A DECISION SUPPORT SYSTEM IN LOGISTICS
: A CASE STUDY FOR THAILAND RUBBER EXPORTS

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ABSTRACT

Thailand is among the top rubber exporters in the world. With the amount of natural rubber exported at about 2.6 million tons in 2008, it is the biggest exporter of natural rubber. This amount will rapidly increase as a result of the one million rai project by the year 2011. This one million rai project was launched in 2004 in a new planting area, in the northeastern part of Thailand. This project will increase the exporting value to 570,362 million THB in the year 2012. It can be expected that when this volume blooms, new alternatives for exporting gateways will be critically needed. This study proposed a multi-criteria decision making system for gateway selections for Thailand rubber exports. First of all, the gateway alternatives were listed with respect to origin, destination and mode of transport. A Fuzzy Analytic Hierarchy Process (FAHP) was used for this problem. Alternatives were evaluated by four main criteria namely, transportation factors, an economic factor, port/customs considerations, and environmental considerations. Then, weights of criteria with twelve sub-criteria were evaluated by a group of logistics experts. It was determined that the optimal route and choice could not be identified since the selection may change upon different circumstances. Hence, a decision support system was developed for appropriate gateway selection on a case by case basis.

KEY WORDS: THAILAND RUBBER EXPORTS / FUZZY ANALYTIC HIERARCHY PROCESS / DECISION SUPPORT SYSTEM / MULTI-CRITERIA DECISION MAKING

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ระบบสนับสนุนการตัดสินใจสำหรับการส่งออกยางพาราของประเทศไทย
A DECISION SUPPORT SYSTEM IN LOGISTICS : A CASE STUDY FOR THAILAND RUBBER EXPORTS

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บทคัดย่อ

อุตสาหกรรมยางพาราเป็นอุตสาหกรรมที่สำคัญของประเทศไทย และสามารถสร้างรายได้จากการส่งออกได้เป็นอย่างมาก ในขณะนี้พื้นที่การปลูกยางพาราได้มีขยายตัวอย่างต่อเนื่องไปสู่บริเวณพื้นที่ภาคตะวันออกเฉียงเหนือและภาคเหนือของประเทศไทย ทำให้คาดการณ์ได้ว่าปริมาณยางพาราของประเทศไทยจะเพิ่มสูงขึ้นมากจากบริเวณพื้นที่ปลูกใหม่นี้ เพื่อรองรับปัญหาด้านการขนส่งอันเป็นจากปริมาณยางพาราที่เพิ่มขึ้น ดังนั้นบทความนี้นำเสนอการออกแบบระบบสนับสนุนการตัดสินใจสำหรับการคัดเลือกระบบการขนส่งต่อเนื่องหลายรูปแบบสำหรับการส่งออกยางพาราของประเทศไทย โดยได้ทำการประเมินพื้นที่ทางเลือกเพื่อใช้เป็นจุดเริ่มต้นของการขนส่งยางพาราใน 5 พื้นที่ของประเทศไทย มีการนำเทคนิคการวิเคราะห์เชิงลำดับชั้นแบบฟัซซี่ (Fuzzy Analytic Hierarchy Process; FAHP) เข้ามาใช้เป็นเครื่องมือในการช่วยตัดสินใจ เนื่องด้วยวิธีนี้สามารถช่วยวิเคราะห์ความคลุมเครือในกระบวนการตัดสินใจ โดยมีปัจจัยหลักในการพิจารณา 4 ด้าน ได้แก่ ด้านการขนส่ง ด้านเศรษฐศาสตร์ ด้านท่าเรือ/ด่านการค้าชายแดน และด้านสิ่งแวดล้อมอื่นๆ ทั้งนี้เส้นทางทางเลือกที่พิจารณานี้ขึ้นอยู่กับจุดต้นทางของการขนส่ง โดยมีวัตถุประสงค์ของการวิเคราะห์เพื่อให้ผู้ส่งออกยางพาราได้รับข้อมูลในการสนับสนุนการตัดสินใจสำหรับการเลือกช่องทางการส่งออกยางพาราที่เหมาะสมภายใต้ปัจจัยที่พิจารณา

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CHAPTER I
INTRODUCTION

1.1 Background and Problem Statement

Thailand is the world's major exporter of natural rubber. Ninety percents of total rubber products are exported in the forms of rubber smoked sheets, concentrated rubber latex, rubber blocks, and other primary rubber products. In Thailand, the Southern region is the heart of rubber production. Recently, rubber plantation was expanded to the North and Northeast of Thailand as a result of the government's "Rubber Cultivation for Raising the Sustainable Income to Farmers in the New Planting Area Phase 1 (2004-2006)" program in 2003. This policy set the target area of 1,000,000 rais (or 160,000 hectares) divided into 300,000 rais for the Northern region and 700,000 rais for the Northeastern region, respectively. Rubber products as a result from this policy can be harvested the latex in 2012. High quantities of rubber product are increasing in Thailand. This is an important problem for logistics system of Thailand rubber exports.

This study presents a case of rubber supply chain in Thailand. The rubber supply chain has been modeled. It is found that gateway selection is a major concern for exporters. Exporters still lack information about alternative gateways. It is a multi-criterion problem on strategic decision making. Decision support information about alternative gateways has not been provided. Decision support technique is a helpful tool for such problems. The decisions for selecting gateways of export are made upon logistics factors. Apart from this, the new planting areas may require a new gateway for exporting. All gateways for Thailand rubber export are considered in this decision support system varied by origins to the target destination. Criteria and sub-criteria for gateways selection acquired from literature survey, practical investigations and logistics experts interviewing are taken into account. This study considered both quantitative and qualitative criteria of alternative gateways. The process of selection among different alternatives is complex and the ranking criteria are uncertain. It depends on each person's preferences. Thus, the Fuzzy Analytic Hierarchy Process (FAHP) method was used as an evaluation tool.

The FAHP technique is an advanced analytical method developed from the traditional Analytic Hierarchy Process (AHP). It is difficult to express the character and significance of criteria exactly or clearly through traditional methods. Using the concept of the fuzzy set theory and natural language to evaluate the route selection criteria are more convenient. Therefore, this research combined the fuzzy set theory and linguistic value concept to establish a model that can provide decision makers with a tool to deal with complex issues in a fuzzy environment. Thus, a fuzzy-based decision model for route selection is more appropriate and effective than traditional precision-based models.

The methodology of Fuzzy Analytic Hierarchy Process (FAHP), based on Chang's extent analysis (Chang, 1996) is applied in this study as an evaluation tool. The appropriate alternative route for Thailand rubber exports to Eastern China will be obtained.

1.2 Research Objectives

1.2.1 To analyze criteria and alternative routes for Thailand rubber export.

1.2.2 To provide and develop a decision support system for evaluating an appropriate alternative route in a case study for Thailand rubber exports by using the Fuzzy Hierarchy Analytic Process (FAHP) method.

1.3 Scope of Work

1.3.1 This research proposes the alternative routes from five origin areas of Thailand rubber exports as follows: Surat Thani, Nakhon Si Thammarat, Songkhla, Rayong, and Nong Khai. The destination here is Eastern China at Qingdao port.

1.3.2 The appropriate route is evaluated by using the Fuzzy Analytic Hierarchy Process based on Chang's extent analysis (Chang, 1996).

1.4 Expected Results

The outcome of this study represents a decision support system for Thailand rubber export to Eastern China. An exporter (user) can evaluate appropriate route selected from each origin.

CHAPTER II
LITERATURE REVIEW

2.1 Thailand Rubber Supply Chain

Rubber industry of Thailand was established in 1900 Rubber production remained one of the country's major industries contributing to the Thai economy. Currently, Thailand is the world's largest natural rubber producer and exporter.

Table 2.1 Rubber exporting value and growth rate by type

Unit: million US$

Type	Exporting value				Growth rate (%)		
	2006	2007	2008	2009	2007	2008	2009
Natural rubbers	**5,396.59**	**5,639.66**	**6,791.72**	**3,633.04**	**4.50**	**20.43**	**-46.51**
Rubber smoked sheet	1,912.73	1,996.13	2,366.36	1,107.91	4.36	18.55	-53.18
Rubber block	2,175.53	181.21	93.38	30.32	-91.67	-48.47	-67.53
Concentrated rubber latex	1,214.79	1,265.86	1,400.14	1,076.92	4.20	10.61	-23.08
Others	93.54	2,196.46	2,931.84	1,417.89	2,248.15	33.48	-51.64
Rubber Products	**3,082.01**	**3,653.23**	**4,550.40**	**4,220.44**	**18.53**	**24.56**	**-7.25**
Tire	1,196.06	1,622.20	2,092.30	1,793.13	35.63	28.98	-14.30
Gloves	558.83	584.48	658.42	628.64	4.59	12.65	-4.52
Rubber band	64.99	53.96	64.01	54.29	-16.97	18.62	-15.19
Hose	105.92	135.52	172.79	94.97	27.95	27.50	-45.04
Conveyer belts	45.52	71.96	77.55	63.81	58.08	7.77	-17.72
Scientific instruments	211.07	213.01	263.06	260.61	0.92	23.50	-0.93
Vulcanized rubber	206.69	212.07	222.56	226.44	2.60	4.95	1.74
Others	692.93	760.03	999.71	1,098.53	9.68	31.54	9.88

Source: The Office of Industrial Economics (2010)

Table 2.1 shows rubber exporting value and growth rate by type. Rubber is one of several exporting products with highest exporting value of Thailand. Ninety percent of total rubber quantity results from natural rubbers such as rubber smoked sheets, rubber blocks, concentrated rubber latex, and other are exported. (Kritchanchai *et al.*, 2009).

China, Japan, Malaysia, USA, and South Korea are major countries which import natural rubber from Thailand. Table 2.2 shows Thailand natural rubber exports by countries in 2004-2008.

Table 2.2 Rubber exporting quantity by countries in 2004-2008

Unit: tons

Countries/Year	**2004**	**2005**	**2006**	**2007**	**2008**
China	619,800	573,385	747,168	827,369	824,833
Japan	525,654	540,485	492,740	405,598	394,742
Malaysia	383,695	403,506	442,664	413,049	398,043
USA	249,196	237,858	210,784	213,081	219,986
South Korea	171,668	185,308	173,477	151,824	154,340

Source: Rubber Research Institute of Thailand (2010)

Rubber is an important plant not only for world economic strategies but also for the use of living of mankind. The more social development, the more requirements of products made of rubber for people utilization is increasing every day.

2.1.1 A Structure of Thailand Rubber Supply Chain

Thailand rubber supply chain composes of 4 stages as follows: rubber farmer, rubber trader and rubber co-operative, rubber plant, and logistics and export. Rubber farmers produce rubber latex, rubber cup lumps or rubber sheets. Rubber products are gathered and are bidden at rubber central markets by rubber traders or rubber co-operatives. Then, they are sent to rubber plant in order to process primary rubber products, i.e. rubber smoked sheets, rubber block, rubber concentrated latex. Finally, almost all of them are exported (Kritchanchai and Chanpuypetch, 2009). A structure of Thailand rubber supply chain is illustrated in Figure 2.1.

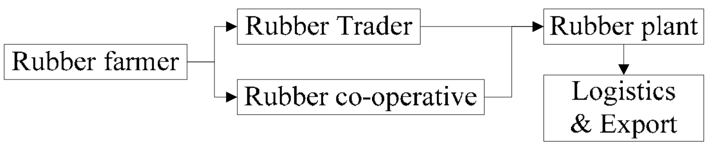


Figure 2.1 A Structure of Thailand rubber supply chain

Table 2.3 Rubber planting areas and harvesting area in 2005-2009

Areas	Province	Planting area (rais)					Harvesting area (rais)				
		2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Upper Southern region	SuratThani	1,813,652	1,807,643	1,830,161	1,871,907	1,900,561	1,507,554	1,574,452	1,551,660	1,674,267	1,685,886
	Nakhon SiThammarat	1,368,824	1,368,042	1,400,808	1,447,302	1,469,569	1,088,078	1,082,729	1,102,911	1,136,190	1,166,751
	Trang	1,302,127	1,311,635	1,309,313	1,310,188	1,332,412	1,142,729	1,135,779	1,094,765	1,109,178	1,127,548
	Pattalung	520,198	525,400	538,411	538,477	548,407	445,800	487,066	477,842	470,200	463,648
	Chumporn	451,079	453,039	459,039	464,662	465,664	363,254	396,499	391,891	391,891	406,138
Lower Southern region	Songkhla	1,410,927	1,418,927	1,444,012	1,444,302	1,461,249	1,231,095	1,242,394	1,241,698	1,222,119	1,198,816
	Yala	1,023,063	1,026,563	1,046,438	1,046,872	1,060,920	803,807	799,411	837,858	892,493	931,369
	Narathiwat	985,673	995,529	1,004,532	1,005,871	1,005,846	802,548	851,221	888,501	896,029	902,616
	Pattani	282,187	287,830	294,607	295,185	302,344	225,687	244,954	246,725	255,358	254,247
	Krabi	605,166	602,147	610,147	625,231	627,265	496,629	508,651	523,836	516,498	507,225
	PhangNga	655,522	650,427	658,427	757,025	791,037	560,580	541,029	525,936	541,437	530,534
	Pukhet	109,302	105,256	101,985	91,787	89,986	97,934	97,640	93,929	84,417	80,182
	Ranong	121,494	120,625	125,625	150,529	157,716	100,530	97,512	100,859	100,667	100,822
Eastern region	Chantaburi	353,680	364,786	369,750	463,799	470,234	268,493	275,686	295,920	306,555	297,112
	Trad	210,169	216,117	223,077	250,031	257,566	153,968	153,284	155,280	164,591	161,468
	Rayong	595,567	602,547	616,956	701,732	718,607	431,517	442,883	470,010	507,312	503,206
	Chonburi	171,373	174,980	176,911	185,757	189,043	120,061	130,185	129,101	129,202	142,944
	Chachoengsao	109,763	112,233	112,966	116,896	122,112	51,798	61,655	63,459	75,287	89,545

Source: Office of Agricultural Economics (2010)

Table 2.4 Rubber new planting areas and harvesting area in 2005-2009

Area	Province	Planting area (rais)					Harvesting area (rais)				
		2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Northeastern region	Nong Khai	255,481	425,216	531,520	637,824	648,973	81,711	93,260	122,182	126,398	162,590
	UdonThani	79,884	101,986	219,270	295,000	315,049	37,424	47,935	50,942	52,000	53,781
	Loei	109,140	195,925	241,513	382,497	427,083	32,576	33,715	37,903	39,375	68,006
	Nakhon Phanom	53,450	82,324	105,876	140,517	148,158	22,134	27,864	30,301	32,368	38,870
	Mukdahan	50,095	67,757	91,895	110,000	131,067	16,560	21,941	24,583	25,633	32,267
	Sakonnakhon	42,580	62,160	93,240	171,665	182,531	14,239	18,919	19,127	21,627	31,208
	Nongbualumphu	24,238	30,969	5,390	94,288	98,136	5,115	5,954	6,290	7,762	8,590
	Buriram	89,558	137,632	174,720	178,331	189,138	45,029	61,021	70,576	75,956	80,468
	UbonRatchathani	62,394	107,898	159,846	168,523	177,151	23,046	28,379	28,647	32,626	45,200
	Sisaket	69,380	105,965	157,229	176,096	189,866	31,050	36,303	40,050	40,950	44,306
	Surin	51,618	64,452	84,978	90,686	93,017	20,107	24,598	26,156	41,912	42,596
	Kalasin	27,971	32,480	50,722	137,398	144,268	13,643	15,948	18,893	19,838	20,744
	Yasothon	26,005	32,629	43,180	49,657	57,106	9,698	9,698	13,990	14,696	15,933
	Roiet	13,694	17,131	21,441	24,657	27,123	9,060	9,776	10,202	11,222	11,788
	Khonkean	12,501	18,587	32,089	38,507	44,283	7,247	7,247	7,864	8,336	8,583
	Chaiyaphum	10,455	18,415	26,163	31,431	34,574	4,895	6,455	6,678	7,012	7,312
	Amnatcharoen	16,573	23,197	35,348	42,418	44,539	1,020	2,044	4,292	4,635	10,830

Source: Office of Agricultural Economics (2010)

Rubber planting area and rubber manufacturers are mostly located in the South and East of Thailand. Major rubber planting areas are in Surat Thani, Nakhon Si Thammarat and Songkhla provinces in the Southern region and Rayong province in the Eastern region are shown in Table 2.3. Recently, rubber plantation expanded in the Northeastern region and the Northern region as a result of the government's "Rubber Cultivation for Raising the Sustainable Income to Farmer in the New Planting Area Phase 1 (2004-2006)" program in 2003. This policy set the target area of 1,000,000 rais (or 160,000 hectares) divided into 300,000 rais for the Northern region and 700,000 rais for the Northeastern region, respectively. Table 2.4 shows new rubber planting and harvesting areas in the Northeast of Thailand. Nong Khai province is the center rubber planting area in the Northeastern region. Mostly, natural rubber products from these areas are exported.

China is the major country that imports Thailand natural rubber products. Rubber smoked sheets and rubber blocks are the main raw material in tire industry. Tire industry is one important industry in China. Shandong is the largest area of tire production. It produces around 45.2 percent of all tire production in China. The second and third largest areas are Guangdong and Shanghai that produce around 15.8 and 13.4 percent respectively (Khompatraporn *et al.*, 2009). Mostly, Thailand natural rubbers are shipped to China at Shanghai and Qingdao ports. The logistics flow of rubber exports in each area is different, varied by origins to the target destination.

2.1.2 Rubber Logistics Flow from the South of Thailand

Rubber planting areas and manufacturers are mostly located in the South of Thailand. The outbound logistics can be classified into two groups related to rubber planting area and the manufacturer locations that are mostly spread in the South of Thailand. The Southern region can divide to the Upper and Lower Southern planting areas. Surat Thani and Nakhon Si Thammarat provinces are center of rubber planting and manufacturing in the Upper South of Thailand. For the Lower Southern region, Songkhla province is the center. Rubber manufacturers in the Upper South of Thailand ship their products to Eastern China via Laem Chabang port (LCB) or Bangkok port (BKK). Inland transportation from Surat Thani province to both ports can access by train, gulf of Thailand coastal vessel, trailer, and truck. Rubber products from Nakhon Si Thammarat province to the port can access by train, trailer and truck are inland mode. From LCB or BKK ports, the natural rubber will finally be shipped to Eastern China via Hong Kong port. Natural rubbers in this area can use Padang Besar border to Penang port in Malaysia. Train can access Penang port via Padang Besar border to ship rubber products to Eastern China. Mostly, the destinations are Shanghai and Qingdao port. Natural rubber products from the Lower South of Thailand are exported via Songkhla port, Padang Besar border and Sadao border. For Songkhla port, truck transportation is only inland mode that can access the port. The capacity of Songkhla port can only be available for feeder vessels. The feeder vessel will then transship natural rubber products to a mother vessel at Singapore port. However, manufacturers mostly use Padang Besar border and Sadao border to Penang port. To transfer to Padang Besar border, trucks and trains can be used whereas Sadao border can be accessed by truck only (Wasusri and Chaichomphoo, 2008). All routes for rubber logistics flow from the Southern region are shown in Table 2.5.

Table 2.5 Alternative routes for rubber logistics flow from the South of Thailand

Route No.	Thailand			International transportation		Eastern China	
	Origin	**Port/customs**	**Inland mode**	**Port**	**Mode**	**Port**	**Mode**
1	Surat Thani	BKK	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
2	Surat Thani	BKK	Truck	Hong Kong	Vessel	Qingdao	Mother vessel
3	Surat Thani	BKK	Train	Hong Kong	Vessel	Qingdao	Mother vessel
4	Surat Thani	LCB	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
5	Surat Thani	LCB	Truck	Hong Kong	Vessel	Qingdao	Mother vessel
6	Surat Thani	LCB	Train	Hong Kong	Vessel	Qingdao	Mother vessel
7	Surat Thani	LCB	Vessel	Hong Kong	Vessel	Qingdao	Mother vessel
8	Surat Thani	Padang Besar	Train	Penang	Train	Qingdao	Mother vessel
1	Nakhon Si Thammarat	BKK	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
2	Nakhon Si Thammarat	BKK	Truck	Hong Kong	Vessel	Qingdao	Mother vessel
3	Nakhon Si Thammarat	BKK	Train	Hong Kong	Vessel	Qingdao	Mother vessel
4	Nakhon Si Thammarat	LCB	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
5	Nakhon Si Thammarat	LCB	Truck	Hong Kong	Vessel	Qingdao	Mother vessel
6	Nakhon Si Thammarat	LCB	Train	Hong Kong	Vessel	Qingdao	Mother vessel
7	Nakhon Si Thammarat	Padang Besar	Train	Penang	Train	Qingdao	Mother vessel
1	Songkhla	Padang Besar	Trailer	Penang	Train	Qingdao	Mother vessel
2	Songkhla	Padang Besar	Train	Penang	Train	Qingdao	Mother vessel
3	Songkhla	Songkhla port	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
4	Songkhla	Sadao border	Trailer	Penang	Trailer	Qingdao	Mother vessel

2.1.3 Rubber Logistics from the East of Thailand

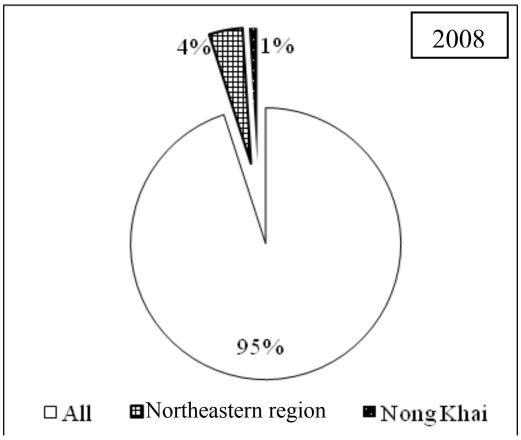
In the East of Thailand, Rayong province is the center of rubber planting area. Rubber manufacturers export their products to Eastern China via LCB or BKK ports. Inland transportation from Rayong province to two ports is trailer. Natural rubber products will finally be shipped to Eastern China via Hong Kong port. The route is displayed in Table 2.6.

Table 2.6 Alternative routes for rubber logistics flow from the East of Thailand

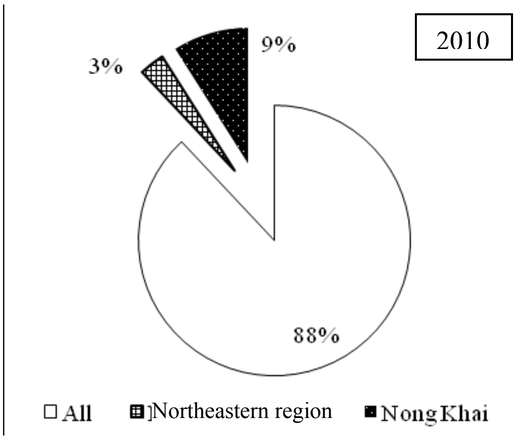
Route No.	Thailand			International transportation		Eastern China	
	Origin	**Port/customs**	**Inland mode**	**Port**	**Mode**	**Port**	**Mode**
1	Rayong	BKK	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
2	Rayong	LCB	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel

2.1.4 Rubber Logistics Flow from New Planting Areas

New rubber planting areas are the Northeastern region. Nong Khai province is the center area in the region. Summary of rubber products in 2007 were 36,000 tons or around 30 percent of all production in the Northeastern region. Nowadays, rubber planting areas in this region are expanding continuously and 5 percent of all rubber products in Thailand as a result of the Northeastern region or about 156,000 tons (Rubber research center, 2008). In year 2010, the new batch of natural rubber in this area will be harvested as a result of the government's "Rubber Cultivation for Raising the Sustainable Income to Farmer in the New Planting Area Phase 1 (2004-2006)" program in 2003. Rubber products will be increased to 375,000 tons as a result of production forecasting. Nong Khai province is 9 percent increase in 2010 for forecasting result from Kritchanchai (2009). The percent of rubber product from the Northeastern region compare with all amount products in Thailand is illustrated in Figure 2.2.



