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Identifying optimal hinterland connections to strengthen food supply chains: a case study of Bangka Island, Indonesia

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Abstract
The hinterland connection in the food supply chain is important for ensuring efficient and sustainable food distribution. This study aims to analyze and determine the best route for hinterland connection in the food supply chain on Bangka Island using the analytical hierarchy process (AHP). By identifying evaluation criteria such as road geometry, road performance, land use, and social conditions, as well as paired assessments by experts and stakeholders, the relative weight for each criterion is then determined. Based on the results, alternative routes are evaluated and ranked to choose the best route. The findings highlight that the primary route choice is the Palembang-Mentok-Puding Besar-Petaling-Pangkalpinang route, with a score of 34.8%. Road performance shows a strong correlation with road geometry and land use, while safety criteria hold the highest score at 0.884, emphasizing their critical importance in the food supply chain. This research provides valuable insights for decision-makers in planning and developing transportation infrastructure to support food supply chains on Bangka Island.

Keywords
Hinterland connection, Food supply chain, Analytical hierarchy process, Transportation infrastructure, Bangka Island.

1.Introduction
Economic development and population growth on Bangka Island have led to a significant increase in demand for food supplies. Therefore, the role of the food supply chain is becoming increasingly important to ensure the availability and efficient distribution of food across the island. Choosing an appropriate hinterland connection route is a key factor in optimizing the food supply chain, ensuring that agricultural products and local economic outputs can reach consumers quickly and effectively [1].

Bangka Island, with its unique geographical characteristics, requires special strategies for route selection to improve the food supply chain. Topographic conditions, the distance between production locations and consumers, as well as the state of transportation infrastructure are the main considerations in determining the best route.

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Choosing the right route not only enhances distribution efficiency but also supports local economic growth, increases farmer incomes, and ensures the sustainability of the food supply chain.

Bangka Island, located in the east of Sumatra Island, Indonesia, is part of the Bangka Belitung Islands province, with Pangkalpinang as its capital. Food supplies for basic needs such as vegetables for the island's communities are supplied from regions beyond its borders, including Jakarta, Yogyakarta, Brebes, Palembang, Padang, Bengkulu, Medan, and even Kendari. This is partly due to the insufficient production by local farmers in meeting the needs of the community. For example, red chili is a frequently imported commodity, with an average daily supply from regions outside Bangka amounting to approximately 400 kilograms, subject to demand fluctuations. The wholesale price of chili is IDR 40,000 per kilogram, while the retail price is IDR 45,000 per kilogram. Additionally, a significant portion of kitchen spices is sourced from regions outside the Bangka Belitung area due to the low productivity of local farmers.

Bangka Island, as an integral part of Indonesia's food ecosystem, faces critical challenges in strengthening its food supply chain. The increasing demand for agricultural and food products on Bangka Island encourages the need for selecting optimal hinterland connection routes. The success of the food supply chain heavily depends on selecting efficient and well-coordinated routes for distributing agricultural products from producers to consumers.

The Bangka Belitung Islands Province has 87 traditional markets accommodating a total of 9,129 traders, with 1,927 kiosks and 3,483 stalls. Pangkalpinang city has 10 traditional markets with a total of 1751 traders and has 495 kiosks and 980 stalls [2].

Hinterland is defined as 'the area where the greater part or a substantial portion of trade passes through a single port' [3]. This definition highlights that hinterland areas are geographic regions served by a specific port. These complementary concepts offer opportunities for shippers to transport goods from their origin to their destination through an integrated system that spans maritime and land transport segments [4].

Hinterland connectivity provides an overview of the connection between ports and the surrounding areas within their buffer zones. This is illustrated by the absence of strict boundaries, as administrative divisions such as districts, cities, or provinces depend on the ports adjacent to the region [5]. Problems with road network services, which facilitate the distribution of goods from the port to the interior and vice versa, can sometimes hinder the port's processes or operational performance. One common issue at ports is the long waiting time for ships due to delays in transport vehicle availability. The performance of the port access infrastructure network to inland areas is a crucial aspect in meeting accessibility indicators, such as safety, comfort, and affordable rates. Meanwhile, indicators that show low performance but are priorities for improvement include capacity, efficiency, regularity, comfort, and timeliness [6]. By selecting the best alternative road, it can contribute to regional development, improve efficiency, and increase accessibility [7]. Using the multi criteria analysis (MCA) methodology, the research evaluated the weighted values of each criterion: geometric, land use, pavement structure, and accessibility, which scored 3.795, 3.787, 3.521, and 3.157, respectively. The findings ultimately reveal that route 2, spanning Lampung-OKU-Prabumulih-Indralaya-Palembang, emerged as the best option [8]. Route 2 offers advantages such as bypassing urban congestion and providing convenient access to industrial zones, distribution centers, warehouses, and ports. These benefits lead to reduced fuel consumption and lower gas emissions [8].

A supply chain refers to a series of interactions among companies or activities in delivering goods or services from their origin to the end consumer. Its principal components manufacturers, distributors, retailers, and customers [9]. The primary issue in the food supply chain on Bangka Island is that the road network service remains inefficient, which hampers the logistics distribution process. This, in turn, affects the smooth flow of logistics supplies in and out of the port. Additionally, there is an imbalance in logistics transportation from outside the island in full containers, while from inside the island, those leaving the island are often empty. In some countries, such as the Netherlands, Belgium, China, Australia, and Malaysia, have efficient inland connections, enabling smooth food supply chains for both inbound and outbound logistics. On Bangka Island, however, the food supply chain from production to consumers remains inadequate, so a hinterland connection study is needed to strengthen the food supply chain on Bangka Island using the analytic hierarchy process (AHP).

The main challenge in this study is designing the optimal route that ensures the smooth operation of the food supply chain from production areas to consumers. In this context, the proposed route must prioritize the shortest distance to minimize delivery time while also considering resilience against various risks, such as road infrastructure damage and potential disruptions caused by natural disasters. Uncertainty arising from geographical and environmental conditions in remote areas adds to the complexity of ensuring fast, safe, and efficient food distribution.

