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RESEARCH ARTICLE

Analysis of Factors Influencing the Selection of Road Transportation Routes for Agricultural Fruit Exports from Thailand to China- A Policy Perspective

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ABSTRACT

This study investigates the factors influencing the selection of transportation routes for agricultural products, specifically fruits, from Thailand to China, utilizing multiple regression analysis. Data was gathered through a comprehensive literature review on agricultural transportation route selection and empirical data from actual transportation routes. A systematic analytical framework was developed to identify and evaluate key influencing factors. The multiple regression analysis identified nine critical factors affecting route selection. The model demonstrated strong explanatory power, with an R^2 value of 0.77319, indicating a high capacity to explain the variance in route selection. Among these, eight factors significantly impacted decision-making: transportation time, cost, distance, road conditions, road surface quality/type, infrastructure/road width, route characteristics, and available facilities. The study provides a detailed understanding of the determinants shaping agricultural transportation route selection and offers strategic insights for enhancing transportation system efficiency. It emphasizes the most influential factors, guiding the development of strategies to optimize route selection and improve overall logistics performance.

INTRODUCTION

Thailand's economic situation is currently facing a crisis, requiring businesses to adapt to ongoing changes. At the same time, increasing competition has made logistics a crucial process that enables companies to operate efficiently. For example, transportation activities must be carried out within a specified timeframe, ensuring the correct quantity of goods while delivering them to customers in optimal condition. The scope of transportation and distribution is not limited to a specific area. Selecting appropriate transportation routes and minimizing the risk of accidents during transit are also essential. Choosing the correct path is a strategic approach to enhancing logistics efficiency and reducing transportation costs.

Road transportation is essential for moving goods and business services due to its convenience, stability, and easy market access. It also provides flexibility in adjusting transportation plans based on demand. Furthermore, road transportation is crucial for promoting economic growth and business expansion in both the public and private sectors. Additionally, it plays a significant role in Thailand's export industry, serving as a vital component of international trade. In 2023, the total volume of freight transportation was 547,082 thousand tons, reflecting a 5.54% decline from 2022. This decrease coincides with a 1.3% drop in international trade value and a slowdown in industrial production. The Industrial Production Index (IPI) fell from 101.9 in 2022 to 98.5 in 2023. However, by the end of 2023 and into the first half of 2024, the volume and value of imports and exports are expected to improve. In October 2023, the total export value at the Chiang Khong Customs House was 1,820.86 million baht, showing a decrease of 2,779.93 million baht compared to September 2023, when the export value was 4,600.79 million baht. (Office of the National Economic and Social Development Council (NESDC), 2567) This underscores a significant decline in export volume. The top ten exported goods at the Chiang Khong Customs House in October 2023 included fresh fruit weighing 17,776,287.04 kilograms, with a value of 1,217,340,004.59 baht. The primary export destinations for these fresh fruits were China and the Lao People's Democratic Republic (Lao PDR). (Chiang Khong Customs House, 2566)

Relevant research on fresh fruit supply and route selection includes the following: Panichakarn and Pochan (2023) identified Route R9 as the most efficient for international trade between Thailand and China, with the lowest transport cost (3.39 USD/km) and highest average speed (44.52 km/h). Border process costs for Routes R9, R8, and R12 accounted for approximately 40% of total costs, while border process times constituted 16–25% of total transit time. Pan et al. (2024) proposed a redesigned fresh fruit logistics network in Guangxi, China, considering economic, logistics, and industry development. An index system assessed cities' logistics capabilities, with hub and spoke cities identified through cluster analysis, refined using the gravitational model and logistics affiliation degree. Additionally, Pan et al. (2023) applied the Boston Matrix model to analyze market competition in 14 Guangxi cities. Liuzhou, Yulin, Wuzhou, Fangchenggang, and Baise were categorized as 'Dog' markets; Guigang, Baise, Hezhou, Hechi, Laibin, and Chongzuo as 'Child' markets; Nanning and Guilin as 'Star' markets; and Qinzhou as a 'Cash Cow' market.

Selecting transportation routes for agricultural products impacts efficiency, cost-effectiveness, and product quality. Insufficient or poor-quality roads in certain areas, such as rural regions, can cause transportation delays and increase the risk of product damage. Truck drivers often need to modify their routes to prevent potential harm to goods, which can affect road conditions and heighten the risk of accidents due to the shared use of roads by trucks and private vehicles. Additionally, there are various route options available for transportation selection.

To tackle the issue of route selection, this study employs multiple regression techniques, which have proven effective in factor analysis research. It examines both domestic and international studies to identify relevant factors influencing the selection of agricultural transportation routes. The research takes a comprehensive view of factors based on a five-part decision support process, which includes (1) transportation cost-related factors, (2) time and speed-related factors, (3) distance-related factors, (4) factors pertaining to route quality and infrastructure, and (5) factors concerning available facilities.

2. RESEARCH METHODOLOGY

This study utilizes multiple regression techniques to analyze the factors influencing the selection of transportation routes for agricultural products, specifically fruits, from Thailand to China. The research process comprises four stages: (1) examining factors related to agricultural product transportation, (2) analyzing factors and collecting relevant data, (3) conducting analysis and calculations using multiple regression techniques, and (4) evaluating and summarizing the significance of the factors used in selecting agricultural transportation routes.