(a)



(b)

Figure 2.2 Comparison of Thailand rubber product in 2008 (a) and 2010 (b)

Rubber in new planting area, Nong Khai province is the most important location which should be considered. A Structure of the Northeastern region rubber supply chain composes of 6 players as follows: rubber farmer, rubber local trader, rubber co-operative, rubber plant in the Northeastern region, rubber plant in the Eastern region and logistics and export. Mostly, rubber farmers in the Northeastern region produce rubber cup lump. Cup lump is one important raw material for rubber blocked. Products from rubber farmers are gathered and are bidden at rubber local central market by rubber trader or rubber co-operatives. Then, these products are sent to rubber manufacturers in the Eastern region or the Northeastern region in order to process primary rubber products. Finally, primary rubber products are exported.

Currently, rubber products from manufacturers in Nong Khai province are exported to Eastern China via BKK and LCB ports. Inland transportation from Nong Khai province to two ports is trailer. Natural rubber products will finally be shipped to Eastern China via Hong Kong port. However in year 2010, the new batch of natural rubber in this area, 700,000 rais, will be harvested. New alternatives for gateways in this region will be needed.

From the fieldwork, researcher sees the opportunities of Mukdahan border, Bueng Kan border, and Nakhon Phanom border. These gateways can be connected with East-West Economic Corridor or highway No.2 (R2). East-West Economic Corridor is one route in Greater Mekong Sub-region (GMS) Economic

Cooperation Program in 1992 supports the transportation among Burma, Thailand, Laos and Vietnam. This economic corridor can be considered as a new alternative route for the Northeastern region. Rubber products from this area can export to Eastern China via Da Nang port in Vietnam. The Economic Corridors in the Greater Mekong Sub-region (GMS) illustrates in Figure 2.3.

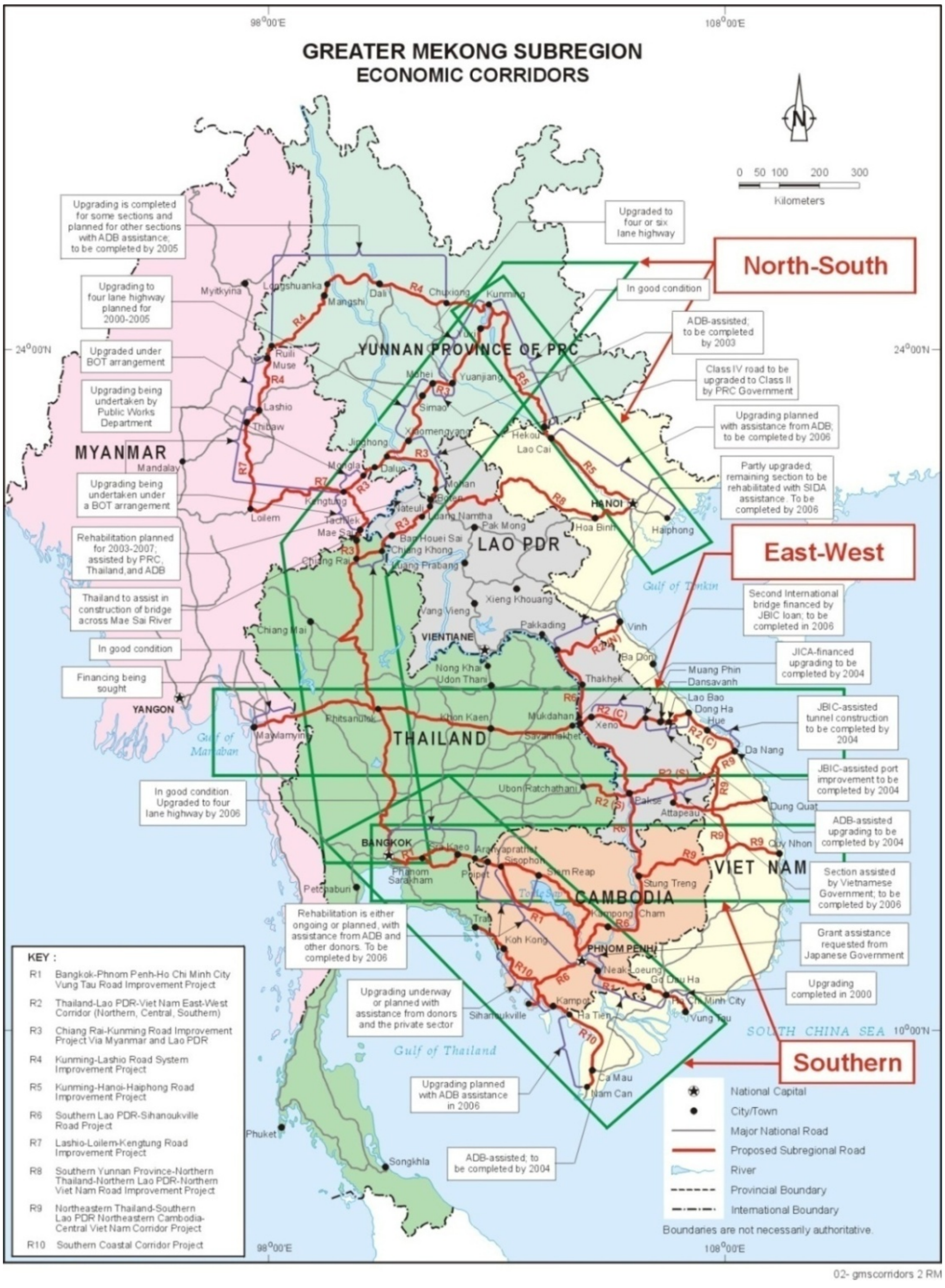


Figure 2.3 The economic corridors in the Greater Mekong Sub-region (GMS)
Source: Asian Development Bank (2002)

From Mukdahan and Nakhon Phanom border, the highway number 9 (R9) leads to Da Nang port in Vietnam via Lao Bao border in Laos and then to China. Bueng Kan border is also another channel to Eastern China. This route uses highway number 8 (R8) to Lak Sao border in Laos and then transport to Vinh in Vietnam. The destination at Da Nang port is accessed by the Asian highway network 1A. All routes are shown in Table 2.7.

Table 2.7 Alternative routes for rubber logistics flow from the Northeast of Thailand

Route	Thailand			International transportation				China	
No.	Origin	Port/ Customs	Inland mode	Port/Customs	Mode	Port	Mode	Port	Mode
1	Nong Khai	BKK	Trailer	Hong Kong	Vessel	-		Qingdao	Mother vessel
2	Nong Khai	LCB	Trailer	Hong Kong	Vessel	-		Qingdao	Mother vessel
3	Nong Khai	Mukdahan border	Truck	Lao Bao border (Laos-Vietnam)	Truck (R9)	Da Nang	Truck (1A)	Qingdao	Mother vessel
4	Nong Khai	Nakhon Phanom border	Truck	Lao Bao border (Laos-Vietnam)	Truck (R9)	Da Nang	Truck (1A)	Qingdao	Mother vessel
5	Nong Khai	Bueng Kan border	Truck	Lak Sao border (Laos-Vietnam)	Truck (13,R8)	Da Nang	Truck (1A)	Qingdao	Mother vessel

2.2 The Criteria for Route Selection

In making a mode and route selection is multi criteria decision making problem. Shippers should consider both quantitative and qualitative factors. Thus, factors that a shipper must evaluate for selecting the appropriate route are reviewed in this section.

Liberatore and Miller (1995) considered the modal and carrier choice decision facing a hypothetical firm. They applied an analytic hierarchy process (AHP) for transport carrier and mode selection. The question of the firm must now answer is: which one of the available air and ocean carriers should it select to ship its products from its plant to its logistics center?

They regarded that transport cost clearly represents an important factor and is one of the criteria selected. Cost represent the critical factors in determining the best transport alternative. In this research divides two main criteria such as “quantitative or cost related” and “qualitative or intangible”. For sub criteria under cost factors consist of freight costs, the inventory carrying costs of inventory in the pipeline, the inventory carrying costs of cycle stock at the receiving location (e.g. logistics center), the inventory carrying costs of the required safety stock at the receiving location, and the investment cost required to produce the inventory to fill the pipeline. For under the qualitative criteria consider with perceived quality of customer services, shipment tracking and tracing capabilities, billing/invoicing accuracy, electronic data interchange (EDI) capabilities, potential to develop mutually beneficial long-term regionnership, cargo capacity limitations, ability to provide service that does not damage goods while in transit, customs clearance capabilities (for international shipments), and impact on the shipper’s negotiating position/leverage on other shipping activities.

Pedersen and Gray (1998) found from early studies of transportation selection criteria that transport cost was the most important criterion. Thus, this paper seeks to determine whether this assumption holds in the context of Norway. They studied in categorization of carrier selection determinants and found that there is no common opinion of how exactly the selection determinants should be categorized. However, despite the different approaches, the consensus of most studies leads to the same direction. This direction suggests that an investigation of the criteria employed by shippers in the selection of transport should include the four factors namely timing; price; security; and service.

Then, they considered the importance of the four key factor categories. Among the timing factors, the carrier’s reliability in collection and delivery time is the most important factor. The evidence that a high transport frequency is regarded as more important than short transit time and directness of the transport route does not seem to have significant impact on the selection of carrier. A low freight rate was found to be clearly the most important price factor. Regarding security and control factors, low damage or frequency of loss and control over delivery time are clearly perceived as more important than the ability to monitor the goods in transit and knowledge of the port used. Among the service factors offered by carriers there is little distinction among the three highest ranked factors.

Banomyong *et al.* (2007) studied in logistics system for trading of Thailand-China to support ASEAN-China FTA in case of border trading. They analyzed the transportation routes that start from Thailand's cross border trade in the North to South China at Kunming and applied with analytic hierarchy process (AHP) for the appropriate transportation route selection. In this research, they considered both quantitative factors and qualitative factors. Seven factors are used in route selection namely length, transportation time, transportation cost, the quality of product, reliability and punctuality, customs procedure, and other factors.

The description of these factors as follows:

1) Length: the distance from origin to destination.
2) Transportation time: the time spent from origin to destination.
3) Transportation cost: the cost per unit including transportation cost, packaging cost, and customs changes.
4) The quality of product: the quality of export products at destination.
5) Reliability and punctuality: products exported to destination in time.
6) Customs procedure: the convenience of customs process for exporting.
7) Other factors: e.g. politic problem, international relationship problem.

Chang *et al.* (2008) identified the factors affecting shipping companies' port choice based on survey to a sample of shipping companies. After considering various important factors affect to liners' decision on port selection. 21 port choice items were developed from a critical literature review and a series of interviews targeting national and foreign container shipping lines. Port choice items consist of geographical location, water draft, feeder connection, inland intermodal connection, port reputation, port dues, terminal handling charge (THC), cargo volume, transshipment cargo volume, possibility of niche market, import and export cargo balance, cargo profitability, berth availability, service reliability, information technology ability, convenience of customs process, relationship between management and workers, acceptance of special requirements, easiness of communication with staff, calling of competitors, and slot exchange with cooperating lines. After evaluation by main haul service companies and feeder service companies, six variables show importance in port choice decision namely local cargo volume, terminal handling charge, berth availability, port location, transshipment volume, and feeder network. Moreover, the main haul shipping lines are more sensitive to port cost factors.

In the existing literature, there are many factors that must be considered for route selection in case of Thailand rubber export. In the majority of the surveyed literature, quantitative criteria and qualitative criteria can be categorized into three main criteria such as transportation factor, economic factor, and port or customs consideration. Under the main criteria, sub-criteria are contained. For more complete, these factors that found from literatures are primary constructed and then will be approved by logistics expert interviewing. In addition, some criteria which derive from experts' opinion are included within the criterion hierarchical structure.

2.3 Fuzzy Analytic Hierarchy Process (FAHP)

The Analytic Hierarchy Process (AHP) is a popular method for solving multi-criteria analysis problems involving qualitative data (Deng, 1999). The Analytic Hierarchy Process (AHP), developed by Saaty, is a decision making method for prioritizing alternatives when multiple criteria must be considered. This approach allows the decision maker to structure problems in the form of a hierarchy or a set of integrated levels, such as, the goal, the criteria, and the alternatives. The primary advantage of the AHP is its use of pair-wise comparisons to obtain a ratio scale of measurement (Liberatore and Nydick, 2008). AHP enables decision-makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in systematic manner under multiple conflicting criteria. AHP is a powerful decision analysis technique in the area of multi-criteria decision making (Lee, Mogi, and Kim, 2008).

The AHP is a tool that can be used for analyzing different kinds of social, political, economic and technological problems, and it uses both qualitative and quantitative variables. The fundamental principle of the analysis is the possibility of connecting information, based on knowledge, to make decisions or derived from the application of other tools. Among the different contexts in which the AHP can be applied, mention can be made of the creation of a list of priorities, the choice of the best policy, the optimal allocation of resources, the prevision of results and temporal dependencies, the assessment of risks and planning (Naghadehi *et al*., 2008).

The AHP is widely used for tackling multi-criteria decision-making problems in real situations. In spite of its popularity and simplicity in concept, this method is often criticized for its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of the decision-maker's perception to crisp values (Chou *et al.*, 2008).

However, the traditional AHP still cannot really reflect the human thinking style. The experiences and judgments of humans are represented by linguistic and vague patterns. Leung and Cao (2000) describe that within the AHP context, the decision maker cannot provide deterministic preferences but perception-based judgment interval instead. This kind of uncertainty in preferences can be modeled using fuzzy set theory. Likewise, Mikhailov and Singh (2003) describe in their study that the human decision maker is uncertain and it is relatively difficult for the decision maker to provide exact numerical values for the comparison ratios.

Kahraman *et al.* (2003) use fuzzy analytic hierarchy process (FAHP) to deal with the vagueness of human thinking. FAHP methodology is originally based on the concept of fuzzy set theory, introduced by Zadeh (1965). Analysis of hierarchical structures in fuzzy environment, initially proposed by Buckley (1985), who was examined expressions of decision makers regarding with the pair-wise comparisons while utilizing fuzzy ratios instead of crisp values (Celik *et al.*, 2007).

2.3.1 Main Stages of the AHP

The AHP divides the decision problem into the following main steps:

1) problem structuring
2) assessment of local priorities
3) calculation of global priorities

The AHP decision problem is structured hierarchically at different levels, each level consisting of a finite number of decision elements. The top level of the hierarchy represents the overall goal, while the lowest level is composed of all possible alternatives. One or more intermediate levels embody the decision criteria and sub-criteria.

The relative importance of the decision elements (weights of criteria and scores of alternatives) is assessed indirectly from comparison judgments during the second step of the decision process. The decision-maker is required to provide his/her preferences by comparing all criteria, sub-criteria and alternatives with respect to upper level decision elements. The value of the weights and scores are elicited from these comparisons and represented in a decision table.

The last step of the AHP aggregates all local priorities from the decision table by a simple weighted sum. The global priorities thus obtained are used for final ranking of the alternatives and selection of the best one (Mikhailov and Tsvetinov, 2004).

2.3.2 Fuzzy Sets and Fuzzy Numbers

To arrange with vagueness of human thought in decision making, Zadeh (1965) first introduced the fuzzy set theory, which was oriented to the rationality of uncertainty due to imprecision or vagueness. A major contribution of fuzzy set theory is its capability of representing vague data. The theory also allows mathematical operators and programming to apply to the fuzzy domain. A fuzzy set is a class of objects with a continuum of grades membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one. A tilde "~" will be placed above a symbol if the symbol represents a fuzzy set. A triangular fuzzy number (TFN), $\tilde{M}$, is shown in Figure 2.4. A TFN is denoted simply as $(l/m, m/u)$ or (l, m, u). The parameters l, m and u, respectively, denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event.

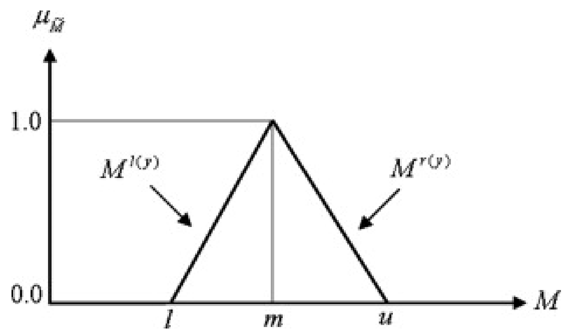


Figure 2.4 A triangular fuzzy number, $\tilde{M}$

Each TFN has linear representations on its left and right side such that its membership function can be defined as

$$\mu(x/\tilde{M}) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \le x \le m, \\ (u-x)/(u-m), & m \le x \le u, \\ 0, & x > u \end{cases} \tag{2.1}$$

A fuzzy number can always be given by its corresponding left and right representation of each degree of membership:

$$\tilde{M} = (M^{l(y)}, M^{r(y)}) = (l + (m-l)y, u + (m-u)y) \;, \qquad y \in [0,1], \tag{2.2}$$

where *l(y)* and *r(y)* denote the left side representation and the right side representation of a fuzzy number, respectively. Many ranking methods for fuzzy number have been developed in the literature. These methods may give different ranking results and most methods are tedious in graphic manipulation requiring complex mathematical calculation (Kahraman *et al.*, 2003).

The algebraic operations with fuzzy numbers in this section, three important operations used in this study are illustrated. Define two TFNs *A* and *B* by the triplets $A = (l_1, m_1, u_1)$ and $B = (l_2, m_2, u_2)$. Then

(i) Addition:

$$\begin{aligned} A + B &= (l_1, m_1, u_1) + (l_2, m_2, u_2) \\ &= (l_1 + l_2, m_1 + m_2, u_1 + u_2) \end{aligned}$$

(ii) Multiplication:

$$A \cdot B = (l_1, m_1, u_1) \cdot (l_2, m_2, u_2)$$
$$= (l_1 l_2, m_1 m_2, u_1 u_2)$$

(iii) Inverse:

$$(l_1, m_1, u_1)^{-1} \approx (1/u_1, 1/m_1, 1/l_1)$$

where ≈ represents approximately equal to.

2.3.3 Extent Analysis Method on FAHP

There are many FAHP methods and applications in the literature proposed by various authors. Chang (1996) introduced a new approach for handling FAHP, with the use of triangular fuzzy numbers for pair-wise comparison scale of FAHP, and the use of the extent analysis method for the synthetic extent values of the pair-wise comparisons. The proposed method with extent analysis is simple and easy for implementation to prioritize decision variables as compared with the conventional AHP. The steps of Chang's extent analysis method are easier than the other FAHP approaches. The reason for using a triangular fuzzy number is that it is intuitively easy for decision makers to use and calculate. In addition, modeling using triangular fuzzy numbers has proven to be an effective way for formulating decision problems where the information available is subjective and imprecise (Dağdeviren and Yüksel, 2008).

In this study the extent FAHP is utilized, which was originally introduced by Chang (1996). Let $X = \{x_1, x_2, x_3, ..., x_n\}$ an object set, and $G = \{g_1, g_2, g_3, ..., g_n\}$ be a goal set. According to the method of Chang's extent analysis, each object is taken and extent analysis for each goal performed respectively. Therefore, *m* extent analysis values for each object can be obtained, with the following signs:

$$M^1{}_{gi}, M^2{}_{gi}, ...M^m{}_{gi,} \qquad i = 1,2,....,n\,,$$

where M_{gi}^j *(j = 1, 2, ...,m)* all are triangular fuzzy numbers. The steps of Chang's extent analysis can be given as follows:

Step 1: The value of fuzzy synthetic extent with respect to the *i* th object is defined as

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \tag{2.3}$$

To obtain $\sum_{j=1}^{m} M_{gi}^{j}$, perform the fuzzy addition operation of *m* extent analysis values for a regionicular matrix such that:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{2.4}$$

and to obtain $\left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$, perform the fuzzy addition operation of M_{gi}^{j} *(j = 1, 2, ...,m)* values such that

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \tag{2.5}$$

and then compute the inverse of the vector above, such that:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \tag{2.6}$$

Step 2: As $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ defined as:

$$V\left(\tilde{M}_2 \geq \tilde{M}_1\right) = \sup_{y \geq x} \left[\min\left(\mu_{\tilde{M}_1}(x), \mu_{\tilde{M}_2}(y) \right) \right] \tag{2.7}$$

and can be equivalently expressed as follows:

$$V\left(\tilde{M}_2 \geq \tilde{M}_1\right) = hgt(\tilde{M}_1 \cap \tilde{M}_2) = \mu_{M_2}(d) \tag{2.8}$$

$$= \begin{cases} 1 & if \quad m_2 \geq m_1 \\ 0 & if \quad l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise \end{cases} \tag{2.9}$$

Figure 2.5 illustrates Eq. (2.9) where d is the ordinate of the highest intersection point D between μ_{M1} and μ_{M1} to compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

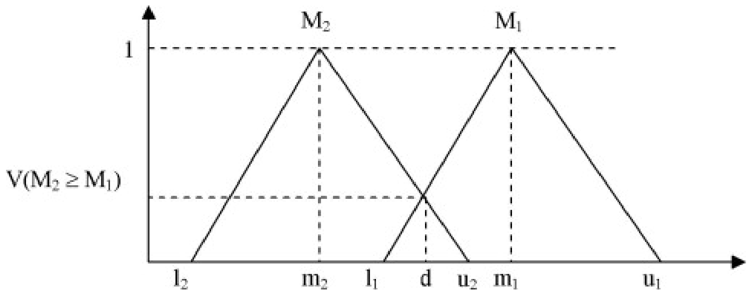


Figure 2.5 The intersection between M_1 and M_2

Step 3: The degree possibility for a convex fuzzy number to be greater than *k* convex fuzzy M_i (i=1, 2, k) numbers can be defined by

$$V(M \geq M_1, M_2, ...M_k) = V\left[(M \geq M_1) \ \ and \ \ (M \geq M_2) \ \ and....and \ \ (M \geq M_k)\right]$$
$$= \min \ V(M \geq M_i), \ \ i = 1,2,3,....,k \tag{2.10}$$

Assume that $d(A_i) = \min V(S_i \geq S_k)$ for $k = 1,2,....,n; k \neq i$. Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), ..., d'(A_n)) \tag{2.11}$$

where $A_i = (i = 1,2,...n)$ are *n* elements.

Step 4: Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), ..., d(A_n))^T \tag{2.12}$$

where W is a non-fuzzy number.

After the criteria and sub-criteria have been determined, a question form has been prepared to determine the importance levels of these criteria and sub-criteria. To evaluate the questions, people only select the related linguistic variable, than for calculations they are converted into the following scale including triangular fuzzy numbers and generalized for such analysis as given in Table 2.8. This scale is proposed by Kahraman *et al.* (2003) and used for solving fuzzy decision making problems.