Based on the problem background described above, the research questions in this study are as follows:

1. How are the factors affecting the food supply chain based on the hinterland conditions on Bangka Island?
2. How is the best food supply chain route determined on Bangka Island?

The objectives of this study are as follows:
1. To identify the food supply chain from the production process, and transportation, to delivery to the customer.
2. To select the optimal route using the AHP.

The outline of this study is as follows: Section 1 explains the background, research questions, goals, and motivation. Section 2 covers the literature review. Section 3 provides a detailed explanation of the methodology. Section 4 presents the results. Section 5 discusses the findings, and Section 6 concludes the study.

2.Literature study

The hinterland refers to the region or area located behind a port. It is often relative and not bound by the administrative boundaries of any specific territory, province, or national border. This classification depends on the proximity of the port to the area. The hinterland is typically characterized by limited accessibility and lower levels of economic development compared to coastal or mountainous regions. The term "hinterland" is often used in relation to ports, referring to the inland areas that a specific port serves. This includes the transportation of goods and people to and from the port [10].

In the past two decades, the relationship between seaports and hinterlands has significantly influenced the spatial structure of a country. Dadashpoor and Arasteh [11] uses social network analysis in his study to highlight the concentration, direction, and intensity of commodity flows while describing the spatial structure of port-hinterland interactions. The results show that the most active ports in commodity interactions are those in the south of Iran, including Tehran, Bandar Abbas, and Mahshahr Port. This emphasizes Tehran's pivotal role in the nation's hinterland's commodity production, consumption, processing, and distribution. Despite their geographical proximity to ports, regional and local logistical nodes are predominantly connected to the core, Tehran. This distinctive pattern of commodity flow signifies a unique phase in the port-hinterland evolution, termed "core-port connectivity"[11].

Exploring the connections within the hinterland and optimizing food supply chains in the context of Bangka Island's development can be enhanced through the application of the AHP. This method, specifically tailored to address the complexities of the food supply chain on Bangka Island, serves as a valuable guide and reference. The findings of this study can be instrumental for both the government and the private sector in overseeing and making decisions regarding mechanisms pertinent to the food supply chain [12].

The AHP, introduced by Saaty [12], is favored by researchers due to its simplicity, efficiency, and reliability [13]. Multi-criteria and sub-criteria analysis utilizing AHP- best-worst method (BWM) models were also carried out to evaluate the degree of accessibility of park-and-ride (PnR) [14]. Sameer has studied the use of a geographic information system and MCA to assist planners and stakeholders in taking into account various land use factors [15].

In the realm of MCA, the predominant approach employed in the decision-making process is the AHP. This decision framework, structured hierarchically, determines the magnitude and significance of criteria and sub-criteria through pairwise comparisons. The hierarchical process analysis unfolds as a methodical procedure, systematically presenting the elements of the problem in an organized and scientific fashion. Addressing decisions fraught with intricate risks requires evaluating of the structure capable of portraying an understanding of the influencing elements [12]. The AHP was proposed as a multi-criteria technique for environmental impact assessment (EIA), recognized for its effectiveness in facilitating qualitative, quantitative, or combined decision-making [16].

The AHP method is used to discern numerous key factors through pairwise comparisons involving stakeholders participating in the decision-making process. A criterion assumes greater importance with a higher weight, while a lower weight designates it as less significant. The ultimate ranking is derived by combining the weights of criteria and the ratings of alternative solutions [12]. After identifying of assessment criteria and alternatives in the AHP, the subsequent step involves constructing a pairwise comparison matrix, where each factor is evaluated against others by assigning relative values ranging from 1 to 9 [16, 17].

The AHP is a versatile and semi-quantitative method for assessing various conditioning factors through matrix-based pairwise comparisons. It is widely used to address complex problems such as site selection, regional planning, routing models, and environmental phenomena [11]. The most comprehensive thing within the multi-criteria examination handle is collecting information concerning particular criteria for analyzing the chosen street course. It is vital to decide whether satisfactory sources are accessible since, for various criteria or sources that are not secured within the data, it is evident that a subjective appraisal is carried out, which needs nitty gritty data around the issue and fitting steps [18].

The MCA Method is an important supporting tool in analyzing various decision-making problems in transportation, especially in the field of safety and improving public transportation services, selecting alternative ways to develop public transportation systems, location of suitable points, and other related problems. With transportation by road, air, train, and sea transportation, which can be generally known [19].

The Association of Southeast Asian Nations (ASEAN) and West China are connected by the International Land-Sea Trade Route, a new route that has an impact on the region's economic growth and transportation development. The selected studies are then examined individually regarding transportation, supply chains, economics, and trade and the development and analysis of their impact [20].

A good corridor is based on the concept of developing docks at ports, where inland areas become part of the port area. After processing from the ship, the goods are considered to be at their final destination for delivery [21].

There are a few cases where there is the possibility of creating short-sea shipping. For illustration, within the harbor from Tanjung Priok Jakarta to Tanjung Perak Surabaya, the activity stack on the north coast of Java, Indonesia, will be decreased to the ordinary constraint of the volume to capacity proportion, lessening the fetched and time of shipping holders as well as support costs: streets and the impacts of discussing contamination [22].

A high-quality port can shorten production waiting times. This enables better logistics connectivity and supply chain efficiency with more options for sourcing from abroad, providing opportunities for the country to produce high-quality products [23].

When a container is delivered directly to the client by truck from the port and then returned empty to the same port, or when a container is delivered directly to the consumer using multimodal transportation such as rail and truck from the port and returned empty via the same route, and when these containers are connected at the port and delivered directly by truck to the client, it represents an alternative cost-saving strategy [24].

Good inland connectivity is a critical factor in port competitiveness, as delays caused by poor inland connections lead to higher logistics costs and slower delivery of products to consumers. As a result, cargo owners may shift to other ports with more affordable and effective inland connectivity [25].

