

# MODE CHOICE MODELS FOR AGRICULTURAL PRODUCTS BY FREIGHT RAIL TRANSPORT IN THE NORTHEAST OF THAILAND

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## Abstract

This research aimed to develop a mathematical model for predicting the mode choice behavior of the manufacturers of processed agricultural products including rice, starch, and sugar. Their decisions must be made between road and rail transport applying the stated preference technique. Self-administered questionnaires were distributed and responses were obtained from 58 transport managers or executives throughout a 3-month period. The data were taken to develop a binary logit model of freight transportation. The variables used for the analysis were punctuality, reliability, freight payment, transport time, and distance from factories to railway stations. It was found that the factors affecting the mode choice decisions were punctuality and distance. Under a given circumstance where a rail station was less than 10 km away and rail delivery could guarantee the goods would arrive no later than 2 h behind the schedule, rail freight transport could receive up to 38% of the market share. The State Railway of Thailand and relevant agencies could use this model to prioritize the improvement of the service elements that would most satisfy the customers' needs.

**Keywords:** Binary logit model, stated preference, freight rail transport, mode choice behavior, Thailand

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## Introduction

At present, effectiveness of business competition is achieved through logistics cost reduction. One of the important components of the logistics costs is transportation. In 2006, Thailand had a proportion of transportation costs at 17.8% of the national gross domestic product (GDP).

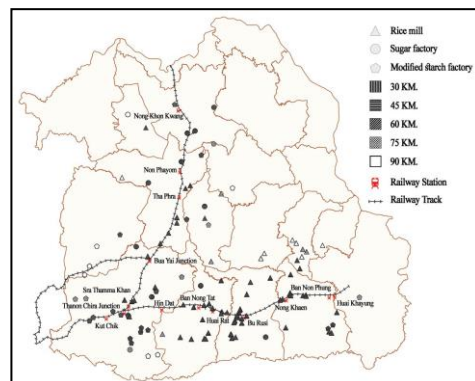
From the Tenth National Economic and Social Development Plan (Office of The National Economic and Social Development Board, 2012), for economic structural adjustment focusing on balance and sustainability, the government determined the strategies for a fuel consumption reduction by freight rail transport and the waterways system. In addition, the agricultural development plan in the Eleventh National Economic and Social Development Plan (Office of The National Economic and Social Development Board, 2016) has placed the scope connected to logistics administrative management, multimodal transport, and freight rail transportation by determining the target of a logistics cost reduction to below 15% of the gross domestic product and increasing the freight rail transport proportion by 5%. At present, a variety of freight rail transport projects are making concrete progress such as a double track project throughout the country, a project studying the suitability of high-speed trains, as well as the project to purchase locomotives, passenger carriages, and freight wagons by auction.

However, these different projects are mainly related to the fundamental infrastructure development. Meanwhile, operational concepts contribute to the comprehension of freight transport's specific characteristics and the entrepreneurs' demand for a quality rail system providing more transportation benefits and advantages than other systems including road and air transportation. This provides the motivation for changing from road to rail transport in the future. The main products that will earn income are agricultural and processed agricultural products which are classified as container-type products that head to Laem Chabang Harbor, Ko Si Chang Harbor, or Bangkok Harbor and wait to be loaded onto ships going to different countries. Only a minor

portion of these products are domestically transported (Shen and Wang, 2012). The northeast of Thailand is the region that mainly produces these income-generating products including rice, starch, and sugar.

According to the interviews with the entrepreneurs and from the statistics of goods transportation by container from 2011 to 2015, numerous firms which had used or been interested in delivering goods by rail freight abandoned their intention and most turned to road consignment for various reasons. This caused a continuous decrease in rail freight.

Many studies have focused on the development of mode choice models. The subject products were mainly clothes, food, and electronics goods (Shinghal and Fowkes, 2002; Arunotayanun and Polak, 2011; Feo *et al.*, 2011; Samimia *et al.*, 2011; Masiero and Hensher, 2012; Moschovou and Giannopoulos, 2012; Wang *et al.*, 2013; Comi *et al.*, 2014; Šimeček and Dufek, 2016; Kiba-Janiak, 2017). This research focused on processed agricultural products which were considered advantageous for rail transportation mode. It analyzed the viewpoint and behavior choice of the executives from the agricultural processed product sector in the northeastern region. The data were analyzed to study the factors affecting freight mode choice and develop a



**Figure 1. Location of processed agricultural product manufacturers in the northeastern region of Thailand**

model to estimate the railway mode share in various circumstances. The main objective was to develop a rail transport service plan that satisfied this specific group of customers. This mode choice model could be used as a guideline for developing a freight service plan for the State Railway of Thailand. The transport mode shift from road to rail would reduce transport costs and enhance the national economic competency.