2.1 Step 1: Examining Factors Related to Agricultural Product Transportation

This research focuses on studying the factors influencing the selection of agricultural product transportation routes. A total of 50 international and domestic literature articles were reviewed in the context of the areas in Thailand. The literature review identifies key factors that play a significant role in route selection for agricultural transportation. The relationships and interconnections among the studied data are illustrated in Figure 1. The reviewed articles highlight critical factors involved in transportation route selection and reflect how others referenced and built upon each work.

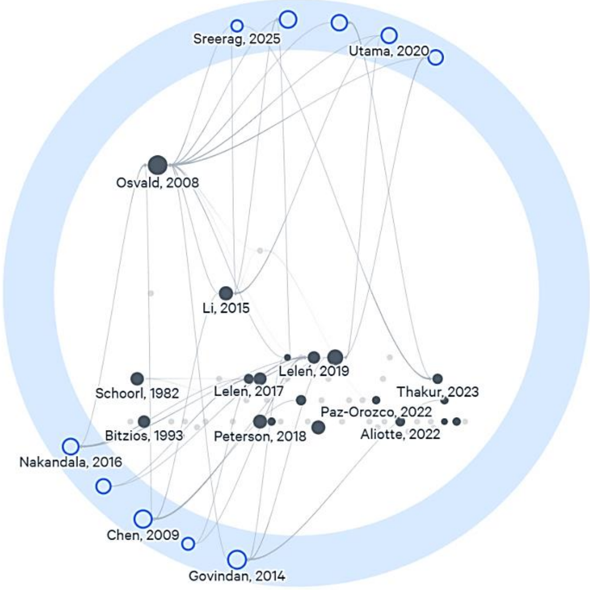

Figure 1 illustrates the relationships and linkages among the information presented in the literature.

Literature identifies the key factors influencing agricultural transportation route selection. As shown in Figure 2, these relationships are presented in a hub-and-spoke structure, with the central node representing route selection for agricultural goods—highlighting it as the primary issue influenced by multiple surrounding factors. The factors can be categorized into five major groups for system-based analysis as follows: Cost and Economic Factors – These affect product competitiveness and logistics management costs. Product Quality and Storage Factors—These are critical for perishable goods such as vegetables, fruits, and fresh agricultural products. Infrastructure and Route Factors influence transportation speed, safety, and fuel efficiency. Environmental and Social Factors – These reflect sustainability considerations and the impacts on agricultural areas and local communities. System and Personnel Factors – These support practical management and route planning.

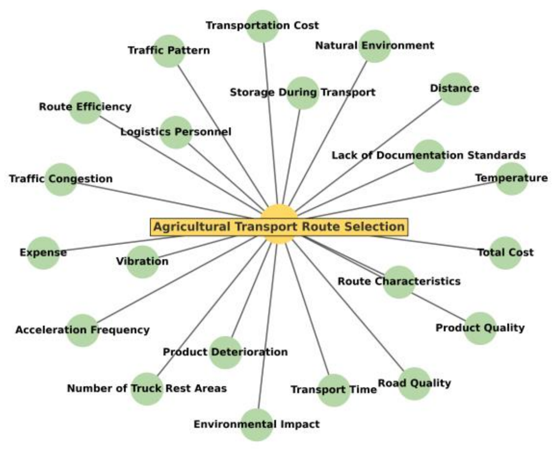

Figure 2 illustrates the various factors influencing the selection of agricultural transportation routes.

A hub-and-spoke network visualization was employed based on the analysis and synthesis of previous research on factors influencing the selection of agricultural transportation routes. This approach enabled the identification of key factors out of a total of 35 studied variables, narrowing them down to 9 critical factors. Among these, transportation time emerged as the most frequently cited factor in literature, highlighting its importance in ensuring rapid delivery and minimizing the risk of product spoilage. Following this, cost and Distance remain central factors in the decision-making process. Infrastructure-related factors also play a significant role in ensuring safety and transportation efficiency. Other factors, while considered less critical, still reflect concerns regarding transportation quality and the availability of support facilities along the route, as illustrated in Figure 3.

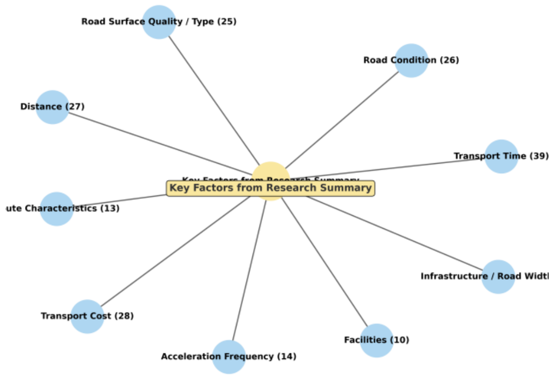

Figure 3 illustrates the key factors influencing the selection of transportation routes for agricultural products.