Several factors, including the growing importance of global supply chains and the increasing impact of regional economic dynamics, influence the development of inland port areas. Therefore, a comprehensive development concept for inland port areas is needed, incorporating various perspectives and applications to enhance these regions [26]. Success in port services also plays a significant role in empowering port users [13].

Ports are integral to extensive land transportation networks, intermodal transport corridors, and inland ports, which are influenced by factors within the port. Therefore, in urban areas, inland ports are part of a more extensive logistics system that connects various facilities and logistics zones. The management, planning, and ownership of inland ports must be considered for the management of diverse logistics spaces on a metropolitan scale, including transportation infrastructure and land-use planning [27]. Road and multimodal transport cannot be directly compared, as each sector offers distinct physical transportation services [28].

Economic growth in inland areas will impact the increase in port output and the externalities of port-to-inland transportation. Several mode-shifting policies need to be considered, including internalizing pricing based on external costs, road construction, improving rail service levels, and providing rail subsidies [29]. The loading and unloading times for rail and waterway transport and the duration of goods reception must consider model construction to achieve optimal results [30].

The cruise ship industry, which is currently a rapidly expanding recreation and tourism business sector, is another example of how public transportation is a valuable option for obtaining hinterland connections when considering safety, efficiency, and environmental protection. In terms of services, an important part of its development lies in accessibility to destinations in attractive hinterland areas [31]. In the shipping industry in the Baltic ports, the port infrastructure is well developed. This is based on essential service for ships in the form of receiving waste and supplying fuel, clean water, and logistics [32].

The main factors in the sustainability of transportation services in the railway sector are influenced by environmental, social, and economic factors. The consideration is how to understand the importance and necessity of these factors and what impact they will have on the freight rail sector. The available literature on freight railways is very scanty and no real effort has been made to explain the sustainability of these factors or to their development. A good understanding of sustainability and constraints in the freight rail sector helps stakeholders to make appropriate plans and undertake improvement efforts to improve sustainability as well as address issues in the supply chain [33].

Analysis of selecting the best hinterland connecting route is carried out using the following mechanism): Determine the quantitative or qualitative value of each alternative for each criterion variable used; perform a scoring process for each alternative, according to the assessment scale applied., and create a performance matrix for each alternative to determine the best option and the next sequence [12]. The selection of hinterland connection routes for the food supply chain on Bangka Island, using the AHP method, incorporates four key criteria, each with specific aspects:

a. Road geometry: Considerations include bends, inclines, gradients, superelevation, and width. **b**. **Road performance:** Factors include service level, speed, pavement condition, distance, and travel time. **c. Land use:** Aspects related to ports, markets, settlements, and agriculture are considered. **d. Social conditions:** Elements such as safety and accessibility are included.

The novelty of this study lies in identifying an optimal route from several hinterland connection options to strengthen the food supply chain on Bangka Island. This is achieved by evaluating multiple criteria, including road geometry, road performance, land use, and social conditions, through the AHP. The methodology provides a systematic approach for determining the best route to support the food supply chain on Bangka Island.

3.Methodology

3.1Research location

In this research, the analysis stages of hinterland connection problems on Bangka Island are presented specifically. There are five routes available for the food supply chain, starting from the production source location up to the customers. These routes cover the journey from the origin of the food production source to the destination port. The available food supply chain routes are as follows: Route 1 involves logistics supplies from Palembang, collected at Jakabaring Market, and transported by truck to Palembang's Tanjung Api-api port. A ro-ro ferry then carries them to Tanjung Kalian port, followed by transport along the Mentok-Puding Besar-Pemali-Sungailiat route, represented by a green and yellow line in *Figure 2*. Route 2 includes logistics supplies from Palembang collected at Jakabaring Market, transported by truck to Tanjung Api-api port in Palembang, and shipped by a ro-ro ferry to Tanjung Kalian port and went through the Muntok-Puding Besar-Petaling-Pangkalpinang route, shown with a green line. Route 3 consists of logistics supplies from Java Island, transported by truck to the port of Sunda Kelapa Jakarta via Tanjung Gudang port and went to Belinyu-Riau Silip-Sungailiat-Pangkalpinang route, illustrated with a light purple and red line. Route 4 involves logistics supplies from Java Island, transported by truck to the port of Sunda Kelapa Jakarta and then by ro-ro ship to the port of Pangkalbalam through the Pangkalpinang-Merawang-Sungailiat route, marked with a red line. Lastly, Route 5 entails logistics supplies from Java Island, transported by truck to the port of Sunda Kelapa and further by ro-ro ships to Sadai port on the Toboali-Koba-Pangkalpinang route, depicted with a dark purple line. The corresponding maps are illustrated in *Figure 1* and *Figure 2*. The research locations were selected purposively, focusing on the Pangkalpinang main market as the primary customer destination before distribution to major markets on Bangka Island. The study also included Pangkalbalam Port, Tanjung Kalian Mentok Port, Tanjung Gudang Belinyu Port, and Sadai Toboali Port. This research was conducted from February 2021 to July 2023.

3.2Research flowchart

The research flowchart was developed as a guide to achieve the objectives of this study. The diagram is presented in *Figure 3*.