Table 2.8 Triangular importance scale

Linguistic scale	**Triangular fuzzy scale**	**Triangular fuzzy reciprocal scale**
Equal	(1,1,1)	(1,1,1)
Weak	(2/3,1,3/2)	(2/3,1,3/2)
Fairly strong	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strong	(5/2,3,7/2)	(2/7,1/3,2/5)
Absolute	(7/2,4,9/2)	(2/9,1/4,2/7)

Source: Kahraman *et al.* (2003)

2.3.4 Geometric Mean Method

The proposed methods can also be employed when there is a group of decision makers. An average of the estimation carried out by each expert for the pair-wise comparison. In order to calculate the elements of the global pair-wise comparison matrix, it is not appropriate to use the arithmetic mean. To solve the problem, we have to use the geometric mean instead of the arithmetic one.

An example could be useful to clarify the problem. The generic element of the pair-wise comparison matrix A= [a_{ij}] is considered. Suppose that n different experts give an evaluation of this generic value. Donate e_{ijk} the judgement of the generic k^{th} expert we can write that $e_{ijk} = 1/e_{jik}$.

Using the arithmetic mean the value of a_{ij} and of a_{ji} are given by the formulas:

$$a_{ij} = \left(\sum_{k=1}^{n} e_{ijk}\right) \Big/ n \qquad a_{ji} = \left(\sum_{k=1}^{n} 1/e_{ijk}\right) \Big/ n \tag{2.13}$$

it is easy to demonstrate that if the expert's judgments are not all identical then $a_{ij} \neq 1/a_{ji}$.

If we use the geometric mean we have:

$$a_{ij} = \left(\prod_{k=1}^{n} e_{ijk}\right)^{(1/n)} \qquad a_{ji} = \left(\prod_{k=1}^{n} 1/e_{ijk}\right)^{(1/n)} \tag{2.14}$$

and on the consequence

$$a_{ij} = 1/a_{ji}$$

The ranking is the same either if the weights are evaluated after the judgment mean or the weights are derived by the judgment of each expert and after the mean (Enea and Piazza, 2004).

2.4 Related Researches

There are many FAHP methods proposed by various authors. These methods are systematic approaches to the alternative selection and justification problem by using the concepts of fuzzy set theory and hierarchical structure analysis. Decision makers usually find that it is more confident to give interval judgments than fixed value judgments. This is because usually he/she is unable to explicit about his/her preferences due to the fuzzy nature of the comparison process.

Chang (1996) introduces a new approach for handling FAHP, with the use of triangular fuzzy numbers for pair-wise comparison scale of FAHP, and the use of the extent analysis method for the synthetic extent values of the pair-wise comparisons. In 1999, this method was discussed on extent analysis method and applications of fuzzy AHP by Zhu, Jing and Chang. They prove the basic theory of the triangular fuzzy number and improve the formulation of comparing the triangular fuzzy number's size.

Chang's extent analysis method is simple and easy for prioritize decision variables. There are many research papers applied the Chang's extent analysis method for evaluate multi criteria decision making problem. The related research papers that used Chang's extent analysis method are reviewed as follows:

Kahraman *et al.* (2003) proposed FAHP to select the best supplier firm providing the most satisfaction for the criteria determined. The purchasing managers of a white good manufacturer established in Turkey were interviewed and the most important criteria taken into account by the managers while they were selecting their supplier firms were determined by a questionnaire. The FAHP was used to compare these supplier firms, with the use of triangular fuzzy numbers for pair-wise comparison scale of FAHP.

Enea and Piazza (2004) selected a project among a set of possible alternatives based upon a fuzzy extension of the AHP. The selection of project is a difficult task decision makers have to face. Difficulties in selecting a project arise because of the different goals involved and because of the large number of attributes to consider. They focus on the constraints that have to be considered within fuzzy AHP in order to take in account all the available information.

Dağdeviren and Yüksel (2008) developed a fuzzy analytic hierarchy process model for behavior-based safety management. Safety management is a very important element within an effective manufacturing organization. One of the most important components of safety management is to maintain the safety of work systems in the workplace. Safety of work systems is a function of many factors which affect the system, and these factors affect the safety of work systems simultaneously. For this reason, measuring work system safety needs a holistic approach. In this study, the work safety issue is studied through the Analytic Hierarchy Process approach which allows both multi-criteria and simultaneous evaluation. Another limitation faced in safety management is the inability to measure the variables exactly and objectively. Generally, the factors affecting work system safety have non-physical structures. Therefore, the real problem can be represented in a better way by using fuzzy number instead of numbers to evaluate these factors. In this study, a fuzzy AHP approach is proposed to determine the level of faulty behavior risk in work systems. In application, factors causing faulty behavior are weighted with triangular fuzzy numbers in pair-wise comparisons. These factors are evaluated based on the work system by using these weights and fuzzy linguistic variables. As a result of this evaluation faulty behavior risk levels of work systems are determined and different studies are planned for work systems according to the faulty behavior risk levels.

Celik *et al.* (2009) evaluated shipping registry alternative using FAHP for the existing fleet or new building ships is one of the critical decision milestones of the shipping business. The main aim of this paper is to structure a practical decision support mechanism on ensuring multiple criteria analysis of shipping registry selection. FAHP methodology, based on Chang's extent analysis, is determined to be utilized in order to model the shipping registry selection. After structuring the fundamental hierarchy, the model is performed with a case application on Turkish maritime industry to be able to obtain illustrative results. The shipping registries of Turkey, Panama, and Malta are determined to evaluate as the potential alternatives for Turkish ship owners. When the literature was examined for the applications of analytical methodologies on maritime business, it was seemed that they were so rare. Therefore, the originality of this study appears on modeling of the critical process under multidisciplinary philosophy in ship management.

Cheong *et al.* (2008) designed and developed a fuzzy multi criteria decision making (MCDM) tool that equipped with Analytic Hierarchy Process (AHP) framework to help user in semi-structured and unstructured decision making task. The tool provides portability and adaptability features by deploying the software on web platform. In addition, this system provides an integrated domain reference channel via a database connection to assist the user obtains relevant information regarding the problem domain before constructing the AHP hierarchy attributes. Their decision making tool combines the characteristics of real time information retrieval through internet and MCDM problem analytical processing logic.

The problem formulation process involves the goal, criteria and alternatives (three level hierarchy) as indicates in Figure 2.6.

Figure 2.6 Main page for defining the goal

When the user has a clear picture in mind regarding the problem, one can start by inserting the values for each level in the main page. Else, the system provides the Domain Information Repository (DIR) and Google Search to assist the user in problem determination (Figure 2.7).

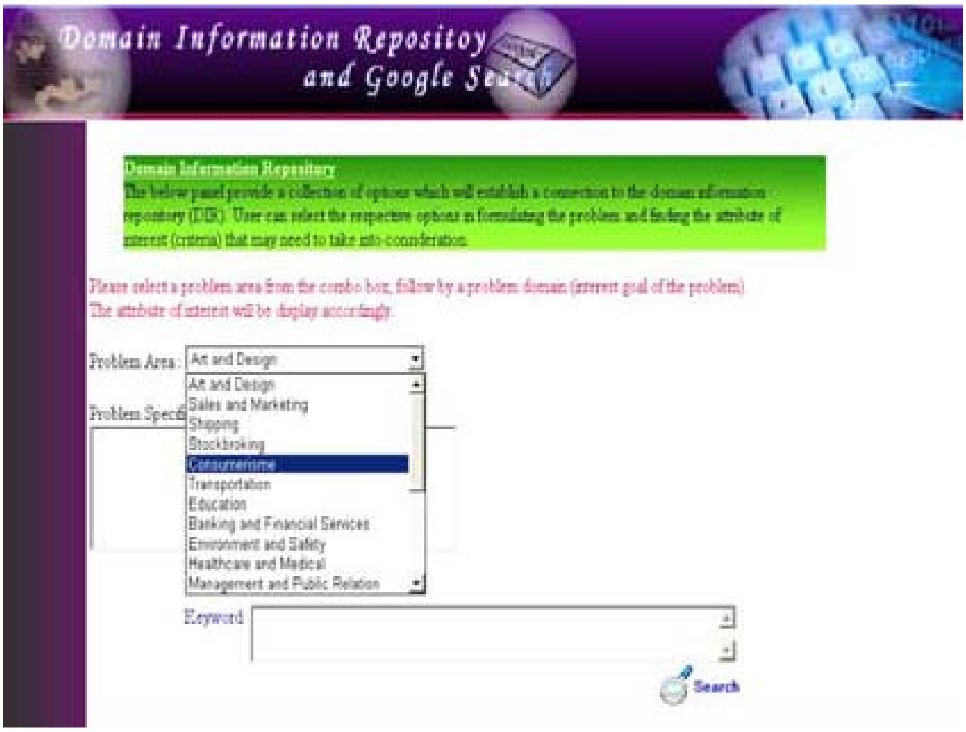


Figure 2.7 Domain Information Repository (DIR) and Google Search

After the problem formulation (goal, criteria and alternatives), the system moves to the state of accepting pair-wise judgment from the user. The scoring scale is according to the Saaty's original scale. Before viewing the result of the AHP operation, user can select Consistency Check button to check whether the evaluations are consistent. If the evaluation is inconsistent, the system will alert the user to redefine the pair-wise comparison. Finally, the results can be indicated (Figure 2.8)

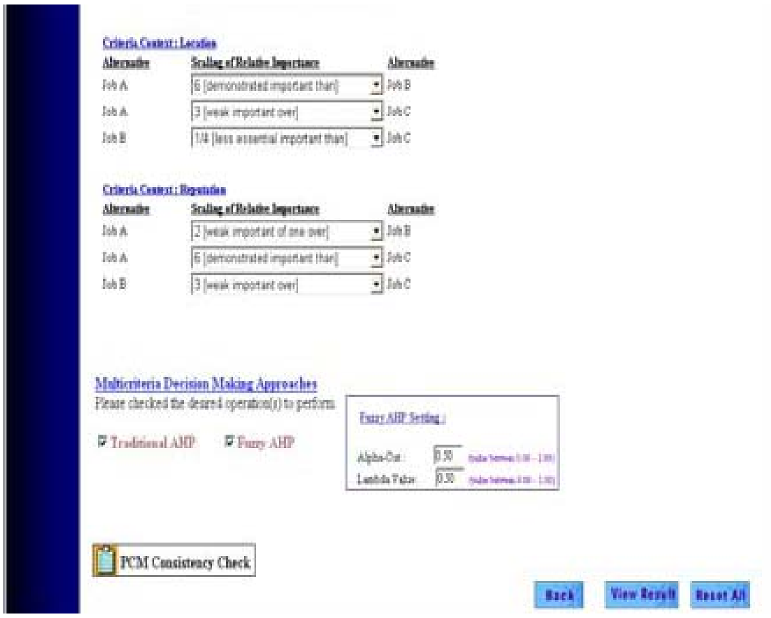


Figure 2.8 The interface for pair-wise comparing relative importance of criteria

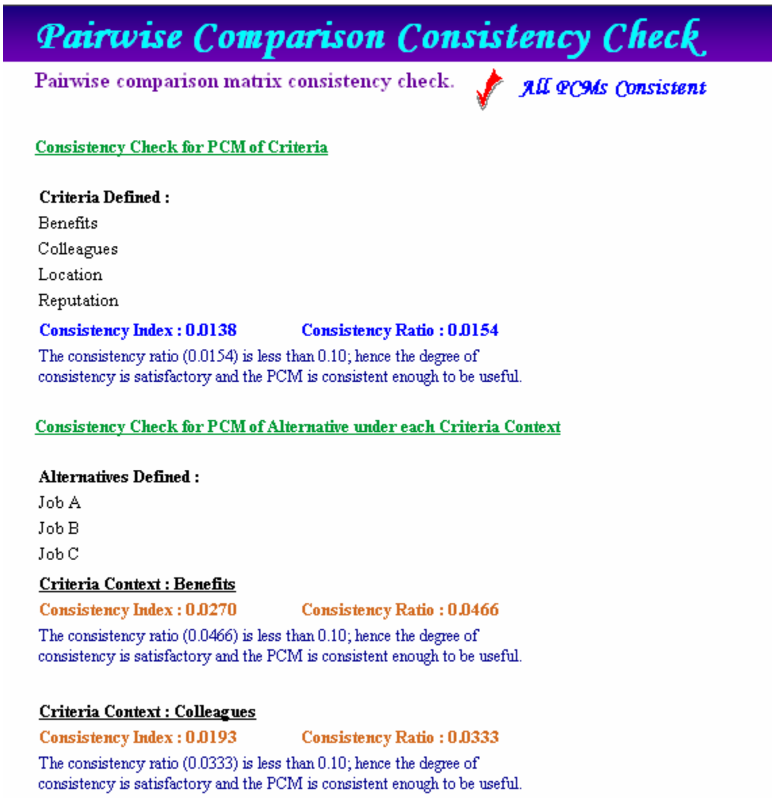


Figure 2.9 Pair-wise Comparison Consistency Check

This program achieves simplicity and abstraction with FAHP algorithm that works behind the scene. The web based feature enhances the accessibility and portability of this tool.

Saiko (2009) describes the main problem concerned with using expert assessment method in consumer preference researches. This research proved the expediency of using a 3-point measurement scale (see Figure 2.10).

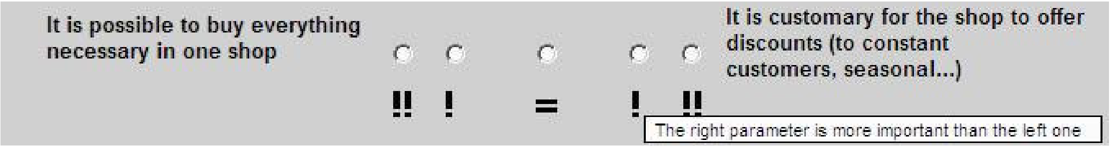


Figure 2.10 Interface fragment of the paired comparison software

The author suggested an algorithm for controlling the judgments' consistency that includes analyzing and correcting the input estimates in real-time mode. The developed software (VBA, Excel) is currently used in teaching process.

From Literature survey focuses on FAHP can be assured that FAHP can use to evaluate on the route selection problem in case study of Thailand rubber export. FAHP method is more appropriate than the traditional AHP because this method can deal with the vagueness of human thinking. Many researches above evaluated multi-criteria decision making problem by using pair-wise comparison questionnaire. In pair-wise comparison step, assessor who uses the questionnaire is an expert in related fields. Moreover, some researches applied FAHP model for developing a decision support system within pattern of web-based application or stand-alone application. Assessor can evaluate the multi-criteria decision making problem via a decision support system instead of the questionnaire. From these related researches, researcher can use to the direction for studying in this research.

2.5 Summary

The surveyed literature in section of Thailand rubber supply chain give an information about current situation in the chain. From an existing literature, research area can be selected and some flows of rubber products export of each area can be obtained. Next, the criteria for route selection problem were reviewed. There are many criteria must be considered for route selection. In the decision making should be considered both qualitative and quantitative criteria. Hence, route selection problem is multi-criteria decision making problem. From the related research, the majority factors that shippers must be considered can be categorized into three main factors namely transportation factor, economic factor, and port or customs consideration. After that the criteria will be addition studied for more complete and used it in the decision making. Then, the appropriate methodology for evaluating the multi-criteria decision making problem was studied. Mostly, multi-criteria decision making problem are evaluated by using the Analytic Hierarchy Process (AHP). AHP enables decision-makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors. However Leang and Cao (2000) and Mikhailov and Singh (2003) depicted that the traditional AHP still cannot really reflect the human thinking style. Fuzzy Analytic Hierarchy Process (FAHP) methodology is based on the concept of the fuzzy set theory can use to deal with the vagueness of human thinking and this method suggested by Kahraman *et al.* (2003). Consequently, FAHP researches are reviewed for assuring that FAHP method can be used to evaluate route selection problem in case of Thailand rubber export. Moreover, the researches about decision support systems that apply FAHP method are searched for using as a direction to design and develop the system.

CHAPTER III
RESEARCH METHODOLOGY

This chapter reviews the research study area selection data sources and collection. The conceptual framework of methodology is described.

3.1 Research Study Area Selection

As reviewed in the previous chapter, the research objective is to study the appropriate route selection for Thailand rubber export. Study areas were selected by amount of rubber planting area and rubber manufacturers. From literature survey, this study could be divided rubber planting areas and rubber manufacturers to three regions of Thailand consisted of the Southern, Eastern and Northeastern regions. The main areas were selected to the origins of case study.

In the South of Thailand, the planting area divided in to the Upper and Lower Southern. Surat Thani and Nakhon Si Thammarat provinces are the center of the Upper South of Thailand. Songkhla province is the center of the Lower South. Rayong province is major rubber planting area in the Eastern region. For the Northeastern region where is new rubber planting area, Nong Khai province is center of rubber planting and manufacturing.

Mostly, Thailand natural rubbers are shipped to China through Shanghai and Qingdao ports. Qingdao is the largest commercial port in Shandong province and is also a hub port for international trade. The port links to highway network which connects to all parts of Shandong province and beyond. Thus, this study selected Qingdao port as the representative destination for Thailand rubber export to Eastern China.

The structure of research study area is illustrated in Figure 3.1.

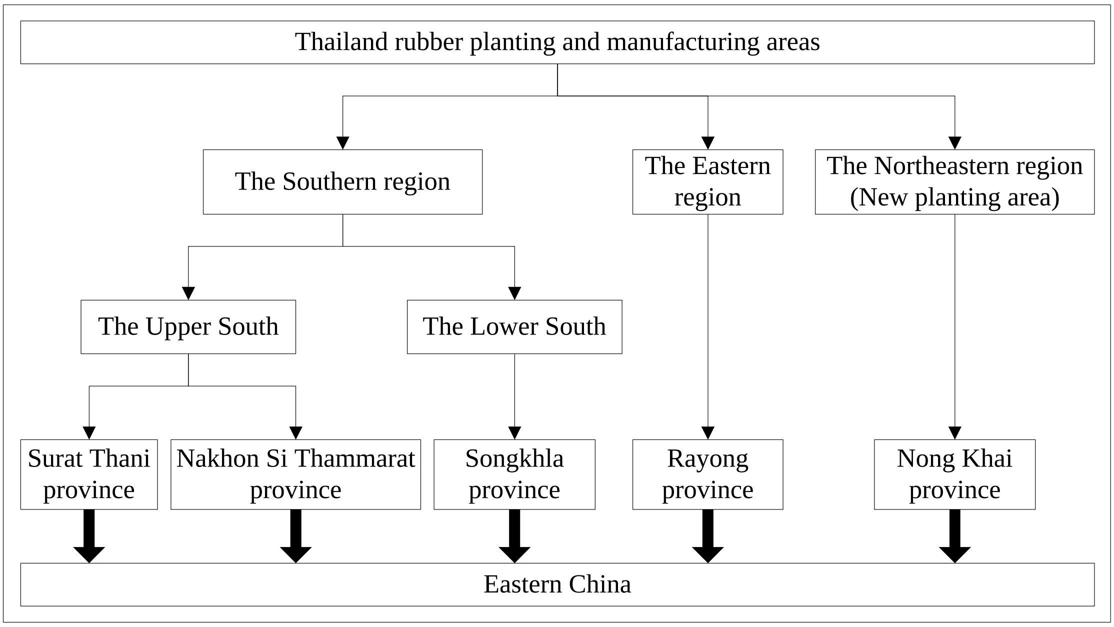


Figure 3.1 The structure of research study area

3.2 Data Sources and Collection

The study gathers literature on different research opinions regarding the transport selection. The study also collects Thailand rubber supply chain facts. There are two types of data (information) sources as primary and secondary data.

For primary data, it is collected specifically for the research project. These are based on the observations (fieldworks) and interviews. Furthermore, the existing research, internet sources, and other references are reviewed to secondary information.

3.3 Methodology

In this section, research methodology will be presented. The proposed system consists of main steps as follows:

3.3.1 Review the Related Information about Thailand Rubber Exports

This study presents a case of rubber supply chain in Thailand. The structure of Thailand rubber supply chain is reviewed by literatures and fieldwork. The main rubber planting areas in Thailand include new areas are selected. All available alternative routes for rubber exporting in each area are studied. The destination country where Thailand rubber exports mostly can be received in this stage.

3.3.2 Identify the Criteria and Sub-Criteria

The main criteria adopted in this study are based on reviewing relevant literature and opinions from logistics experts. The criteria and sub-criteria used to evaluate the appropriate route for Thailand rubber export are determined in this step.

3.3.3 Structure the Decision Model

Many criteria can be utilized in the alternative selection problem. The AHP model formed by the criteria and sub-criteria determined in 3.3.2. AHP model is structured by objective in the first level, criteria in the second level, and sub-criteria in the third level. The final level represents the alternate choices of the feasible gateways. Figure 3.3 presents hierarchical structure of the decision problem.

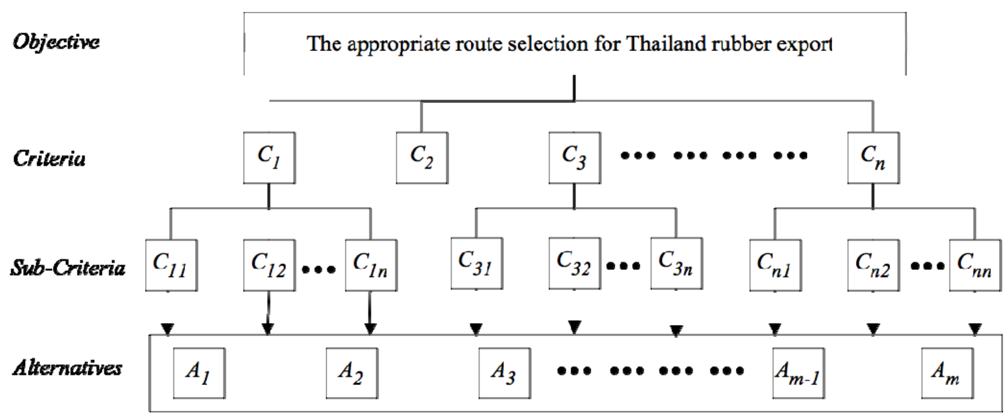


Figure 3.2 The hierarchical structure of the decision problem

3.3.4 Determine Criteria and Sub-Criteria Weights

In this step, local weights of the criteria and sub-criteria which take part in the second and third level of AHP model are calculated.

3.3.4.1 Pair-wise Comparison Matrix

Pair-wise comparisons matrices are formed by the expert team. Group of experts in this study are presented in Table 3.1.

Table 3.1 Group of experts for criteria and sub-criteria evaluation

Groups of experts	**Number of experts**
Logistics and transportation academic	5
Thai Logistics Alliance (TLA)	2
Transportation Institute, Chulalongkorn University	1
Office of Transport and Traffic Policy and Planning (OTP), Ministry of Transportation, Thailand	1
Office of the National Economic and Social Development Board (NESDB), Thailand	1
Total	**10**

Table 3.1 shows groups of logistics experts. These experts evaluate relative importance of criteria and sub-criteria by using questionnaire. Expert team is logistics and transportation academic and other relevant organizations. Group of experts are as follows:

Logistics and transportation academic

- Asst. Prof. Dr. Aat Pisanwanich: He is a Lecturer in Department of Economics and Director of Center for International Trade Studies at University of the Thai Chamber of Commerce.
- Asst. Prof. Thananya Wasusri: She is currently Lecturer in Logistics Management Program of Graduate School of Management and Innovation (GMI) at King Mongkut's University of Technology Thonburi (KMUTT).
- Assoc. Prof. Duangpun Kritchanchai Singkarin: she is currently serving in Department of Industrial Engineering and Director of the Centre of Logistics

Management at Mahidol University. Moreover, she is holding the position of Coordinating Chair of Logistics Research Group at Thailand Research Fund (TRF).