## Materials and Methods

Random utility theory is commonly applied to explain choice behavior such as for travel and transport modes. An individual will choose the alternative with the maximum utility, whether it is the cheapest, least time-consuming, or most satisfying. The researchers have applied the random utility theory to the study of the entrepreneurs' transport mode choice behavior. The utility function can be written as (Ben-Akiva and Lerman, 1985):

$$U_{in} = V_{in} + \varepsilon_{in} \quad (1)$$

where  $U_{in}$  is the utility of person  $n$  when choosing to transport with mode  $i$ ,  $V_{in}$  is the systematic component of the utility function of  $i$ , and  $\varepsilon_{in}$  is the disturbances (or random components).

The systematic or observable components ( $V_{in}$ ) can be further expressed as:

$$V_{in} = \beta_0 + \beta_1 X_{in1} + \beta_2 X_{in2} + \dots + \beta_n X_{ink} \quad (2)$$

where  $\beta_0, \beta_1, \beta_2, \dots, \beta_n$  are the parameters calibrated from the utility function, and  $X_1, X_2, \dots, X_n$  are the variables affecting the utility of transport mode  $i$  for person  $n$ .

Nonetheless, some random components, taste for instance, cannot be easily measured, and the maximum utility alternative may not be certainly determined. This fact puts mode choice in the form of probability in which alternative  $i$  is chosen by person  $n$ . Let  $C_n$  be the set of possible alternatives of each

individual and  $j_n$  is the number of available alternatives of person  $n$ . The probability is that person  $n$  will choose alternative  $i$  from the set  $C_n$ ;  $P_n(i) = \text{prob}(U_{in} \geq U_{jn}; \forall j \in C_n, i \neq j)$ ; This means the probability that person  $n$  will choose alternative  $i$  equals the probability that the use of  $i$  is more than those of all other alternatives  $j$  (Koppelman and Ben-Akiva, 1977).

The binary logit model is the model that forecasts mode share between 2 modes. The utility function is used to quantify the difference of the utility of both modes. The freight mode choice model is the model used to predict only 2 situations including the situation of mode choice between truck and rail (Ben-Akiva and Lerman, 1985; Hensher *et al.*, 2005; Koppelman and Ben-Akiva, 1977). The models can be patterned as follows:

$$U_T = \text{ASC}_1 + \beta_i X_i \quad (3)$$

$$U_R = \text{ASC}_2 + \beta_{i'} X_{i'} \quad (4)$$

where,  $U_T$  is the utility function of the freight mode choice model by truck,  $U_R$  is the utility function of the freight mode choice model by rail,  $\text{ASC}_i$  is the alternative specific constant of the alternative,  $\beta_i$  is the coefficients of the variable at order in the utility function of the freight mode choice of truck,  $\beta_{i'}$  is the coefficients of the variable in the utility function of rail, and  $X_i$  is the significant variable of the model.

The researchers have taken the data of the utility function obtained from the interviews to be adjusted and studied by choosing a suitable logit model structure. The model was one showing a simple freight mode choice in Gumbel Type I distribution (Ben-Akiva and Lerman, 1985) in the following equation:

$$P(A) = \frac{e^{-\lambda U_A}}{\sum_{m \in M} e^{-\lambda U_m}} \quad (5)$$

where,  $P(A)$  is the chance of the entrepreneurs' mode choice for freight A from alternative M,  $\lambda$  is the parameter showing the distribution, and  $U_A$  is the utility function of freight A.

The researchers established the hypothesis that the mode choices that the entrepreneurs chose were limited only to truck (T) and rail (R). Thus, the chances of the entrepreneurs' mode choices of road freight and rail freight were, respectively:

$$P_T = \frac{1}{1 + e^{-\lambda(U_R - U_T)}} \quad (6)$$

$$P_R = 1 - P_T = \frac{e^{-\lambda(U_R - U_T)}}{1 + e^{-\lambda(U_R - U_T)}} \quad (7)$$

### The Measurement of Model Reliability

The measurement of model reliability consisted of 4 procedures as follows

1. Measurement of the coefficients mark. For the first procedure of model reliability measurement, the coefficients mark was the first issue indicating whether the established model was accurate or not. If the model had the coefficients mark which was not in accordance with the determined value, the model could not be used in practice.