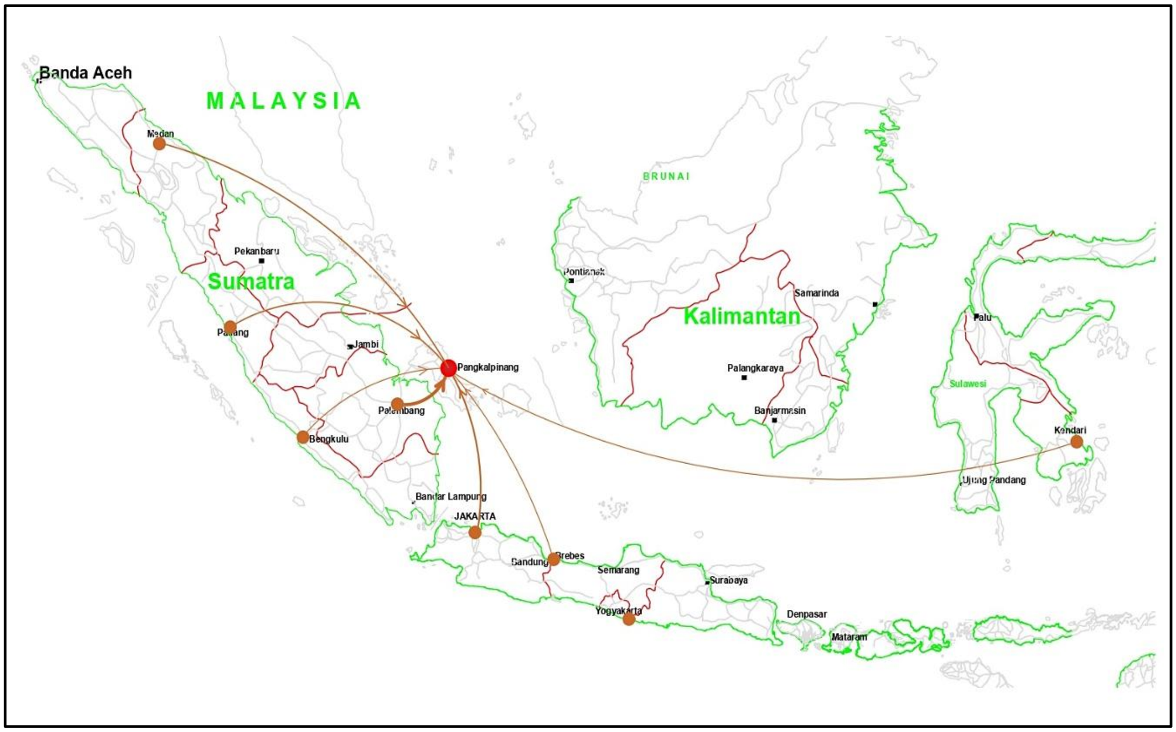

Figure 1 Map of alternative routes connection to hinterland

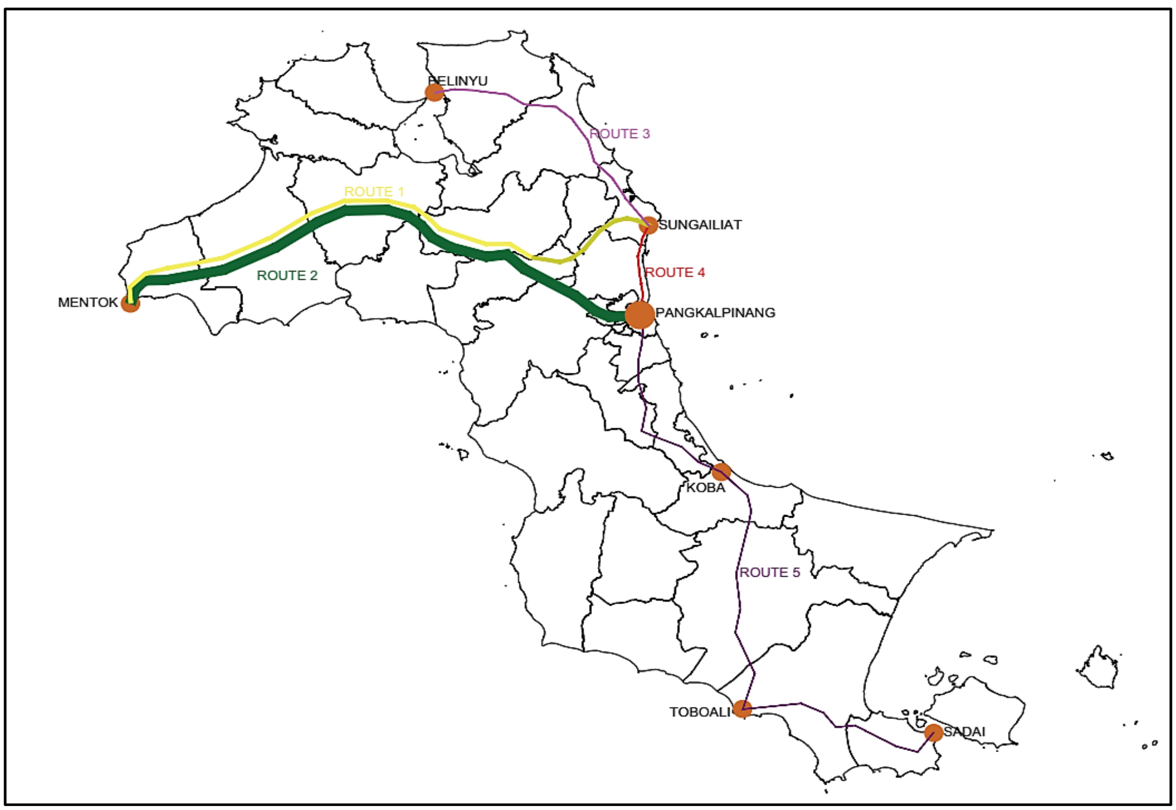

Figure 2 Map of food supply chain routes on Bangka Island

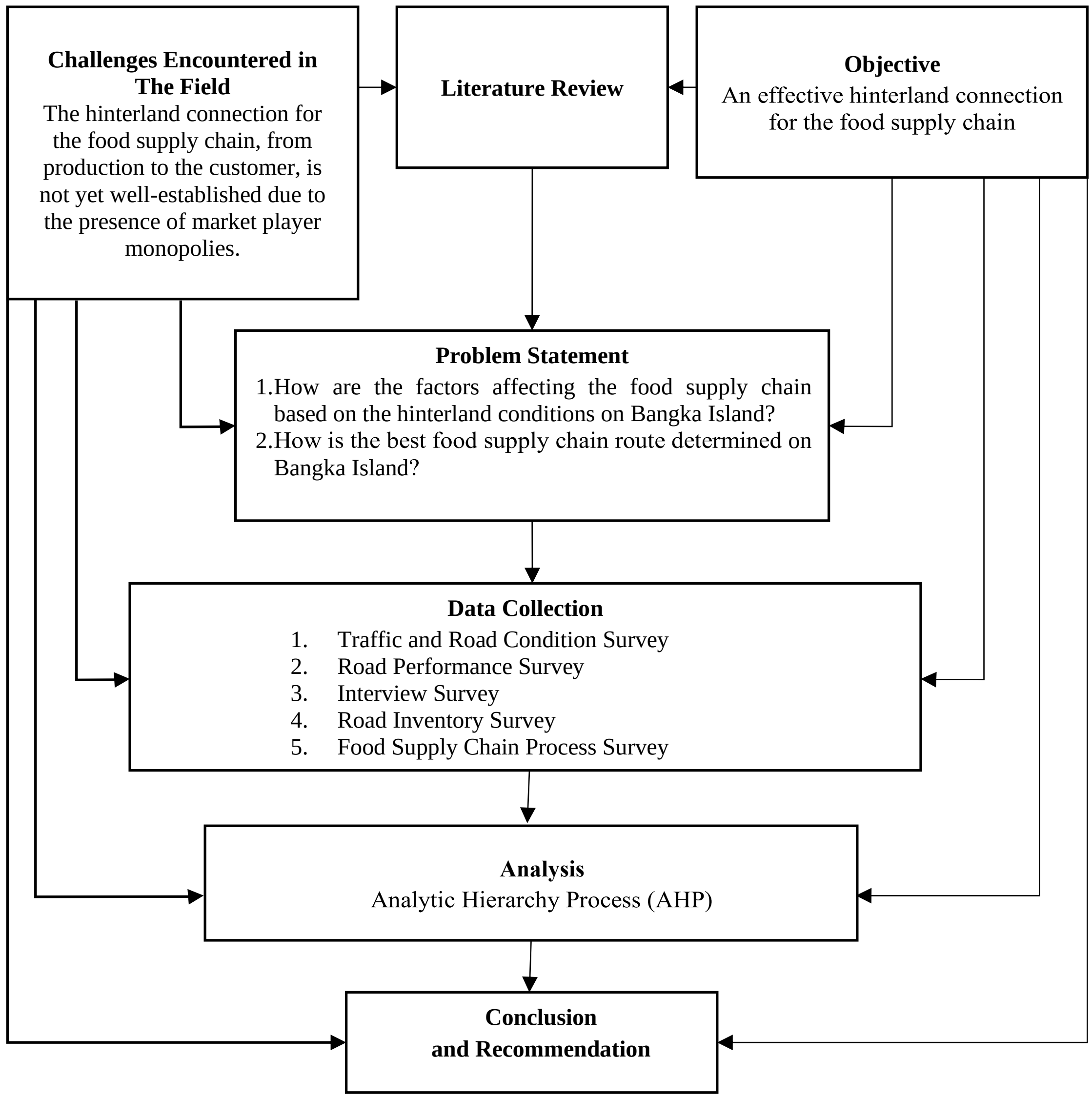

Figure 3. Research flowchart

The method used is a case study method. The data in this research includes primary and secondary data. The steps taken during the research process are as follows:

Stage 1: Collection of primary and secondary data.

According to data from the Bangka Belitung Islands Province's central bureau of statistics (BPS) the year 2023 [34], there are 1,186,570 people living on Bangka Island alone. The Slovin formula [35] was then used to determine the number of respondents, yielding 100. Primary data was collected through observation and direct interviews with the respondents. The sample was divided into 5 wholesalers, 30 drivers, and 65 retailers, with questionnaires distributed directly through structured interviews. The next primary data collection from stakeholders responsible for determining transportation policies for roads on Bangka Island includes a group of road experts and managers. With the authority to operate and maintain transportation roads, this group comprises academics, the road transportation management center, the public works department, and road development organizations. The interview process involved 7 stakeholders, who used a questionnaire to categorize criteria into 4 main criteria and 16 sub-criteria.

Meanwhile, secondary data provides an overview of the field and supports the information gathered. It was obtained from various sources, including the provincial transportation agency, district/city transportation agencies, Pelindo II, harbormaster and port authority office (KSOP) Pangkalbalam, the Bangka Belitung Islands Province Industry and Trade Service, the Bangka Belitung Islands Province Food and Agriculture Service, as well as other related literature such as journals and other publications. The interview generates weights and performance values for each criterion based on the respondents' feedback.

