aimed at fostering sustainable growth within the sector, particularly through the procurement of raw materials within each country's geographical scope. As demand continues to drive growth, there is a focused effort on adjusting production structures by expanding into regions that offer economic and logistical

* This research was supported by the Faculty of Logistics, Burapha University Research Fund

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feasibility. Consequently, strategic investment and analysis to identify suitable areas for raw material sourcing and the expansion of rubber production zones remain pivotal factors driving the development of the rubber industry Countries possessing favorable geographic conditions for both sourcing raw rubber materials and expanding production sources include Thailand, Malaysia, Vietnam, and others.

Thailand has advantageous geography and transportation systems that support efficient raw material sourcing and the expansion of production bases to meet global consumer demand (Sharma, 2013). Rubber can be grown in Thailand because of its geography and favorable weather conditions. There is a high rate of rubber production. In the land model, the infrastructure of transport includes both the Asian Highway and the North-South Economic Corridor. Connects every area, every region, covering the northeastern region of Thailand. The water transportation is geographically next to the sea. Maritime transport is therefore an important transport that entrepreneurs and domestic and foreign investors recognize its importance. Including rail transportation as a new form of transportation and transportation. Because Thailand has a developed economic structure that allows for more rail transportation. However, geography and economic structure transportation, transportation of the country. Therefore, expanding the production base in Thailand is a country that investors cannot overlook.

Explains that the trend in Thailand's rubber industry is continuously increasing. The government sector is involved in supporting the export rate. Including strategic support in logistics and transportation. Provide opportunities for foreign investors to participate in driving the rubber industry economy. Therefore, the geographic factors of government support in the field of transportation and transportation readiness of both domestic and foreign investors and the rate of demand increasing as a result, Thailand is one of the countries that are the world's leaders in the rubber production industry.

In addition, explain that the demand rate for rubber tends to grow continuously. The survey found that the current rubber production industry still cannot respond to consumer demand. As a result, investors and entrepreneurs are increasingly aware of plans to expand production sources. Because in Thailand there are geographic factors conducive to rubber cultivation and high yields. Government policies that can facilitate foreign entrepreneurs and investors to conduct industrial businesses in the Kingdom of Thailand and provide opportunities for import-export businesses. Transportation routes that can be beneficial in terms of transporting goods abroad. Therefore, these factors are consistent with planning to expand the production sources of the rubber industry to balance the current demand for rubber.

Many areas of Northeastern Thailand are rapidly expanding their rubber plantation areas. Due to the climate and the fertility of the soil is suitable for growing rubber trees that produce effective results. The northeastern region has the largest population in the country. As a result, the labor factor can support the production capacity. The transportation sector in the northeastern region is highly developed.

Because the Northeastern region has an advantageous area with water, rail, and land transportation, these factors facilitate planning to effectively expand production areas in the rubber industry sector. Despite this, the study revealed that the Northeast has a large area. Therefore, the researcher examined the search for appropriate locations for rubber processing plants in the Northeast region. This resulted in the creation of a supply chain network that can quickly export rubber to customers. This research study applies the theory of finding locations for rubber processing plants using the Center of Gravity method to analyze suitable factory locations and the Facility Location Problem method for network planning throughout the supply chain. The remainder of this research is divided into 5 sections, consisting of section 1 which is a collection of articles, theories, and research studies in the country and abroad. Section 2 aims to gather information about the central market location of farmers, as well as the locations of customs checkpoints, sea ports, and train stations. Acquiring this location data will help in formulating hypotheses for identifying appropriate factory locations. This will enable the analysis of the supply chain network design for efficient exportation of rubber. Section 3 after making assumptions about finding the appropriate factory location, this research has considered a total of 7 locations, with 5 locations in the upper Northeastern region and 2 locations in the lower Northeast. In Section 4, we will analyze the supply chain network in three steps. Step 1 involves using the Center of Gravity tool to find the factory location closest to the assumed location from Section 3. In Step 2, we will analyze factory locations and select 3 of them based on the shortest distance between the central market location and the location of the customs checkpoint, port, and train station.

Using the Location Allocation tool, Step 3 involves obtaining the appropriate locations of 3 factories. After this step, a cost analysis is conducted. Section 5 provides a summary of the research results to aid decision-making in choosing an appropriate factory location.