- Asst. Prof. Dr. Somchai Pathomsiri: he is Lecturer in Department of Civil Engineering and Director of Transportation, Traffic and Logistics Expert Center (T-LEX Center) at Mahidol University.
- Assoc. Prof. Padermsak Jarayabhand: he is a Lecturer in Department of Marine Science and Director of Aquatic Resources Research Institute at Chulalongkorn University.

Thai Logistics Alliance (TLA)

- Mr. Chumpol Saichuer: he is Chairman of Thai Logistics Alliance (TLA) and Committee of The Transportation Association.
- Mr. Arnuwatr Ramyaprayoon: he is General Manager of Thai Logistics Alliance (TLA).

Transportation Institute, Chulalongkorn University

- Mrs. Sumalee Sukdanon: she is Researcher (level 7) in Transportation Institute at Chulalongkorn University.

Office of the National Economic and Social Development Board (NESDB)

- Mr. Suriyon Tunkijjanukip: he is Plan and Policy Analyst (Senior Professional Level) of Office of the National Economic and Social Development Board.

Office of Transport and Traffic Policy and Planning (OTP), Ministry of Transportation

- Dr. Chula Sukmanop: he is Deputy Director-General at Office of Transport and Traffic Policy and Planning (OTP), Ministry of Transportation.

Experts use the scale given in Table 3.2 to pair-wise comparison of criteria. Expert’s opinions are described by linguistic term in the questionnaires.

Table 3.2 Triangular fuzzy scales

Linguistic scale	**Triangular fuzzy scale**	**Triangular fuzzy reciprocal scale**
Equal	(1,1,1)	(1,1,1)
Weak	(2/3,1,3/2)	(2/3,1,3/2)
Fairly strong	(3/2,2,5/2)	(2/5,1/2,2/3)
Very strong	(5/2,3,7/2)	(2/7,1/3,2/5)
Absolute	(7/2,4,9/2)	(2/9,1/4,2/7)

Source: Kahraman *et al.* (2003)

The responses collected from the questionnaire are transformed to triangular fuzzy scale and input to the fuzzy AHP model. The pair-wise comparison matrix is represented in Table 3.3.

Table 3.3 Representation of pair-wise comparison matrix

	C_1	C_2	C_3	C_4
C_1	*(1,1,1)*	(l_{12}, m_{12}, u_{12})	(l_{13}, m_{13}, u_{13})	(l_{14}, m_{14}, u_{14})
C_2		*(1,1,1)*	(l_{23}, m_{23}, u_{23})	(l_{24}, m_{24}, u_{24})
C_3			*(1,1,1)*	(l_{34}, m_{34}, u_{34})
C_4				*(1,1,1)*

3.3.4.2 Calculation in Fuzzy AHP

The value of fuzzy synthetic with respect to criteria and sub-criteria object is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \tag{3.1}$$

The scores are calculated by geometric mean method.

$$a_{ij} = \left(\prod_{k=1}^{n} e_{ijk} \right)^{(1/n)} \qquad a_{ji} = \left(\prod_{k=1}^{n} 1/e_{ijk} \right)^{(1/n)} \tag{3.2}$$

As $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ defined as:

$$V\left(\tilde{M}_2 \geq \tilde{M}_1\right) = \begin{cases} 1 & if\ m_2 \geq m_1 \\ 0 & if\ l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases} \tag{3.3}$$

To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$. Then assume that $d(A_i) = \min V(S_i \geq S_k)$ for $k = 1,2,....,n; k \neq i$. The weight vector is given by

$$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T \tag{3.4}$$

Finally, the normalized weight vectors can be determined by

$$W = (d(A_1), d(A_2), ..., d(A_n))^T \tag{3.5}$$

3.3.5 Calculate Global Weights of Sub-Criteria

Using local weights of the criteria and sub-criteria, global weights for the sub-criteria are calculated in this step. Global sub-criteria weights are computed by multiplying local weight of the sub-criteria with the local weights of the criteria in which it belongs.

3.3.6 Evaluate the Appropriate Route for Thailand Rubber Exports

In this stage, the alternatives in each origin will be evaluated by the experts again with respect to sub-criteria and criteria weights identified from 3.3.5. Then the score of each alternative will be calculated with the criteria weights. The appropriate alternative route of each origin for Thailand rubber export is determined through the proposed FAHP model by using the global weights of sub-criteria and the linguistic measurement scale.

3.4 Decision Support System

A decision support system utilized FAHP to handle decision-making based on Chang's extent analysis (Chang, 1996). Within the system, one user can define the problem as a hierarchical structure of alternatives. The priority weights of criteria and sub-criteria are evaluated by group of logistics experts by using research questionnaires. Geometric means of weights based on the group of experts are combined in the system.

A decision support system has been developed in Microsoft Office Excel 2007. The calculations and graphics are programmed in Visual Basic Application (VBA).

CHAPTER IV
RESULT

In this chapter, the criteria found from the literature survey and expert interviewing are categorized and the hierarchical structure of criteria and sub-criteria can be structured in section 4.1. Section 4.2 shows in the detail of routes for Thailand rubber export in each origin. Next in section 4.3, the hierarchical framework for a decision support system can be structured. Then, the weight of criteria by group of experts in field of transportation and logistics evaluation are shown in section 4.4. In section 4.5, the framework is applied to develop a decision support system. The application is presented in section 4.6.

4.1 The Hierarchical Structure of Criteria and Sub-Criteria

The first step in developing the Analytic Hierarchy Process (AHP) is to identify and then define those factors that will be included as criteria. The main criteria adopted in this study are based on reviewing relevant literature and opinions from a group of logistics experts. The studies reviewed in the literatures found that transportation factor is one of the most important criterions. Perdersen and Gray (1998) believed that the transportation factors should cover timing, price, security/control, quality of route, and service. The quality of route includes frequency, capacity, convenience, directness, and flexibility. Security factor means safe arrival of the goods at the destination point. Service factor refers to delays, reliability and urgency, damage avoidance, loss and theft, fast response to any problems, co-operation with the carrier, and traceability.

A more recent work by Banomyong *et al.* (2007) categorized the factors that influence the choices of route for Thailand-China border trade. These are cost, transportation length, transportation time, security of product, reliability and urgency, and customs procedure. Celik *et al.* (2009) proposed three main categories of shipping registry selection, namely economic factors, political considerations, and social factors.

Comments by experts stated that rules of international trade and insurance policy are important factors in case of international trade. Also quality of route is one factor that influences transport alternatives. For port considerations, the selection should include facilitation equipment and capacity. Accessibility to the port is also important.

Based on literature survey and experts' opinion, four main criteria are proposed for selecting alternative routes. These are transportation factor, economic factor, port/customs consideration, and environment consideration. These criteria were approved by experts and summarized in Figure 4.1.

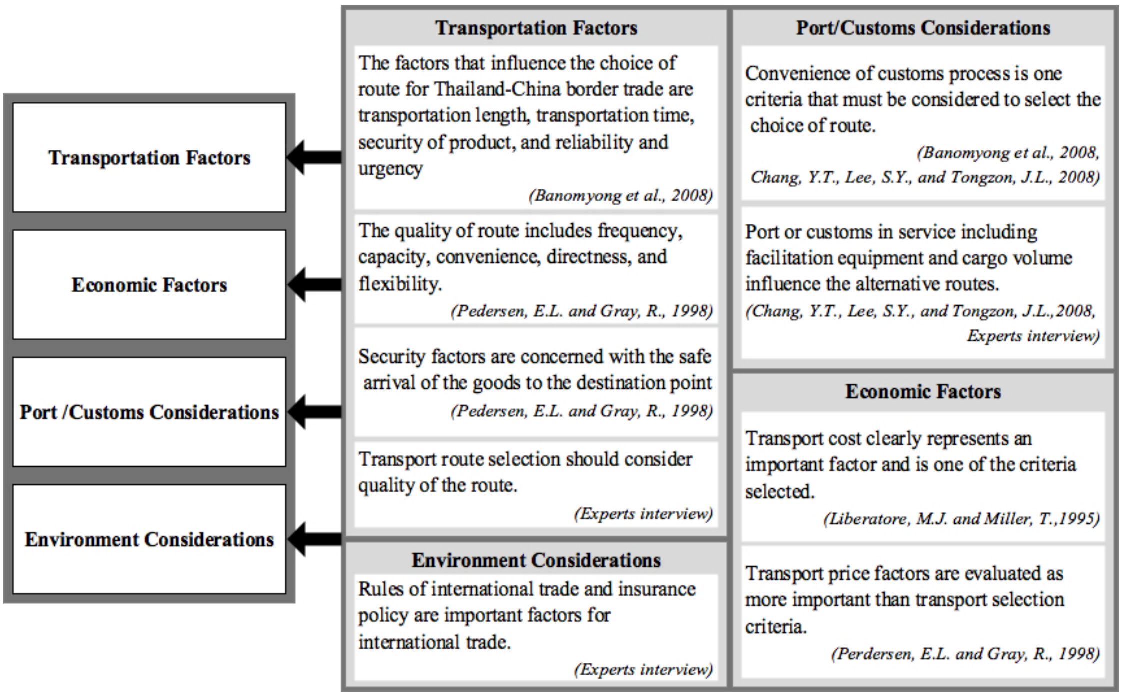


Figure 4.1 The development of criteria for Thailand rubber export route selection

Table 4.1 shows the development of these criteria for Thailand rubber export route selection.

Table 4.1 Criteria and sub-criteria for Thailand rubber export route selection

Criteria		**Sources**
Transportation factors	C_1	
Length	C_{11}	Banomyong *et al*. (2007)
Transportation time	C_{12}	Banomyong *et al*. (2007), Pedersen and Gray (1998)
Route quality	C_{13}	Pedersen and Gray (1998) and experts
Security of products	C_{14}	Banomyong *et al*. (2007), Pedersen and Gray (1998)
Reliability and punctuality	C_{15}	Banomyong *et al*. (2007)
Economic factor	C_2	
Logistics cost	C_{21}	Banomyong *et al*. (2007), Liberatore and Miller (1995), Pedersen and Gray (1998), Celik, Er, and Ozok (2009)
port/customs considerations	C_3	
Facilitation equipment	C_{31}	Chang, Lee, and Tongzon (2008) and experts
Capacity	C_{32}	Chang, Lee, and Tongzon (2008) and experts
Customs procedure	C_{33}	Banomyong *et al*. (2007), Chang, Lee, and Tongzon (2008)
Accessibility	C_{34}	Chang, Lee, and Tongzon (2008) and experts
Environment considerations	C_4	
Rules of international trade	C_{41}	Experts
Insurance Policy	C_{42}	Experts

From the literature survey, sub-criteria under the transportation factors are proposed as follows: length, transportation time, route quality, security of products, and reliability and punctuality. Logistics cost is the economic factor including transportation cost, packaging cost, and customs charges. Under the port/customs considerations factor, sub-criteria include facilitation equipment, capacity, custom procedure, and accessibility. Rules of international trade and insurance policy are the sub-criteria within the environment considerations.

The definitions of sub-criteria are described in Table 4.2.

Table 4.2 Definitions of sub-criteria

Criteria	**Sub-criteria**	**Definition**
Transportation factors	Length	The distance from origin to gateway
	Transportation time	The time spent from origin to destination
	Route quality	The quality of route from origin to destination
	Security of products	The quality of export products at destination
	Reliability and punctuality	Products exported to destination in time
Economic factor	Logistics cost	The logistics cost per unit including transportation cost, packaging cost, and customs changes.
port/customs considerations	Facilitation equipment	The facilitation equipment for service supporting at port or customs
	Capacity	The capacity of port or customs that can support volume of products required
	Customs procedure	The convenience of customs process for exporting
	Accessibility	The ability to access by inland transportation to port or customs
Environment considerations	Rules of international trade	Law and rules of international transportation that facilitate the logistics flow
	Insurance Policy	The availability of insurance agreement

The criteria and sub-criteria above can be constructed to the hierarchical structure. The hierarchy of criteria for Thailand rubber export route selection is illustrated in Figure 4.2.

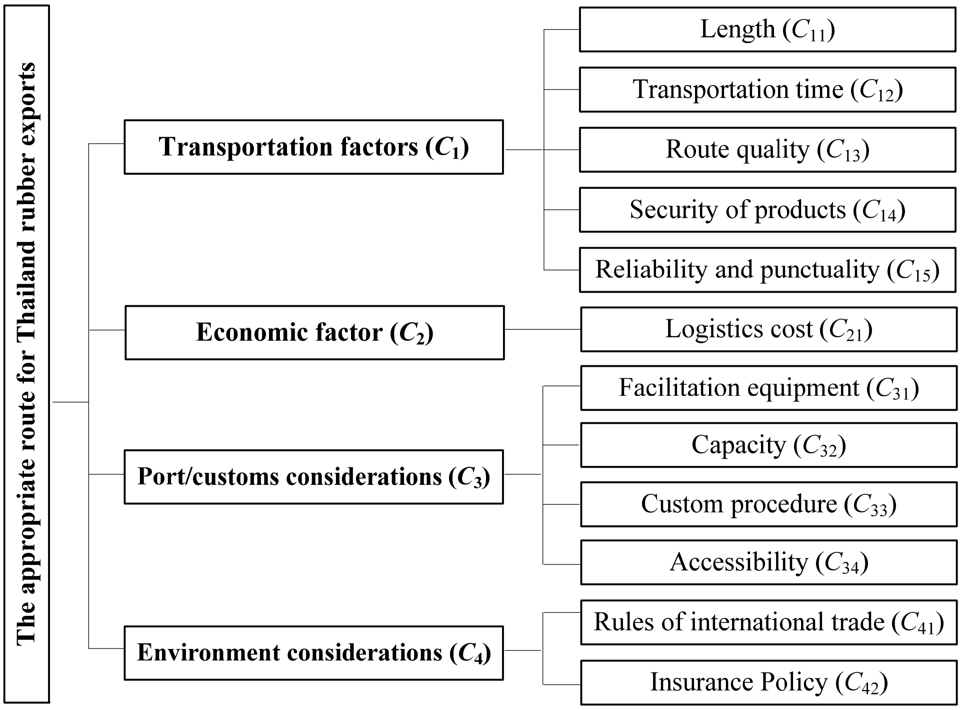


Figure 4.2 The structure of criteria and sub-criteria

From Figure 4.2 shows the structure of criteria and sub-criteria. First level of the hierarchy is the objective of decision analysis. Here, the appropriate route for Thailand rubber export will be received. That is the objective for decision-making problem in this study. Next, second and third levels of hierarchy are main criteria and sub-criteria respectively.

4.2 Routes for Thailand Rubber Export

From the literature survey, study areas for this research were selected based on amount of rubber planted and manufactured. This study can divide into four regions of Thailand namely the Upper and Lower Southern, Eastern, and Northeastern regions (new planting area). Five main areas were selected to be the origins of case study for the decision support system as follows: Nakhon Si Thammarat, Surat Thani, Songkhla, Rayong, and Nong Khai provinces.

The alternative routes were determined based on the logistics flow of rubber in Thailand from origins to destinations. This research considered the routes with mode of transportation. For this research, the destination here is Eastern China which imports natural rubber products from Thailand with the highest quantities.

4.2.1 Alternative Routes for Surat Thani Province

Surat Thani province can export rubber products to Eastern China via three gateways namely Bangkok port, Laem Chabang port, and Padang Besar border (Khompatraporn *et al.*, 2009). The detail of transportation routes of rubber products from Surat Thani province to Eastern China are as follows:

4.2.1.1 Bangkok Port

From Surat Thani province, shipper can access Bangkok port by truck, trailer, or train. Then, Thailand rubber products are exported via Bangkok port and transit to mother vessel at Hong Kong port. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Surat Thani province to Eastern China via Bangkok port is illustrated in Figure 4.3.

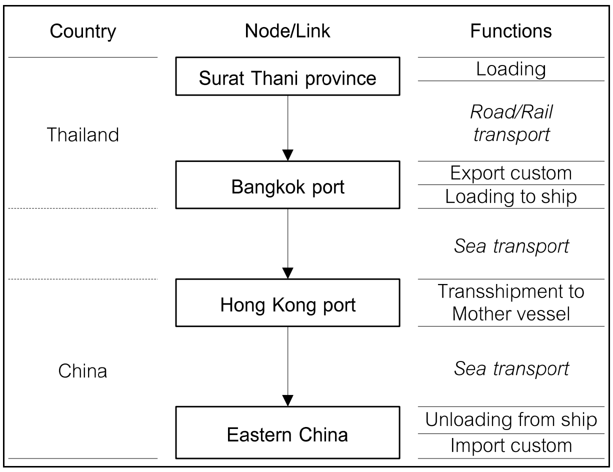


Figure 4.3 A transportation route of rubber products from Surat Thani province to Eastern China via Bangkok port

4.2.1.2 Laem Chabang Port

From Surat Thani province, shipper can access Laem Chabang port by truck, trailer, train, or vessel. Then, Thailand rubber products are exported via Laem Chabang port and transit to mother vessel at Hong Kong port. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Surat Thani province to Eastern China via Laem Chabang port is illustrated in Figure 4.4.

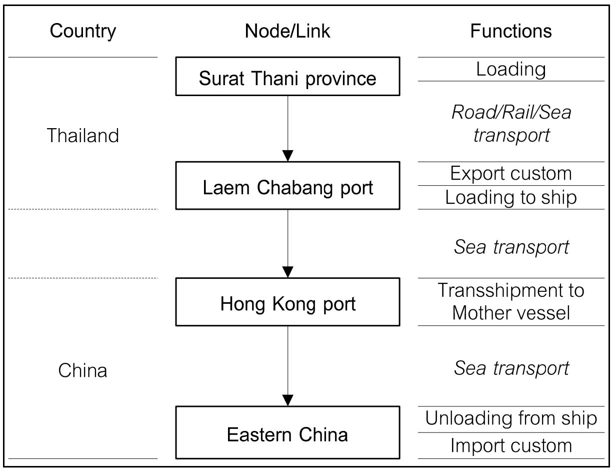


Figure 4.4 A transportation route of rubber products from Surat Thani province to Eastern China via Laem Chabang port

4.2.1.3 Padang Besar Border

From Surat Thani province, shipper can access Padang Besar border by train. Then, Thailand rubber products are exported via Penang port at Malaysia. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Surat Thani province to Eastern China via Padang Besar border is illustrated in Figure 4.5.

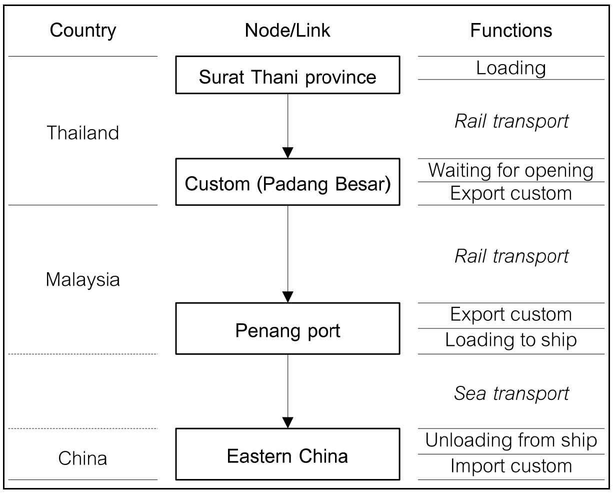


Figure 4.5 A transportation route of rubber products from Surat Thani province to Eastern China via Padang Besar border

Eight transportation routes for rubber products flow from Surat Thani province to Eastern China can be summarized in Table 4.3.

Table 4.3 Alternative routes of rubber logistics flow from Surat Thani province to Eastern China

Route	Thailand			International transportation		Eastern China	
No.	**Origin**	**Port/customs**	**Inland mode**	**Port**	**Mode**	**Port**	**Mode**
1	Surat Thani	BKK	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
2	Surat Thani	BKK	Truck	Hong Kong	Vessel	Qingdao	Mother vessel
3	Surat Thani	BKK	Train	Hong Kong	Vessel	Qingdao	Mother vessel
4	Surat Thani	LCB	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
5	Surat Thani	LCB	Truck	Hong Kong	Vessel	Qingdao	Mother vessel
6	Surat Thani	LCB	Train	Hong Kong	Vessel	Qingdao	Mother vessel
7	Surat Thani	LCB	Vessel	Hong Kong	Vessel	Qingdao	Mother vessel
8	Surat Thani	Padang Besar	Train	Penang	Train	Qingdao	Mother vessel

Source: Khompatraporn *et al.* (2009)

4.2.2 Alternative routes for Nakhon Si Thammarat Province

Nakhon Si Thammarat province can export rubber product to Eastern China via three gateways namely Bangkok port, Laem Chabang port, and Padang

Besar border (Khompatraporn *et al*., 2009). The detail of transportation routes are as follows:

4.2.2.1 Bangkok Port

From Nakhon Si Thammarat province, shipper can access Bangkok port by truck, trailer, or train. Then, Thailand rubber products are exported via Bangkok port and transit to mother vessel at Hong Kong port. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Nakhon Si Thammarat province to Eastern China via Bangkok port is illustrated in Figure 4.6.

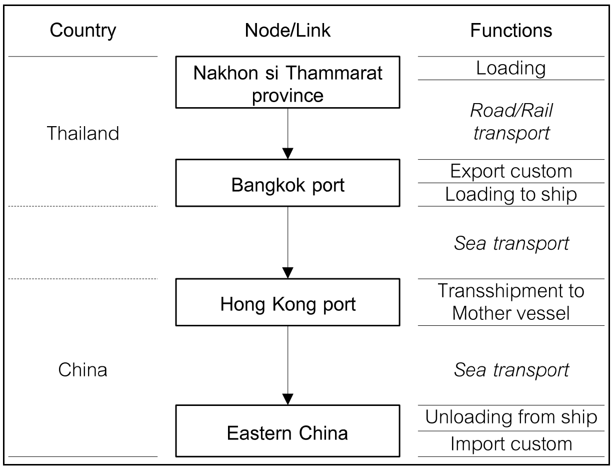


Figure 4.6 A transportation route of rubber products from Nakhon Si Thammarat province to Eastern China via Bangkok port

4.2.2.2 Laem Chabang Port

From Nakhon Si Thammarat province, shipper can access Laem Chabang port by truck, trailer, or train. Then, Thailand rubber products are exported via Laem Chabang port and transit to mother vessel at Hong Kong port. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Nakhon Si Thammarat province to Eastern China via Laem Chabang port is illustrated in Figure 4.7.