The assessment was conducted by selecting a rating on a scale of 1 to 5, where a score of 5 was given to alternatives that fully met the requirements with a significantly higher level of importance, while a score of 1 reflected a lower level of importance, as shown in *Table 1*. Further development of the selection criteria can include evaluation variables used in the AHP, as presented in *Table 2*.

Table 1 The range of AHP scales

Intensity Interest	Definition verbal	Explanation
1	Less important	Both elements have the same level of importance with no difference in influence
2	A little more Important	One element is slightly more important than the other
3	More important	The evaluation strongly favors one element compared to its counterpart.
4	Very important	One element is highly influential, and its dominance is clearly evident.
5	Absolute more Important	The evidence that one element is more important than its counterpart is very clear.

Table 2 Criteria and sub-criteria

Criteria	Sub-criteria	Explanation
Road geometric	Bends, inclines, descents, superelevation, wide	Condition of the existing connecting road network
Road Performance	Service level, speed, pavement condition, punctuality	The level of service on the roads used
Land Use	Ports, markets, settlements, agriculture	Access land use from origin to destination
Social conditions	Safety, accessibility	The effect on road access is whether it supports the food supply chain

Stage 2: Data Discussion/Processing:
The obtained data, including primary and secondary data, are processed at this step. The analysis uses the AHP method.

Stage 3: Data Analysis: The analysis of the data processing results was conducted quantitatively using the AHP method to evaluate all parameters and variables for each route performance. Through pairwise comparisons, the hierarchy underlying decision-making in the AHP determines how criteria and sub-criteria are measured and prioritized. Thomas L. Saaty first proposed AHP in the 1970s [36, 37]. AHP is a systematic approach that organizes and scientifically analyzes the elements of a problem. It requires a framework evaluation capable of conveying information through influencing aspects to make decisions on complex risks [38].

