

DESIGN OF A DECISION SUPPORT SYSTEM FOR EMERGENCY TRANSPORTATION DURING AN ASEAN ECONOMICS COMMUNITY FLOOD

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Abstract

The objective of this research was to design a decision support system in emergency logistics for selecting the optimal emergency multimodal transport routing for a logistics service provider of non-profit service organisations to help a country within the ASEAN Economics Community countries. The decision support system model begins with the user introducing consistent decision criteria weighted by the analytic hierarchy process (AHP) in subjective measures from the decision maker's viewpoint. Then, the optimal transportation route in a flood situation was calculated by the zero-one goal programming method which can combine weight from the AHP based upon limitations of the lowest budget and risk, and on the time for delivery. The new area of this research showed that the risk number assessment was divided into 2 parts. The first is the route in the Thailand assessment based on the past 11 years of flood information, and the other part is the assessment by the experts in the area. Then, both risk levels can be concluded by the distance to weight ratio assessment.

Keywords: Decision support system, flood risk assessment, distance to weight ratio assessment, multimodal emergency logistics, analytic hierarchy process, zero-one goal programming

Introduction

Natural disasters are increasing around the world, for example the 2004 tsunami in Southeast Asia, the 2010 earthquake in Haiti, and regular hurricanes in the USA; consequently, there is an overwhelming need for assistance with victims waiting for hours and even days to receive life support. The response activities in emergencies involve dispatching commodities (e.g., medical materials, specialised rescue equipment and rescue teams, water, and food)

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with distribution in the affected areas, and evacuation and transfer of injured people; another type of response involves speeding up aid from other countries within the budget, time, and capability for transportation (Yi and Ozdamar, 2007). For example, during the 4th quarter of 2011-2012, the ASEAN Economics Community (AEC) area experienced major flooding, particularly in Thailand, and the World Bank estimated 1,425 billion baht (US \$45.7 billion) in economic damage and loss resulting from flooding, as at 15 January 2012. Dutta and Herath (2004) presented the 5-year average flood statistics for the last 30 years showing the flooding frequency; Thailand showed an increased rate in flood frequency compared to its neighbouring countries during the last 15 years.

Emergency logistics differs from general business logistics in several ways. First, the severity of disasters is unpredictable. Secondly, unlike business logistics management, emergency logistics resources may be under the control of both businesses and governments. Thirdly, relief-distribution risks contribute to the need for a specific emergency logistics network planning and design, especially for large-scale international disasters (Sheu, 2007). Fei *et al.* (2011) found a better time effectiveness to solve the problems of the logistics distribution path optimization for emergency medical equipment and spend less time for delivery using MAX-MIN and ant colony optimization models. Liu and Zhao (2008) studied an emergency rescue network that integrated the distribution centres, cities, and replenishment resources into a multi-level system to achieve time-based efficiency. Yuan and Wang (2009) found that most of the existing research work on emergency logistics management determined that time was the most important parameter to be considered. Banomyong and Sopadang (2010) developed emergency logistics response models in a preparedness planning process for disaster by using simulation models.

During the fourth quarter of 2011-2012, a flood starting in the north of Thailand caused a shortage of medicines as it advanced from the north (1st - 4th weeks), through the central plains (5th - 7th weeks), to Bangkok (8th - 9th weeks),

before entering the Gulf of Thailand (10th - 12th weeks). Within the AEC, Vietnam and Thailand have a long history of trading and economic support; therefore, for this research these countries were chosen as the case study for emergency logistics relating to social services. In a flood disaster scenario, the country receiving the aid has a limited budget, and the situation is constantly changing (both the infrastructure and routes) with regard to the damage; the most important factors are the delivery times and the lowest transport risks.

The objective of this research was to design a decision support system (DSS) for the emergency logistics that can optimise multimodal transportation routes in a flood emergency for the transport of medicines by the logistics service provider (LSP) of a non-profit organisation within the AEC countries. This would be similar to Thailand's flood disaster in 2011 when there was a shortage of medicine, such as saline and those medicines used for dialysis treatment. Additionally, the major quantitative and qualitative criteria for selecting optimal multimodal transportation routes were the lowest cost and risks, and the time. Hallikas *et al.* (2004) presented the probability and the effect of the risks which are mainly based upon subjective estimation assessment, so that the model for the risks must be simple. In risk assessment, the risk scale can be obtained by having an impact assessment scale multiplied by the probability of assessment scale (Hallikas *et al.*, 2004; Kengpol *et al.*, 2012). This research develops the practical representative risk number for the overall route. The risk assessment is calculated by the overall assessment, and represented by the risk selected numbers for all routes.