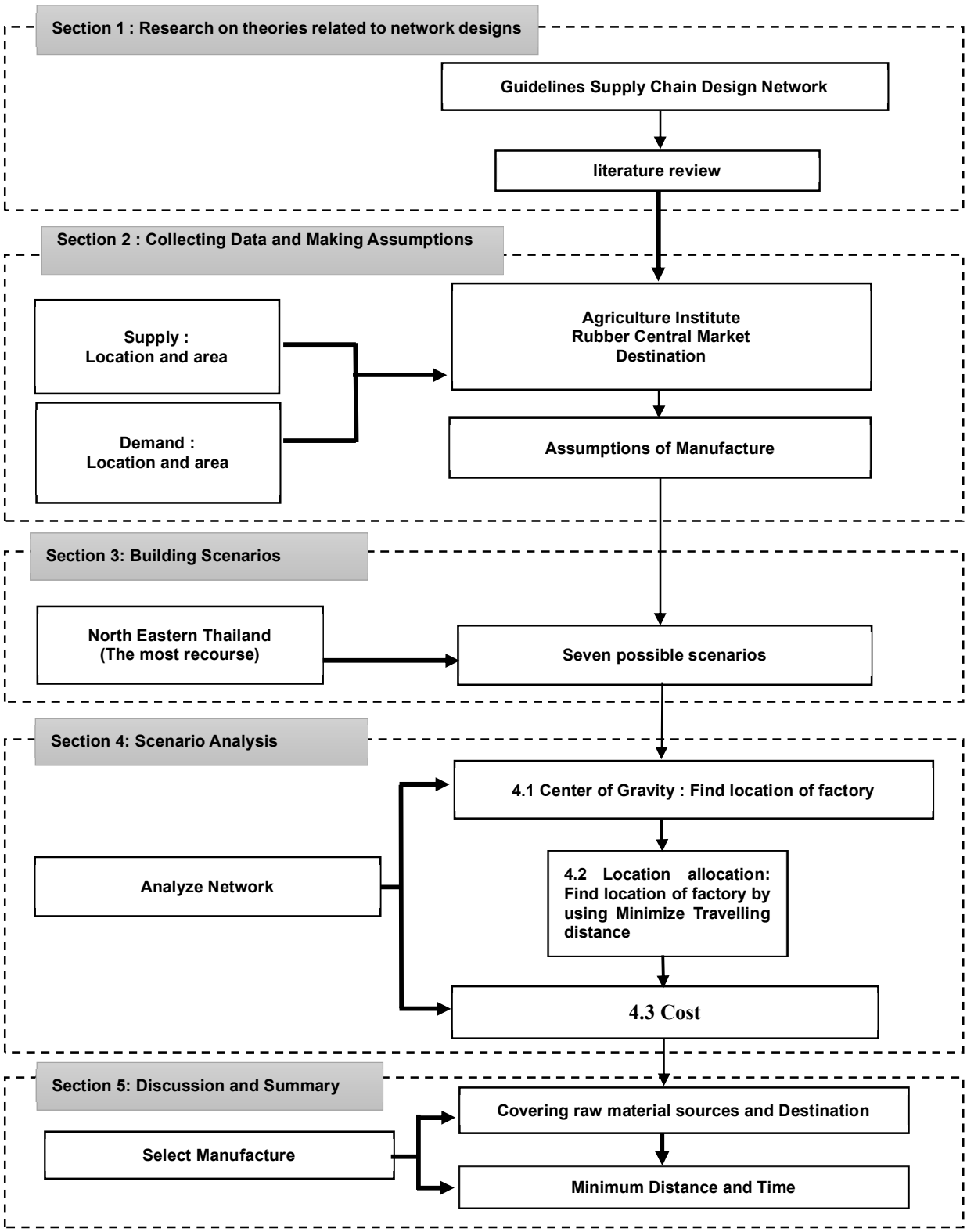


Figure 1: Research Methodology

2. Logistics Network Design

It is one of the networks providing raw material transportation services, delivering products to customers through routing arrangements between origin and destination, and choosing the method of transporting goods with the lowest cost and shortest time. It also involves selecting the service location. In general, the factors considered in selecting the location of the service property some factors are taken into consideration, including the needs of customers, the location of the customer, etc. (Facility Location Problem). These factors lead to a mathematical model, namely the least total distance problem (Minimum Facility Location Problem). By solving the issue of choosing the location of the service location. The objective is to keep the total transportation costs as low as possible. By the general form of the distribution science model as follows

$$\text{Minimize} \quad \sum_{i}\sum_{j} w_i \; d_{ij} \; Y_{ij} \qquad (1)$$

$$\text{subject to} \quad \sum_{j} \quad = P \qquad (2)$$

$$\sum_{i} Y_{iJ} = 1 \qquad ;\forall_J \qquad (3)$$

$$\sum_{i} W_i Y_{iJ} \leq S_j \; X_J \; ;\forall_J \qquad (4)$$

$$X_j \in \{0,1\} \qquad ;\forall j \qquad (5)$$

$$Y_{ij} \in \{0,1\} \qquad ;\forall j \qquad (6)$$

The import data is

W_i is the quantity of goods or services provided by customers at that location τ

d_{ij} is the distance between customers at that location τ with the service location
located at j

S_j is the service capability of the service location that is located at τ and the decision variables are j

$$x_j = \begin{cases} 1 \; if \; you \; choose \; to \; provide \; service \; at \; that \; location \; j \\ 0 \; if \; not \end{cases}$$

$$Y_{ij} = \begin{cases} 1 \;\; if \text{ the customer at that location } \iota \text{ receive from} \\ \qquad\qquad \text{the service location at } j \\ 0 \; if \; not \end{cases}$$

Target equation (1) it is to find the total distance between the customer and the service location. Constraint equations (2) It is a constraint in choosing the location of the service source to be equal to the specified number of service sources. (P place) Finite equations (3) Guarantee that customers receive service from the service source. Finite equations (4) Position customer i Receive service from location j if location j has a service location located and the service location will not exceed the available service capacity.

Analysis of the network under conditions Center of Gravity

To proceed with finding a suitable processing plant location to lead the most efficient design of the rubber export network abroad. The main criteria to consider are the transport distance function and the transport volume to the destination location. Therefore, the formula for calculating the center of gravity is as follows

$$\text{Criteria} \quad \bar{X} = \frac{\sum X_i \; Q_i}{\sum \; Q_i} \qquad\qquad \bar{Y} = \frac{\sum Y_i \; Q_i}{\sum \; Q_i}$$

when Q_i is distance of transportation of rubber to the destination.

Table 1: Presents Details of Research Related to Logistics and Supply Chain Operations.

Name and Year of research publication	Objective	Representative	Research Methods	Review of research
Amiri, 2021	Minimize the cost associated with the walnut industry as a whole	Walnut raw material	Mixed integer liner programming (MILP)	Results for simulations using mathematical methods found that it can reduce delivery cost.
Baghizadeh, 2021	Sustainable agriculture supply chain network design	Agriculturist	MINLP mathematical	After analyzing the simulation model mathematic reveal that choosing a path transportation and warehousing location affecting the agricultural supply chain sustainable
Jouzdani, 2021	On the sustainable perishable food	Perishable product	Mathematical	Result from using mathematical model to analyze traffic problem and economic problem can help to solve the problem of perishable food in a sustainable way.
Kambli, 2021	Network design for local agriculture	Agriculturist	Optimization models	Since one of the constraints in models is that farmer can travel only to their nearest the model sacrifices a better objective functions value in order to accommodate farmer' travel requirement
Varsei, 2017	Sustainable supply chain network design	Wine industry	Mixed-integer program	Social implication of the feasible scenarios are examined through introducing social impact coefficients. Non-dominated solution are obtained

X_i is the X-axis position of the destination point.
Y_i is the Y-axis position of the destination point.

3. GIS: Geographic Information System

Geographic Information System refers to a tool that can store and collect information from various sources in a systematic way and process that information to analyze results and display results for decision-making. However, the objective of applying geographic information systems is to support management, and spatial information can analyze and display results in making decisions regarding operations

4. Research Tools in the ArcGis Program used in Research

4.1. Choose Best Facilities: ArcGIS

It is a tool that will facilitate the determination of the location of the rubber processing factory. The locations obtained from the analysis can cover the customer demand and the nearest source of raw materials and can process the analysis to have the shortest distance and travel time. The research work has applied the method of minimizing travel to be consistent with the objectives of the research, the goal being to select a processing plant location to minimize travel time or overall distance from all desired locations to the assigned facility. This goal is usually used when there is travel between all desired places and locations. From a review of related research, it was found that the tools in the ArcGis program were used in research on designing networks in various types of business.

Geographic information systems have been studied and applied to improve shipping routes. A case study of an ice factory business entrepreneur to analyze network data the shortest route. From the analysis, it is found that shipping distance and costs are reduced by using the original route that the driver chooses. It is a route delivered according to habit and redundant, and there is no planning in arranging the appropriate route.

In addition, to learn about using geographic information systems to support the distribution of equipment in responding to disasters, especially when it comes to hurricanes (Albert, 2011). A logistics management system is not something the government will have. There is no central electronic system that facilitates communication or coordination between individuals. The process of tracking resources that can help with disaster response becomes inefficient, leading to a significant delay. Therefore, this research discusses the application of Geographic Information Systems. (GIS) to help facilitate tracking disaster response equipment to cities for future emergencies. Therefore, geographic information systems are an important technology that will help make these resources more easily accessible. It also greatly alleviates the need to save people's lives.

Study methods for improving product distribution to be most suitable and efficient by applying geographic information systems to participate in designing and simulating the most appropriate distribution model to serve hundreds of thousands of retailers.

Currently, the case study company in this research acknowledges that customer demand and customer locations are continuously fluctuating. Additionally, they recognize that faulty management of the types of vehicles in distribution, and lack of suppliers' operational efficiency, lead to higher distribution costs. The company uses geographic information systems to help manage complex product distribution to increase efficiency in product distribution, reduce distribution costs, and create satisfaction for customers in the future.

Study the integration concept of Geographic Information Systems and Location Problems (GIS-LP) to select suitable locations for logistics hubs (Shahrooz, 2020). This research solves the problem of establishing a logistics center that serves as a distribution center in the northwestern region of Iran using GIS as a decision-making tool to identify possible regions. Including integration with other concepts setting up appropriate logistics hubs, the results of this research show that the concept can help in decision-making in solving complex location problems, help reduce costs, and improve logistics efficiency even more, along with increasing operational efficiency in the region as well.