The AHP is a methodological approach that systematically and scientifically structures the components of a problem. In decision-making involving complex risks, it is necessary to evaluate a framework that can effectively communicate information through the variables influencing it [38].

The AHP approach is used to identify several critical aspects based on pairwise comparisons conducted by stakeholders in decision-making. Factors with higher weights are considered more important, while those with lower weights are deemed less significant. The weights of the criteria and the scores of alternative solutions are combined to determine the final ranking [39]. This involved comparing all aspects of the criteria and sub-criteria according to the hierarchical levels, as shown in *Figure 3*.

Stage 4: Conclusion and recommendations:
The study on hinterland connections to strengthen the food supply chain using the AHP methods results in a hierarchy of criteria that serves as the basis for route selection by food logistics managers. Based on the research findings, recommendations can be made for the relationship between hinterland and food supply chain on Bangka Island, including addressing obstacles from production to distribution to customers, as well as determining the best route using AHP.

4.Result

4.1Evaluation of the performance of each criterion

The outcome of this AHP dictates the selection of the most favorable alternative in the hinterland connection handling program, ultimately fortifying the food supply chain.

The interview process involved seven stakeholders, who utilized a questionnaire to categorize criteria into four main criteria and sixteen sub-criteria. From the questionnaire, a pairwise comparison matrix between criteria and sub-criteria was obtained. For example, *Table 3* shows the pairwise comparison matrix among the sub-criteria of road performance.

Tabel 3 Matriks berpasangan antar sub-criteria road performance

	A1	A2	A3	A4	A5	Jumlah		A1	A2	A3	A4	A5	Jumlah	Eigen Vector	Z	λ
A1	1,000	3,106	2,081	1,327	3,106	10,621	A1	0,376	0,553	0,316	0,211	0,267	1,723	0,345	1,874	5,438
A2	0,322	1,000	2,315	1,327	3,106	8,070	A2	0,121	0,178	0,352	0,211	0,267	1,129	0,226	1,207	5,346
A3	0,480	0,432	1,000	2,315	1,327	5,554	A3	0,181	0,077	0,152	0,368	0,114	0,891	0,178	0,954	5,353
A4	0,753	0,753	0,432	1,000	3,106	6,045	A4	0,283	0,134	0,066	0,159	0,267	0,909	0,182	0,905	4,977
A5	0,104	0,322	0,753	0,322	1,000	2,501	A5	0,039	0,057	0,114	0,051	0,086	0,348	0,070	0,371	5,330
	2,659	5,614	6,581	6,291	11,646	32,792		1,000	1,000	1,000	1,000	1,000	5,000	1,000	5,311	26,444

A1, A2, A3, A4, and A5 represent different alternatives evaluated under the road performance sub-criteria. "Jumlah" means "Sum". Z is the weighted sum vector. Λ is used to check the consistency.

The random index (RI) is shown in *Table 4*. *Table 5* presents the weighting calculation for criteria and sub-criteria using eigen vector values. The main criteria include road geometry, road performance, land use, and social conditions, each with weights assigned to their respective sub-criteria. The consistency level is measured through the consistency index (CI) and consistency ratio (CR). CI is a measure used to assess the level of logical consistency in a pairwise comparison matrix. The matrix is considered perfectly consistent if the CI=0. The smaller the CI value, the more consistent the decisions made. The equation for calculating CI is as follows (Equation 1):

$$CI=\frac{\lambda_{max}-\eta}{\eta-1} \quad (1)$$

λ_{max}= The maximum eigenvalue of the comparison matrix.

η=The number of criteria or elements being compared.

CR is a ratio that indicates how consistent the comparisons made in the matrix are, relative to a random value. CR is used to evaluate whether the level of consistency is acceptable

Interpretation of CR:

- Jika CR<0.1, the consistency is considered acceptable
- Jika CR≥0, the comparison matrix is considered inconsistent, and the input data needs to be revised.

The equation for calculating CR is as follows (Equation 2):

$$CR=\frac{CI}{RI} \quad (2)$$

CI= Consistency index and RI= Random index

To determine the value of the RI, refer to the *Table 4.*

Table 4 Value of the RI

Matrix size	RI
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

The following is an example of the CI and CR calculation for the road performance criterion.

$$CI = \frac{\lambda_{max}-\eta}{\eta-1}$$

$$CI = \frac{5.438-5}{5-1} = 0.109$$

$$CR = \frac{CI}{RI}$$

$$CR = \frac{0.109}{1.12} = 0.098$$

Table 5 Weighting calculation for criteria and sub-criteria levels

Criterion	Eigen vector value						CI	CR
		Sub-Criterion						
		1	2	3	4	5		
Road Geometry	0.289	0.359	0.251	0.188	0.132	0.070	0.025	0.023
Road Performance	0.372	0.345	0.226	0.178	0.182	0.070	0.109	0.098
Land Use	0.221	0.366	0.257	0.207	0.171	-	0.021	0.023
Social Conditions	0.119	0.403	0.597	-	-	-	0	0

Table 6 presents the consistency calculation for the main criterion, road performance. The maximum eigenvalue (λ maks) is 5.438, with the number of elements (n) being 5. The CI is 0.109, and the CR is 0.098, indicating that the calculation results are consistent as CR < 0.1.

Table 6 Consistency index calculation

Hyrarchy Level	λ maks	η	RI	CI	CR
Main Criteria	5.438	5	1.120	0.109	0.098

The comparison lattice of the weights of the criteria and sub-criteria that produce eigenvector values is calculated and displayed in *Table 7*. The basis for street performance, indicated by the highest value, 0.372, in the eigenvector column, represents the most critical factor in the evaluation.

The street execution criteria are imperative in improving the nourishment supply chain on Bangka Island. The most noteworthy number of sub-criteria is security, 0.119. This implies that smoothness within the hinterland association course bolsters territorial advancement on Bangka Island. From *Table 8* results, it is evident that the most important criterion significantly influencing the assessment is road performance, whereas the least important criterion is social conditions.