The study of transportation route selection concepts reveals that several critical factors must be considered when selecting routes for freight trucks to ensure efficiency and cost reduction. Travel distance and time are fundamental; choosing the shortest or fastest route can help reduce fuel consumption and enhance transportation performance. Road conditions and traffic are also essential considerations, as poor road surfaces and traffic congestion can negatively impact speed and safety. Avoiding heavily congested areas or deteriorated roads can help minimize delays and risks. Transportation cost is another key factor, encompassing expenses such as fuel, tolls, and vehicle maintenance, all of which influence the cost-effectiveness of a given route. Safety is also vital selecting routes with lower accidents or cargo theft risks can enhance overall reliability. Flexibility and accessibility contribute to smoother logistics operations, allowing easier access to multiple destinations and better responsiveness to customer demands. Additionally, regulatory compliance, such as vehicle weight limits or restricted access zones during certain times, must be considered when choosing appropriate routes. The causal relationships among these influencing factors can be effectively visualized using a Network Diagram (Directed Graph), as illustrated in Figure 4.

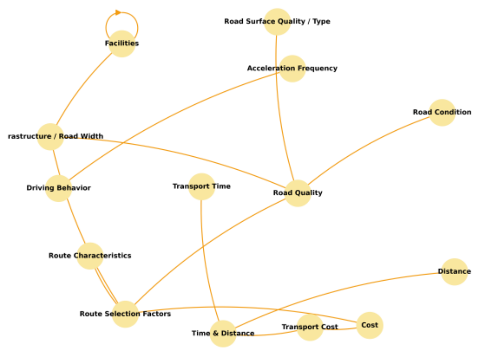

Figure 4 presents the cause-and-effect relationships between the key factors affecting transportation route selection.

The study's selection and classification of relevant factors were derived from an overview of the key considerations in agricultural transportation route selection. These factors were grouped into five main categories: Factors related to transportation cost, Factors related to time and speed (e.g., acceleration capacity of trucks, transportation time), Factors Related to Distance, Factors related to the quality and infrastructure of the route (e.g., number of traffic lanes, road width, road surface conditions, and road design) and Factors related to supporting facilities (e.g., rest areas, fuel stations, accommodations, restaurants or convenience stores, and vehicle maintenance service points). These classifications are summarized in Table 1.

Table 1. Factors Used in Agricultural Transportation Route Selection Derived from the Literature Review

No.	Research review	Transportation cost	transportation distance	transportation time and speed	route quality and infrastructure	available facilities
1	Bigaran Aliotte & Ramos de Oliveira, 2022		/	/	/	/
2	Peterson et al., 2018	/		/		
3	Bitzios & Ferreira, 1993		/	/	/	
4	Leleń & Wasiak, 2018	/			/	
5	Igilar, 2023				/	/
6	Osvald & Stirn, 2008	/		/	/	
7	Schoorl & Holt, 1982				/	/
8	Thakur et al., 2023	/		/	/	
9	Antonio-González et al., 2012	/	/		/	/
10	Jun & Wei, 2010	/		/	/	/
11	Li et al., 2015	/	/			
12	Paz-Orozco et al., 2022	/	/		/	/
13	Mu et al., 2023	/	/	/		/
14	Tirkolaee et al., 2020	/		/	/	
15	Rahul et al. 2022		/	/	/	
16	Fulzele et al., 2019	/		/		/
17	Singh et al., 2024	/	/		/	
18	Mushtaq et al., 2018	/		/		
19	Negi & Wood, 2019			/	/	/
20	Negi & Trivedi, 2021		/		/	/
21	Lü et al., 2010			/	/	/
22	Sarjono, 2014	/	/	/		
23	Orjuela-Castro et al., 2019	/	/	/	/	
24	Yin et al., 2012	/	/	/	/	
25	Moreno-Quintero, 2016			/	/	
26	Pamučar & Ćirović, 2018	/	/	/	/	/
27	Soleimani & Ahmadi, 2015			/	/	/
28	Karimi et al., 2019			/		/
29	Jarimopas et al., 2005		/		/	/
30	Al-Dairi et al., 2022			/	/	
31	Nasution et al., 2022			/	/	
32	Issa et al., 2021	/	/	/	/	
33	Zheng et al., 2022			/	/	/
34	Ren, 2022		/		/	/
35	Fernando et al., 2018	/	/	/	/	
36	Pretorius, 2016			/	/	
37	Taki, 2023			/	/	
38	Goodwin & Khachaturov, 1983	/	/	/		
39	Padilla et al., 2018	/	/	/	/	
40	Kim et al., 2008		/		/	
41	Preeyaphon, 2020		/	/	/	
42	Sasitorn, 2016	/			/	/
43	Warapoj & Somchai, 2011	/	/	/	/	
44	Namfon & Pattarnid, 2020	/	/	/	/	
45	Suwannee, 2017		/	/		
46	Nitidetch, 2017		/	/	/	
47	Panjaporn, 2021	/		/	/	/
48	Patcharida & Klairung, 2015	/		/		/
49	Tidatip & Piyamas, 2024	/	/	/	/	/
50	Thitima et al., 2018	/	/	/		

2.2 Step :2 Factor Analysis and Data Collection from Factors

The literature review identified the key factors that influence the selection of agricultural transportation routes. The researcher analyzed these factors by grouping those with similar meanings, excluding irrelevant elements, and focusing on factors that affect the study area in Thailand. Consequently, nine factors were identified, as summarized in Table 2.

