# THE DECISION MAKING OF FREIGHT ROUTE IN MULTIMODAL TRANSPORTATION

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## Abstract

**The transportation of beverage products from Thailand to neighboring ASEAN countries has been rising fast, especially in Cambodia, Laos and Myanmar (Department of Foreign Trade, Ministry of Commerce, Thailand 2015). Nevertheless, the main transportation routes of this product are still restricted to road transportation, though it involves with higher cost compared to rail and waterway. This paper develops a framework for route selection in multimodal transportation about the case study of beverage transportation from Thailand to Cambodia. One of the objectives is to determine the optimized route that optimizes cost, lead time, and risk in the system by using a five phases framework. The first phase is to define areas of study and identify all the related routes. The second phase is to calculate time and cost of each route. The third phase is to integrate qualitative decision making (Quantitative risk assessment) which are assessed by the experts or Logistics Service Providers (LSPs) for each criterion. The fourth phase is to prioritize criteria by using Analytic Hierarchy Process. The final phase is to optimize the route by using the Zero-one goal programming. The results have shown that the approach can provide a guidance in choosing the optimal cost, time and risk for multimodal transportation in beverage industry effectively.**

**Keywords: Analytic hierarchy process (AHP), multimodal transportation, beverage industry transportation, quantitative risk assessment (QRA), zero-one goal programming model (ZOGP)**

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## Introduction

Multimodal or intermodal transportation, as defined by Multimodal Transportation Handbook published by UNCTAD (UNCTAD, 2003), is the transportation of products by several modes of transport from one point or port of origin via one or more interface points to a final point or port where one of the carriers organize the whole transport. Nowadays, The Government of Thailand has considered multimodal transportation as an important strategy that may help trade logistics and transportation industry to be more efficient and competitive, when compared to other countries in the region.

According to Multimodal Transport Act B.E. 2005, the benefits of multimodal transportation are smoother flow of goods and better control over transportation chain which results in lower transport cost, time and less risk in door-to-door delivery. Recognizing the benefits of the multimodal transport concept, Thailand has taken initiatives in improving laws and regulations that would create the necessary environment for their development.

Since 2015, the ASEAN Economic Cooperation (AEC) has been fully functional, Thailand attempts to develop economics corridors and increase the trade volume with neighboring countries, including Cambodia. According to statistic from General Department of Customs and Excise of Cambodia in 2014, the main import origins were Thailand ($4.44 B), which was higher than China ($3.26 B), Vietnam ($2.52 B) and Singapore ($1.05 B). This shows an opportunity for Thailand to strengthen the trade with Cambodia.

Recently, Thai products are very well known and considered high in quality among their neighboring countries in the Southeast Asian Region. Demand for Thai products from buyers in Cambodia, Laos and Myanmar in particular has been rising fast. Among all the export products from Thailand to Cambodia, the top export product was soft drinks, beer and beverages (SCB EIC Analysis based on data from Department of Foreign Trade, 2015).

Thailand's border trade share, in percentage, can be shown in Figure 1.

In the past, most of the studies about multimodal transportation route selection have focused on minimizations of cost and time objectives only. (Min, 1991; Southworth and Peterson, 2000; Ham *et al.*, 2005; Chang, 2008) For example, in 2001, Banomyong and Beresford considered only a cost model in their multimodal transportation route selection study. In Tsai and Su, 2004; Scenna and Cruz, 2005; and Verma, 2011, risk assessment technique was applied on unimodal