The new model in this paper shows the risk number assessment by the distance to weight ratio assessment, and the route selection criteria for a flood disaster.

Material and Methods

The emergency logistics DSS model has 3 main parts: the route database, user limits, and calculations, as illustrated in Figure 1.

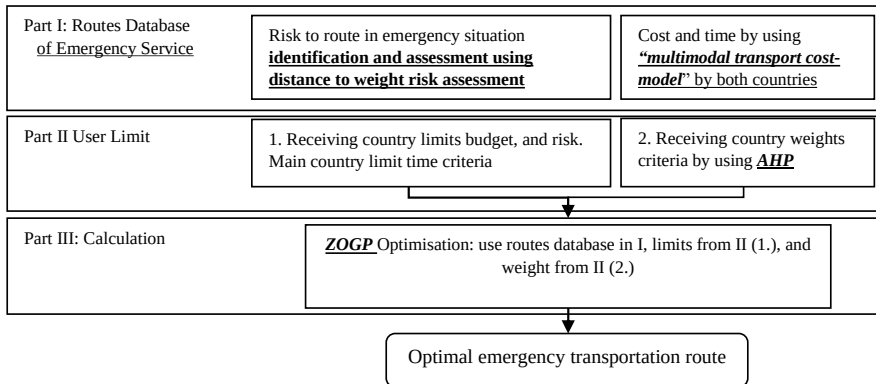


Figure 1. System model of the emergency transportation DSS

Part I: Route database

The route database consists of the feasible routes, costs, times, and transport risks of each route in the emergency. Banomyong and Sopadang (2010) identified the risk to transportation in an emergency situation. They suggested that factors influencing the emergency route and mode selection depend largely on the handling, storage, and efficiency of the port and the infrastructure from the port to the crisis-stricken area, the political situation, and topology. Further, the seasonal weather fluctuations need to be considered.

Next, 3 experts were interviewed for the risks of the emergency routes. The first is an academic expert in Thailand who does international research on flood routes and transport in the area. The second expert is from a logistics company in Thailand who has experience in flood transport. The last is from a logistics company in Vietnam who has experience of flood transport in the area. In summary, there are 4 risks of multimodal emergency logistics routes as follows:

- 1) Risk of routes damaged during transportation by the spread of flooding.
- 2) Risk to route flexibility during flood transport to the target destination.
- 3) Risk to the distribution network with which the carriers have to operate.
- 4) Risks of infrastructure and equipment when handing over at the point of trans-shipment, the width and gradients of roads, capacity of bridges and tunnels on routes,

routes in the rain, ferries, and facilities for handling equipment and materials.

According to the consensus from the 3 experts, the results can be grouped into 2 qualitative factors as a cluster approach: (i) the risk to the routes in the emergency area (risk of a damaged route, risk to route flexibility, and risk to the distribution network (RR), and (ii) risk to infrastructure and equipment in the emergency (RF).

The quantitative criteria, cost, and time in the emergency are found in a multimodal transport cost-model.

Part II: User Limit

The user sets up the origin and the destination for the transport, the transportation budget by the receiving country, the target date for that country, the risks of the route, and the risks of the infrastructure in the emergency area. Figure 2 shows the structure of the problem for the user and the decision criteria by the analytic hierarchy process (AHP) based on the situation, products, and/or country.

Part III: Calculation

There are 4 objective functions of zero-one goal programming (ZOGP) for minimising deviation by the decision maker. The first objective is the budget (g_1) provided by the receiving country that is the lowest cost for the possible route and which is less than the decision maker's set limit. The second objective is the time for transportation in the emergency

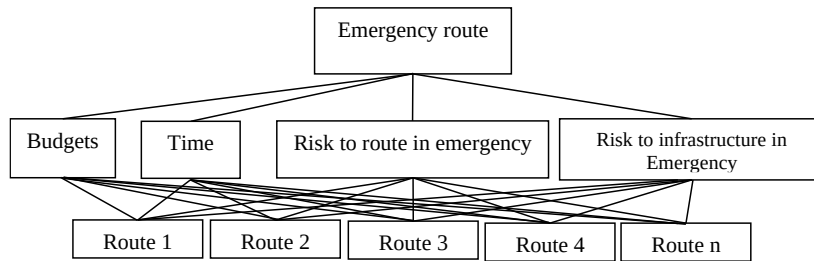


Figure 2. AHP structure and criteria in emergency route selection

(g_2) which is a minimising deviation and must be less than the limit of the receiving country. The third objective is the risk to the emergency route (g_3) that is the lowest on the risk scale and is less than the limit set by the country providing the aid. Lastly, the risk to the infrastructure and equipment in the emergency is the lowest risk scale of the possible route, and it cannot exceed what the receiving country can request (g_4). Each objective has a different unit; therefore, there is a need to convert all the units to a percentage from each goal of the user's needs by using a normalisation procedure.