Table 2: Factors Used in Agricultural Transportation Route Selection

No.	Factors	Description	Measurement Method
1. Factors related to transportation costs			
1.1	Transportation Cost/Expense	The total transportation expenses encompass fuel costs, driver salaries, vehicle depreciation, and maintenance expenses.	Measured by the cost per unit of distance traveled.
2. Factors related to time and speed			
2.1	Transportation Time	The overall time needed to travel from the starting point to the destination.	Measured in terms of journey duration.
2.2	Acceleration Frequency	The duration a truck can keep its speed on the transportation route.	Measured in average speed (km/h).
3. Factors related to distance			
3.1	Distance	The total distance from the starting point to the destination.	Measured by the distance traveled.
4. Factors related to route quality and infrastructure			
4.1	Road Condition/Road Surface	The width of the road on the transportation route.	Measured according to the road width.
4.2	Road Surface Quality	The features of the road surface on the transportation route.	Measured by the materials used in road construction.
4.3	Road Type	The characteristics of the route include flat roads, inclines, or hilly terrain.	Measured by the characteristics of the route.
4.4	Road Width	The count of traffic lanes on the transportation route.	Measured by the lane count.
5. Factors related to available facilities			
5.1	Facilities	The quantity of truck rest areas, convenience stores, restaurants, truck maintenance centers, roadside hotels, and fuel stations along the transportation route.	Evaluated by the number of facilities available along the route.

And determine the transportation routes for agricultural products. This study uses durian transportation as a case study to establish the transportation route from Chanthaburi Province (origin) to Chiang Khong Customs House in Chiang Rai Province (destination). The data collection is based on the identified factors, leading to the classification of transportation routes into four datasets, as follows:

Dataset 1 consists of transportation routes from the origin (Chanthaburi Province) to the connection point (Phitsanulok Province). There are three routes: Route 1-1 passes through 14 provinces, Route 1-2 passes through 12 provinces, and Route 1-3 passes through 10 provinces.

Dataset 2 consists of transportation routes from the connection point (Phitsanulok Province) to the destination (Chiang Khong Customs House, Chiang Rai Province). There are four routes: Route 2-1 passes through six provinces, Route 2-2 passes through six provinces, Route 2-3 passes through seven provinces, and Route 2-4 passes through five provinces.

Dataset 3 consists of routes from the origin (Chanthaburi Province) to the connection point (Tak Province). There are three routes: Route 3-1 passes through 14 provinces, Route 3-2 passes through 14 provinces, and Route 3-3 passes through 12 provinces.

Dataset 4 consists of transportation routes from the connection point (Tak Province) to the destination (Chiang Khong Customs House, Chiang Rai Province). There are three routes: Route 4-1 passes through five provinces, Route 4-2 passes through four provinces, and Route 4-3 passes through six provinces.

2.3 Step *:3* Analysis and Calculation Using Multiple Regression Technique

Based on the data collected for each studied route according to the identified factors, selecting agricultural transportation routes is a complex process influenced by multiple factors, such as transportation costs, distance, road conditions, transportation time, and other relevant factors. Therefore, Multiple Regression Analysis (MRA) is an appropriate technique for analyzing route selection factors.)Khaliqur et al., 2018) Since selecting agricultural transportation routes does not depend on a single factor, such as transportation cost alone, but also involves other relevant factors like transportation time, safety, and road quality, Multiple Regression Analysis (MRA) is suitable for simultaneously analyzing the relationships between multiple variables. This method allows for the calculation of regression coefficients, which indicate the extent to which each factor influences route selection. The multiple regression model is used to explain the relationship between the dependent Variable, Y) and independent Variables, X_1, X_2, X_3, …, X_n( )Yijun Ruan, 2024) The regression equation is formulated as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_n X_n + \in \quad (1)$$

Where: Y is the dependent variable, β_0 is the intercept (constant term), β_1, β_2,..., β_n are the regression coefficients of the independent variables, X_1, X_2, X_3, …, X_n are the independent variables or factors influencing Y and ϵ is the error term. (Maxwell, S. E., 2000)

The calculation of the intercept β_0 (Intercept) in Multiple Regression Analysis (MRA) (Stolzenberg, R. M., 2004) follows the equation:

$$\beta_0 = \bar{Y} - \beta_1 \bar{X}_1 - \beta_2 \bar{X}_2 - \cdots - \beta_n \bar{X}_n \quad (2)$$

Where: $\bar{Y}$ is the meaning of the dependent variable, $\bar{X}_1, \bar{X}_2, \ldots, \bar{X}_n$ are the means of the independent variables และ $\beta_1, \beta_2, \ldots, \beta_n$ are the regression coefficients of each independent variable obtained from the calculation.

The calculation of the constant β_n (coefficient of the independent variable X_n) in Multiple Regression Analysis (MRA) (Ngo, T. H. D., & La Puente, C. A., 2012) follows the equation:

$$\beta_n = \frac{\sum(X_n - \bar{X}_n)(Y - \bar{Y})}{\sum(X_n - \bar{X}_n)^2} \quad (3)$$

Where: X_n is the value of the n-th independent variable, Y is the value of the dependent variable, $\bar{X}_n$ is the mean of X_n และ $\bar{Y}$ is the mean of Y

2.4 Step *4:* Evaluation and Summary of the Significance of Factors Used in Agricultural Transportation Route Selection.

The selection of key factors for agricultural transportation route selection can be analyzed using the R square (R^2) or Coefficient of Determination. This measure evaluates how well the multiple regression model explains the variance of the dependent variable, with values ranging from 0 to 1 (or 0% - 100%) (D.C. Montgomery, 2012) The equation is formulated as follows:

$$R^2 = 1 - \frac{\sum(Y_i - \hat{Y})^2}{\sum(Y_i - \bar{Y})^2} \quad (4)$$

Where: R^2 = 1 means the model explains 100% of the variance in Y)perfect prediction), R^2 = 0 means the model does not explain any variance in Y.