Study the water supply pipeline network in China using geographic information systems and apply the Arc GIS platform to design a new model for water pipeline system planning (Yoo, 2016). System of the water supply pipeline network. And analyze the condition of the pipe network by using geographic information systems to design the water supply pipe network. It can help with statistical information on burst pipes as well as help operators know the condition of every part of the water pipe. The system predicts pipe burst events according to the needs of the system. The algorithmic data can promote the quick locating of plumbing repairs to reduce the time needed to locate objects. Therefore, introducing GIS tools into the design of pipeline networks can promote safety, improve the speed of object location, and help operators analyze the condition of pipelines more effectively.

Study the improvement of the distribution network in China using the GIS system. The two-dimensional distribution network is the main tool in this research and creates an implementation plan and establishes a distributed network system, Platform-SuperMap, as the result of the

tool GIS in distribution network design shows results that the distribution network system is more efficient.

Study the design of industrial factory locations by analyzing ground condition factors, sloping area distance, proximity to main roads, distance from residential areas, and distance from water sources using GIS tools to analyze and find the appropriate location (Wanore, 2023). The results show that land use factors, land cover, and distance from geological faults greatly determine industrial area selection and the elevation and slope determine the minimum compared to other factors. The majority of the study area (47.5%) is suitable for building an industry and the minority (0.2%) is less suitable. Therefore, the application of GIS technology and remote sensing in the study area has not been fully used to select suitable locations for the industry.

Studying the design of appropriate landfill locations in India using the AHP tool to analyze together with the

geographic information system GIS it was found that locations 7 and 2 were selected because the analysis of the selected locations found that they were environmentally friendly places, the community has suitable land conditions, and is quite a distance from the city (Kang, 2024).

Study the design of appropriate power plant locations using geographic information tools, taking into account environmental factors, roads, energy transmission lines, transformer centers, slope, nature, location of dams and rivers, natural gas pipelines, fault lines, land cover, and living areas. It was found that, after analyzing the data, a suitable location for the power plant was found in Turkey, which is more suitable than the current power plants (Colak, 2020).

Study of the design of wind turbine locations in the country using sequence analysis Analytical Hierarchy Process (AHP) and using GIS geographic information tools in China. The results showed that 2 percent of the study area was suitable for installing wind energy facilities, but only 3.36 percent were considered highly suitable. By comparing the optimized results to the actual locations of existing wind farms, it was found that the ideological framework of this study is practical and effective in guiding wind farm site selection, and it is also useful for application in selecting locations to use other alternative energy sources as well (Xu, 2020).

5. Methods

Research on the design of distribution networks for rubber exports: a case study of the northeastern region of Thailand. It is intended 1.) To determine the appropriate location of rubber processing factories in the Northeast. 2.)

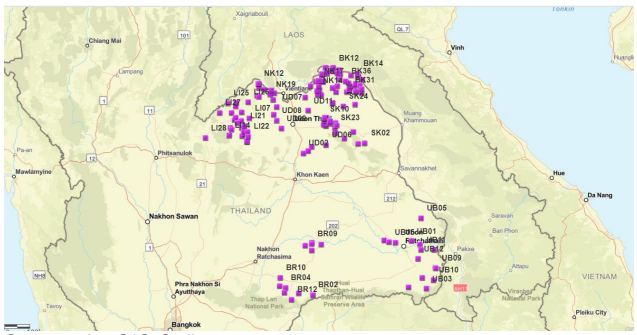
Table 2: Shows Details of Research Related to GIS Theory.

Name and Year of research publication	Objective	Representative Sample	Research Methods	Review of research
Colak, 2020	Using geographic information systems to analyze and find suitable location for solar power plants.	Solar power plant within Malatya province, Turkey	Geographic tools : GIS	The study found that using GIS tools to analyze suitable location for setting up solar power plants is more effective when compare to currently existing power plants
Kang, 2024	Choosing a sanitary land fill location in India taking into consideration environment factor.	A sanitary landfill location in India	AHP, FTOPSIS, DGIS	Using the geography system using the AHP method to analyze the appropriate location for the garbage dump location, talking into consideration the environment.
Wanore, 2023	Analysis of location selection industry in Hawassa town appropriately using GIS geography tools.	Industry in Hawassa town	Geographic tools : GIS	Use GIS tool to analyze industrial location in the result of the research found that most of the study area appropriate (47.5%) for industrial settings
XU, 2020	Wind farm location selection using GIS and muti-criteria decision-making method in Wafangdian City,China	Wind farm in Wafangdian City,China	AHP,GIS	From the analyze using AHP and GIS tools, the research found that 21% of the study area is suitable for installing wind energy facilities, but only 3.36% is considered highly suitable
Yoo, 2016	Analysis is of water supply pipeline network.	Water supply pipeline network in China	Geographic tools : GIS	Using GIS tool to analyze. The result is can help with statistical information on burst pipes as well as help operators know the condition of every part of the water network.

To analyze and plan appropriate routes in the distribution network for exporting rubber. Through this research, the researcher has collected information related to the network of transportation routes for rubber and processed rubber throughout the supply chain for export abroad. The scope of the case study data ranges from the location of the raw material sources and the number of farmer institutions with the highest production volume of cup lump rubber of the total number of the Northeast region, the location of the central market, and the location of the end customer, with the decision criteria being the optimum transport route with the shortest distance, etc., designing the optimum route in the supply chain network for rubber export. Geographic information system tools: GIS is used as a distribution science model to solve the problem in this case study for designing an optimal route.

6. Data Collection

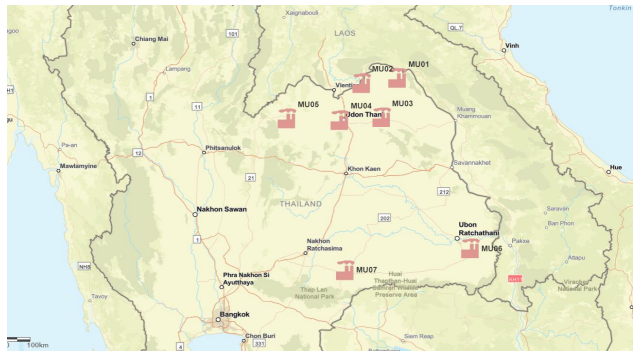
Relevant information includes the location of farmers as shown in figure 2, the location of processing plants (Assumption data) as shown in figure 3, the location of the central market as shown in figure 4 and the locations of customs checkpoints, train stations, and ports as shown in figure 5.



Source: ArcGIS Online

Figure 2: Location of farmers

The figure shows the location of the Bueng Kan Province Farmers Institute. It is divided into 8 districts and has a total of 36 farmer institute groups. The location of the Farmer Institute Group in Loei Province is divided into 9 districts, and there is a total of 28 Farmer Institute Groups. The location of Farmer's Institute Group in Udon Thani Province is divided into 10 districts, and there are 11 Farmer's Institute Groups in total. The location of the Sakon Nakhon Province Farmers Institute Group is divided into 9 districts, and there are 24 Farmer Institute Groups in total. The location of the Nong Khai Province Farmers Institute Group is divided into 6 districts, and there are 19 Farmer Institute Groups in total. The location of the Farmers Institute Group, Buriram Province, is divided into 9 districts and has a total of 12 Farmer Institute Groups. The location of the Farmers Institute Group, Ubon Ratchathani Province, is divided into 10 districts and has a total of 15 Farmer Institute Groups. Therefore, all locations of Farmer Institute Groups or raw materials sources are included in 145 locations.