$$\text{Minimise } Z = \sum_{i=1}^4 (w_i d_i^+) \quad (1)$$

$$= w_1(d_1^+) + w_2(d_2^+) + w_3(d_3^+) + w_4(d_4^+) \quad (2)$$

Subject to:

Budget,

$$c_1X_1 + c_2X_2 + c_nX_n \leq CE \quad (3)$$

Time,

$$t_1X_1 + t_2X_2 + t_nX_n \leq TE \quad (4)$$

Risk of route,

$$re_1X_1 + re_2X_2 + re_nX_n \leq RE \quad (5)$$

Risk of Infrastructure and equipment,

$$fe_1X_1 + fe_2X_2 + fe_nX_n \leq FE \quad (6)$$

$$X_1 + X_2 + X_n = 1 \quad (7)$$

$$w_i d_i^+ \geq 0; i = 1, 2, 3, 4$$

$$w_i d_i^+ \geq 0; i = 1, 2, 3, 4$$

$$X_j = 0 \text{ or } 1; j = 1, 2, \dots, n$$

$$CE, TE, RE, FE, c_j, t_j, re_j, fe_j \geq 0$$

In Equation (2), the d_i^+ deviation variables are the percentage vectors of the underachievements and overachievements of

each objective target. The weight for each criterion of coefficients relating to the deviation of each target is w_i (the budget weight is w_1 , time weight is w_2 , risk to route weight is w_3 , and risk to infrastructure and equipment weight is w_4).

The X_j is 0-1 variables (it is 0 for non-selection or 1 for selection of $j = 1, \dots, n$ route, subject to the criteria constraint on the right-hand side (budget, time, risk)).

In Equation (3), the c_j is the coefficient of X_j in the budget constraint.

$c_j = [(\text{receiving country's budget for cost of route } j) \times 100 / \text{budget of the receiving country}]$. The right-hand side of this equation is CE .

$CE = (\text{the receiving country's budget-minimum cost of all routes}) \times 100 / \text{budget of the receiving country}$.

In Equation (4), the t_j is the coefficient of X_j in the time constraint, and it is the percentage of the time of each route and the receiving country's time limit. The right hand side of this equation, TE , is the percentage of the user's time limit (100 %).

$t_j = (\text{time of route } j \times 100 / \text{the receiving country's time limit})$.

In Equation (5), re_j is the coefficient of X_j in the risk constraints. RE is right-hand side of the risk constraint: risk to route in the emergency.

$re_j = [(\text{risk scale of the receiving country's need} - \text{risk scale of route } j) \times 100] / \text{risk scale of the receiving country}$.

$RE = [(\text{risk scale of the receiving country's need} - \text{minimum risk scale of all routes} \times 100) / \text{risk scale of the receiving country}]$.

In Equation (6), fe_j is the coefficient of X_j in the risk constraints. FE is the right-hand side of the risk constraint: risk to infrastructure and equipment in the emergency.

$fe_j = [(risk\ scale\ of\ the\ receiving\ country's\ need - risk\ scale\ of\ route\ j) \times 100] / risk\ scale\ of\ the\ receiving\ country]$.

$FE = [(risk\ scale\ of\ the\ country's\ need - minimum\ risk\ scale\ of\ all\ routes \times 100) / risk\ scale\ of\ the\ receiving\ country]$

Equation (7) suggests that 1 route is the optimum for 1 situation.

Results and Discussion

In this part, this DSS model is used for a case study in an AEC flood emergency. The social service centres are established in Hanoi (the capital of Vietnam) and the destination is Bangkok (the capital of Thailand). The cost, time, risk to routes, and risk to infrastructure and equipment in the emergency are surveyed based upon information from the LSPs in both countries.