Interpretation of R^2 values:

If R^2 is between 0.7 and 1.0, the model has high accuracy.

If R^2 is between 0.3 and 0.7, the model moderately explains the variance.

If R^2 is below 0.3, the model has low explanatory power and may require improvement. (Gujarati, D. N., & Porter, D. C., 2009)

The calculation of the Multiple Correlation Coefficient (Multiple R) measures the relationship between the dependent variable (Y) and multiple independent variables (X_1, X_2,…, X_n) (Cohen, J., 1988) The equation is formulated as follows:

$$R = \sqrt{R^2} \quad (5)$$

Where the Multiple R value ranges between 0 and 1:

If R = 1 1 indicates a perfect relationship between the dependent and independent variables.

If R = 0, it indicates no relationship between the dependent and independent variables.

If $0 < R < 1$, it indicates varying degrees of relationship, depending on the R value. (Torgerson, W. S., 1958) The interpretation of correlation values is presented in Table 3.

Table 3: **Levels of Correlation for Multiple R Values**

Multiple R	**Levels of Correlation**
0.90 - 1.00	Very Strong Correlation
0.70 - 0.89	Strong Correlation
0.50 - 0.69	Moderate Correlation
0.30 - 0.49	Low Correlation
0.10 - 0.29	Very Low Correlation
0.00 - 0.09	No Correlation

Source: Torgerson, W. S., (1958)

3. Analysis

The results from the data collection on factors influencing the selection of agricultural transportation routes in the case study allow for the classification of these factors into two categories: (1) Quantitative Factors: The dependent and independent variables are defined as follows:

Dependent variable (Y): Number of vehicles passing through the route (Mei-Yu Wu, 2022)

Independent variable (X_1): Transportation time

Independent variable (X_2): Transportation cost

Independent variable (X_3): Distance

Independent variable (X_7): Acceleration frequency

(2) Qualitative Factors: The independent variables are defined as follows:

Independent variable (X_4): Road conditions. Score 10: National highway (main road), Score 8: Regional connecting highway (secondary road), Score 6: Minor highway branching from the main road, and Score 4: Rural Road

Independent variable (X_5): Road surface quality/type. Score 10: Reinforced concrete road (R.C.), Score 9: Asphalt concrete road (A.C.), Score 8: Crushed rock compacted road (C.R.), Score 7: Compacted laterite road (L.), Score 6: Interlocking brick road (I.B.) and Score 5: Earthen Road (E.R.)

Independent variable (X_6): Infrastructure/Road Width. Score 10: 8 lanes, Score 9: 6–8 lanes, Score 8: 6 lanes, Score 7: 4–6 lanes, Score 6: 4 lanes, Score 5: 2–4 lanes and Score 4: 2 lanes

Independent variable (X_8): Route Characteristics. Score 10: Flat Road, Score 8: Steep Road, and Score 6: Mountain Road

Independent variable (X_9): Available Facilities. The score is assigned based on the presence of facilities, including Truck rest areas, Convenience stores or restaurants, Truck maintenance centers, Roadside or nearby accommodations, and Fuel or gas stations.

To ensure accuracy in data analysis, a five-year historical dataset (2023–2019) is utilized, incorporating data from transportation routes with potential travel paths from the origin to the destination. Subsequently, the data values are standardized into a single numerical dataset by categorizing them into nine levels, as presented in Table 4.

Table 4: **Example of Dependent and Independent Variable Data in One Year**

Route	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9
1-1 & 2-1	645	2.16	28,274.95	1,119.80	15.599	18.00	14.474	124.738	18.67	7.705
1-1 & 2-2	633	2.15	27,365.95	1,083.80	14.599	18.00	14.141	121.402	18.67	7.205
1-1 & 2-3	640	2.37	30,895.90	1,223.60	15.440	18.00	14.308	122.985	17.43	7.110
1-1 & 2-4	640	2.87	29,928.83	1,185.30	14.488	18.00	13.908	119.407	19.20	7.138
1-2 & 2-1	562	2.36	28,565.33	1,131.30	14.809	18.00	13.258	121.161	18.67	7.894
1-2 & 2-2	550	2.34	27,656.33	1,095.30	13.809	18.00	12.924	117.824	18.67	7.394
1-2 & 2-3	557	2.56	31,186.28	1,235.10	14.649	18.00	13.091	119.407	17.43	7.299
1-2 & 2-4	557	3.07	30,219.20	1,196.80	13.698	18.00	12.691	115.829	19.20	7.327
1-3 & 2-1	593	2.69	29,320.30	1,161.20	13.889	18.00	12.056	117.540	18.67	7.833
1-3 & 2-2	482	2.68	28,411.30	1,125.20	12.889	18.00	11.722	114.203	18.67	7.333
1-3 & 2-3	483	2.90	31,941.25	1,265.00	13.730	18.00	11.889	115.786	17.43	7.238
1-3 & 2-4	488	3.40	30,974.18	1,226.70	12.778	18.00	11.489	112.209	19.20	7.267
3-1 & 4-1	610	2.76	30,244.45	1,197.80	16.369	18.00	14.862	125.207	18.00	8.154
3-1 & 4-2	624	2.91	28,211.83	1,117.30	15.769	18.00	14.712	120.094	19.50	8.154
3-1 & 4-3	604	2.41	29,661.18	1,174.70	15.103	18.00	14.128	120.697	19.00	7.821
3-2 & 4-1	508	2.84	30,539.88	1,209.50	15.292	18.00	13.400	119.523	18.00	8.077