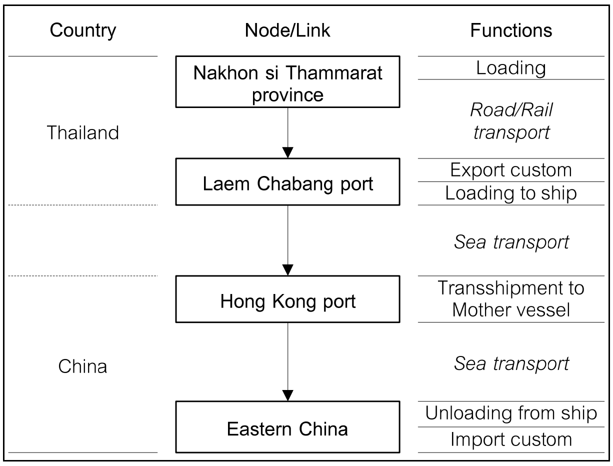


Figure 4.7 A transportation route of rubber products from Nakhon Si Thammarat province to Eastern China via Laem Chabang port

4.2.2.3 Padang Besar Border

From Nakhon Si Thammarat province, shipper can access Padang Besar border by train. Then, Thailand rubber products are exported via Penang port at Malaysia. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Nakhon Si Thammarat province to Eastern China via Padang Besar border is illustrated in Figure 4.8.

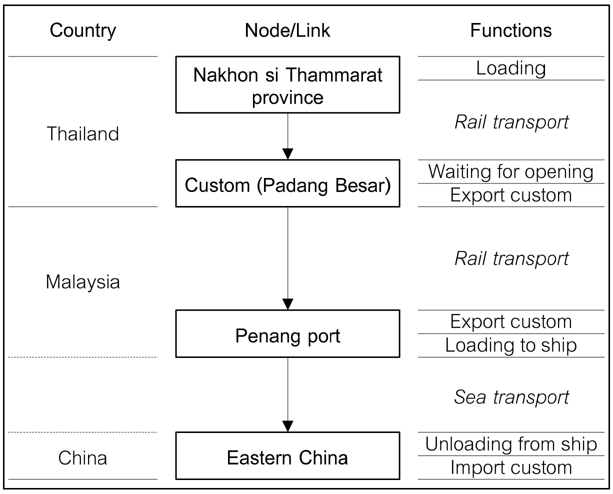


Figure 4.8 A transportation route of rubber products from Nakhon Si Thammarat province to Eastern China via Padang Besar border

Seven transportation routes of rubber products flow from Nakhon Si Thammarat province to Eastern China can be summarized in Table 4.4.

Table 4.4 Alternative routes of rubber logistics flow from Nakhon Si Thammarat to Eastern China

Route No.	**Thailand**			**International transportation**		**Eastern China**	
	Origin	**Port/customs**	**Inland mode**	**port**	**Mode**	**Port**	**Mode**
1	Nakhon Si Thammarat	BKK	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
2	Nakhon Si Thammarat	BKK	Truck	Hong Kong	Vessel	Qingdao	Mother vessel
3	Nakhon Si Thammarat	BKK	Train	Hong Kong	Vessel	Qingdao	Mother vessel
4	Nakhon Si Thammarat	LCB	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
5	Nakhon Si Thammarat	LCB	Truck	Hong Kong	Vessel	Qingdao	Mother vessel
6	Nakhon Si Thammarat	LCB	Train	Hong Kong	Vessel	Qingdao	Mother vessel
7	Nakhon Si Thammarat	Padang Besar	Train	Penang	Train	Qingdao	Mother vessel

Source: Khompatraporn *et al.* (2009)

4.2.3 Alternative routes for Songkhla Province

From Songkhla province, shipper can export rubber products to Eastern China via three gateways namely Padang Besar border, Songkhla port, and Sadao border (Khompatraporn *et al*., 2009). The detail of transportation routes as follows:

4.2.3.1 Padang Besar Border

From Songkhla province, shipper can access Padang Besar border by train or trailer and then transported to Penang port at Malaysia by train. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Songkhla province to Eastern China via Padang Besar border is illustrated in Figure 4.9.

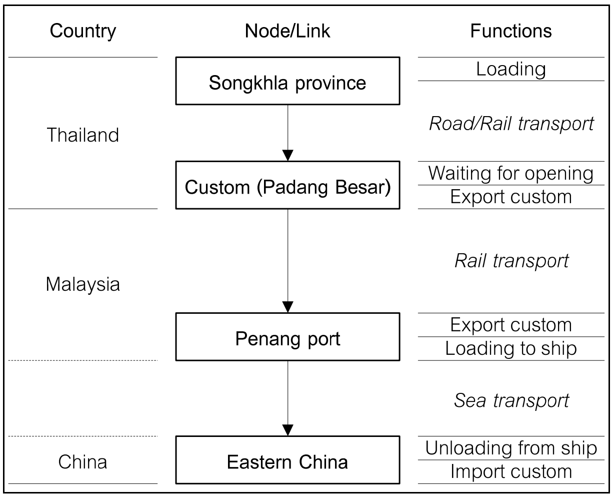


Figure 4.9 A transportation route of rubber products from Songkhla province to Eastern China via Padang Besar border

4.2.3.2 Songkhla Port

From Songkhla province, shipper can access Songkhla port by trailer. Then, Thailand rubber products are exported via Songkhla port and transit to mother vessel at Hong Kong port. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Songkhla province via Songkhla port to Eastern China is illustrated in Figure 4.10.

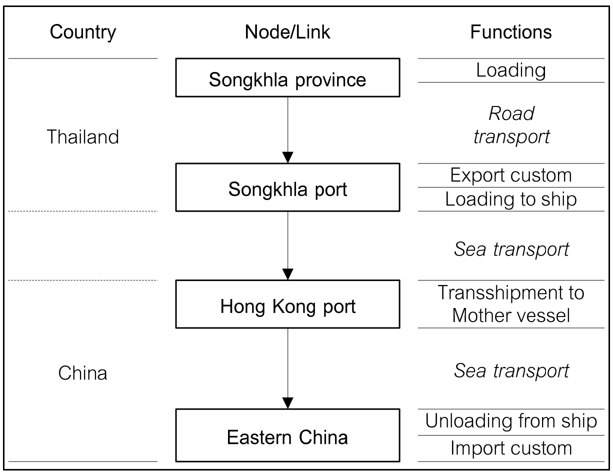


Figure 4.10 A transportation route of rubber products from Songkhla province to Eastern China via Songkhla port

4.2.3.3 Sadao Border

From Songkhla province, shipper can access Sadao border by trailer and then products are loaded to ship at Penang port in Malaysia. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Songkhla province to Eastern China via Sadao border is illustrated in Figure 4.11.

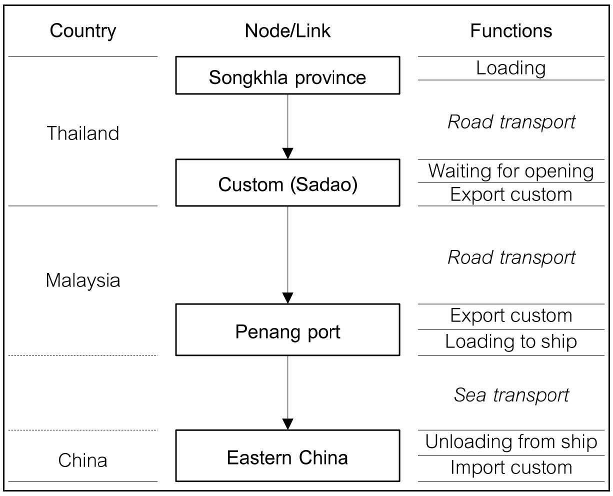


Figure 4.11 A transportation route of rubber products from Songkhla province to Eastern China via Sadao border

Four transportation routes for rubber products flow from Songkhla province to Eastern China can be summarized in Table 4.5.

Table 4.5 Alternative routes of rubber logistics flow from Songkhla province to Eastern China

Route No.	**Thailand**			**International transportation**		**Eastern China**	
	Origin	**port/customs**	**Inland mode**	**port**	**Mode**	**port**	**Mode**
1	Songkhla	Padang Besar	Trailer	Penang	Train	Qingdao	Mother vessel
2	Songkhla	Padang Besar	Train	Penang	Train	Qingdao	Mother vessel
3	Songkhla	Songkhla port	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
4	Songkhla	Sadao border	Trailer	Penang	Trailer	Qingdao	Mother vessel

Source: Khompatraporn *et al.* (2009)

4.2.4 Alternative Routes for Rayong Province

From the interview with rubber manufacturer in Rayong province, Currently, rubber products from Rayong province are exported to Eastern China via two gateways namely Laem Chabang port and Bangkok port. The detail of transportation routes are as follows:

4.2.4.1 Laem Chabang Port

From Rayong province, shipper can access Laem Chabang port by trailer. Then, Thailand rubber products are exported via Laem Chabang port and transshipped to mother vessel at Hong Kong port. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Rayong to Eastern China via Laem Chabang port is illustrated in Figure 4.12.

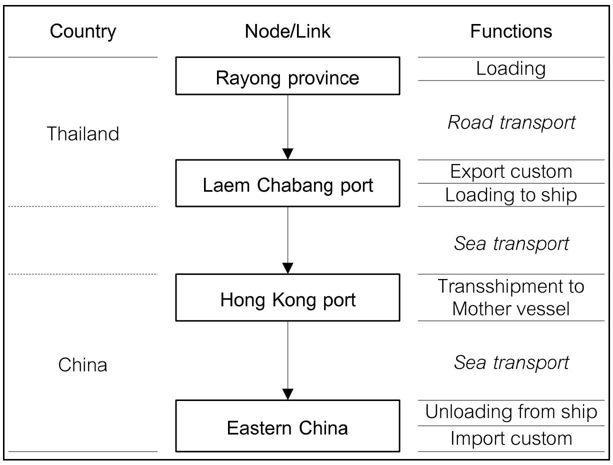


Figure 4.12 A transportation route of rubber products from Rayong province to Eastern China via Laem Chabang port

4.2.4.2 Bangkok Port

From Rayong province, shipper can access Bangkok port by trailer. Then, Thailand rubber products are exported via Bangkok port and transit to mother vessel at Hong Kong port. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Rayong to Eastern China via Bangkok port illustrates in Figure 4.13.

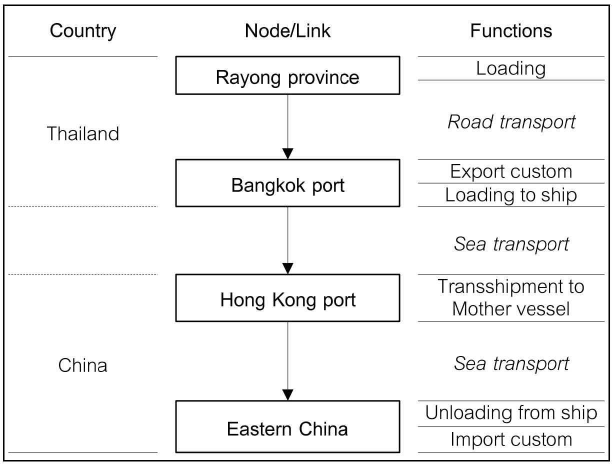


Figure 4.13 A transportation route of rubber products from Rayong province to Eastern China via Bangkok port

Two transportation routes for rubber products flow from Rayong province can be summarized in Table 4.6.

Table 4.6 Alternative routes of rubber logistics flow from Rayong province to Eastern China

Route No.	**Thailand**			**International transportation**		**Eastern China**	
	Origin	**port/customs**	**Inland mode**	**port**	**Mode**	**port**	**Mode**
1	Rayong	BKK	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
2	Rayong	LCB	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel

4.2.5 Alternative Routes for Nong Khai Province

From the interview with rubber manufacturer in Nong Khai, Currently, rubber products from Nong Khai export to Eastern China via two gateways namely Laem Chabang and Bangkok ports by trailer. Apart from the existing alternatives, new route alternative were also found in the literature survey and fieldwork. We see the opportunities of Mukdahan border, Bueng Kan border, and Nakhon Phanom border which can support rubber in the Northeast of Thailand. These new alternatives can connect to the East-West Economic Corridor (EWEC).

The East-West Transport (Road) Corridor will see the linking of Mawlamyine in Myanmar with Mae Sot and Mukdahan in Thailand, across the Mekong River by the Second Mekong River International Bridge to Savannakhet in Laos, to Dong Ha and Da Nang in Vietnam. This is one of the most exciting new road networks in Southeast Asia (Krongkaew, 2004).

4.2.5.1 Bangkok Port

From Nong Khai province, shipper can access Bangkok port by trailer. Then, Thailand rubber products are exported via Bangkok port and transit to mother vessel at Hong Kong port. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Nong Khai to Eastern China via Bangkok port illustrates in Figure 4.14.

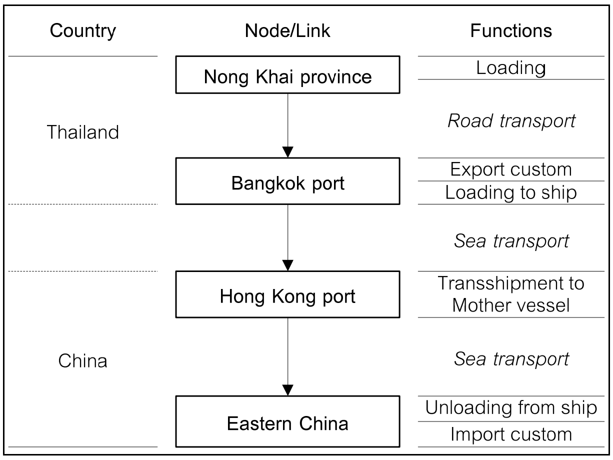


Figure 4.14 A transportation route of rubber products from Nong Khai province to Eastern China via Bangkok port

4.2.5.2 Laem Chabang Port

From Nong Khai province, shipper can access Laem Chabang port by trailer. Then, Thailand rubber products are exported via Laem Chabang port and transit to mother vessel at Hong Kong port. Finally, these products are unloaded from ship to destination at Eastern China. A transportation route of rubber products from Nong Khai province to Eastern China via Laem Chabang port is illustrated in Figure 4.15.

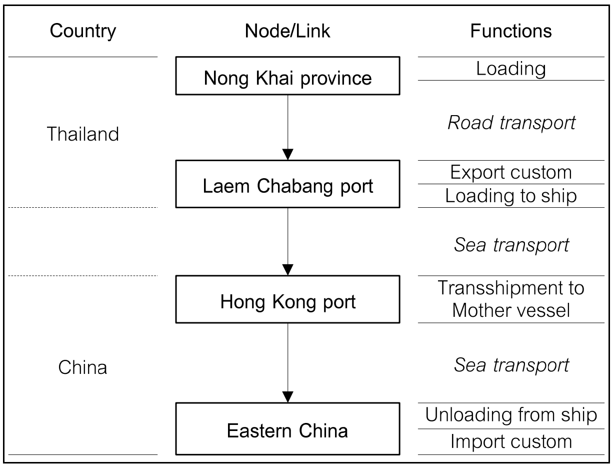


Figure 4.15 A transportation route of rubber products from Nong Khai province to Eastern China via Laem Chabang port

4.2.5.3 Mukdahan Border

From Nong Khai province, shipper can access Mukdahan border by truck. Then, Thailand rubber products are exported via Mukdahan (Thailand)-Savannakhet (Laos) border and transport to Savannakhet customs at Savannakhet province of Laos. This route uses the Second Thai-Lao Friendship Bridge crossing Mekong River. Next, shipper accesses to Den Savan (Laos)-Lao Bao (Vietnam) border by using the National Highway route number 9 (R9) under the East-West Transport Corridor Project. Afterward, shipper leads to Da Nang port in Vietnam via Asian Highway 1 (1A). Finally, these products are loaded to ship and transport to Eastern China. A transportation route of rubber products from Nong Khai province to Eastern China via Mukdahan border is illustrated in Figure 4.16.

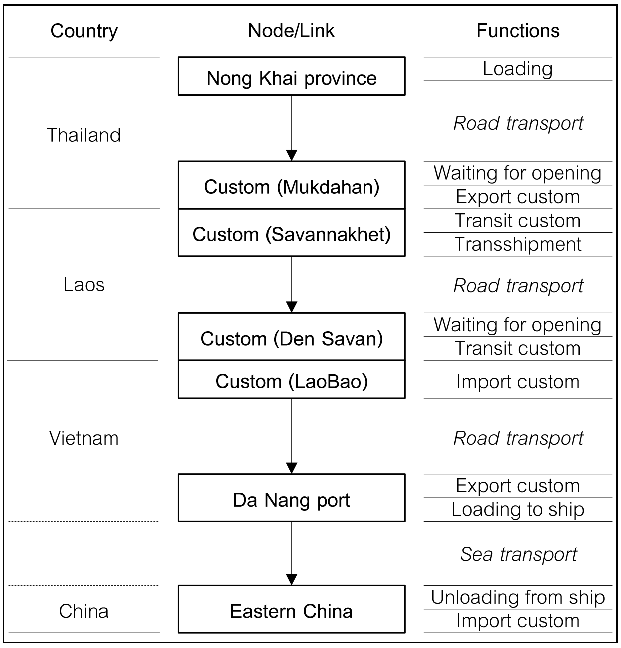


Figure 4.16 A transportation route of rubber products from Nong Khai province to Eastern China via Mukdahan border

4.2.5.4 Nakhon Phanom Border

Currently, at Nakhon Phanom border, the Third Thai-Lao Friendship Bridge crossing Mekong River is in process of construction. This bridge can facilitate rubber transportation to China via Da Nang port in Vietnam. From Nong Khai province, shipper can access Nakhon Phanom border by truck. Then, Thailand rubber products are exported via Nakhon Phanom (Thailand) - Thakhek (Laos) border and transport to Thakhek customs at Thakhek province of Laos. Next, shipper accesses to Den Savan (Laos)-Lao Bao (Vietnam) border by using the National Highway route number 9 (R9). Afterward, shipper leads to Da Nang port in Vietnam via Asian Highway 1 (1A). Finally, these products are loaded to ship and transport to Eastern China. A transportation route of rubber products from Nong Khai to Eastern China via Nakhon Phanom border is illustrated in Figure 4.17.

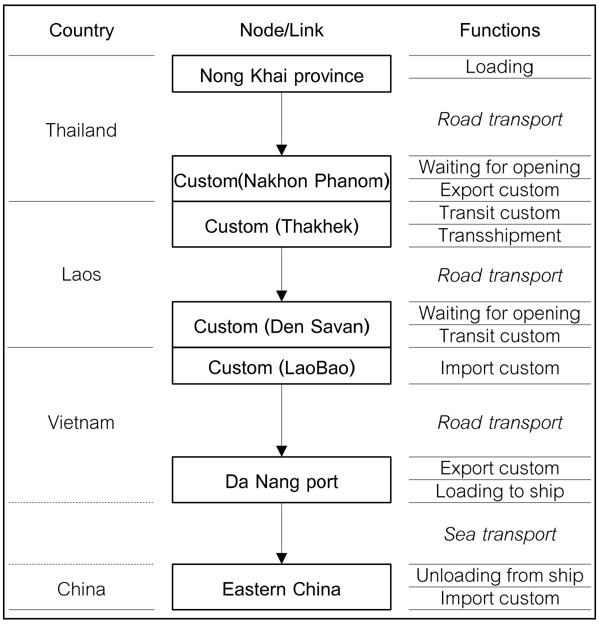


Figure 4.17 A transportation route of rubber products from Nong Khai to Eastern China via Nakhon Phanom border

4.2.5.5 Bueng Kan Border

From Nong Khai province, shipper can access Bueng Kan border by truck. Then, Thailand rubber products are exported via Bueng Kan (Thailand)-Pakxan (Laos) border and transport to Pakxan customs in Bolikhamxai province of Laos by ferryboat. Next, shipper accesses to Nam pao (Laos)-Cau Trea (Vietnam) border via National Highway route number 13 (R13) and number 8 (R8). Afterward, shipper leads to Da Nang port in Vietnam via Asian Highway 1 (1A). Finally, these products are loaded to ship at Da Nang port and transport to Eastern China. A transportation route of rubber products from Nong Khai to Eastern China via Bueng Kan border is illustrated in Figure 4.18.

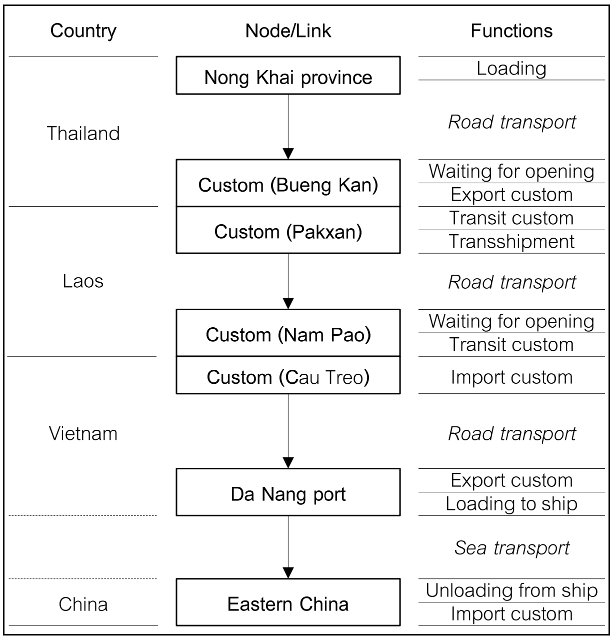


Figure 4.18 A transportation route of rubber products from Nong Khai to Eastern China via Bueng Kan border

Five transportation routes for rubber products flow from Nong Khai province to Eastern China can be summarized in Table 4.7.

Table 4.7 Alternative routes of rubber logistics flow from Nong Khai province to Eastern China

Route No.	**Thailand**			**International transportation**				**Eastern China**	
	Origin	**Port/customs**	**Inland mode**	**Port/customs**	**Mode**	**Port**	**Mode**	**Port**	**Mode**
1	Nong Khai	BKK	Trailer	Hong Kong	Vessel	-	-	Qingdao	Mother vessel
2	Nong Khai	LCB	Trailer	Hong Kong	Vessel	-	-	Qingdao	Mother vessel
3	Nong Khai	Mukdahan border	Truck	Lao Bao border (Lao-Vietnam)	Truck (R9)	Da Nang	Truck (1A)	Qingdao	Mother vessel
4	Nong Khai	Nakhon Phanom border	Truck	Lao Bao border (Lao-Vietnam)	Truck (R9)	Da Nang	Truck (1A)	Qingdao	Mother vessel
5	Nong Khai	Buengkan border	Truck	Lak Sao border (Lao-Vietnam)	Truck (R13,R8)	Da Nang	Truck (1A)	Qingdao	Mother vessel

The alternative routes with mode of transportation were developed based on the logistics flow from rubber in Thailand from origins to destinations. The alternative routes are presented as follows: Laem Chabang port, Bangkok port, Songkhla port, Padang Besar border, Sadao border, Mukdahan border, Nakhon Phanom border, and Bueng Kan border. Alternatives routes for each case are made upon origins and destinations. The alternatives of origin can be summarized in Figure 4.19.