Part 1: Route database

The first step is the transportation risk; in the assessment phase, each risk cluster is divided into 2 elements by the characteristics of the element. The first element is the risk in Thailand referring to the past 11 years of information from the Statistical Geographic Information System Office (2017), Thailand Flood Monitor System (2017), and Hydro and Agro Informatics Institute (2017) for damaged routes, flexible routes, distribution network, and risk to the infrastructure and equipment from the flood. The second part is the risk outside Thailand assessed by flood route experts in the area. The risk number of each route in the element is assessed in 2 phases: in the first step, the assessment ranks the probability factor and severity of the risk to the routes in the flood area (RRF) and the risk to infrastructure and equipment in the flood area (RIF). After that, the risk number can be calculated by multiplying the probability number and severity number that is weighted by the ratio of the route distance in each

element (in Thailand and out of Thailand) per all the distance of the route, as shown in Equation (8):

$$RS = \sum_{k=1}^2 (P_k S_k \times \frac{a_k}{A}) \quad (8)$$

where

RS is the risk number of each route ,

P_k is the probability number in each element,

S_k is the severity number in each element,

$\frac{a_k}{A}$ is the ratio of k distance (a_k) and all distance (A) in kilometre

k is 1 or 2 (1= risk element in Thailand, and 2 = risk element out of Thailand).

In the second step, the cost and time in the flood emergency are obtained from the LSPs and shipping companies referring to a multimodal transport cost model. Table 1 shows the results that are used as a database of the DSS.

Part 2: The needs of the users

The users (Vietnam social service centres) sets up the origin (Hanoi) and the destination (Bangkok) in which the medicines, transportation budget limited at US \$1,800 within 7 days, risk to routes in the emergency area at low risk level (4) Joyce *et al.* (2012), and risk to infrastructure at low risk level (4) Joyce *et al.* (2012), are identified.

Figure 2 shows that the users can perform pairwise comparisons of the criteria by using the AHP. There are 3 users from Thailand and Vietnam using the mathematics mean to achieve the relative weight for each criterion, as illustrated in Table 2.

Part 3: Zero-one goal programming

The aim of the ZOGP is to optimise multimodal transportation routing for emergency logistics. The result of the medicines emergency logistics route by the DSS programme is shown in Figure 3 and Table 3. These illustrate the optimal route which is route code No.17 (Hanoi---Hai Phong###BKK). This means transportation from Hanoi by truck to Hai Phong, and by sea to Bangkok with a budget of

Table 1. Flood emergency multimodal transportation route between Vietnam (Hanoi)- Thailand (Bangkok) database

Route	Transport Cost (USD)	Time (days)	Risk scale of RRF	Risk scale of RIF
1. Hanoi+++Dong Ha---Lao Boa---BKK	1,508	4	3.03	4.39
2. Hanoi---Hai Phong####Da Nang---Lao Boa---BKK	3,147	7	1.74	4.71
3. Hanoi+++Hai Phong####Da Nang---Lao Boa---BKK	3,164	8	1.74	4.71
4. Hanoi---HMC###BKK	2,777	9	7.52	3.86
5. Hanoi+++HMC###BKK	1,265	10	7.55	3.87
6. Hanoi---Hai Phong####HMC###BKK	1,981	10	1.93	3.86
7. Hanoi+++Hai Phong####HMC###BKK	1,219	10	1.93	3.86
8. Hanoi+++Da Nang####HMC---BKK	3,303	11	3.75	3.84
9. Hanoi---Da Nang####HMC---BKK	3,147	11	3.74	3.82
10. Hanoi+++HMC---BKK	3,101	10	7.45	3.84
11. Hanoi---Hai Phong####HMC---BKK	3,178	9	1.92	3.83
12. Hanoi+++Hai Phong####HMC---BKK	3,195	10	1.92	3.83
13. Hanoi---Da Nang####BKK	1,806	9	3.76	3.84
14. Hanoi+++Da Nang####BKK	1,190	10	3.77	3.85
15. Hanoi---Hai Phong####Da Nang###BKK	1,250	9	1.92	3.84
16. Hanoi+++Hai Phong####Da Nang###BKK	1,267	10	1.92	3.84
17. Hanoi---Hai Phong####BKK	1,081	7	1.91	3.83
18. Hanoi+++Hai Phong####BKK	1,347	8	1.92	3.83
19. Hanoi+++Da Nang***BKK	5,890	4	4.00	4.00
20. Hanoi---Da Nang***BKK	6,080	3	4.00	4.00
21. Hanoi***BKK	5,580	1	2.21	1.31