3-2 & 4-2	521	2.98	28,507.25	1,129.00	14.692	18.00	13.250	114.410	19.50	8.077
3-2 & 4-3	500	2.48	29,956.60	1,186.40	14.026	18.00	12.667	115.013	19.00	7.744
3-3 & 4-1	488	2.96	30,534.83	1,209.30	15.691	18.00	13.673	121.693	18.00	8.091
3-3 & 4-2	502	3.11	28,502.20	1,128.80	15.091	18.00	13.523	116.580	19.50	8.091
3-3 & 4-3	482	2.61	29,951.55	1,186.20	14.424	18.00	12.939	117.183	19.00	7.758

After transforming the data values, the next step is to calculate the R square)$\boldsymbol{R^2}$(value and the Multiple Correlation Coefficient (Multiple R). The calculation considers all nine identified factors by starting with a single factor (one variable) and gradually adding one factor at a time until all nine factors are included. This approach helps analyze the trend and impact of increasing factors on the model. The equation used for this calculation is as follows:

$$\boldsymbol{Y = \beta_0 + \beta_1 X_1} + \in \quad (6)$$

$$\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2} + \in \quad (7)$$

$$\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3} + \in \quad (8)$$

$$\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4} + \in \quad (9)$$

$$\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5} + \in \quad (10)$$

$$\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6} + \in \quad (11)$$

$$\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7} + \in \quad (12)$$

$$\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8} + \in \quad (13)$$

$$\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9} + \in \quad (14)$$

Based on the specified equation, the multiple regression model can be presented by gradually adding independent variables)X1 - X9) and comparing them with the dependent variable. This process results in the creation of 512 equations, derived from comparing all factors. The summary of these comparisons is shown in Table 5.

Table 5: **Calculation Results of R Square for All** 9 **Factors**

1 **Factors**		4 **Factors**		7 **Factors**	
X6	0.31213	X2, X4, X5, X6	0.66756	X2, X3, X4, X5, X6, X8, X9	0.72356
X4	0.14870	X1, X4, X6, X9	0.42286	X1, X2, X3, X4, X6, X7, X8	0.69405
X7	0.05373	X2, X4, X5, X7	0.33486	X2, X3, X5, X6, X7, X8, X9	0.65154
X5	0.03600	X2, X6, X7, X8	0.21956	X1, X4, X5, X6, X7, X8, X9	0.57876
X9	0.00102	X5, X7, X8, X9	0.06818	X1, X3, X4, X5, X7, X8, X9	0.26839
2 Factors		5 Factors		8 Factors	
X2, X6	0.52745	X2, X4, X6, X8, X9	0.71484	X1, X2, X3, X4, X5, X6, X8, X9	0.77319
X1, X4	0.20753	X1, X2, X5, X6, X9	0.57536	X2, X3, X4, X5, X6, X7, X8, X9	0.76486
X4, X9	0.17700	X1, X4, X5, X6, X8	0.42152	X1, X2, X3, X4, X5, X6, X7, X9	0.72692

X1, X9	0.11420	X3, X5, X6, X7, X9	0.33213	X1, X2, X3, X5, X6, X7, X8, X9	0.68792
X8, X9	0.00297	X3, X5, X7, X8, X9	0.10793	X1, X2, X3, X4, X5, X7, X8, X9	0.61564
3 Factors		6 Factors		9 Factors	
X2, X4, X6	0.65096	X2, X4, X5, X6, X8, X9	0.72238	X1, X2, X3, X4, X5, X6, X7, X8, X9	0.71986
X1, X2, X5	0.34518	X1, X2, X3, X6, X7, X9	0.64842		
X2, X3, X9	0.30847	X1, X2, X3, X4, X7, X9	0.57172		
X4, X7, X9	0.17712	X1, X4, X5, X6, X7, X8	0.43427		
X7, X8, X9	0.03176	X1, X3, X5, X7, X8, X9	0.14530		

Table 5 presents the results of R Square calculations derived from analyzing nine key factors. This is an example of the computational results comparing the relationships among all combinations from Factor 1 through Factor 9, resulting in a total of 512 R Square values. Subsequently, key statistical measures including Multiple R, R Square, Adjusted R Square, and Standard Error—were analyzed to identify the most influential factors in agricultural transportation route selection based on the highest R Square values obtained.

4. RESULTS

Through the application of the Simple Additive Weighting (SAW) method in calculating R Square values, the explanatory capability of the model can be interpreted as follows:

(1) Multiple R consistently increases from 0.03193 (when only X9 is included) to 0.87931 (when X1–X6 and X8–X9 are used). This indicates that adding independent variables enhances the relationship between the model and the dependent variable. However, Multiple R slightly decreases to 0.84844 when X9 is included in the model, suggesting that X9 may not improve model accuracy or could be correlated with other existing variables.