Source: ArcGIS Online

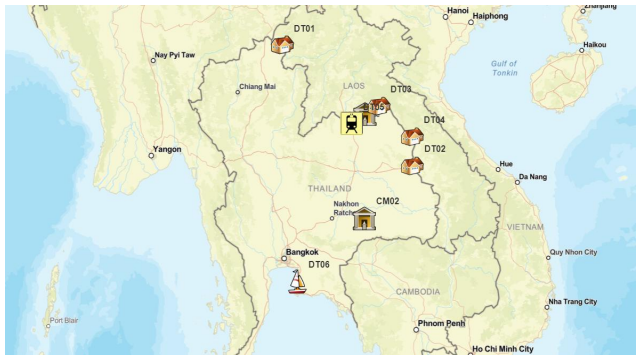
Figure 3: Location of the processing factory (Assumption data)

From figure 3, the analysis assumes that the factory location corresponds to the province with the highest rubber production in the Northeast. Therefore, it was announced in the provinces that they were expected to find suitable locations. A total of 7 places were identified, including Loei Province, Bueng Kan Province, Nong Khai Province, Sakon Nakhon Province, Udon Thani Province, Buriram Province, and Ubon Ratchathani Province, as shown in the picture above by applying the Center of Gravity tool to support in finding the assumed location of the factory that is most appropriate and close to the facts.

Source: ArcGIS Online

Figure 4: Location of the central market

The figure shows the location of the central market. In the research, the central market is divided into the upper northeastern region, one is Nong Khai Province, and the lower northeastern region, one is Buriram Province.



Source: ArcGIS Online

Figure 5: Location of customs checkpoints, train stations, and ports

The figure shows the location of 6 customs checkpoints, train stations, and seaports, consisting of Chiang Khong Customs Checkpoint, Bueng Kan Customs Checkpoint, Mukdahan Customs Checkpoint, Nakhon Phanom Customs Checkpoint, Nong Khai Train Station, and the port of Laem Chabang.

7. Framework

The research has determined the assumed locations of 7 rubber processing factories, divided into 5 in the upper northeastern region and 2 in the lower northeastern region, to analyze the most appropriate locations, including the supply chain network that consists of market locations, 2 central locations, customs checkpoints, train stations, and 6 ports, as shown in figure 8.

Figure 6 shows the design of the rubber distribution network with the assumption of the locations of seven rubber processing factories. The research has designed a supply chain from the central rubber transport market for the rubber processing factory and export to customs checkpoints, train stations, and ports in Thailand in preparation for export abroad. The export network was found to have a total of 27 routes. Therefore, having a total of 7 rubber processing factory locations is too large and has an impact on the network of rubber transportation routes, which is very large. An analysis of suitable locations for rubber processing factories is necessary to select the best location, leading to an efficient rubber export network abroad.

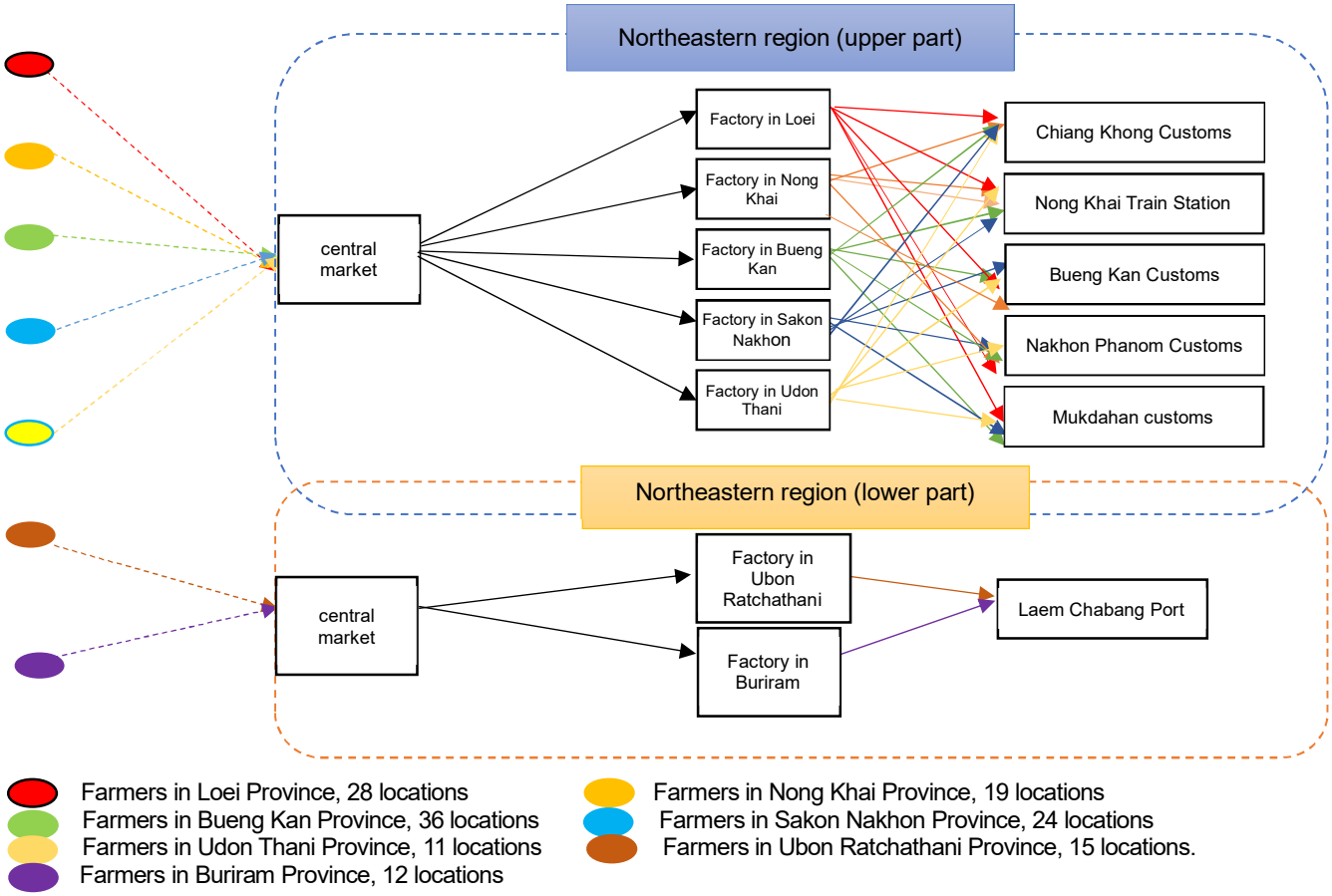


Figure 6: Assumed supply chain network model

8. Results

Data analysis is used to design distribution networks for exporting processed rubber by using distribution science tools (GIS: Geographic Information System), which analyzes to find a suitable factory location (Center of Gravity). The location of the production plant can be in line with the location of the farmers' institute and rubber exports in the destination country (Location allocation Problem), and plan appropriate transportation routes under the condition of the shortest transportation distance (Minimize Travelling distance) throughout the supply chain for rubber exports in the northeastern region.

8.1. Analysis of an Appropriate Factory Location (Center of Gravity)

8.1.1. Rubber Processing Factory in Bueng Kan Province

Table 3: Locations of rubber processing factories in Bueng Kan Province

Location of rubber processing factories in Bueng Kan Province			
Original Location		**New Location**	
Latitude	**Longitude**	**Latitude**	**Longitude**
18.1791	103.7488	18.1789	103.7397

Source: https://www.google.com/maps

Figure 7: Location of the rubber processing factory in Bueng Kan Province.