2. Measurement of the significance of independent variables. The determination of independent variable significance to measure the hypothesis whether the variables were significantly different from 0 could be done with the consideration of the statistical value  $t$  (t-statistics) by testing that the calculated value of each variable from the model was in the range of the critical value or not. In this research, the researchers used the 95 degree of confidence of which the critical value was in the range of -1.96 to 1.96. If the statistical  $t$  value obtained from the model was in the mentioned range, it meant that the variables taken for the analysis were not significantly different from zero.

3. Measurement of the model congruence. It was the ability measurement of the model describing the factors that affected the entrepreneurs' freight mode choice decision. The model ability was measured by the level of accuracy that it could explain the freight rail

mode choice decision by considering the  $\rho^2$  value. If it was close to 1, it meant that the model had high efficiency. The acceptable proportion should be more than 0.20 (Rujopakarn, 1999).

4. Measurement of the overall accuracy. The measurement of overall accuracy was the analysis of how accurate the prediction was by considering the percentage of accuracy. If the percentage of accuracy was high, it meant that the accuracy of the model's prediction was correspondingly high.

### Determination of Area Studied

The researchers determined that the studied areas were only for the groups of entrepreneurs in the northeast region who manufactured 3 kinds of processed agricultural products, which were cassava flour, rice, and sugar. These products had outstanding characteristics of low value-to-weight ratio and suitability for bulk consignment handling. These outstanding characteristics were the specific advantages of freight rail. The researchers have determined that the current railway network has 14 railway stations with double tracks, but did not include the new routes that were in the process of a suitability study; these were BanPhai-Nakhon Phanom, Petchaboon-Loei, and Ubon Ratchathani-Chong Mek. The container freight stations or storage yards in this study were available at present and have the potential to be developed into suitable areas for freight work.

### Target Group and Sample Size of Population

The target groups to be surveyed were the entrepreneurs who manufactured processed agricultural products. They could be divided into small, medium, and large size enterprises which used trucks as vehicles for carrying goods. Due to the clear categorization of the entrepreneurs, the researchers calculated the sample size by simple random sampling. Then, stratified random sampling was used to determine the proportional samples of the population (Yamane, 1973; Kothari, 1990).

There are 1,015 factories manufacturing processed agricultural products. To calculate the sample size, simple random sampling was used to obtain 279 samples, which was the minimum sample size for the survey. Thus, the researchers collected the data from 300 samples. After the calculation of the samples by simple random sampling, the researchers used the stratified random sampling method. This could identify that the data must be collected from 18 modified starch factories, 275 rice mills, and 7 sugar cane mills.

The researchers collected the data by mailing the questionnaires and telephoning. The sample groups which cooperated in responding to the researchers' questions were 58 factories, or 19.3% of all samples. From the amount of data, it was accepted that the size of the data was sufficient to build the model (Hensher *et al.*, 2005; Ortúzar and Willumsen, 2011). To measure an appropriate sample size, the researchers used a chi-squared test for the population proportion.

### Tool Used for Surveying

The researchers surveyed the data by using self-administered questionnaires which were divided into 3 parts. The first part was about the basic data of the entrepreneurs such as types of products and production power. The second part was about freight such as the frequency of product transportation and the quantity of products moving out from their factories; the third part was their stated preference between truck and train. The respondents would choose the most satisfying stated preference. Each respondent would be presented with various stated preference choice sets provided by a systematic random method.

### Variables Chosen to be used in the Model

The researchers took the following factors from the analysis of the revealed preference in the questionnaires. This analytical method was the approach used to measure the

entrepreneurs' satisfaction influencing freight transport modes and consisted of 5 factors which were punctuality, service reliability, payment, transport time, and the distance from railway stations to the factories. These factors were factors which could be controlled by developing the policy or the improvement of freight rail transport in various perspectives according to the freight mode choice decision. This could result in more use of double-track railways by the entrepreneurs. The researchers defined the factors used to build the model as follows:

1. Punctuality refers to the ability to transfer the products from origin to destination at the determined time. The h is the unit of punctuality.
2. Reliability refers to the certainty and regularity of a locomotive service. Its unit is a percentage.
3. Payment refers to the payment for transport which includes the expenditure of freight and that of unloading the containers. Its unit is in baht per time.
4. Transport time refers to the total time of the process of freight transport from origin to destination. Its unit is a percentage.
5. Distance refers to the shortest path from the factory to the train station. Its unit is in kilometers.