(2) R Square increases from 0.00102 (0.102%) to 0.77319 (77.319%), demonstrating a significant improvement in the model's explanatory power as more independent variables are added.

(3) Adjusted R Square rises as more independent variables are incorporated but drops when X7 is included. The highest value occurs when X1, X2, X3, X4, X5, X6, X8, and X9 are used, with Adjusted R Square reaching 0.75429. This suggests that the model achieves its highest accuracy when incorporating eight independent factors. However, when the independent variable X7 is included, Adjusted R Square decreases to 0.69332, indicating that X7 may not be beneficial to the model or could be an insignificant variable.

(4) Standard Error gradually decreases from 74.40601 to 36.72331, suggesting that the model provides more accurate predictions as more independent variables are included. However, when X7 is added, the error increases from 36.72331 to 41.02705, implying that X7 may not positively contribute to the model and instead adds complexity to the prediction process.

These findings are illustrated in Table 6, which presents an example of the computational results derived from the analyzed factors.

Table 6: Calculation Results of Statistical Analysis

Factors	Regression (df)	Multiple R	R Square	Adjusted R Square	Standard Error
X6	1	0.55868	0.31213	0.30545	61.74226
X4		0.38561	0.14869	0.14043	68.68645
X7		0.23180	0.05373	0.04454	72.41636
X5		0.18972	0.03599	0.02663	73.09181
X9		0.03193	0.00102	-0.00867	74.40601

Factors	Regression (df)	Multiple R	R Square	Adjusted R Square	Standard Error
X2, X6	2	0.72625	0.52745	0.51818	51.42457
X1, X4		0.45555	0.20752	0.19198	66.59480
X4, X9		0.42071	0.17700	0.16086	67.86513
X1, X9		0.33793	0.11419	0.09682	70.40712
X8, X9		0.05449	0.00297	-0.01658	74.69685
X2, X4, X6	3	0.80682	0.65096	0.64059	44.41429
X1, X2, X5		0.58752	0.34518	0.32573	60.83421
X2, X3, X9		0.55540	0.30846	0.28792	62.51627
X4, X7, X9		0.42085	0.17712	0.15267	68.19544
X7, X8, X9		0.17820	0.03176	0.00299	73.97403
X2, X4, X5, X6	4	0.81704	0.66756	0.65425	43.56196
X1, X4, X6, X9		0.65027	0.42286	0.39977	57.39685
X2, X4, X5, X7		0.57866	0.33485	0.30825	61.61777
X2, X6, X7, X8		0.46857	0.21956	0.18834	66.74472
X5, X7, X8, X9		0.26111	0.06818	0.03091	72.93120
X2, X4, X6, X8, X9	5	0.84548	0.71484	0.70044	40.54827
X1, X2, X5, X6, X9		0.75533	0.57053	0.54884	49.76180
X1, X4, X5, X6, X8		0.64924	0.42152	0.39230	57.75288
X3, X5, X6, X7, X9		0.57630	0.33213	0.29840	62.05484
X3, X5, X7, X8, X9		0.32852	0.10793	0.06287	71.71835
X2, X4, X5, X6, X8, X9	6	0.84993	0.72238	0.70538	40.21208
X1, X2, X3, X6, X7, X9		0.80524	0.64842	0.62689	45.25275
X1, X2, X3, X4, X7, X9		0.73486	0.54002	0.51186	51.76095
X1, X4, X5, X6, X7, X8		0.65899	0.43426	0.39963	57.40373
X1, X3, X5, X7, X8, X9		0.38117	0.14530	0.09296	70.55749
X2, X3, X4, X5, X6, X8, X9	7	0.85062	0.72356	0.70361	40.33299
X1, X2, X3, X4, X6, X7, X8		0.83309	0.69404	0.67197	42.43148
X2, X3, X5, X6, X7, X8, X9		0.80718	0.65154	0.62639	45.28329
X1, X4, X5, X6, X7, X8, X9		0.76076	0.57875	0.54835	49.78835
X1, X3, X4, X5, X7, X8, X9		0.51806	0.26839	0.21559	65.61474
X1, X2, X3, X4, X5, X6, X8, X9	8	0.87931	0.77319	0.75429	36.72331
X2, X3, X4, X5, X6, X7, X8, X9		0.87456	0.76486	0.74526	37.39148
X1, X2, X3, X4, X5, X6, X7, X9		0.85259	0.72691	0.70416	40.29571
X1, X2, X3, X5, X6, X7, X8, X9		0.82941	0.68792	0.66191	43.07684
X1, X2, X3, X4, X5, X7, X8, X9		0.78462	0.61564	0.58361	47.80578
X1, X2, X3, X4, X5, X6, X7, X8, X9	9	0.84844	0.71986	0.69332	41.02705

When considering the R Square values from the analysis, the study presents the results by incrementally incorporating variables—from a single factor up to all nine factors—into the calculation. The findings reveal that the highest R Square value obtained is 0.77319, which occurs when eight factors are included in the model. Therefore, it can be concluded that the key factors influencing the selection of agricultural transportation routes are as follows: (X1) transportation time, (X2) transportation cost, (X3) Distance, (X4) road conditions, (X5) road surface quality/type, (X6) infrastructure/road width, (X8) route characteristics, and (X9) supporting facilities. These findings are illustrated in Figures 5 through 7.