Finding the coordinates for the factory's location in Bueng Kan Province uses the Central Feature tool in the ArcGIS program, which is processed and shows the results with coordinates 18.1791, 103.7488. The coordinates of the area are in the province's center, and the distance is 800 meters from National Highway No. 222. When compared with the Mean Center and Median Center tools in the ArcGIS program, it shows that the use of the Central feature tool is more appropriate due to the factors of the area being the center of the province and the distance from the National Highway 222, which is 8 and 12 kilometers. However, the coordinates obtained from the processing of the central feature tool in the actual area are small and are close to community areas. As a result, it is not an appropriate location for a processing factory. The location coordinates were moved to the east, with a distance of 100 meters from the original location. When measuring the area from the Google Maps program, the coordinates were 18.1789, 103.7497. There was a total of 25 rai of space (40,000 square meter). There is a distance of 1.5 kilometers from National Highway No. 222. As a result, the new coordinates are more convenient for transporting processed rubber than the original coordinates.

8.1.2. Rubber Processing Factory in Nong Khai Province

Table 4: Locations of rubber processing factories in Nong Khai Province

Location of rubber processing factories in Nong Khai Province			
Original Location		**New Location**	
Latitude	**Longitude**	**Latitude**	**Longitude**
18.0899	103.0968	18.0897	103.0970

Source: https://www.google.com/maps

Figure 8: Location of rubber processing factory in Nong Khai Province.

Finding the coordinates for the factory's location in Nong Khai province uses the Central feature tool in the ArcGIS program, which can be processed and displayed in the coordinates 18.0899, 103.0968. The coordinates of this area are 800 meters away from National Highway No. 212, creating a transportation advantage when compared to the Mean Center and Median Center tools in the ArcGIS program. When processed, the results were obtained according to the coordinates of the geographic area that was located outside of Nong Khai Province and was located far from the national highway. However, the coordinates obtained from the processing by the central feature tool were in the actual area. This location is close to the location of the Rubber Plantation Fund

Cooperative Limited. Therefore, it cannot be a factory

location because the area can be a factory location. Be in an area of 20 rai (40,000 square meter) or more. (insert Ref)

Therefore, the move to a new location was carried out by moving it from the original area within a distance of 6 meters or 20 feet on the east side, where the new area has coordinates 18.0897, 103.0970, and the empty area size is 86 rai (137,600 square meter). The new location is close to National Highway No. 212 (Chayangkul Road), as shown in the picture. As a result, choosing location coordinates using the Central feature tool can create convenience for transporting processed rubber.

8.1.3. Rubber Processing Factory in Sakon Nakhon Province

Table 5: Locations of rubber processing factories in Sakon Nakhon Province.

Location of rubber processing factories in Sakon Nakhon Province			
Original Location		**New Location**	
Latitude	**Longitude**	**Latitude**	**Longitude**
17.4723	103.4675	17.4688	103.4622

Source: https://www.google.com/maps

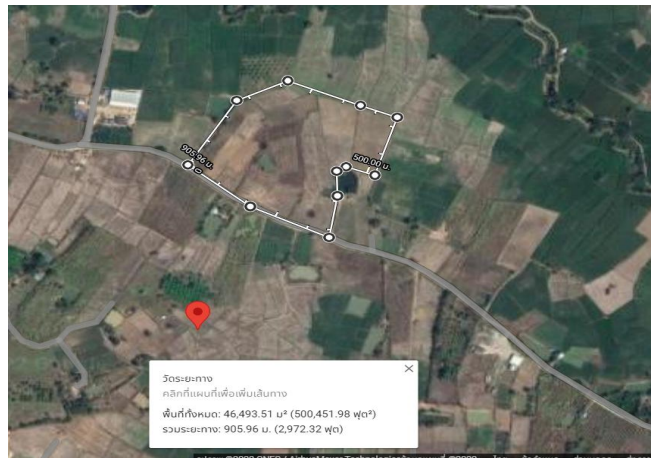
Figure 9: Location of the rubber processing factory in Sakon Nakhon Province.

Finding the coordinates for the location of the factory in Sakon Nakhon Province is done by using the Median center tool in the ArcGIS program, which is processed and shows the results as coordinates 17.4723, 103.4675. The coordinates of the area are 400 meters away from Asian Highway 15, which is compared to the Mean center tool, which is 10 kilometers from Asia Highway 15, and the Central feature tool. According to the findings, the factory's proximity to the Sawang Daen Din Provincial Court causes environmental disturbances to nearby communities due to truck transportation, including road pollution, air pollution, and noise. As a result, this location is not conducive to being a factory location. Therefore, in choosing the tool, Median center is the best location when comparing the tool's Mean center and Central feature. However, the actual geography of the area, according to satellite maps, reveals that this location is close to the community area and the Sawang Daen Din School location, at a distance of 114.38 meters, making the area insufficient to be a factory location. Therefore, the location has been moved from the original location to the southeast, at a distance of 846.47 meters, with the new location having coordinates 17.4688, 103.4622, and an area of 42 rai (67,200 square meter) and is next to Asia Highway No. 15 at a distance of 747.31 meters, which gives the new location a transportation advantage.

8.1.4. Rubber Processing Factory in Loei Province

Table 6: Locations of rubber processing plants in Loei Province.

Location of rubber processing factories in Loei Province			
Original Location		**New Location**	
Latitude	**Longitude**	**Latitude**	**Longitude**
17.4501	101.7500	17.4523	101.7499



Source: https://www.google.com/maps

Figure 10: Location of the rubber processing factory in Loei Province.

Finding the coordinates for the location of the factory in Loei Province is done by using the Central feature tool in the ArcGIS program, which can be processed, and the results are displayed as coordinates 17.4501, 101.7500. The coordinates of this location are 3 kilometers from National Highway 2015. When comparing the mean center tool, which is 6 kilometers from National Highway 2015, and the median center tool, which is 6 kilometers from National Highway 2015, Land 2015 is located 10 kilometers. The geographic features adjacent to the road facilitate transportation.

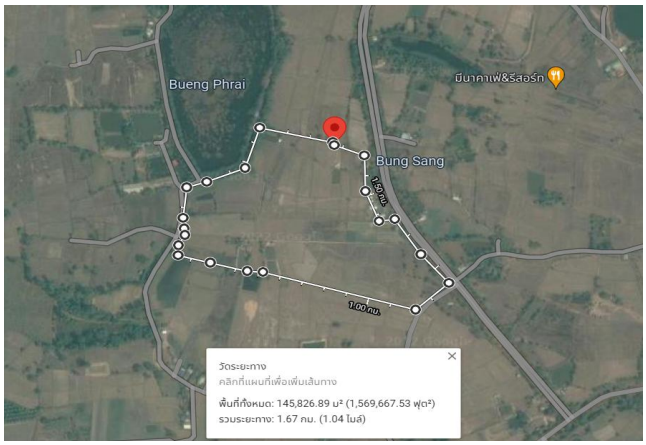
Consequently, the central feature tool is the best tool when compared to others. However, when data is processed through Google Maps, it accurately depicts the area's characteristics, with the area size being close to the location

of the Rubber City Community Enterprise in Loei. The original location obtained from processing through the Central feature tool has been moved to a distance of 200 meters to the northern area with the coordinates 17.4523, 101.7499, an area size of 29 rai (46,400 square meter). The location is close to rural highway number 4004, at a distance of 600 meters, and the distance from national highway number 2015, as shown in the picture, makes the location of this factory a convenient location for transportation.

8.1.5. Rubber Processing Factory in Udon Thani Province

Table 7: Locations of rubber processing factories in Udon Thani Province.