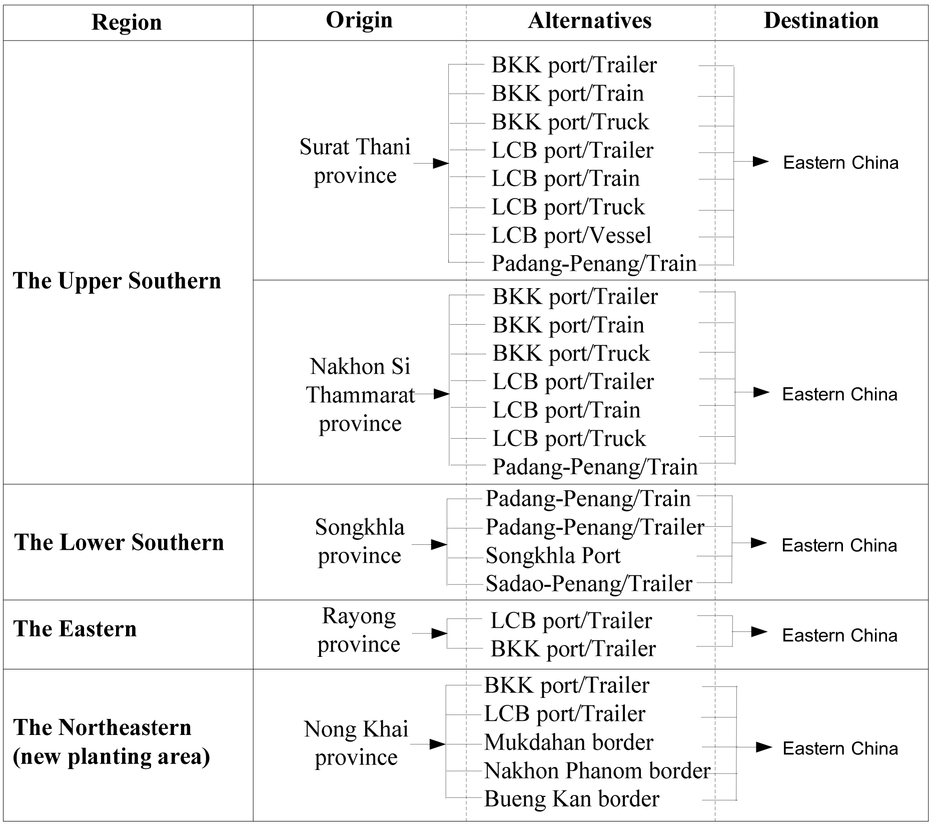


Figure 4.19 Rubber logistics flow: origins and destinations to Eastern China

4.3 A Framework of Decision Support System

A framework presented here illustrates all alternatives discussed earlier, together with criteria and sub-criteria obtained from literature, fieldwork, and interview. The alternative gateways are presented as follows: Laem Chabang port (LCB), Bangkok port (BKK), Songkhla port, Padang Besar border, Sadao border, Mukdahan border, Nakhon Phanom border, and Bueng Kan border. Alternative routes for each case are made upon origins and destinations. For the Upper Southern region, Surat Thani and Nakhon Si Thammarat provinces 8 alternatives and 7 alternatives are considered respectively. Songkhla province composes of 4 alternatives whereas Rayong province has 2 alternatives. In new planting area, Nong Khai province is the origin of the Northeastern region that exports rubber to Eastern China via 5 alternatives. In each alternative route, modes of transport are also identified.

The decision support system is proposed for multi-criteria analysis. The first level of hierarchical structure is objective or goal of multi-criteria analysis. Next, second and third level present criteria and sub-criteria respectively. Final level presents the alternative routes with mode of transport for each case. Figure 4.20 illustrates the hierarchical structure of decision support system for Thailand rubber export (Kritchanchai and Chanpuypetch, 2009).

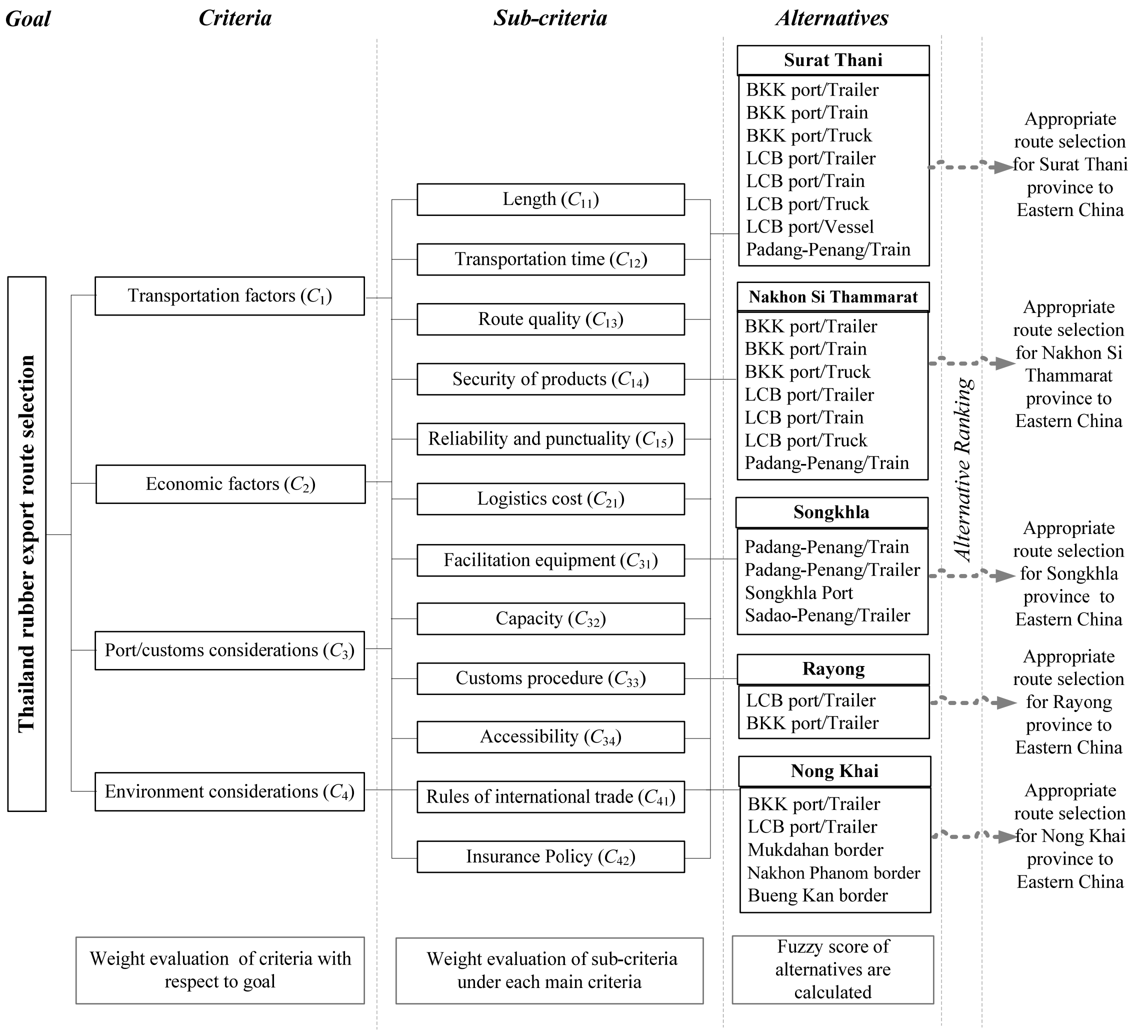


Figure 4.20 The hierarchical structure of the decision support system

This hierarchical organization depicts the conceptual flow from the research approach. The decision support system can be designed and developed from this hierarchical structure.

4.4 Evaluation of Criteria and Sub-Criteria Weights

Evaluation criteria, main criteria and sub-criteria are identified with respect to the problem situation. In this study, the Fuzzy Analytic Hierarchy Process (FAHP) base on Chang's extent analysis method (Chang, 1996) was applied to describe the multi criteria evaluation. The main criteria and sub-criteria on route selection are compared. The comparison matrices of criteria, sub-criteria and decision alternatives are developed based on logistics and transportation experts' opinion in Table 4.8 and Table 4.9. Linguistic and subjective evaluations take place in the questionnaire form (Appendix A). Each linguistic variable has its own numerical value in the predefined scale. The evaluation scale (Kahraman, Cebeci, and Ulukan, 2003), used by experts, is illustrated in Table 3.2 (Chapter III).

Table 4.8 Group of experts on criteria and sub-criteria evaluation

Expert	**Number of experts**
Logistics and transportation academic	5
Thai Logistics Alliance (TLA)	2
Transportation Institute, Chulalongkorn University	1
Office of Transport and Traffic Policy and Planning (OTP), Ministry of Transportation, Thailand	1
Office of the National Economic and Social Development Board (NESDB), Thailand	1
Total	**10**

Table 4.9 List of Experts by name

Name of expert	Position	Office
Asst. Prof. Dr. Aat Pisanwanich	Lecturer	Department of Economics, University of the Thai Chamber of Commerce
	Director	Center for International Trade Studies, University of the Thai Chamber of Commerce
Asst. Prof. Dr. Thananya Wasusri	Lecturer	Logistics Management Program, King Mongkut's University of Technology Thonburi (KMUTT)
Assoc. Prof. Dr. Duangpun Kritchanchai Singkarin	Lecturer	Department of Industrial Engineering, Mahidol University
	Director	Centre of Logistics Management, Mahidol University
	Coordinating Chair of Logistics Research Group	Thailand Research Fund (TRF)
Asst. Prof. Dr. Somchai Pathomsiri	Lecturer	Department of Civil Engineering, Mahidol University
	Director	Transportation, Traffic and Logistics Expert Center (T-LEX Center), Mahidol University
Assoc. Prof. Padermsak Jarayabhand	Lecturer	Department of Marine Science, Chulalongkorn University
	Director	Aquatic Resources Research Institute, Chulalongkorn University
Mr. Chumpol Saichuer	Chairman	Thai Logistics Alliance (TLA)
Mr. Arnuwatr Ramyaprayoon	General Manager	Thai Logistics Alliance (TLA)
Mrs. Sumalee Sukdanon	Researcher (level 7)	Transportation Institute, Chulalongkorn University
Dr. Chula Sukmanop	Deputy Director-General	Office of Transport and Traffic Policy and Planning (OTP), Ministry of Transportation
Mr. Suriyon Tunkijjanukip	Plan and Policy Analyst (Senior Professional Level)	Office of the National Economic and Social Development Board (NESDB)

The responses collected from the questionnaires were transformed to the triangular fuzzy scale as shown in Table 3.2 in Chapter III. These are input to the FAHP model. It aims to identify the weight of criteria and sub-criteria. The scores are calculated by using geometric mean method. The weight vectors are also calculated, and then the normalized weight vectors can be determined.

4.4.1 Weights Evaluation for Criteria

The local weights of criteria were calculated by using the fuzzy comparison. Their geometric mean values are presented in Table 4.10 through Chang's extent analysis method (Chang, 1996).

Table 4.10 Evaluation of criteria with respect to goal for route selection

	C_1	C_2	C_3	C_4
C_1	(1,1,1)	(0.52,0.57,0.64)	(1.44,1.76,2.03)	(1.47,1.81,2.23)
C_2	(1.55,1.76,1.92)	(1,1,1)	(1.39,1.64,1.92)	(0.89,1.10,1.35)
C_3	(0.49,0.57,0.7)	(0.52,0.61,0.72)	(1,1,1)	(0.93,1.23,1.6)
C_4	(0.45,0.55,0.68)	(0.74,0.91,1.13)	(0.62,0.81,1.08)	(1,1,1)

The pair-wise judgments from Table 4.10 are evaluated as follows.

From Table 4.10, applying Equation (2.3) in Chapter II for calculating the values of the fuzzy synthetic extents $S_i = (S_{li}, S_{mi}, S_{ui})$.

Table 4.11 Sum of rows and columns base on different criteria

	Row sums	**Column sums**
Transportation Factors (C_1)	(4.43, 5.14, 5.90)	(3.49, 3.88, 4.29)
Economic Factors (C_2)	(4.83, 5.51, 6.19)	(2.78, 3.08, 3.49)
port/customs considerations (C_3)	(2.94, 3.41, 4.01)	(4.46, 5.22, 6.03)
Environment considerations (C_4)	(2.81, 3.27, 3.89)	(4.29, 5.15, 6.18)
Sum of column sums		**(15.02, 17.33, 20.00)**

The values of the fuzzy synthetic extents are calculated based on the data in Table 4.11 as follows:

$$S_1 = (4.43, 5.41, 5.90) \cdot \left(\frac{1}{20.00}, \frac{1}{17.33}, \frac{1}{15.02} \right) = (0.2216, 0.2968, 0.3932)$$

$$S_2 = (4.83, 5.51, 6.19) \cdot \left(\frac{1}{20.00}, \frac{1}{17.33}, \frac{1}{15.02} \right) = (0.2418, 0.3179, 0.4122)$$

$$S_3 = (2.94, 3.41, 4.01) \cdot \left(\frac{1}{20.00}, \frac{1}{17.33}, \frac{1}{15.02} \right) = (0.1471, 0.1966, 0.2672)$$

$$S_4 = (2.81, 3.27, 3.89) \cdot \left(\frac{1}{20.00}, \frac{1}{17.33}, \frac{1}{15.02} \right) = (0.1407, 0.1887, 0.2588)$$

According to the method proposed by Chang, the value of fuzzy synthetic extent is defined. Figure 4.21 shows a graphic representation of the synthetic extent value based on group of experts' opinion. The values of the fuzzy synthetic extents represent the performance of these criteria in comparison.

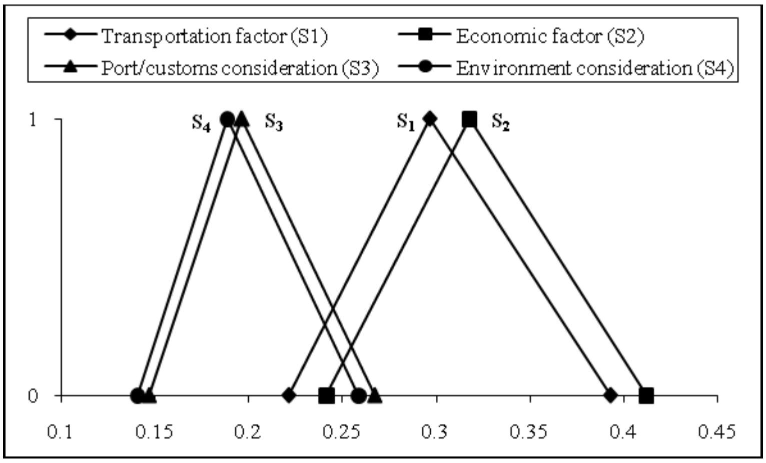


Figure 4.21 Synthetic extents for four main criteria

From Figure 4.21, four triangular fuzzy numbers represent the importance ratio of all main criteria. Group of experts evaluated that the economic factor is the most important criteria. Next criteria are transportation factor, port/customs consideration, and environment consideration, respectively. Then, the fuzzy synthetic extents are compared and used to determine the weight vector.

Using Equations (2.7) - (2.9) in Chapter II for comparing M_1 and M_2, obtains:

$$V(S_1 \geq S_2) = \frac{(0.2418 - 0.3932)}{(0.2968 - 0.3932) - (0.3179 - 0.2418)} = 0.8776$$

$$V(S_1 \geq S_3) = 1.00$$

$$V(S_1 \geq S_4) = 1.00$$

$$V(S_2 \geq S_1) = 1.00$$

$$V(S_2 \geq S_3) = 1.00$$

$$V(S_2 \geq S_4) = 1.00$$

$$V(S_3 \geq S_1) = \frac{(0.2216 - 0.2672)}{(0.1966 - 0.2672) - (0.2968 - 0.2216)} = 0.3132$$

$$V(S_3 \geq S_2) = \frac{(0.2418 - 0.2672)}{(0.1966 - 0.2672) - (0.3179 - 0.2418)} = 0.1737$$

$$V(S_3 \geq S_4) = 1.00$$

$$V(S_4 \geq S_1) = \frac{(0.2216 - 0.2588)}{(0.1887 - 0.2588) - (0.2968 - 0.2216)} = 0.2561$$

$$V(S_4 \geq S_2) = \frac{(0.2418 - 0.2588)}{(0.1887 - 0.2588) - (0.3179 - 0.2418)} = 0.1164$$

$$V(S_4 \geq S_3) = \frac{(0.1471 - 0.2588)}{(0.1887 - 0.2588) - (0.1966 - 0.1471)} = 0.9340$$

Using Equation (2.10) in Chapter II, it follows that:

$$d'(C_1) = V(S_1 \geq S_2, S_3, S_4) = \min(0.8776, 1.00, 1.00) = 0.8776$$

$$d'(C_2) = V(S_2 \geq S_1, S_3, S_4) = \min(1.00, 1.00, 1.00) = 1.00$$

$$d'(C_3) = V(S_3 \geq S_1, S_2, S_4) = \min(0.3132, 0.1737, 1.00) = 0.1737$$

$$d'(C_4) = V(S_4 \geq S_1, S_2, S_3) = \min(0.2561, 0.1164, 0.9340) = 0.1164$$

Then, the weight vector was given by Equation (2.11) in Chapter II as

$W' = (0.8776, 1.00, 0.1737, 0.1164)$

Thus, the weight vector of main criteria after normalization with respect to goal from Table 4.10 were calculated as

$$W_{Goal} = (0.4048, 0.4613, 0.0801, 0.0537)^T$$

This means, according to this group of experts, the economic factor (C_2) is the most important criteria with the priority weight of 0.4613. Transportation factor (C_1) is more important than port/customs consideration (C_3) and environment consideration (C_4) with the priority of 0.4048. The port/customs consideration is more important than environment consideration with the priority weight of 0.0801 and 0.0537 respectively.

4.4.2 Evaluation of Sub-Criteria with Respect to Transportation Factors

After ranking the main criteria factors, the sub-criteria under each factor were compared. The local weights of sub-criteria under transportation factors were calculated by using the fuzzy comparison. The values are presented in Table 4.12.

Table 4.12 Evaluation of sub-criteria with respect to transportation factors

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}
C_{11}	(1,1,1)	(0.62,0.72,0.85)	(0.52,0.63,0.76)	(0.40,0.47,0.57)	(0.33,0.38,0.45)
C_{12}	(1.34,1.55,1.78)	(1,1,1)	(1.03,1.13,1.23)	(0.45,0.57,0.73)	(0.34,0.39,0.47)
C_{13}	(1.31,1.6,1.93)	(0.81,0.89,0.97)	(1,1,1)	(0.38,0.44,0.51)	(0.36,0.44,0.53)
C_{14}	(1.76,2.13,2.47)	(1.36,1.76,2.22)	(1.95,2.29,2.63)	(1,1,1)	(0.56,0.61,0.68)
C_{15}	(2.13,2.64,3.06)	(2.13,2.55,2.96)	(1.87,2.29,2.74)	(1.48,1.64,1.79)	(1,1,1)

The pair-wise judgments from Table 4.12 are evaluated as follows.

From Table 4.12, applying formula (2.3) for calculating the values of the fuzzy synthetic.

Table 4.13 Sum of rows and columns base on different sub-criteria under transportation factors

	Row sums	Column sums
Length (C_{11})	(2.87, 3.19, 3.63)	(7.54, 8.92, 10.24)
Transportation time (C_{12})	(4.16, 4.64, 5.22)	(5.92, 6.92, 7.99)
Route quality (C_{13})	(3.86, 4.36, 4.95)	(6.37, 7.33, 8.37)
Security of products (C_{14})	(6.63, 7.79, 9.00)	(3.71, 4.12, 4.61)
Reliability and punctuality (C_{15})	(8.61, 10.12, 11.56)	(2.59, 2.82, 3.13)
Sum of column sums		**(26.13, 30.10, 34.35)**

The values of the fuzzy synthetic extents are calculated based on the data in Table 4.13 as follows:

$$S_{11} = (2.87, 3.19, 3.63) \cdot \left(\frac{1}{34.35}, \frac{1}{30.10}, \frac{1}{26.13} \right) = (0.0834, 0.1061, 0.1389)$$

$$S_{12} = (4.16, 4.64, 5.22) \cdot \left(\frac{1}{34.35}, \frac{1}{30.10}, \frac{1}{26.13} \right) = (0.1212, 0.1542, 0.1996)$$

$$S_{13} = (3.86, 4.36, 4.95) \cdot \left(\frac{1}{34.35}, \frac{1}{30.10}, \frac{1}{26.13} \right) = (0.1125, 0.1448, 0.1893)$$

$$S_{14} = (6.63, 7.79, 9.00) \cdot \left(\frac{1}{34.35}, \frac{1}{30.10}, \frac{1}{26.13} \right) = (0.1931, 0.2587, 0.3444)$$

$$S_{15} = (8.61, 10.12, 11.56) \cdot \left(\frac{1}{34.35}, \frac{1}{30.10}, \frac{1}{26.13} \right) = (0.2507, 0.3362, 0.4423)$$

Figure 4.22 shows a graphic representation of the synthetic extents value of sub-criteria under transportation factors.

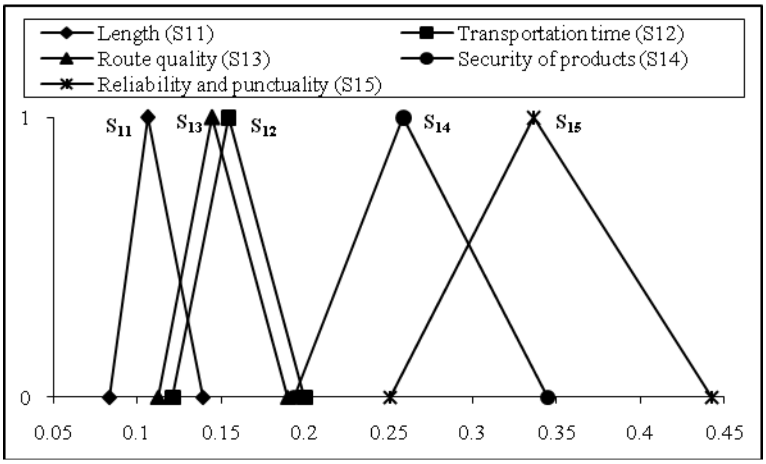


Figure 4.22 The synthetic extents value of sub-criteria under transportation factors

From Figure 4.22, five triangular fuzzy numbers represent the importance ratio of all sub-criteria under transportation factors. A Group of experts prefers reliability and punctuality is the most important sub-criteria under transportation factors. The second is security of products. For transportation time, route quality, and length are sub-criteria which less important than security of products and reliability and punctuality. Then, the fuzzy synthetic extents are compared and used to determine the weight vector.