Remark: transported by truck ---, train +++, sea ###, and air ***

Table 2. Relative weight based upon criteria from 3 users

Criteria	Thai Academic	Vietnam Logistics 1	Vietnam Logistics 2	Average
Budget	0.168	0.185	0.324	0.226
Time	0.484	0.370	0.324	0.393
Risk to route	0.231	0.345	0.249	0.275
Risk to infrastructure	0.117	0.100	0.103	0.107
C.R.	0.045	0.004	0.099	-

Table 3. The results of emergency logistics DSS

Route for drug	Budget	Time	RRF	RIF
Criteria Weight by AHP	0.226	0.393	0.275	0.107
User Target	1,800 USD	7 days	4	4
17. Hanoi--- HaiPhong####BKK	1,081 USD	7 days	1.91	3.83

US \$1,081 in 7 days, a risk to the route equal to 1.91, and a risk to the infrastructure equal to 3.83.

Figure 4 shows the route code No. 17 map.

For the DSS sensitivity, when the user needs to change the budget to US \$6,000 in a time of 4 days, the optimal route is route No. 19. In this case, when the time is changed

from 4 days to 10 days, the optimal route is

No. 7. For the last sensitivity test, when the criteria weights consider both risks, the optimal route is No. 21, as shown in Table 4. The sensitivity test shows this DSS could perform in other situations, with different limitations and different weights.

Table 4. DSS sensitivity

	User Target 1 (weight, target)	User Target 2 (weight, target)	User Target 3 (weight, target)
Budget (USD)	(0.226, 6,000)	(0.226, 6,000)	(0.00, 6,000)
Time (days)	(0.393, 4)	(0.393, 10)	(0.00, 10)
RRF risk scale	(0.275, 4)	(0.275, 4)	(0.50, 4)
RIF risk scale	(0.107, 4)	(0.107, 4)	(0.50, 4)
Optimal route	No.19	No.7	No.21

Decision Support System for Flood Emergency Route in AEC						
1. Phase Select Origin and Destination Country						
Origin Country	Vietnam	Destination Country	Thailand			
Origin City	Ha Noi	Destination City	Bangkok			
2. Phase Select container size						
			20'fts.			
3. Phase Input Limit Value						
3.1 Budget	1800	USD				
3.2 Time	7	Days				
3.3 Risk of Route	4	Scale				
3.4 Risk of Infrastructure	4	Scale				
4. Phase Input Criteria weight						
Total Weight	1.001					
4.1 Budget	0.226					
4.2 Time	0.393					
4.3 Risk of Route	0.275					
4.4 Risk of Infrastructure	0.107					
Calculate						
Result Route for Those Condition						
Route Code	Route	Cost(USD)	Time (day)	Risk of Route	Risk of Infrastructure	D
17	Ha Noi—Hai Phong##BKK	1081	7	1.912	3.825	7.905
--- TRUCK, +++ TRAIN, ### SEA, *** AIR						

This programme is designed for supporting research of Meethom @ KMUTNB.

Figure 3. The result of the DSS programme for the case of medicines**Figure 4. Map of the optimised multimodal emergency logistics for medicines**

Conclusions

The objective of this research was to develop a DSS model for selecting the multimodal transportation route for emergency logistics for LSPs of a non-profit service organisation. The first value is the multimodal emergency logistics DSS model. The multimodal transport cost model is used for the cost and time of each feasible multimodal transportation route, risk identification, and risk assessment by a distance to weight ratio assessment. Then, weight quantitative and qualitative criteria by the AHP

are used for the ZOGP to optimise the route. If the user needs to transport other things, or to other countries, the user must change the weight and/or limitation in this DSS. The second value is the flood emergency route criteria for selecting the emergency route consisting of: risk to the route in the emergency (whether the risk is that the route is damaged, the risk relates to flexible routes, or the risk is to the distribution network), and the risk to the infrastructure and

equipment in the emergency for assessment in the DSS. The last value is the new method to assess the risk scale of the emergency route: step 1) classify the route by data characteristics into 2 parts: in Thailand route assessment will be based on the flood information in the past 11 years, and the flood risk number outside Thailand is assessed by the flood area experts; and step 2) the distance to weight ratio to assess the risk scale used in the risk assessment for a real situation. According to the case study, during emergency logistics it is necessary that the time for transport should be very punctual because an earlier or later delivery can cause difficulties for the receiver. For example, limited facilities might not be available because of the flood situation.

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