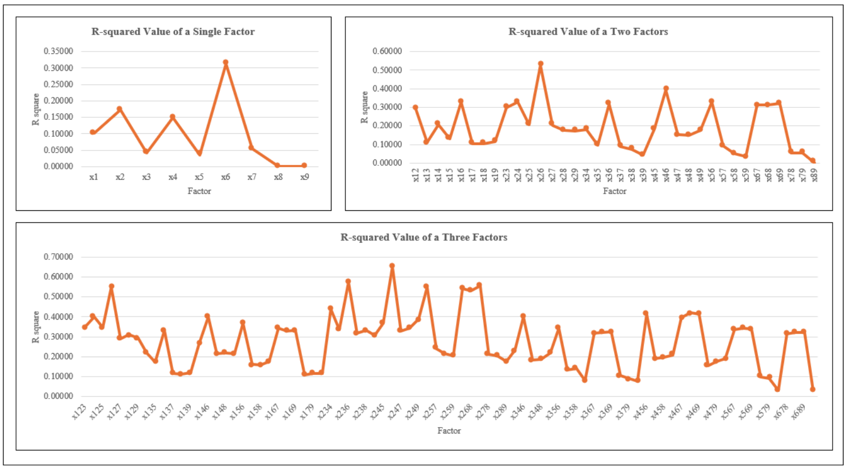

Figure 5 presents the R Square calculation results based on the inclusion of 1 to 3 factors.

Figure 6 presents the R Square calculation results based on the inclusion of 4 to 5 factors.

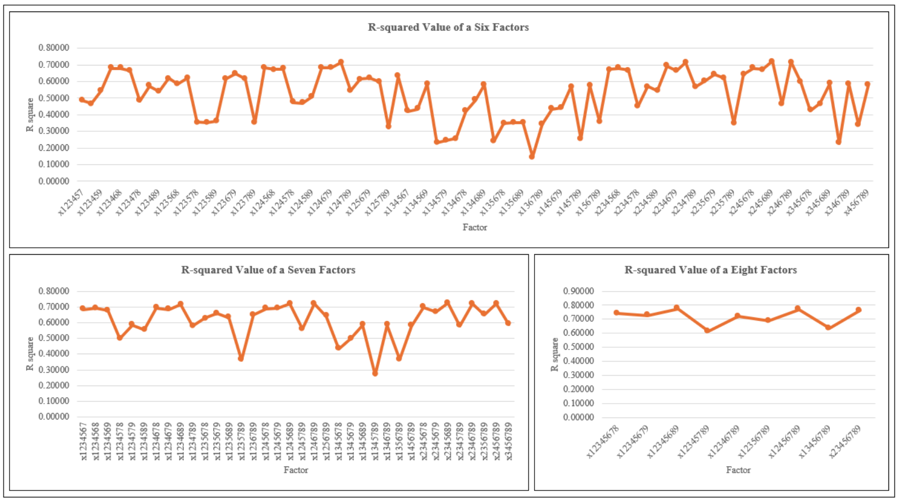

Figure 7 presents the R Square calculation results based on the inclusion of 6 to 8 factors.

5. CONCLUSION

This study applied multiple regression techniques to identify factors influencing agricultural transportation route selection, focusing on routes used for distributing agricultural products from Thailand to China. Data was collected on elements affecting route selection and actual transportation routes. Nine key factors were initially assessed: (1) transportation time, (2) transportation cost, (3) distance, (4) road conditions, (5) road surface quality/type, (6) infrastructure/road width, (7) acceleration frequency, (8) route characteristics, and (9) available facilities. The relationship between the dependent variable (route selection) and independent variables was analyzed using the R Square (R^2) statistic, which measures the model's explanatory power, ranging from 0 to 1. The highest R^2 value obtained was 0.77319, identifying eight significant factors: transportation time (X1), transportation cost (X2), distance (X3), road conditions (X4), road surface quality/type (X5), infrastructure/road width (X6), route characteristics (X8), and available facilities (X9). The second highest R^2 value, 0.76686, included transportation time (X1), transportation cost (X2), road conditions (X4), road surface quality/type (X5), infrastructure/road width (X6), acceleration frequency (X7), route characteristics (X8), and available facilities (X9). The third highest R^2 value, 0.76486, encompassed transportation cost (X2), distance (X3), road conditions (X4), road surface quality/type (X5), infrastructure/road width (X6), acceleration frequency (X7), route characteristics (X8), and available facilities (X9). These findings provide critical insights into the factors shaping transportation route selection for agricultural products and offer strategies for improving logistics and transportation efficiency. The results align with Cordero et al. (2023), who emphasized the significant influence of infrastructure and distance on transportation planning for fruit distribution. Their research also highlighted the value of mathematical modeling in calculating transportation costs and optimizing route selection to minimize travel distance, thereby enhancing efficiency and reducing overall costs.

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Data availability

The data presented in this article is openly accessible and obtained from drae.io, Litmap, the following official sources: the Truck Transport Data Center, Department of Freight Transport, Department of Land Transport; the Information and Communication Technology Center, Office of the Permanent Secretary, Ministry of Transport; the Office of Transport and Traffic Policy and Planning (OTP); and the Department of Highways, Thailand.

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