Table 7 Weight of criteria and sub-criteria

Point	Criteria	Criteria for exemption
A	**Road geometry**	**0.289**
	Bend	0.359
	Incline	0.251
	Derivative	0.188
	Superelevation	0.132
	Wide	0.070
B	**Road Performance**	**0.372**
	Level of Service	0.345
	Speed	0.226
	Pavement condition	0.178
	Distance	0.182
	Traveling Time	0.070
C	**Land Use**	**0.221**
	Port	0.366
	Market	0.257
	Settlement	0.207
	Agriculture	0.171
D	**Social Conditions**	**0.119**
	Safety	0.403
	Accessibility	0.597

Table 8 Criteria weighting

Order	Criteria	Percentage
2	Road Geometry	28.9%
1	Road Performance	37.2%
3	Land Use	22.1%
4	Social Conditions	11.9%

A study of hinterland connections and food supply chains on Bangka Island highlights the potential to strengthen food supply chains by developing these connections. Using the AHP, this study provides valuable insights into improving the food supply chain on Bangka Island. It can serve as a guide and reference for the government and private sector in monitoring and making informed decisions related to food supply chain mechanisms.

Analysis of selecting the best hinterland connecting route is carried out using a mechanism, namely determining the quantitative or qualitative value of each alternative for each criterion variable used; carrying out a scoring process for each alternative variable, according to the assessment scale used. The food supply chain route selection process is conducted using the stage variables outlined in *Figure 4.*

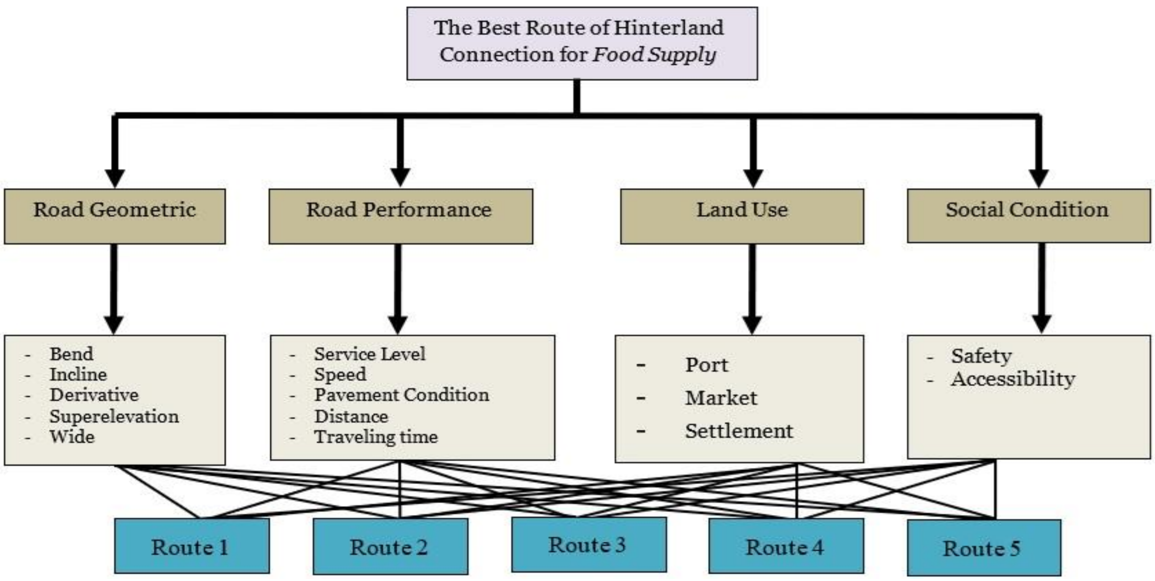

Figure 4 Flowchart of the best route for hinterland connection in the food supply chain

In this study, sensitivity analysis is employed to evaluate the impact of changes in the input data or criteria weights on the outcomes of a decision-making process. Finding pertinent criteria, which stand for the crucial elements in assessing and contrasting the options, is the first step in the process. Sensitivity analysis, which evaluates how modifications to these weights affect the ranking or rating of the alternatives, comes after the weight assignment process. The sensitivity of the matrix findings is examined to determine the ratio deviation consistency value for each pairwise comparison matrix vector value produced. If the range is less than 10%, the pairwise comparison matrix is said to be fully consistent, or if λ max = η. Based on the results of the RI value that is obtained by averaging the main eigenvalues (λ max) and criteria elements (η) against the partial weights in each variable, the CI and CR values are used in this calculation. The results are presented in *Table 9.*

It is evident from the computation results in *Table 10* that route 2 achieved the maximum value of 4.150 for the road geometry criteria. Route 2 also achieved the highest value of 4.150 for the road performance parameter. The same route 2, yielded the greatest result for the land use criteria, 3.520. Furthermore, route B also obtained the maximum rating of 2.260 for the social condition's criterion. The quality of road geometry and performance is influenced by routes that provide connected access to strategic ports, such as the route from Sumatra (Palembang) through Tanjung Api-Api Port to Bangka Island via Tanjung Kalian Port (Mentok). In this case, the route offers better road geometry and a higher road service level than other routes.

The advantages of Route 2 include its direct access from Muntok Port to Pangkalpinang, the economic hub of Bangka Island, which facilitates faster food distribution, reduces logistics costs, and generates positive social impacts for communities along the route. Recommendations for future research include optimizing infrastructure, integrating advanced monitoring technologies, and evaluating economic and environmental impacts to enhance sustainability.