| Trading partner | Thailand's exports | | | | Thailand's imports | | | |
|---|---|---|---|---|---|---|---|---|
| | 2009 | Share (%) | 2014 | Share (%) | 2009 | Share (%) | 2014 | Share (%) |
| Cambodia | Sugar | 10.5 | **Beverages** | **5.1** | Oil crops & oils | 27.0 | **Electronic parts** | **34.8** |
| | Tire | 4.3 | Vehicles & parts | 4.6 | Vegetables | 23.8 | **Wire & cable** | **12.4** |
| | Machinery | 3.1 | Machinery | 4.3 | Cereals | 12.2 | **Machinery** | **12.1** |
| | Motorcycle & parts | 3.0 | Autos & parts | 4.1 | Metals | 9.0 | Vegetables | 11.7 |
| Laos | Diesel | 13.8 | Diesel | 16.1 | Copper | 62.5 | Copper | 61.9 |
| | Autos & parts | 11.8 | Autos & parts | 12.5 | Wood | 13.7 | **Electronic parts** | **16.9** |
| | Benzene | 5.2 | Benzene | 5.4 | Cereals | 6.2 | Wood | 4.2 |
| | Metals | 4.3 | Metals | 5.1 | Wire & cable | 1.6 | Vegetables | 4.0 |
| Myanmar | Diesel | 14.9 | **Beverages** | **12.1** | Natural gas | 95.0 | Natural gas | 95.5 |
| | Beverages | 7.3 | Diesel | 8.5 | Crustaceans | 2.7 | Livestock | 1.4 |
| | Benzene | 4.1 | Benzene | 5.9 | Wood | 0.7 | Wood | 0.7 |
| | Textiles | 4.2 | Textiles | 4.7 | Ores | 0.1 | Crustaceans | 0.5 |
| Malaysia | Latex & rubber | 43.2 | Latex & rubber | 39.2 | Recording parts | 21.8 | Computers & parts | 18.4 |
| | Computers & parts | 13.3 | Computers & parts | 9.4 | Computers & parts | 12.8 | Recording parts | 10.1 |
| | Auto parts | 2.8 | Wood | 5.4 | Electrical resistors | 6.2 | Integrated circuits | 9.4 |
| | Wood | 2.7 | Auto parts | 3.4 | Integrated circuits | 5.6 | Industrial machinery | 7.8 |

**Figure 1. Thailand's border trade in 2014: by partner and share of total trade Unit: %, Billion THB**

transportation route selection in their studies. The studies of multimodal transportation of dangerous products by Reniers and Dullaert, 2013, it was suggested that minimization of associated risks is one of the important objectives in a decision process. Kengpol *et al.* (2012), Kengpol and Tuammee (2016) suggested that risk associates with accidents that cause more direct cost and less competitive advantage. Therefore, in transportation route selection decision making process, it is important to consider all three objectives, i.e., cost, time, and risk, in the optimization model.

Therefore, the objective of this research to develop a framework for route selection in multimodal transportation for beverage of Thailand and Cambodia by considering cost, time, and associated risk.

## Materials and Methods

### Areas of Study, Experts, and Identification of All the Routes

In order to identify areas of study and appropriate multimodal transportation routes from Bangkok, Thailand to the destination in Phnom Penh, Cambodia, eleven experts from three different areas of works associated with multimodal transportation of beverage products were interviewed. These following expert groups are asked to determine the significant weight of criteria:

i) LSPs that serve logistics service between Thailand to Cambodia.

ii) Experts from beverage company who take care of logistics and transportation.

iii) Government officers who are responsible for the transportation routes in The Department of Rural Roads between Thailand and Cambodia.

From brainstorming and interview with the experts, there are 10 possible transportation routes. These routes are combinations of several different modes of transport (i.e. rail, sea and road). These 10 possible multimodal transportation routes are as illustrated in Table 1.

### The Calculation of Quantitative Factors: Transportation Cost and Time

From the possible multimodal transportation routes identified in the previous phase, the selection of transport route has different impact on transportation cost and time. Transportation cost and time for each possible multimodal transportation route is determined from the interviews of Logistics Service Providers. The results were illustrated as shown in Table 1.

### The Calculation of Qualitative Factor: Transportation Risk

This phase is risk calculation process. There are two processes in this phase. The first process is risk identification. The second process is risk assessment. More detail can be seen as follows:

**Process I: Risk Identification** is the analysis of the nature of multimodal transportation risk. This research adopts the non- overlapping risk factors employed by previous researchers of Kengpol *et al.* (2012); Meethom and Chimmanee (2013), where the risk factors can be assessed in terms of the following criteria:

i) *Risk of Freight Damaged* is identified by using percentage of damaged goods value and loss information. It can be defined as the situation of loss of products during transfer mode, damage from transportation, damage from delivery to customer, damage from changing the transport mode.

ii) *Risk of infrastructure and equipment* can be defined as slope and the width of roads, capacity of road, train or ship, risk of shipment in the rainy season, accident rate, traffic volume. It is by use of the main percentage of accident rate of each route, quality of road, rail, port, and traffic facility of equipment material handling in each route. The route has a higher accident rate, the rank of probability assessment scale can be increased. With those risks, delay of transportation can also occur and increase time of transportation on each route. (Kengpol *et al.*, 2012).