Location of rubber processing factories in Udon Thani Province			
Original Location		**New Location**	
Latitude	**Longitude**	**Latitude**	**Longitude**
17.4206	102.7056	-	-



Source: https://www.google.com/maps

Figure 11: Locations of the rubber processing factory in Udon Thani Province.

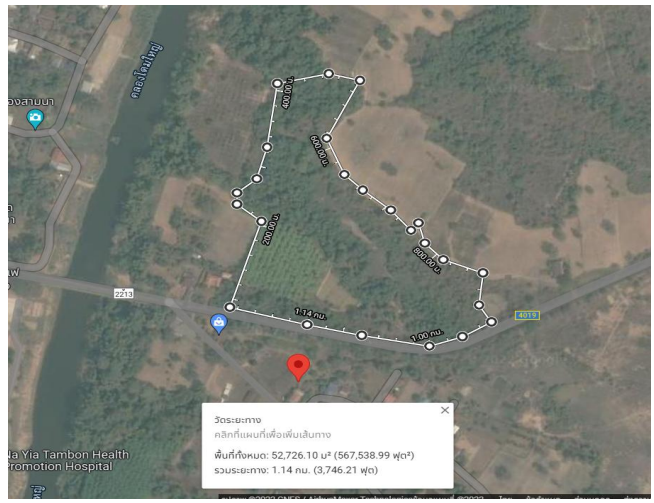
Finding the coordinates for the location of the factory in Udon Thani province is done by using the Mean Center tool in the ArcGIS program, which is processed and results in coordinates 17.4206, 102.7056. The coordinates of this location are 1 kilometer from National Highway No. 2263 when comparing the mean center tool, which is 6 kilometers away from National Highway No. 2263, and the central feature tool, which is 16 kilometers away from National Highway No. 2263. Therefore, in terms of geographic characteristics, processing through the Mean center tool is the best tool in terms of transportation compared to other tools. Therefore, in real-world data, the results are analyzed through satellite maps with the analyzed locations using the Mean center tool. It has the characteristics of an open area with a long distance to the community.

The total area is 91 rai (145,600 square meter), which is a suitable location for setting up a rubber processing factory in Udon Thani Province.

8.1.6. Rubber Processing Factory in Ubon Ratchathani Province

Table 8: Locations of rubber processing plants in Ubon Ratchathani Province.

Location of rubber processing factories in Ubon Ratchathani Province			
Original Location		**New Location**	
Latitude	**Longitude**	**Latitude**	**Longitude**
15.0696	105.0697	15.0703	105.0697



Source: https://www.google.com/maps

Figure 12: Location of the rubber processing factory in Ubon Ratchathani Province

Finding the coordinates for the location of the factory in Ubon Ratchathani Province was done by using the Mean Center tool in the ArcGIS program, which processed and displayed the coordinates 15.0696 105.0697. The coordinates for this location are 15 kilometers from National Highway No. 24. When comparing the central feature and Median center tools, the distance from National Highway No. 24 is 19 kilometers, making the Mean center tool have an advantage in being located close to the national highway. However, when processing data through the satellite map, it shows the actual area, with the coordinates of the area being located in a community area, making it impossible to be a factory location. Therefore, move the original location obtained from processing through the Mean center. At a distance of 76.14 meters to the north, with coordinates of 15.0703, 105.069, the area is 33 rai (52,800 square meter). There is a new location that is adjacent to National Highway No. 24, making this factory location a convenient location for transportation.

8.1.7. Rubber Processing Factory in Buriram Province

Table 9: Locations of rubber processing factories in Buriram Province

Location of rubber processing factories in Buriram Province			
Original Location		**New Location**	
Latitude	**Longitude**	**Latitude**	**Longitude**
14.6761	102.8033	14.6767	102.8072

Source: https://www.google.com/maps

Figure 13: Locations of rubber processing factories in Buriram Province

Finding the coordinates for the location of the factory in Buriram Province was done by using the Median Center tool in the ArcGIS program, which processed and displayed the coordinates 14.6761, 102.8033. This location's coordinates are 6 kilometers from Asia Highway No. 121. When comparing the Central feature tool, which is 12 kilometers away from Asian Highway No. 121, and the Mean Center tool, which is 10 kilometers away from Asian Highway No. 121. Therefore, the Median Center tool is the best tool for transportation when compared to other tools. However, when processing satellite data using Google Maps, it shows the actual area characteristics based on the size of the area near the community source. The coordinates of this area did not have a sufficient size to set up the factory, so the process was moved to the original location obtained through the Median Center tool, a distance of 466 meters. To the east, with coordinates 14.6767, 102.8072, an area size of 77 rai (123,200 square meter), and adjacent to Asian Highway 121, this factory location is a convenient location for transportation.

The coordinates for the location of the rubber processing factory were applied using the tool find summarize center and dispersion: ArcGIS. The coordinates for the location of each factory were used by using the central feature mean center and median center tools to analyze and find the appropriate location coordinates in each area. This is because, in reality, after applying the said tool to find the location coordinates of a rubber processing factory, the topography is not conducive to being a location for a rubber processing factory. Transportation routes are difficult to access, and the area is not sufficient to be a location for a drug processing factory. This resulted in the analysis of the factory location as slightly moved from the original location. However, there are still coordinates close to reality by applying the Center of Gravity theory, resulting in new coordinates for the locations of many processing plants. To be able to facilitate analysis in the design of the supply chain network in the next process.

9. Analyze Factory Locations using the Shortest Possible Distance (Location Allocation)

In this research, entrepreneurs and investors have the objective of finding 3 suitable manufacturing locations in the Northeast. The assumption for setting up a factory area is approximately 11,200 square meter, or 7 Rai, which is based on the area of setting up a rubber factory to cover the area of farmer institutes. Central market and as many locations as possible for ports, train stations, and customs checkpoints. Under the constraints of Eq. Therefore, in this research, the researcher has collected data on distance and total time from the central market location to each factory to analyze which factory location has the shortest distance and total time. To be used as an option in deciding to establish an appropriate production plant, as shown in Table 10.

Table 10: Distance numbers and duration from the central market-factory location (assumption)

Northeast	Symbol	CentralMarket-Factory (Assumotion)	Distance (Kilometer)	Time (Minute)	Ranking
Upper Part	CM01– MU01	Ningkhai Central Market – Buengkan Factory	100.948	96.406	2
	CM01– MU02	Ningkhai Central Market – Nongkhai Factory	11.820	11.412	1
	CM01– MU03	Ningkhai Central Market – Sakon Nakhon Factory	109.628	145.350	4
	CM01– MU04	Ningkhai Central Market – Udon Thani Factory	121.267	133.138	3
	CM01– MU05	Ningkhai Central Market –Loei Factory	240.630	260.285	5
Lower Part	CM02– MU06	Buriram Central Market – Ubon Ratchathani Factory	252.420	239.016	2
	CM02– MU07	Buriram Central Market – Buriram Factory	63.931	66.187	1

The table above shows the results of the total distance and duration numbers when analyzing the location of a suitable production facility. When entrepreneurs and investors want to locate a production facility that is close to the source of raw materials, therefore, the distance and duration numbers Including the central market area and the production plants in the upper northeastern region, the factory in Nong Khai province has the shortest distance and time. The lower northeastern region is the factory in Buriram province, which has the shortest distance and period. However, in making decisions about finding suitable factory locations throughout the supply chain, Analyzing the locations of factories that are close to the source of raw materials may still not be able to cover the entire supply chain. Therefore, the researcher has collected numerical data on the total distance and duration from the central market, production plant (hypothetical), customs house, port, and train station. To analyze for entrepreneurs and investors to make decisions on finding a truly appropriate location.