### Orthogonal Design

The researchers have determined the simulating scenarios using stated preferences. The factors taken to build scenarios were brought from the analysis of the revealed preferences in the questionnaires. The diverse scenarios were built from the different factors at different factor levels to allow the respondents to choose the most satisfying situations (Kroes and Sheldon, 1988; Louviere *et al.*, 2010). The researchers distributed the diverse factor levels into 3, 4, and 5 levels since they could explain the true relationships of the utility function (Hensher *et al.*, 2005). Furthermore, the advantages of distributing the factors into levels were that the respondents had alternative decisions in choosing the factors they needed because the

factor levels helped them simulate transportation scenarios and they could make decisions on transport mode choices. These different factors could replace the patterns of scenarios which really occurred when there was an improvement, and the diverse factor levels were differently determined as shown in Table 1.

According to the adaptation of each factor pattern, the number of the situations to be considered by the respondents increased according to the number and levels of the variables or attributes. If both the main effect and interaction effect between the variables were to be considered, a full factorial design was required (Louviere *et al.*, 2000; Hensher *et al.*, 2005) to meticulously analyze the effect of the variables. However, the alternative situations were too plentiful for each respondent to consider all possible combinations. A fractional factorial design was adopted to attain more suitable situations by decreasing alternative situations and combining them by limiting the correlation at zero in order to exactly segregate the effect of the variables. The fractional factorial design technique was used in this research to determine situations and choice sets. At the end, the design only presented 3 sets of scenarios to reduce the burden on the

respondents. Each respondent would only answer 1 of these sets which contained only 3 situations or choice sets.

## Results

The estimation of the freight mode share was derived from the binary logit mode choice model using a utility function. The common pattern of the utility function consisted of independent variables affecting the freight mode choice decision (Koppelman and Bhat, 2006; Saeed, 2013) such as punctuality, payment, and distance from the factory to the railway station or the access to service use. These variables were weighed according to the importance to the decision.

Finally, the utility function of transport modes was developed as follows:

$$U_A = 1.23 - (0.494) Punct - (0.0913) Dist \quad (8)$$

where,  $U_A$  is the utility function of freight mode choice, *Punct* is the punctuality (h), and *Dist* is the distance from the factory to the railway station (kilometer).

**Table 1. Factors and factor levels between truck and rail**

| Factors               | Levels | Truck              | Rail               |
|-----------------------|--------|--------------------|--------------------|
| Punctuality<br>(h)    | 1      | Current situations | +1                 |
|                       | 2      |                    | +2                 |
|                       | 3      |                    | +6                 |
| Reliability<br>(%)    | 1      | Current situations | 90                 |
|                       | 2      |                    | 95                 |
|                       | 3      |                    | 100                |
| Payment<br>(%)        | 1      | Current situations | Current situations |
|                       | 2      |                    | -10                |
|                       | 3      |                    | -20                |
|                       | 4      |                    | -30                |
|                       | 5      |                    | -40                |
| Transport time<br>(%) | 1      | Current situations | Current situations |
|                       | 2      |                    | +10                |
|                       | 3      |                    | +20                |
|                       | 4      |                    | +30                |
|                       | 5      |                    | +40                |
| Distance<br>(km)      | 1      | Current situations | 10                 |
|                       | 2      |                    | 20                 |
|                       | 3      |                    | 30                 |

**Table 2. Results of coefficients analysis in the model**

| Attributes                | Coefficients Value | t-ratio | p-value   |
|---------------------------|--------------------|---------|-----------|
| $\beta_0$                 | 1.223              | 7.033   | 0.000     |
| Punct                     | -0.494             | -4.974  | 0.000     |
| Dist                      | -0.0913            | -6.812  | 0.000     |
| Number of observations    |                    |         | 348       |
| Log likelihood function   |                    |         | -175.9123 |
| Restricted log likelihood |                    |         | -241.2152 |
| $\rho^2$                  |                    |         | 0.2707    |

The results of the coefficients analysis and statistical values were shown in Table 2. When measuring the model reliability by considering the coefficients mark of this model which was accurate according to the determination, it showed that this model was accurate in the coefficients mark. For the measurement of significant independent variables at the degree of confidence of 95% and the critical values in the range of -1.96 to 1.96, it was found that the statistical value t of each variable in the model was not in the mentioned range. It showed that those variables were significantly different from 0. According to the measurement of the model congruence, it was found that  $\rho^2$  of the model was equal to 0.2707.