**Table 1. Database of 10 Possible Multimodal Transportation Routes with cost, time and risks assessment**

| No.of route | Route | Time (h) | Cost (baht) | Distances (km) | Risk of freight damaged | Risk of infrastructure | Operational Risk | Other Risks |
|---|---|---|---|---|---|---|---|---|
| 1 | Bangkok - Aranyaprathet - Banteaymeanchey - Battambang - Pursat - Kampong Chhnang - Phnom Penh | 15 | 70200 | 670 | 6 | 4 | 4 | 4 |
| 2 | Bangkok - Aranyaprathet - Banteaymeanchey - Siem Reap - Kampong Thom - Kampong Cham - Phnom Penh | 16 | 71047 | 690 | 6 | 6 | 4 | 4 |
| 3 | Bangkok - Trat - Koh Kong - Kampong Speu - Phnom Penh | 16 | 72317 | 720 | 16 | 9 | 6 | 9 |
| 4 | Bangkok - Trat - Koh Kong - Sihanoukville - Phnom Penh | 16 | 76552 | 820 | 16 | 10 | 6 | 9 |
| 5 | Bangkok - Ban Laem, Chanthaburi - Pailin - Battambang - Pursat - Kampong Chhnang - Phnom Penh | 15 | 79432 | 888 | 6 | 6 | 9 | 6 |
| 6 | Bangkok - Ban Pak kad, Chanthaburi - Pailin - Battambang – Pursat - Kampong Chhnang – PhnomPenh | 12 | 72105 | 715 | 6 | 9 | 9 | 6 |
| 7 | Bangkok - Aranyaprathet = Banteaymeanchey = Battambang = Pursat = Kampong Chhnang = Phnom Penh | 20 | 41650 | 593 | 4 | 9 | 6 | 4 |
| 8 | Bangkok - Ban Hat Lek Port, Trat # Sihanoukville Port - Phnom Penh | 72 | 42581 | 754 | 2 | 9 | 16 | 4 |
| 9 | Bangkok - Laemchabang Port # Sihanoukville Port - Phnom Penh | 72 | 46581 | 712 | 2 | 9 | 12 | 6 |
| 10 | Bangkok - Ban Hat Lek Port, Trat # Koh Kong Port - Phnom Penh | 72 | 30849 | 694 | 2 | 9 | 16 | 6 |

iii) *Operational Risks* can be defined as lack of the skilled workers, standardization of document, interpretation problems with document or contracts.

iv) *Risk of other factors* can be defined as political risk and traffic rules, financial crisis, and etc. It affects the limit of transportation cost and increased time.

**Process II: Risk Assessment**. It is a quantitative risk analysis process. This is used to determine the risk level of an activity by which people, environment or system might be in hazard. In transportation risk assessment, quantitative risk can be calculated by the probability of accident occurrence multiply with the accident consequence as indicated in Equation (1) (Tsai and Su, 2004; Soons *et al.*, 2006; Kengpol *et al.*, 2012).

$$R = P \times C \qquad (1)$$

Where R is risk level, P is the probability or frequency of accident occurrence, C is the consequences of the accident.

Table 2 presents the level of the probability or frequency of accident occurrence (P) and Level of the consequences of the accident (C) (Hallikas *et al.*, 2004; Meethom and Chimmanee, 2013).

The significant weights of each criterion for each transportation situation is obtained by conducting AHP methodology.

The risk factors in multimodal transportation were obtained from previous research, and confirmed by the LSPs interviews. The results of risk assessment analysis of the multimodal transport routes can be as shown in Table 1.