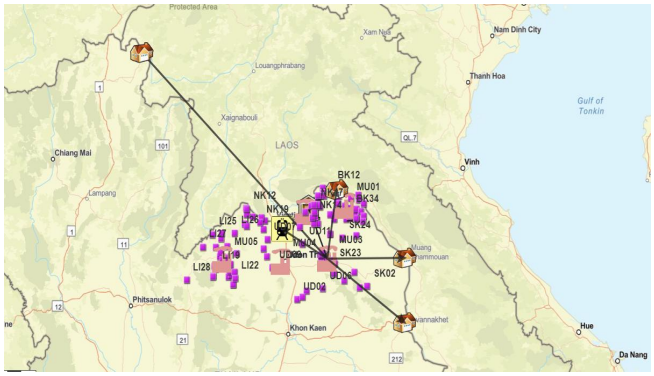
Table 11: Information on distance and duration of the factory location (assumption) —customs house/port/train station in the upper northeastern region.

Factory	Customs / Port /Railway station	Distance (Kilometer)	Time (Minute)	Ranking(Minimum distance/time)
MU01 BuengKan	DT01 : Chiang Khong Customs	940.324	881.903	2
	DT02 : Mukdahan Customs:	306.784	302.355	
	DT03 : Bueng Kan Customs	91.024	92.914	
	DT04 : Nakhon Phanom Customs	265.663	242.660	
	DT05 : Nong Khai Railway Station	68.037	64.241	
	Total	1,671.832	1,584.073	
MU02 Nong Khai	DT01 : Chiang Khong Customs	926.283	900.752	5
	DT02 : Mukdahan Customs:	652.608	682.883	
	DT03 : Bueng Kan Customs	563.912	590.937	
	DT04 : Nakhon Phanom Customs	628.350	661.306	
	DT05 : Nong Khai Railway Station	415.746	462.160	
	Total	3,186.899	3,298.038	
MU03 Sakon Nakhon	DT01 : Chiang Khong Customs	739.803	694.668	1
	DT02 : Mukdahan Customs:	283.270	276.301	
	DT03 : Bueng Kan Customs	210.157	179.768	
	DT04 : Nakhon Phanom Customs	230.134	226.314	
	DT05 : Nong Khai Railway Station	188.127	175.791	
	Total	1,651.491	1,552.842	
MU04 Udon Thani	DT01 : Chiang Khong Customs	953.036	909.454	4
	DT02 : Mukdahan Customs:	402.354	416.128	
	DT03 : Bueng Kan Customs	313.893	329.992	
	DT04 : Nakhon Phanom Customs	378.096	394.550	
	DT05 : Nong Khai Railway Station	183.719	202.116	
	Total	2,231.098	2,252.240	
MU05 Loei	DT01 : Chiang Khong Customs	1,108.550	1,030.534	3
	DT02 : Mukdahan Customs:	357.527	364.542	
	DT03 : Bueng Kan Customs	133.948	137.844	
	DT04 : Nakhon Phanom Customs	261.525	250.285	
	DT05 : Nong Khai Railway Station	251.550	235.326	
	Total	2,113.100	2,018.531	
	Total	19,595.740	19,392.917	

9.1. Upper Northeastern Region, If Entrepreneurs and Investors Choose 1 Location

In the data analysis, the province that was selected was the appropriate factory location. If the entrepreneur chose only one location for the rubber processing factory, the location that was selected was the location in Sakon Nakhon Province because the location of the factory in Sakon Nakhon Province is the province that is at the center of the customs checkpoint and train station. Therefore, it has an advantage over factories in other provinces, including the shortest distance and time for transporting processed rubber to the customs checkpoint

and the destination port, making the Sakon Nakhon factory the chosen province, as shown in figure 14.

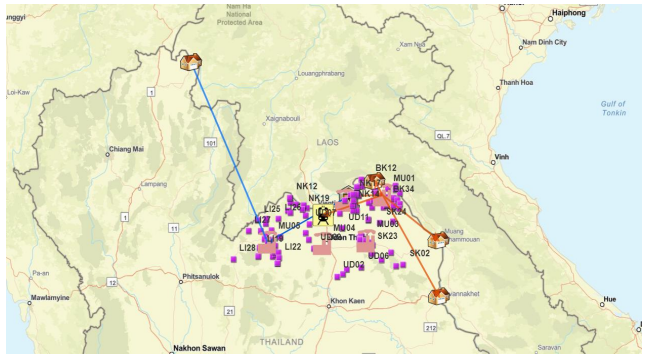


Source: ArcGIS Online

Figure 14: Upper Northeastern Region Network if choosing 1 location

9.2. Upper Northeast Region, If Entrepreneurs and Investors Choose 2 Locations

If an entrepreneur chooses the location of 2 rubber processing factories, the chosen location is Bueng Kan Province and Loei Province because the locations of Bueng Kan Province and Loei Province are central provinces covering customs checkpoints and train stations, thus giving them more advantages than the provincial standard factories. Others include the shortest distance and time for transporting processed rubber to the customs checkpoint and the destination port. Therefore, the factories in Bueng Kan Province and Sakon Nakhon Province were the provinces chosen, as shown in figure 15.



Source: ArcGIS Online

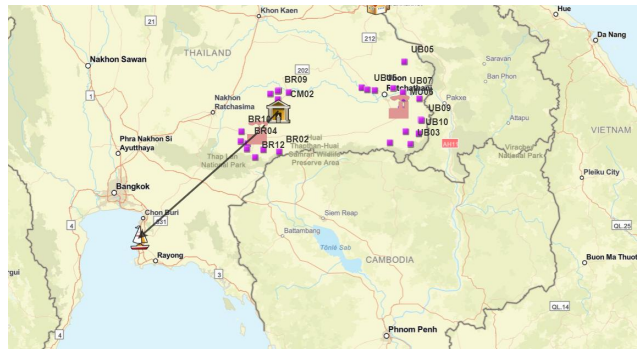
Figure 15: Upper Northeast region network if 2 locations are selected

Table 12: Information on distance and duration from factory location (assumption) to customs house/port/train station in the lower northeastern region.

Factory	Customs /Port /Railway station	Distance (Kilometer)	Time (Minute)	Ranking (Minimum distance/time)
MU06 Ubon Ratchathani	DT06 : Laem Chabang port	887.124	854.141	2
MU07 Buriram	DT06 : Laem Chabang port	335.126	234.700	1
	Total	1,222.250	1,088.841	

9.3. Lower Northeast Region, If Entrepreneurs and Investors Choose 1 Location

In the data analysis, the provinces were selected as suitable factory locations in the lower Northeast region. The selected province is Buriram Province. Because the location of the factory in Buriram Province is closest to the source of raw materials or the central market when compared to the location of the rubber processing factory in Ubon Ratchathani Province, as well as being closest to the port, it creates a competitive advantage in terms of distance and transportation time. Therefore, the location of the rubber processing factory in Buriram Province was the chosen province, as shown in figure 16.



Source: ArcGIS Online

Figure 16: Network of the lower Northeastern region, choosing 1 location

The table and image above show the results of the total distance and duration numbers when analyzing the location of a suitable production facility. Entrepreneurs and investors want to locate an appropriate production facility throughout the supply chain, covering the market central - factory

(assumption) - customs house/port/train station, considering distance and delivery time factors. However, in determining the appropriate location of the production plant. In fact, the analysis using a Geographic Information System (GIS) may not be enough because entrepreneurs and investors need to take into account the factor of land prices. The assumed area of each factory is the cost of construction and transportation costs, which are another factor to be analyzed in conjunction with geographic information tools (GIS: Geographic Information System) as well. Therefore, the researcher has collected information on the above factors, as shown in Table 17.