The equation of the utility function obtained from the analysis could replace the values in the equation of utility function as follows:

$$U_T = -0.494(0) - 0.0913(0) = 0 \quad (9)$$

$$U_R = 1.23 - 0.494(2) - 0.0913(10) = -0.671 \quad (10)$$

when the values of the utility function of road and rail freight were obtained, the calculation for feasibility or the chance that the entrepreneurs would make a decision on freight rail was as follows:

$$P_R = \frac{e^{-0.671}}{e^{-0.671} + e^0} \quad (11)$$

$$P_R = 0.3802 \quad (12)$$

Thus, the feasibility or the chance that the entrepreneurs decided to choose road freight mode should be calculated from:

$$P_T = 1 - P_R = 0.6198 \quad (13)$$

## Discussion

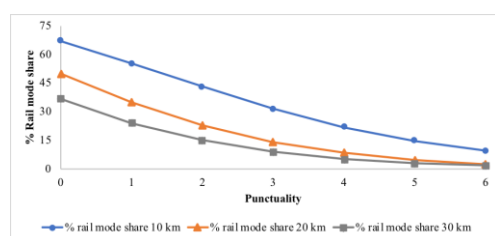
The analysis results suggested that both models were fitted to the data as they could explain the variance of response variables at 27.07%, respectively. In addition, the feasibility or the chance that the entrepreneurs would make a decision to choose freight rail transport was at 38.02%, while freight truck transport was at 61.98% in the case that the train reached a destination 2 h later than a truck.

Thus, from the analysis results, it could be concluded that if the shipment of goods by rail reached a destination 2 h later than a truck and the distance from the railway stations to factories was 10-30 km, it would lead the entrepreneurs to use freight rail transport at 42.85%, 22.75%, and 14.78%, respectively. It showed that the distance from the factories to the railway stations in the radius of 30 km had not much effect on a freight rail mode decision. This was relevant to the entrepreneurs' interviews indicating that if the railway station was located 45 km from the factory, the entrepreneurs would arrange for a truck to transfer the goods from factory to the railway station. This result was in line with a previous study by Shi *et al.* (2014).

However, in case that the distance was farther than that, it would not be worthwhile transporting them. In the case that the train was likely to be delayed at the destination by more

**Table 3. The results of feasibility calculation for entrepreneur's freight rail mode choice**

| Punctuality | % Rail mode share<br>10 km | % Rail mode share<br>20 km | % Rail mode share<br>30 km |
|-------------|----------------------------|----------------------------|----------------------------|
| 0           | 66.82                      | 49.44                      | 36.53                      |
| 1           | 55.13                      | 34.92                      | 24.01                      |
| 2           | 42.85                      | 22.75                      | 14.78                      |
| 3           | 31.39                      | 13.92                      | 8.69                       |
| 4           | 21.82                      | 8.15                       | 4.96                       |
| 5           | 14.55                      | 4.64                       | 2.79                       |
| 6           | 9.41                       | 2.60                       | 1.55                       |

**Figure 2. The feasibility trend of rail transportation mode choice of entrepreneurs**

than 2 h, more entrepreneurs would decide to use freight road transport, which could be noticed by the trend line tending to be close to 0. In other words, the chance that the entrepreneurs decided to use freight rail transport decreased correspondingly. On the other hand, it would affect entrepreneurs to increasingly use road transport. This confirmed the findings from several studies on intermodal mode choices (Kofteci *et al.*, 2010; Arencibia *et al.*, 2015; Moschovou and Giannopoulos, 2012). The detailed analysis is shown in Table 3 and Figure 2.

The results suggested that the State Railway of Thailand should improve the punctuality of trains to avoid delays, and the stations for goods storage should be developed to serve the entrepreneurs' needs with sufficient freight wagons suitable for the quantity of goods delivery. The locomotives should also be modernized to be relevant to the people's needs.

## Conclusions

According to the analysis results, they show that the factor of freight payment has no influence on the entrepreneurs' freight rail transport decision about carrying processed agricultural products at the 0.05 level of significance. This may be caused by the communicative variance of the operational definition of factors since the researchers have designed the factor unit as a percentage which may lead to the respondents' confusion.

According to the responses of the entrepreneurs from the stated preference questionnaires which were taken to develop the binary logit model, the respondents may not be the actual people authorized to make decisions. This may be because of an organization's structure which appoints the authorized people to choose the freight mode. In addition, the analysis results reveal that the product owners are not the decision makers, and that third-party logistics decision-makers are the determiners of the freight mode choice. Thus, this research has given importance to the factors rather than the coefficients values.

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