**Prioritized Criteria by Using AHP Methodology**

In the 1970s, Thomas L. Saaty developed the analytic hierarchy process (AHP) technique, which constructs a decision-making problem in various hierarchies as goal, criteria, sub- criteria, and decision alternatives. The theoretical background and mathematical concept of the AHP methodology have been expressed in several books and articles (Vargas, 1990; Saaty, 1990, 2001b; Saaty and Vargas, 2001; Sipahi and Timor, 2010). In this phase, the LSPs are requested to identify the significant weights of criteria under different transportation situations by using the AHP method (Satty, 1990). Through the utilization

**Table 2. Level of the probability or frequency of accident occurrence (P) and Level of the consequences of the accident (C)**

| Level | The probability or frequency of accident occurrence | Description |
|---|---|---|
| 1 | Not definitely possible | The accident occurrence is not definitely possible. |
| 2 | Not quite possible | The accident occurrence is not quite possible. |
| 3 | Moderate | The accident occurrence is moderate possible. |
| 4 | Might be Possible | The accident occurrence might be possible. |
| 5 | Definitely possible | The accident occurrence is definitely possible. |

| Level | The consequences of the accident impact on logistics service provider | Description |
|---|---|---|
| 1 | No impact at all | The consequences of the accident are not impact at all. |
| 2 | Not quite impact | The consequences of the accident are not quite impact. |
| 3 | Moderate impact | The consequences of the accident are moderate impact. |
| 4 | Might be impact | The consequences of the accident might be impact. |
| 5 | Definitely impact | The consequences of the accident are definitely impact. |

of Expert Choice software, there are three criteria integrated in the objective function of zero- one goal programming, which are: transportation cost; transportation time; and transportation risk. The AHP Model is as shown in Figure 2.

From Expert Choice Software, the resulting relative weight criteria for transportation cost is 0.549, for transportation time is 0.171, for total risk is 0.28, (for sub-criteria; risk of freight damaged is 0.110, for risk of infrastructure is 0.069, for operational risk is 0.055 and for risk of other factors is 0.046). The maximum eigenvalue ($\lambda_{max}$) obtained is 6.445. The Consistency Index (CI) for the above paired comparison matrix is 0.089 and the corresponding Consistency Ratio (CR) is 0.072. Because CR is less than 0.1, the pairwise comparison matrix is considered to have an acceptable consistency. The results from AHP technique can be shown in Table 3.

**Optimization by using Zero-One Goal Programming (ZOGP) methodology**

The final phase is to apply the ZOGP methodology to optimize the multimodal transportation routes selection. This approach has been applied to many diverse problems such as project selection, course assignments, media planning and defense management. ZOGP model has been applied very frequently because it is simple to use and understand (Chen and shyu, 2005). The literatures as in Ho (2008) are specifically brought to review, as they are a good source of ideas in integrating the AHP with ZOGP. Schniederjans and Garvin (1997) have also emphasized how AHP weighting can be combined in ZOGP model to include resource limitation in a cost driver selection process. The significant weights obtained from the AHP method in the previous stage, associated parameters and limitations were applied to the objective function of ZOGP. (Charnes and Cooper, 1961; Kengpol *et al.*, 2012; Meethom and Chimmanee, 2013). Integrated model of AHP and ZOGP can be presented below:

$$\text{Minimize } Z = \sum \boldsymbol{m} (\boldsymbol{w}_i d_i^{-} + w_i d_i^{+}) \tag{2}$$
$$= 0.55(d^+_c) + 0.17(d^+_t) + [0.11(d^+_f) + 0.07(d^+_r) + 0.05(d^+_o) + 0.05(d^+_l)]$$

*Subject to*

*Budget*
$$-8.00x_1-18.41x_2-3.31x_3-9.36x_4+0.71x_5+9.87x_6+16.69x_7+14.84x_8+7.04x_9+38.30x_{10} - di^+ + di^- = 0.38 \tag{3}$$

*Time*
$$-25.00x_1-33.33x_2-33.33x_3-33.33x_4-36.36x_5-20.00x_6+(0)x_7-50.00x_8-50.00x_9-50.00x_{10} - di^+ + di^- = 1 \tag{4}$$

*Risk of freight damaged*
$$-50.00x_1-50.00x_2-33.33x_3-33.33x_4+(0)x_5+(0)x_6+(0)x_7+(0)x_8+(0)x_9+50.00x_{10} - di^+ + di^- = 0.67 \tag{5}$$

*Risk of infrastructure*
$$-100x_1-50.00x_2-50.00x_3+(0)x_4-50.00x_5-50.00x_6+(0)x_7-50.00x_8-50.00x_9+(0)x_{10} - di^+ + di^- = 0.78 \tag{6}$$