10. Analysis of Factors such as Land Prices, Factory Construction Costs, and Transportation Costs

Table 13: Numerical data on land prices, factory building costs, and transportation costs.

Province	Land price/square wa	Cost of purchase land	Factory construction costs (assumptions)	Transportation costs (assumptions)
MU05 Loei	13,750 baht/square meter	154,000,000 baht	80,000,000 baht	33 bath/kilometers
MU01 Buengkan	4,375 baht/ square meter	49,000,000 baht	80,000,000 baht	33 bath/kilometers
MU02 Nongkhai	11,250 baht/ square meter	126,000,000 baht	80,000,000 baht	33 bath/kilometers
MU03 Sakon Nakhon	18,750 baht/ square meter	210,000,000 baht	80,000,000 baht	33 bath/kilometers
MU04 Udonthani	45,000 baht/ square meter	504,000,000 baht	80,000,000 baht	33 bath/kilometers
MU06 Ubon Ratchathani	27,500 baht/ square meter	308,000,000 baht	80,000,000 baht	33 bath/kilometers
MU07 Buriram	12,500 baht/ square meter	140,000,000 baht	80,000,000 baht	33 bath/kilometers

Source: The Treasury Department of Thailand ,2023

From the numbers above, Data on land prices has been collected. Cost of purchasing land (Factory construction assumption uses an area of 11,200 square meter Figures based on construction cost assumptions include transportation costs for each hypothetical factory location. From the table above, the results show that in the upper northeastern region. Bueng Kan Province has the cheapest land price, ranking number 1 with a price of 4,375 baht/square meter, cost of purchasing land is 49,000,000 baht. followed by Nong Khai Province, price of 11,250 baht/ square meter, cost of purchasing land is 126,000,000 baht, the lower northeastern region is Buriram Province 12,500 baht/ square meter, cost of purchasing land is 140,000,000 baht, etc. However, the researcher has conducted this research to analyze and locate appropriate rubber production plants throughout the supply chain. Taking into account the distance and total duration factors are the main factors. As for the facts, factors regarding land prices Factory construction costs, and transportation costs are only additional factors in the decision-making of entrepreneurs and investors.

11. Conclusion

This research is an analysis to determine the appropriate location of the rubber processing factory. To analyze and plan appropriate routes in the distribution network for rubber exports. At present, one rubber entrepreneur sees the importance of increasing production capacity because the demand for rubber in the international market tends to continually increase. From the overall picture, it was found that the existing rubber processing plants were unable to support the increasing demand from customers, which led to an increase in suitable locations for the rubber processing plants and the design of the network. The distribution network for exporting rubber and delivering it to customers is comprehensive and fast. This research therefore conducts a study to analyze and find suitable locations for rubber processing plants under conditions of distance and time to deliver processed rubber to customers quickly and efficiently. The researcher has collected information on the locations of farmers' institutes, the hypothesized locations of 7 rubber processing factories, and the locations of customs checkpoints, train stations, and 6 ports covering the upper and lower northeastern regions in this work. The research analyzed the application of geographic information systems to find the results of appropriate rubber transport routes by comparing the distance and duration numbers for each route.

After studying and analyzing data using geographic information systems to design a distribution network for exporting rubber with minimum distance and duration conditions and covering raw material sources and customers, it was found that the former was in the Southeast. There are only a few rubber processing factories in the North, which cannot cope with customer demand. The researcher studied and analyzed ways to increase the location of rubber processing factories to benefit entrepreneurs and investors who to invest in or expand processing plants in line with current and future customer demand. This research uses the Geographic Information System by applying the Center of Gravity tool to analyze and locate suitable processing plant locations that are closest to the facts of the hypothesized location. Divided into 2 parts: the upper northeastern region,

namely Bueng Kan Province. Nong Khai Province, Loei Province, Sakon Nakhon Province, Udon Thani Province, and the lower northeastern region is Ubon Ratchathani Province. Buriram Province this is to find a suitable factory location. Under the criteria of the shortest distance and duration, location-allocation. From the analysis using the tool, it was found that the upper Northeastern region has a total distance of 19,595.740 kilometers and a total time of 19,392.917 minutes, and the lower Northeastern region's total distance is 1,222.250 kilometers. The total time is 1,088.841 minutes. If an entrepreneur chooses to invest in building 1 rubber processing factory in the upper northeastern region, the rubber processing factory in Sakon Nakhon Province will be selected and divided into 5 routes, with a total distance of 1,651.491 kilometers from a total of 19,595.740 kilometers and a total duration of 1,552.842 minutes from a total of 19,392.917 minutes. If an entrepreneur chooses to invest in building 2 rubber processing plants in the upper northeastern region, the rubber processing plants of Bueng Kan Province and Loei Province will be selected by the rubber processing plants of Bueng Kan Province, divided into 5 routes, with a total distance of 1,671.832 kilometers from a total of 19,595.740 kilometers, a total distance of 1,584.073 minutes from a total of 19,392.917 minutes, and the rubber processing factory in Loei Province is divided into 5 routes, with a total distance of 2,113.100 kilometers from a total of 19,595.740 kilometers and a total of 2,018.531 minutes from a total of 19,392.917 minutes. If an entrepreneur chooses to invest in building only 1 rubber processing factory in the lower northeastern region, the rubber processing factory in Buriram Province will be selected, divided into 1 route, with a total distance of 335.126 kilometers from a total of 1,222.250 kilometers, including the duration of 234.700 minutes from a total of 1,088.841 minutes.

However, based on the results of the analysis of the distribution network using the tools Center of Gravity and Location Allocation under the shortest distance and time frame, there are still cost factors that operators and investors must consider when deciding on the most appropriate factory location. The results of the study found that in the northeastern region, the province with the lowest land prices is Bueng Kan Province, 2nd place is Nong Khai Province, 3rd place is Loei Province, 4th place is Sakon Nakhon Province, and 5th place is Udon Thani Province. In the Northeast, the first-lowest province is Buriram Province. If entrepreneurs and investors use the criteria to find a suitable factory location under the criteria of distance and shortest time in the upper Northeastern region, the factory location in Sakon Nakhon Province will have a cost of purchasing land of 210,000,000 baht. Bueng Kan Province will use the cost of purchasing land at 49,000,000 baht. Loei Province will cover the cost of purchasing land at 154,000,000 baht. Buriram Province will cover the cost of buying land at 140,000,000 baht.

12. Research Suggestions

1. Entrepreneurs or investors in the industrial sector who wish to expand their factories can use this study's information on suitable factory locations to study and plan the development of their industries appropriately, as the data analysis has shown that having an efficient location can lead to investment development plans in terms of expanding factory locations and effectively increasing production results.

2. Entrepreneurs or investors in the industrial sector who estimate to export products to foreign markets can use this research information to study and plan transportation routes throughout the supply chain appropriately, as well as be able to understand the distance. The shortest way and time for transporting goods to foreign markets according to the results of the analysis of geographic information systems.

13. Suggestions for Further Research

1. The next research should study the transportation of rubber from farmer groups to prepare for the production and processing of rubber in line with the demand of the international market.

2. The next research should study improving and developing rubber transportation routes to reduce the costs of logistics and distribution activities.

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