Using Equations (2.7) - (2.9) in Chapter II for comparing M_1 and M_2, obtains:

$$V(S_{11} \geq S_{12}) = \frac{(0.1211 - 0.1389)}{(0.1061 - 0.1389) - (0.1542 - 0.1061)} = 0.2692$$

$$V(S_{11} \geq S_{13}) = \frac{(0.1125 - 0.1389)}{(0.1061 - 0.1389) - (0.1448 - 0.1389)} = 0.4057$$

$$V(S_{11} \geq S_{14}) = 0$$

$$V(S_{11} \geq S_{15}) = 0$$

$$V(S_{12} \geq S_{11}) = 1$$

$$V(S_{12} \geq S_{13}) = 1$$

$$V(S_{12} \geq S_{14}) = \frac{(0.1931 - 0.1996)}{(0.1531 - 0.1996) - (0.2587 - 0.1931)} = 0.0588$$

$$V(S_{12} \geq S_{15}) = 0$$

$$V(S_{13} \geq S_{11}) = 1$$

$$V(S_{13} \geq S_{12}) = \frac{(0.1212 - 0.1893)}{(0.1448 - 0.1893) - (0.1542 - 0.1212)} = 0.8787$$

$$V(S_{13} \geq S_{14}) = 1$$

$$V(S_{13} \geq S_{15}) = 0$$

$$V(S_{14} \geq S_{11}) = 1$$

$$V(S_{14} \geq S_{12}) = 1$$

$$V(S_{14} \geq S_{13}) = 1$$

$$V(S_{14} \geq S_{15}) = \frac{(0.2507 - 0.3444)}{(0.2587 - 0.3444) - (0.3362 - 0.2507)} = 0.5475$$

$$V(S_{15} \geq S_{11}) = 1$$

$$V(S_{15} \geq S_{12}) = 1$$

$$V(S_{15} \geq S_{13}) = 1$$

$$V(S_{15} \geq S_{14}) = 1$$

Using Equation (2.10) in Chapter II, it follows that:

$$d'(C_{11}) = V(S_{11} \geq S_{12}, S_{13}, S_{14}, S_{15}) = \min(0.2692, 0.4057, 0, 0) = 0$$

$$d'(C_{12}) = V(S_{12} \geq S_{11}, S_{13}, S_{14}, S_{15}) = \min(1, 1, 0.0588, 0) = 0$$

$$d'(C_{13}) = V(S_{13} \geq S_{11}, S_{12}, S_{14}, S_{15}) = \min(1, 0.8788, 0, 0) = 0$$

$$d'(C_{14}) = V(S_{14} \geq S_{11}, S_{12}, S_{13}, S_{15}) = \min(1, 1, 1, 0.5475) = 0.5475$$

$$d'(C_{15}) = V(S_{15} \geq S_{11}, S_{12}, S_{13}, S_{14}) = \min(1, 1, 1, 1) = 1$$

Then, the weight vector was given by Equation (2.11) in Chapter II as

$$W' = (0, 0, 0, 0.5475, 1)$$

Thus, the weight vector of sub-criteria under transportation factors after normalization with respect to transportation factors from Table 4.12 were calculated as

$$W_{C1} = (0, 0, 0, 0.3538, 0.6462)^T$$

From the results, reliability and punctuality (C_{15}) and security of products (C_{14}) are more important than length (C_{11}), transportation time (C_{12}), and route quality

(C_{13}). The normalization weight of reliability and punctuality is 0.6462 and security of products is 0.3538.

4.4.3 Evaluation of Sub-Criteria with Respect to Port/Customs Factors

The local weights of sub-criteria under port/customs consideration were calculated by using the fuzzy comparison. The values are presented in Table 4.14.

Table 4.14 Evaluation of sub-criteria with respect to port/customs considerations

	C_{31}	C_{32}	C_{33}	C_{34}
C_{31}	(1,1,1)	(1.17,1.41,1.71)	(0.36,0.43,0.52)	(0.63,0.68,0.74)
C_{32}	(0.7,0.82,0.97)	(1,1,1)	(0.56,0.64,0.75)	(0.81,0.87,0.95)
C_{33}	(1.93,2.35,2.79)	(1.34,1.55,1.78)	(1,1,1)	(1.09,1.26,1.46)
C_{34}	(1.35,1.47,1.59)	(1.05,1.15,1.24)	(0.69,0.79,0.92)	(1,1,1)

The pair-wise judgments from Table 4.14 are evaluated as follows.

From Table 4.14, applying formula (2.3) for calculating the values of the fuzzy synthetic.

Table 4.15 Sum of rows and columns base on different sub-criteria under port/customs considerations

	Row sums	**Column sums**
Facilitation equipment (C_{31})	(3.16, 3.52, 3.97)	(4.98, 5.56, 6.35)
Capacity (C_{32})	(3.07, 3.34, 3.67)	(4.56, 5.11, 5.73)
Customs procedures (C_{33})	(5.36, 6.16, 7.02)	(2.61, 2.86, 3.18)
Accessibility (C_{34})	(4.09, 4.41, 4.76)	(3.52, 3.81, 4.15)
Sum of column sums		**(15.67, 17.43, 19.41)**

The values of the fuzzy synthetic extents are calculated based on the data in Table 4.15 as follows:

$$S_{31} = (3.16, 3.52, 3.97) \cdot \left(\frac{1}{19.41}, \frac{1}{17.43}, \frac{1}{15.67} \right) = (0.1627, 0.2018, 0.2532)$$

$$S_{32} = (3.07, 3.34, 3.67) \cdot \left(\frac{1}{19.41}, \frac{1}{17.43}, \frac{1}{15.67} \right) = (0.1579, 0.1914, 0.2341)$$

$$S_{33} = (5.36, 6.16, 7.02) \cdot \left(\frac{1}{19.41}, \frac{1}{17.43}, \frac{1}{15.67} \right) = (0.2760, 0.3536, 0.4482)$$

$$S_{34} = (4.09, 4.41, 4.76) \cdot \left(\frac{1}{19.41}, \frac{1}{17.43}, \frac{1}{15.67} \right) = (0.2105, 0.2532, 0.3036)$$

Figure 4.23 shows a graphic representation of the synthetic extents value of sub-criteria under port/customs considerations.

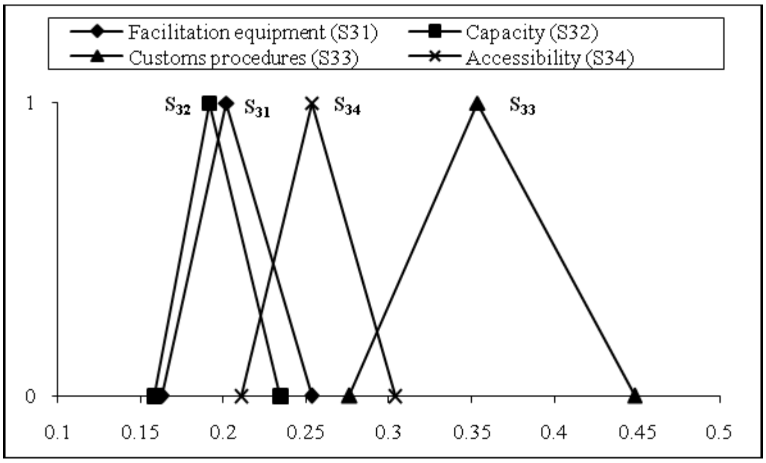


Figure 4.23 The synthetic extents value of sub-criteria under port/customs considerations

From Figure 4.23, four triangular fuzzy numbers represent the importance ratio of all sub-criteria under port/customs considerations. Group of experts prefers customs procedure is the most important. The second is accessibility to the port or customs. For facilitation equipment and capacity are sub-criteria which less important than the others. Then, the fuzzy synthetic extents are compared and used to determine the weight vector.

Then, using Equations (2.7) - (2.9) in Chapter II for comparing M_1 and M_2, obtains:

$$V(S_{31} \geq S_{32}) = 1$$

$$V(S_{31} \geq S_{33}) = 0$$

$$V(S_{31} \geq S_{34}) = \frac{(0.2105 - 0.2532)}{(0.2018 - 0.2532) - (0.2532 - 0.2018)} = 0.4533$$

$$V(S_{32} \geq S_{31}) = \frac{(0.1627 - 0.2341)}{(0.1914 - 0.2341) - (0.2018 - 0.1627)} = 0.8727$$

$$V(S_{32} \geq S_{33}) = 0$$

$$V(S_{32} \geq S_{34}) = \frac{(0.2105 - 0.2341)}{(0.1914 - 0.2341) - (0.2532 - 0.2105)} = 0.2754$$

$$V(S_{33} \geq S_{31}) = 1$$

$$V(S_{33} \geq S_{32}) = 1$$

$$V(S_{33} \geq S_{34}) = 1$$

$$V(S_{34} \geq S_{31}) = 1$$

$$V(S_{34} \geq S_{32}) = 1$$

$$V(S_{34} \geq S_{33}) = \frac{(0.2760 - 0.3036)}{(0.2532 - 0.3036) - (0.3536 - 0.2760)} = 0.2157$$

Using Equation (2.10) in Chapter II, it follows that:

$$d'(C_{31}) = V(S_{31} \geq S_{32}, S_{33}, S_{34}) = \min(1, 0, 0.4533) = 0$$

$$d'(C_{32}) = V(S_{32} \geq S_{31}, S_{33}, S_{34}) = \min(0.8727, 0, 0.2754) = 0$$

$$d'(C_{33}) = V(S_{33} \geq S_{31}, S_{32}, S_{34}) = \min(1, 1, 1) = 1$$

$$d'(C_{34}) = V(S_{34} \geq S_{31}, S_{32}, S_{33}) = \min(1, 1, 0.2157) = 0.2157$$

Then, the weight vector was given by Equation (2.11) in Chapter II as

$$W' = (0, 0, 1, 0.2157)$$

Thus, the weight vector of sub-criteria under port/customs consideration after normalization from Table 4.14 were calculated as

$$W_{C3} = (0, 0, 0.8225, 0.1775)^T$$

It is shown that the convenience of customs process for exporting and the accessibility of inland transportation to port are more important than the other sub-criteria under port/customs considerations. The normalization weight of customs procedure is 0.8225 and accessibility is 0.1775.

4.4.4 Evaluation of Sub-Criteria with Respect to Environment Factors

The local weights of sub-criteria under environment consideration are calculated by using the fuzzy comparison. The values are presented in Table 4.16.

Table 4.16 Evaluation of sub-criteria with respect to environment considerations

	C_{41}	C_{42}
C_{41}	(1,1,1)	(0.93,1.03,1.14)
C_{42}	(0.8,0.87,0.95)	(1,1,1)

Table 4.17 Sum of rows and columns base on different sub-criteria under environment considerations

	Row sums	**Column sums**
Rules of international trade (C_{41})	(1.93, 2.03, 2.14)	(1.80, 1.87, 1.95)
Insurance policy (C_{42})	(1.80, 1.87, 1.95)	(1.93, 2.03, 2.14
Sum of column sums		**(3.73, 3.90, 4.09)**

The values of the fuzzy synthetic extents were calculated based on the data in Table 4.17 as follows:

$$S_{41} = (1.93, 2.03, 2.14) \cdot \left(\frac{1}{4.09}, \frac{1}{3.90}, \frac{1}{3.73} \right) = (0.4712, 0.5203, 0.5747)$$

$$S_{42} = (1.80, 1.87, 1.95) \cdot \left(\frac{1}{4.09}, \frac{1}{3.90}, \frac{1}{3.73} \right) = (0.4396, 0.4797, 0.5232)$$

Figure 4.24 shows a graphic representation of the synthetic extents value of sub-criteria under environment considerations.

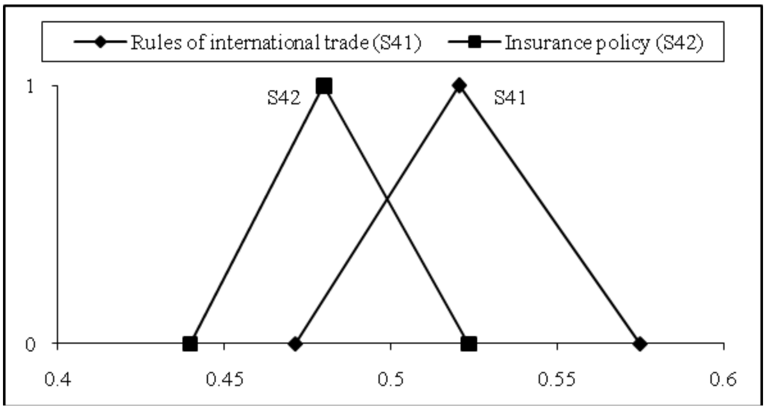


Figure 4.24 The synthetic extents value of sub-criteria under environment considerations

Then, using Equations (2.7) - (2.9) in Chapter II for comparing M_1 and M_2, obtains:

$$V(S_{41} \geq S_{42}) = 1$$

$$V(S_{42} \geq S_{41}) = \frac{(0.4712 - 0.5232)}{(0.4797 - 0.5232) - (0.5203 - 0.4712)} = 0.5610$$

Using Equation (2.10) in Chapter II, it follows that:

$$d'(C_{41}) = V(S_{41} \geq S_{42}) = \min(1) = 1$$

$$d'(C_{42}) = V(S_{42} \geq S_{41}) = \min(0.5610) = 0.5610$$

Then, the weight vector was given by Equation (2.11) in Chapter II are

$$W' = (1, 0.5610)$$

Thus, the weight vector of sub-criteria after normalization with respect to environment factors from Table 4.16 was calculated as

$$W_{C4} = (0.6406, 0.3594)^T$$

We can see that the most important sub-criteria under environment considerations are rule of international trade. This also shows that insurance policy is also significant but less important than the international trade regulations.

4.4.5 Global Weights for Sub-Criteria

The comparison of main criteria and sub-criteria weights are summarized in Table 4.18.

Table 4.18 Weights of criteria and sub-criteria

Main criteria and local weights	Sub-criteria		Local weights	Global weights
Transportation factors (C_1) (0.4048)	Length	C_{11}	0.0000	0.0000
	Transportation time	C_{12}	0.0000	0.0000
	Route quality	C_{13}	0.0000	0.0000
	Security of products	C_{14}	0.3538	0.1432
	Reliability and punctuality	C_{15}	0.6462	0.2616
Economic factor (C_2) (0.4613)	Logistic cost	C_{21}	0.4613	0.4613
port/customs considerations (C_3) (0.0801)	Facilitation equipment	C_{31}	0.0000	0.0000
	Capacity	C_{32}	0.0000	0.0000
	Customs procedure	C_{33}	0.8225	0.0659
	Accessibility	C_{34}	0.1775	0.0142
Environment considerations (C_4) (0.0537)	Rules of international trade	C_{41}	0.6406	0.0344
	Insurance policy	C_{42}	0.3594	0.0193

From Table 4.18, this is a result according to one group of experts. Seven sub-criteria will be concerned in the decision analysis. These sub-criteria are logistics cost, reliability and punctuality, security of products, customs procedure, rules of international trade, insurance policy, and accessibility. From the result, the logistics cost is the major concern for evaluating route for Thailand rubber export. The logistics cost is the most importance on the sub-criteria with weight is 0.4613. It means that the greatest impact on route selection is cost. The second and third is reliability and punctuality and security of products, respectively. Surprisingly, some sub-criteria have weight was zero. Those sub-criteria are length, transportation time, route quality, facilitation equipment, and capacity. It is as a result from FAHP method. The relative importance of the decision criteria were evaluated by Equation 2.8. Equation 2.8 uses to compare between two triangular fuzzy numbers. Then, the highest intersection points were calculated by using Equation 2.9. The value will be adjusted between 0 and 1 based on the fuzzy set theory. Next, Equation 2.10 considers the minimum of intersection point value of one criteria when is compared with the others. The minimum values were presented to weight of criteria. Consequently, Equation 2.10 gives a zero weight to some decision criteria. The zero weight means that decision criteria with zero weight have less importance when is compared with the other criteria. Chang's FAHP method neglects the criteria which less important than others. The decision maker can focus on the more important criteria. Finally, Table 4.18 presents the weights of criteria as a result from evaluating by this group of experts only.

From the information above, the hierarchical structure will be used to design and develop the decision support system. Moreover, the weights of criteria and sub-criteria based on experts' opinion are integrated to the decision support system.

4.5 The Application of the Framework to System Development

Five major rubber planting areas in Thailand were selected as origins of case study namely Surat Thani, Nakhon Si Thammarat, Songkhla, Rayong, and Nong Khai provinces. Then, the framework of decision support system is framed to hierarchical structure as illustrated in Figure 4.20. Hence, this section applies this framework to develop the decision support system for Thailand rubber export.

The framework of decision support system is illustrated in Figure 4.20. It aims to develop route selection for Thailand rubber export. Within the framework, the structure proposes alternative routes for rubber export from five origin planting areas of Thailand to Eastern China. FAHP extent analysis method (Chang, 1996) was applied for developing the decision support system.

4.5.1 System Design

Technically, the proposed framework outlines a fuzzy decision support system divided into modules. The major components of the system are user interface, Visual Basic for Application (VBA), and database information system. The system integration is illustrated in Figure 4.25.

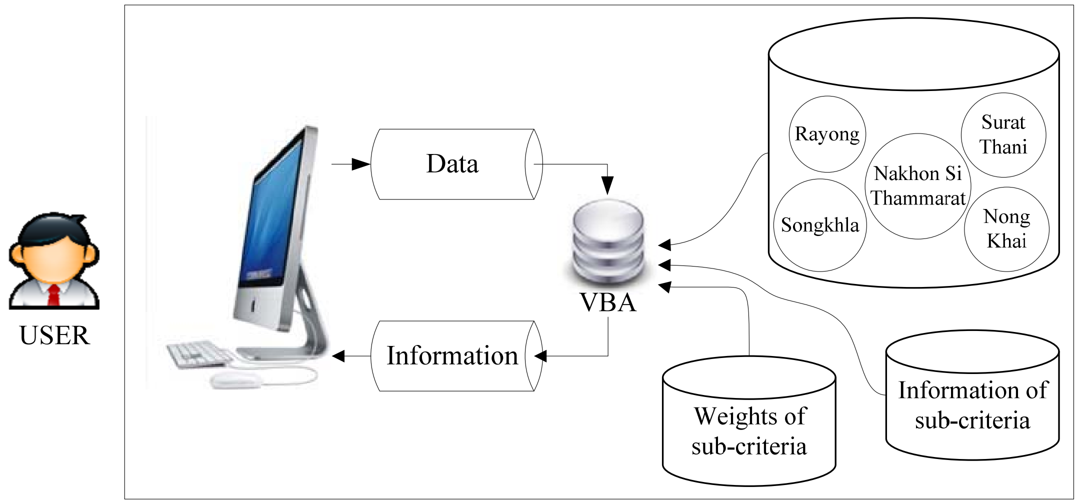


Figure 4.25 The system integration for proposed framework

The database of decision support system was comprised of three components:

- Alternative routes of five origins namely Surat Thani, Nakhon Si Thammarat, Songkhla, Rayong, and Nong Khai province.
- Global weights of criteria and local weights of sub-criteria from evaluation by logistics experts.
- Information of each gateway under each sub-criteria for supporting user in decision making via the application.

The decision support system allows for interfaces between databases and FAHP model. Within the system, one user can define the origin of rubber exporting. Then, user's problem as a hierarchical structure of alternatives for route selection is considered with weights of sub-criteria identified in Table 4.18.

The concept module development is used in this system. From this concept, many modules can be developed at the same time. In addition, information of sub-criteria are provided in the system for understanding and supporting user in gateway comparison phase.

State transition diagram of fuzzy decision support system for route selection is illustrated in Figure 4.26.

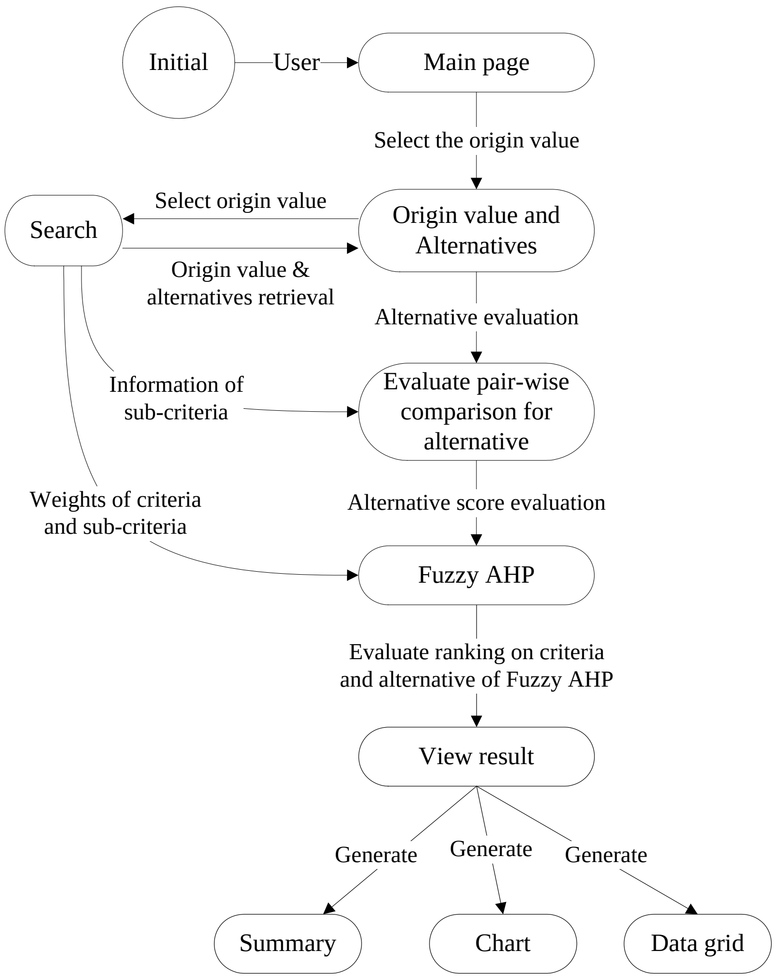


Figure 4.26 State transition diagram of decision making tool

Decision making process via this decision support system starts from main page of program. User determines the origin for rubber exporting at first panel for defines the objective of decision making. Next, the alternatives of origin are retrieved to user. User determines the importance degree of alternative routes comparison with respect to sub-criteria with linguistic scale in Table 3.2. Then, the system transforms to triangular fuzzy scale and input in the FAHP model. The evaluation algorithm for determining to overall priorities of the decision support system for gateway selection uses Chang's extent analysis method (see the detail in chapter III). The Chang's extent analysis is relatively easier while comparing to others approaches on FAHP (Celik *et* *al*., 2007). The fuzzy pair-wise comparison matrices are represented behind the interface. Afterwards, priority weights of alternatives with respect to sub-criteria are calculated by using the fuzzy comparison values through Chang's extent analysis method. Finally, global priorities weights of the alternatives will be calculated with global weights of sub-criteria. The decision support system generates the result to user in the form of data grid and bar chart.

4.5.2 Information of Gateway under Sub-Criteria

Most users or manufacturers, in principle, make decision on selecting a specific route according to the criteria. Thus, it is necessary for user to understand the sub-criteria which affect the gateway pair wise comparison. The data categories are relevant to gateway selection analysis which can be defined by hierarchical structure of criteria. Then, the data of these criteria are provided on user interface of the decision support system.

The descriptions of sub-criteria data namely: length data, transportation time data, and cost data are quantitative criteria of route selection. Data of length and transportation time is the distance and time spent from origin to destination (Eastern China). Cost data is one of the primary concerns of multimodal transportation selection. The logistics cost per unit including transportation cost, packaging cost, and customs charges are shown on the interface of application. The categories of quantitative sub-criteria are provided in the decision support system and can be summarized in Table 4.19.