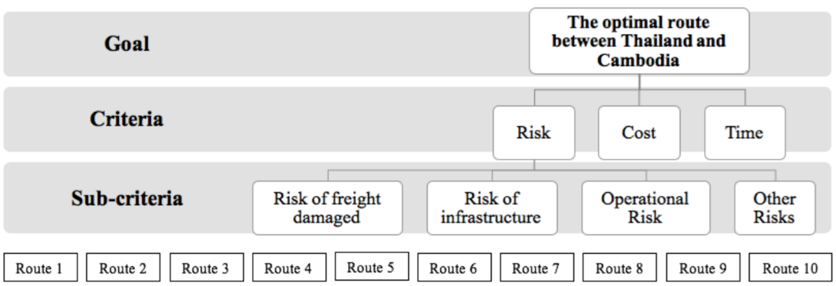


**Figure 2. AHP Model**

*Operational Risks*

$$(0)x_1-100.00x_2-200.00x_3+(0)x_4 -50.00x_5-50.00x_6+(0)x_7-33.33x_8 -33.33x_9-33.33x_{10}-di^+ + di^- = 1.00 \quad (7)$$

*Risk of other factors*

$$(0)x_1+(0)x_2-50.00x_3-50.00x_4+(0)x_5 +(0)x_6+(0)x_7+33.33x_8+(0)x_9 -50.00x_{10}-di^+ + di^- = 0.33 \quad (8)$$

$$x_1+x_2+\ldots+x_n=1$$
$$w_i d_i+ \geq 0, \text{ for } i = 1,2,\ldots,m \quad (9)$$
$$c_j, t_j, f_j, r_j, o_j, l_j \geq 0 \text{ for } j = 1,2,\ldots,n$$
$$x_j = 0 \text{ or } 1 : j = 1,2,\ldots,n$$

The Equations (2)-(9) can be defined by the deviation variables, decision variables and parameter below. Equation (9) control that only one route is optimum for one situation. All data in each objective function have a different unit thus it need to convert unit by formulating all units to percentage (Kengpol *et al.*, 2012b; Kengpol *et al.*, 2013).

**Deviation Variables**

$d_i^+$ = The positive deviation variables for i = 1,2,…,n optional activities goals

$d_i^-$ = The negative deviation variables for i = 1,2,…,n optional activities goals

$x_j$ represents the Zero-one variables representing the non-selection (i.e. zero) or selection (i.e. one) of route j = 1, 2, 3,…, n, subject to criteria right hand side (budget, time and risk) (Kengpol *et al.*, 2012b).

**Parameters**

$w_i$ = Weight of decision criteria that can obtain from AHP

$c_j$ = The coefficient of $x_j$ in budget constraint that is cost of each route in percentage of the under budget:

$$c_j = \left[\frac{(\text{Budget limited by user})-(\text{Cost of route } j)}{(\text{Budget limited by user})}\right] x\ 100 \quad (10)$$

$C$ = The right-hand side of Equation (3) is percentage of budget limited by user that is presented below:

$$C = \left[\frac{(\text{Budget limited by user})-(\text{Minimum cost of all route } j)}{(\text{Budget limited by user})}\right] \quad (11)$$

$t_j$ = The coefficient of $x_j$ in transport time constraint that is a percentage of transport time of each route which is limited by user:

**Table 3. The relative weight criteria from AHP**

| Expert | Cost | Time | Risk of freight damaged | Risk of infrastructure | Operational Risk | Risk of other factors |
|---|---|---|---|---|---|---|
| **Government Officer** | 0.355 | 0.247 | 0.143 | 0.097 | 0.084 | 0.074 |
| **Beverage Company 1** | 0.583 | 0.164 | 0.097 | 0.071 | 0.047 | 0.038 |
| **Beverage Company 2** | 0.592 | 0.145 | 0.098 | 0.068 | 0.054 | 0.043 |
| **Beverage Company 3** | 0.526 | 0.140 | 0.136 | 0.100 | 0.053 | 0.044 |
| **Beverage Company 4** | 0.602 | 0.159 | 0.088 | 0.064 | 0.048 | 0.039 |
| **Logistics Service Provider 1** | 0.600 | 0.161 | 0.088 | 0.062 | 0.050 | 0.040 |
| **Logistics Service Provider 2** | 0.604 | 0.151 | 0.091 | 0.055 | 0.050 | 0.049 |
| **Weight (Eigen Vector)** | **0.549** | **0.171** | **0.110** | **0.069** | **0.055** | **0.046** |
| **Summary of Weight (Eigen Vector): Cost 0.549, Time 0.171 and Risk 0.280** | | | | | | |
| **Maximum Eigen Value 6.445 C.I. 0.089 C.R. 0.072** | | | | | | |