Table 9 Calculation of food supply chain sub-criteria for each route

Description	Sub Criteria															
EIGEN VECTOR	**A1**	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**C1**	**C2**	**C3**	**C4**	**D1**	**D2**
	0.359	**0.251**	**0.188**	**0.132**	**0.070**	**0.345**	**0.226**	**0.178**	**0.182**	**0.070**	**0.366**	**0.257**	**0.207**	**0.171**	**0.403**	**0.597**
Route 1	0.479	0.371	0.308	0.252	0.190	0.465	0.346	0.298	0.302	0.190	0.486	0.377	0.327	0.291	0.523	0.717
Route 2	0.989	0.881	0.818	0.762	0.700	0.975	0.856	0.808	0.812	0.700	0.996	0.887	0.837	0.801	1.033	1.227
Route 3	0.419	0.311	0.248	0.192	0.130	0.405	0.286	0.238	0.242	0.130	0.426	0.317	0.267	0.231	0.463	0.657
Route 4	0.509	0.401	0.338	0.282	0.220	0.495	0.376	0.328	0.332	0.220	0.516	0.407	0.357	0.321	0.553	0.747
Route 5	0.399	0.291	0.228	0.172	0.110	0.385	0.266	0.218	0.222	0.110	0.406	0.297	0.247	0.211	0.443	0.637

A - Road Geometry (A1, A2, A3, A4, A5); B - Road Performance (B1, B2, B3, B4, B5); C - Land Use (C1, C2, C3, C4); D - Social Conditions (D1, D2)

Table 10 Final calculation of the best route hinterland for the food supply chain

Code Route	Alternative Route	∑A Road Geometry	∑B Road Performance	∑C Land Use	∑D Social Conditions	Level of Significant
1	Muntok – Puding Besar – Pemali - Sungailiat	1.600	1.600	1.480	1.240	1.480
2	Muntok – Puding Besar – Petaling - Pangkalpinang	4.150	4.150	3.520	2.260	3.520
3	Belinyu – Riau Silip – Sungailiat - Pangkalpinang	1.300	1.300	1.240	1.120	1.240
4	Pangkalbalam – Pangkalpinang – Merawang - Sungailiat	1.750	1.750	1.600	1.300	1.600
5	Sadai - Toboali – Koba – Pangkalpinang	1.200	1.200	1.160	1.080	1.160

5.Discussion

Policies for regulating hinterland connection management to strengthen food supply chains, which consider only transportation facilities, road infrastructure, and ports, are insufficient. The novelty of this study lies in determining the optimal route of food supply chain from several hinterland connection options for strengthening the food supply chain on Bangka Island, based on various criteria, including road geometry, road performance, land use, and social conditions. This novelty is achieved by using the AHP to identify the best route for strengthening the food supply chain in Bangka Island. Therefore, in the hinterland connection policy to support the food supply chain, aspects such as road geometry, road performance, land use, and social conditions are essential.

The recommendation for further research is to explore the development of hinterland routes for food supply chains using information systems to control and monitor the movement of food supply chains entering and leaving Bangka Island. Ensuring the accuracy of the selected criteria, aligned with the study's objectives, is a critical aspect of this research. Future studies will aim to address these limitations.

Limitations

The limitations and potential future directions related to the AHP model for hinterland connections aimed at strengthening the food supply chain in Bangka Island, Indonesia, are as follows:

1. The AHP method heavily relies on respondents' opinions in providing pairwise comparison judgments. This can lead to subjective bias as it depends on human judgment, perception, and interpretation
2. The research findings are focused on the specific context of Bangka Island, making their application potentially less relevant to other regions with different geographical, social, or economic characteristics.
3. AHP is less effective in managing a large number of criteria or elements, as an increase in elements results in higher complexity and a greater risk of inconsistency.

Recognizing and selecting the appropriate criteria is essential; therefore, the selection and weighting of criteria and sub-criteria must be approached with precision. Defining and identifying relevant criteria, assigning accurate weights, and justifying the weight selection for each stakeholder can pose challenges. Additionally, data availability and quality are critical, as incomplete or poor-quality data can affect the reliability of AHP results in evaluating hinterland connections for the food supply chain. A complete list of abbreviations is listed in *Appendix I.*

6.Conclusion and future work

Road geometry and road performance are critical criteria for evaluating inland connectivity in the food supply chain on Bangka Island. Both criteria, road geometry and road performance, scored 4.150, reflecting their "very important" significance in the food supply chain. Other notable criteria include land use, with a score of 3.520, considered "important," and social conditions, with a score of 2.260, indicating a "moderately important" level of significance.

Based on the evaluation, the optimal route for the food supply chain is Route 2: Palembang-Mentok-Puding Besar-Petaling-Pangkalpinang, which accounts for 37.2% of the total significance. This route strategically connects Sumatra (Palembang) through Tanjung Api-Api Port to Bangka Island via Tanjung Kalian Port (Mentok), supporting the fact that a significant portion of food sold on Bangka Island originates from Sumatra.

Effective hinterland connectivity and reliable information flow within the food supply chain are crucial for reducing logistics and commodity prices, particularly food, as Bangka Island heavily depends on supplies from external regions. Enhancing these connections, particularly through road geometry, road performance, land use, and social conditions, is essential for achieving an efficient food supply chain and, ultimately, improving the economic well-being of the people on Bangka Island.

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Conflicts of interest

The authors have no conflicts of interest to declare.

Data availability

The study utilized both primary and secondary data. Primary data were collected through observation and direct interviews with respondents, while secondary data were obtained from KSOP, traders, experts, and the Department of Industry and Trade. These data are available upon reasonable request from the corresponding author.

Author's contribution statement

Ormuz Firdaus: Conceptualization, investigation, data collection, result interpretation, writing – original draft. **Erika Buchari**: Conceptualization, writing-review, and supervision. **Melawaty Agustien**: Conceptualization, supervision, review, and editing.

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Appendix I

S. No.	Abbreviation	Description
1	AHP	Analytic Hierarchy Process
2	ASEAN	Association of Southeast Asian Nations
3	BPS	Central Bureau of Statistics
4	BWM	Best-Worst Method
5	CI	Consistency Index
6	CR	Consistency Ratio
7	EIA	Environmental Impact Assessment
8	KSOP	Harbormaster and Port Authority Office
9	MCA	Multi Criteria Analysis
10	RI	Random Index