$$t_j = \left[\frac{(\text{Transport time limited by user})-(\text{Transport time of route } j)}{(\text{Transport time limited by user})}\right] x\ 100 \quad (12)$$

$T$ = The right-hand side of Equation (4) is percentage of transport time limited by user that is presented below:

$T$ = $100\% = 1$

$f_j$ = The coefficient of $x_j$ in risk of freight damaged constraints:

$$f_j = \left[\frac{(\text{Risk of freight damaged limited by user})-(\text{Risk of freight damaged of route } j)}{(\text{Risk of freight damaged limited by user})}\right] x\ 100 \quad (13)$$

$F$ = The right-hand side of risk of freight damaged constraints in Equation (5):

$$F = \left[\frac{(\text{Risk of freight damaged limited by user})-(\text{Minimum Risk of freight damaged of all route } j)}{(\text{Risk of freight damaged limited by user})}\right] \quad (14)$$

$r_j$ = The coefficient of $x_j$ in risk of infrastructure constraints:

$$r_j = \left[\frac{(\text{Risk of infrastructure limited by user})-(\text{Risk of infrastructure of route } j)}{(\text{Risk of infrastructure limited by user})}\right] x\ 100 \quad (15)$$

$R$ = The right- hand side of risk of infrastructure constraints in Equation (6):

$$R = \left[\frac{(\text{Risk of infrastructure limited by user})-(\text{Minimum Risk of infrastructure of all route } j)}{(\text{Risk of infrastructure limited by user})}\right] \quad (16)$$

$o_j$ = The coefficient of $x_j$ in operational risks constraints:

$$o_j = \left[\frac{(\text{Operational risk limited by user})-(\text{Operational risk of route } j)}{(\text{Operational Risk limited by user})}\right] x\ 100 \quad (17)$$

$O$ = The right- hand side of Operational Risks in Equation (7):

$$O = \left[\frac{(\text{Operational Risk limited by user})-(\text{Minimum Operational Risk of all route } j)}{(\text{Operational Risk limited by user})}\right] \quad (18)$$

$l_j$ = The coefficient of $x_j$ in Risk of other factors constraints:

$$l_j = \left[\frac{(\text{Risk of other factors limited by user})-(\text{Risk of other factors of route } j)}{(\text{Risk of other factors limited by user})}\right] x\ 100 \quad (19)$$

$L$ = The right-hand side of Risk of other factors in Equation (8):

$$L = \left[\frac{(\text{Risk of other factors limited by user})-(\text{Minimum Risk of other factors of all route } j)}{(\text{Risk of other factors limited by user})}\right] \quad (20)$$

## Results

This mathematical model of integrated AHP and ZOGP was solved by employing a spreadsheet software and CPLEX Programming. The results show that the optimal route is truck transportation mode departing from Bangkok to Phnom Penh (route1). Transportation cost involved is 70200 Baht for 15-h period of transportation. The risk of freight damaged is 6. The risk of infrastructure and equipment is 4. The operational risk is 4 and the risk of other factors is also 4. In principle, multimodal transportation should help the industry save transportation cost. However, at the moment, the risks, shipping and handling costs involved in multimodal transportation are still quite high and make it incomparable to transportation by truck only.

## Conclusion and Discussions

The contribution of this research lies in the development of a new decision support approach that is flexible and applicable to the LSPs, in selecting a multimodal transportation route under the multi-criteria in terms of cost, time, and risk. For further study, this research plans to develop a new algorithm to solve the multimodal transport problem at a large scale and more i.e., risk model, fuzzy AHP, analytic network process (ANP) approach.

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