Table 4.19 Categories of quantitative sub-criteria for route selection

Sub-criteria	**Information of gateway**
Length data	The distance from origin to gateway
transportation time data	The time spent from origin to destination at Eastern China
cost data	Logistics cost includes transportation cost, packaging cost, and customs charge

Table 4.20 Categories of qualitative sub-criteria for route selection

Sub-criteria	**Information**
Route quality	- Road evaluation - Surface condition - Number of lanes - Maximum total vehicle weight
Reliability and punctuality	- port performance
Facilitation equipment	- Number of sea-shore container gantries - Number of yard gantries
Capacity	- Number of container berth - Terminal facilities - Container freight station - Cargo handling volume - Container throughput
Accessibility	- Highway - Railway - Inland water transport (IWT)
Customs procedure	- Charge for customs service in non-office hours - Standard hours of customs clearance - Barcode use - Customs clearance EDI
Rules of international trade	- Standard on logistics - License approvals on logistics service - Special traffic control area

From Table 4.20, the categories of qualitative sub-criteria are provided and summarized. The route quality consists of road evaluation data, surface condition, number of lanes, and maximum total vehicle weight. For reliability and punctuality data, on time delivery is affected by port performance. Facilitation equipment of ports or customs is considered by number of sea-shore container gantries and number of yard gantries. Data in category of port’s capacity is measured by number of container berth, terminal facilities, container freight stations, cargo handling volume, and container throughput. Three modes of transport for accessing to the port or customs such as road, railway, and inland water transport (IWT) are used to assess for the accessibility. Customs procedure concerns with charge for customs service in non-office hours, standard hours of customs clearance, barcode use, and customs clearance EDI. The rules of international trade consideration can be measured by standards on logistics, licenses approvals on logistics service, and special traffic control area.

User can consider information of sub-criteria for comparing the routes. The information of gateways under these criteria for supporting user who uses the decision support system are detailed in Appendix B.

4.6 The Application

Visual Basic Application (VBA) for Microsoft Excel 2007 is selected as a tool for application development. User interface of application is designed by using object-based interaction method. Image objects are used instead of any function in decision support system. User can start the application by selecting image objects that are illustrated on interface. Therefore, this application is convenient and easy to uses for working decision.

In this section demonstrates a hypothetical case on how to deploy fuzzy decision support system for route selection. Next, the results of all origins are presented. It is an experiment by using decision support information in the system.

4.6.1 Define the Objective

The objective defining process involves the goal and alternative routes as indicated. User starts by selecting the values for origin of rubber exporting in the first page. The origins that use to case study in this decision support system are illustrated in form of Thailand map. First panel for defining the objective of decision-making is shown in Figure 4.27.

Afterward, the alternative routes for the origin are defined (see Figure 4.28). Then, user starts the pair-wise comparison by clicking the start button.

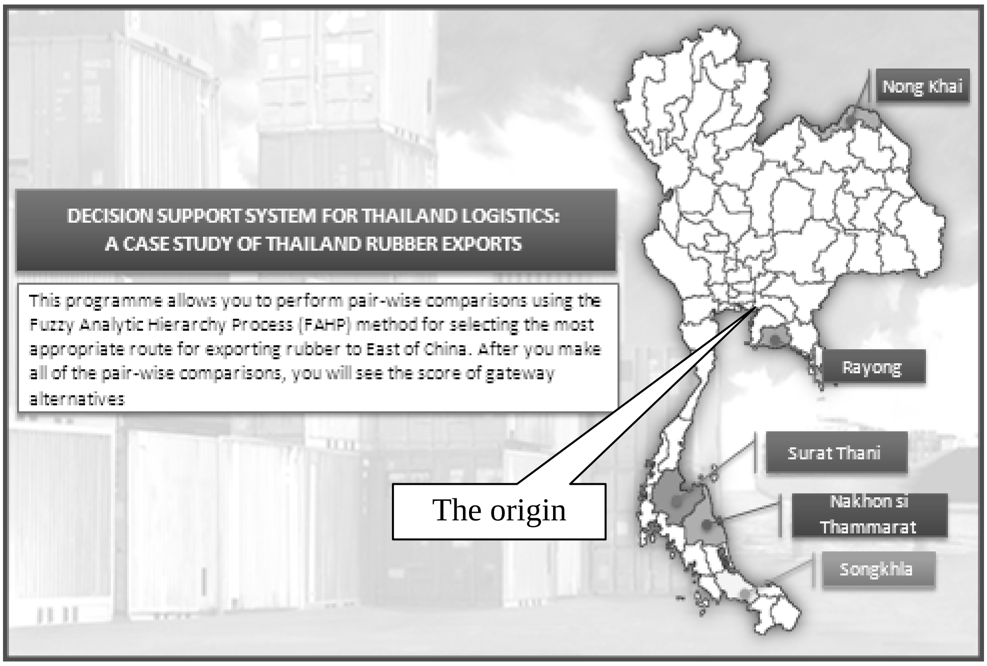


Figure 4.27 The first panel for defining the objective of decision-making

Alternative Routes for Songkhla to East of China

Route No.	Thailand			International transportation		China	
	Origin	Port/customs	Inland mode	Port/customs	Mode	Port	Mode
1	Songkhla	Padang Besar	Trailer	Penang	Train	Qingdao	Mother vessel
2	Songkhla	Padang Besar	Train	Penang	Train	Qingdao	Mother vessel
3	Songkhla	Songkhla port	Trailer	Hong Kong	Vessel	Qingdao	Mother vessel
4	Songkhla	Sadao border	Trailer	Penang	Trailer	Qingdao	Mother vessel

Start

Figure 4.28 The alternative routes under the objective defined

4.6.2 Pair-wise comparison

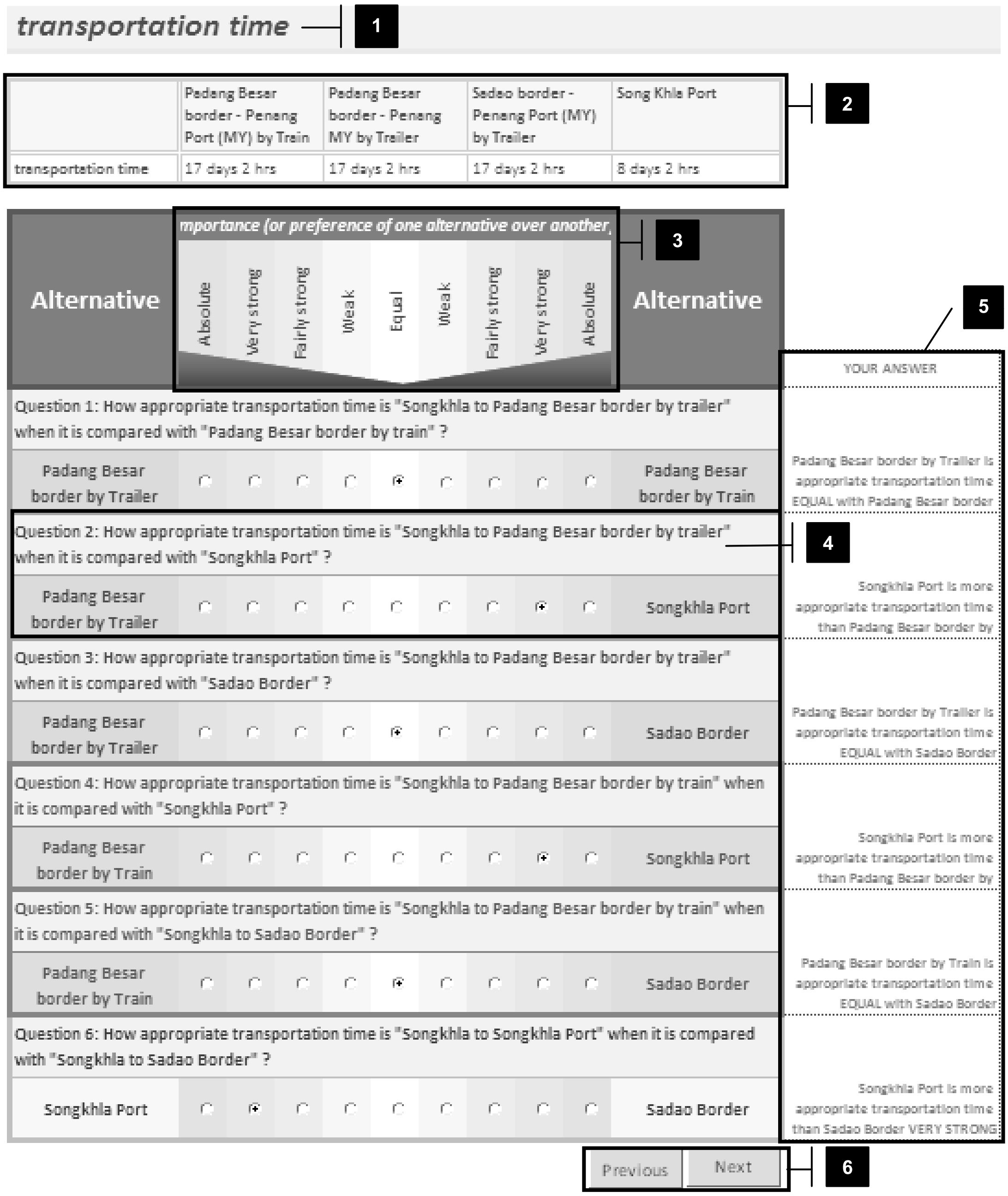


Figure 4.29 Interface design of pair-wise comparison

Interface design of pair-wise comparison is illustrated in Figure 4.29. The pair-wise comparison panels represent in an interaction form to allow users to enter the decision values. The pages of pair-wise comparison are consisted of major components as follows:

1. The heading of sub-criteria.
2. The information of alternative routes under sub-criteria for supporting user in decision-making process. Example of information is shown in Figure 4.30.

	Padang Besar border - Penang Port (MY) by Train	Padang Besar border - Penang MY by Trailer	Sadao border - Penang Port (MY) by Trailer	Song Khla Port
transportation time	17 days 2 hrs	17 days 2 hrs	17 days 2 hrs	8 days 2 hrs

Figure 4.30 The information of alternative under sub-criteria

3. The linguistic scale with five levels for comparing alternatives as follows: "Equal", "Weak", "Fairly strong", "Very strong", and "Absolute". The linguistic scale is illustrated in Figure 4.31.

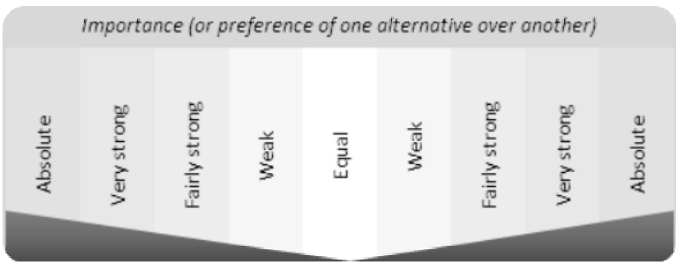


Figure 4.31 The linguistic scale

4. Question for pair-wise comparison i.e. "How appropriate length is "Songkhla to Padang Besar border by trailer" when it is compared with "Padang Besar border by train"?". User evaluates this question by using interaction form in Figure 4.32.

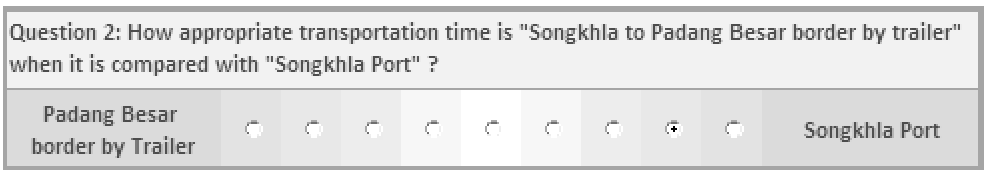


Figure 4.32 Question and interaction form for pair-wise comparison

5. Linguistic context of user evaluation will be shown when user compares alternatives. Example of linguistic context is shown in Figure 4.33.

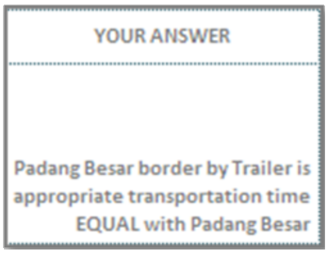


Figure 4.33 Linguistic context of user evaluation

6. Next and previous button for starting the next pair-wise comparison or back to previous sheet.

Thereupon, the scores from user evaluation are transformed into fuzzy score and contained to pair-wise comparison matrices (see Appendix C).

4.6.3 Result Visualization

After pair-wise comparison under all sub-criteria, the user's result will be shown overall priorities of alternative gateways as summary result and priorities under each sub-criteria. In this section, alternative routes were evaluated based on information which support in the decision support system. The result is presented in the layout of data grid and graphic view. The result visualizations in this section are examples for presenting and interpreting the priority weights. The corresponding weights of each evaluation are obtained from the FAHP model based on real information.

4.6.3.1 Result Visualization for Nong Khai Province

The result shows the priority weights of alternative gateways for Nong Khai province. Figures 4.34 - 4.37 present the result from evaluation under each sub-criteria. Then, overall scores of all alternatives are presented in Figure 4.38. Manufacturer can consider the overall scores of alternative gateways for selecting the appropriate route.

Priority weights of alternatives with respect to sub-attributes of Economic factor

Logistics cost

Rank	Alternatives	Priority weight
1	BKK port	0.5593
2	LCB port	0.4407
3	Mukdahan border	0.0000
3	Nakhon Phanom border	0.0000
3	Bueng Kan border	0.0000

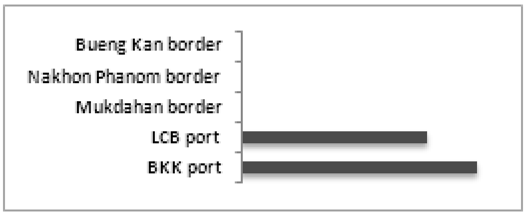


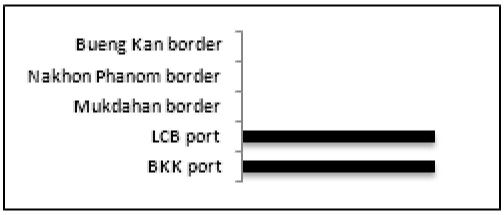
Figure 4.34 The priority weights of alternatives for Nong Khai province to Eastern China under economic factor

Figure 4.34 presents that the transportation route from Nong Khai province to Eastern China via Bangkok port (BKK port) is the chepest logistics cost. The second is route via Laem Chabang port (LCB port). For Mukdahan, Nakhon Phanom, and Bueng Kan border, the weights are zero as a result of FAHP. It means that the transportation routes via these gateways are very expensive when are compared with BKK and LCB ports. FAHP based on Chang's extents analysis method neglects the alternative gateways with very high logistics cost.

Priority weights of alternatives with respect to sub-attributes of Environment considerations

Rules of international trade

Rank	Alternatives	Priority weight
1	BKK port	0.5000
1	LCB port	0.5000
3	Mukdahan border	0.0000
3	Nakhon Phanom border	0.0000
3	Bueng Kan border	0.0000



Insurance policy

Rank	Alternatives	Priority weight
1	BKK port	0.5000
1	LCB port	0.5000
3	Mukdahan border	0.0000
3	Nakhon Phanom border	0.0000
3	Bueng Kan border	0.0000

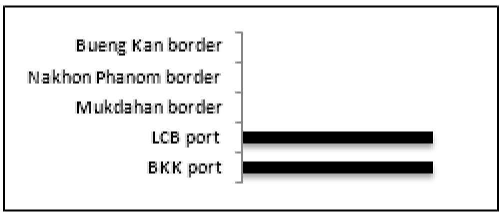


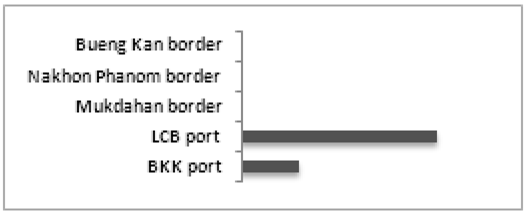
Figure 4.35 The priorities of alternative gateways for Nong Khai province to Eastern China under environment considerations

From Figure 4.35, LCB and BKK ports are not different when compare with rules of international trade and insurance policy.

Priority weights of alternatives with respect to sub-attributes of Port/customs considerations

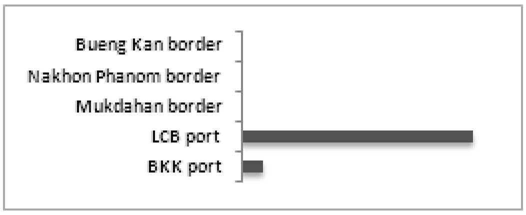
Facilitation equipment

Rank	Alternatives	Priority weight
2	BKK port	0.2280
1	LCB port	0.7720
3	Mukdahan border	0.0000
3	Nakhon Phanom border	0.0000
3	Bueng Kan border	0.0000



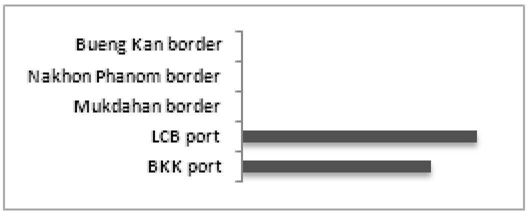
Capacity

Rank	Alternatives	Priority weight
2	BKK port	0.0840
1	LCB port	0.9160
3	Mukdahan border	0.0000
3	Nakhon Phanom border	0.0000
3	Bueng Kan border	0.0000



Custom procedure

Rank	Alternatives	Priority weight
2	BKK port	0.4477
1	LCB port	0.5523
3	Mukdahan border	0.0000
3	Nakhon Phanom border	0.0000
3	Bueng Kan border	0.0000



Accessibility

Rank	Alternatives	Priority weight
2	BKK port	0.2512
1	LCB port	0.4726
3	Mukdahan border	0.1777
4	Nakhon Phanom border	0.0985
5	Bueng Kan border	0.0000

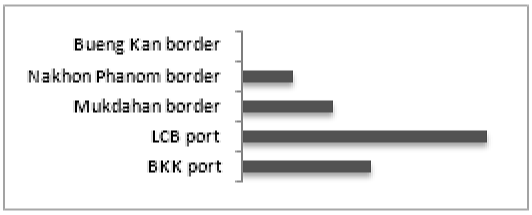


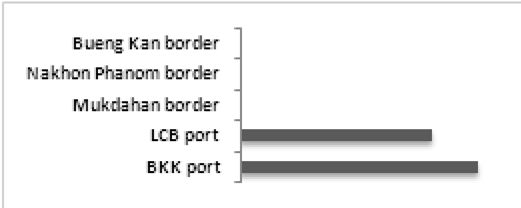
Figure 4.36 The priorities of alternatives for Nong Khai province to Eastern China under port/customs considerations

From Figure 4.36, the evaluation under port/customs considerations, LCB port is more appropriate than the others when considers with all sub-criteria.

Priority weights of alternatives with respect to sub-attributes of Transportation factors

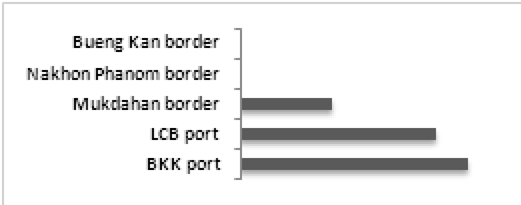
Length

Rank	Alternatives	Priority weight
1	BKK port	0.5523
2	LCB port	0.4477
3	Mukdahan border	0.0000
3	Nakhon Phanom border	0.0000
3	Bueng Kan border	0.0000



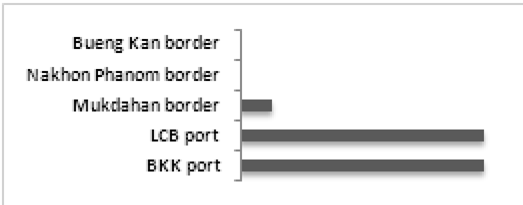
Transportation time

Rank	Alternatives	Priority weight
1	BKK port	0.4410
2	LCB port	0.3818
3	Mukdahan border	0.1772
4	Nakhon Phanom border	0.0000
4	Bueng Kan border	0.0000



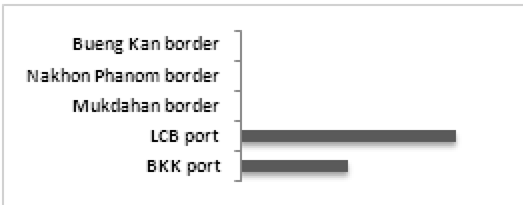
Route quality

Rank	Alternatives	Priority weight
1	BKK port	0.4703
1	LCB port	0.4703
3	Mukdahan border	0.0593
4	Nakhon Phanom border	0.0000
4	Bueng Kan border	0.0000



Security of products

Rank	Alternatives	Priority weight
2	BKK port	0.3342
1	LCB port	0.6658
3	Mukdahan border	0.0000
3	Nakhon Phanom border	0.0000
3	Bueng Kan border	0.0000



Reliability and punctuality

Rank	Alternatives	Priority weight
2	BKK port	0.2712
1	LCB port	0.7288
3	Mukdahan border	0.0000
3	Nakhon Phanom border	0.0000
3	Bueng Kan border	0.0000

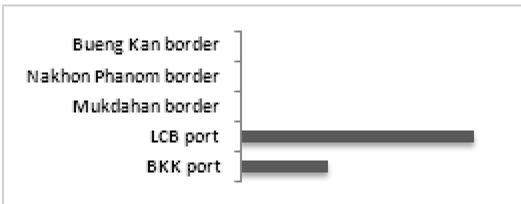
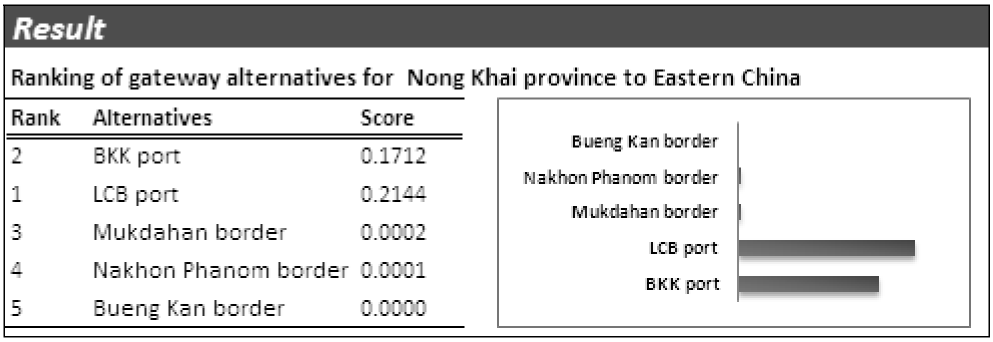


Figure 4.37 The priorities of alternative weights for Nong Khai province to Eastern China under transportation factors

Figure 4.37 presents that the transportation route from Nong Khai province via BKK port uses the shortest time with the shortest length. LCB port is more reliability and punctuality and security than the other routes. LCB and BKK ports also have the same priority weight when consider with route quality.

After all alternative gateways were compared under all sub-criteria, the overall scores of alternative gateways will be calculated via FAHP model. The overall scores of each gateway for Nong Khai province to Eastern China are shown in Figure 4.38.



Result

Ranking of gateway alternatives for Nong Khai province to Eastern China

Rank	Alternatives	Score
2	BKK port	0.1712
1	LCB port	0.2144
3	Mukdahan border	0.0002
4	Nakhon Phanom border	0.0001
5	Bueng Kan border	0.0000

Figure 4.38 Overall scores of alternative gateways for Nong Khai province to Eastern China

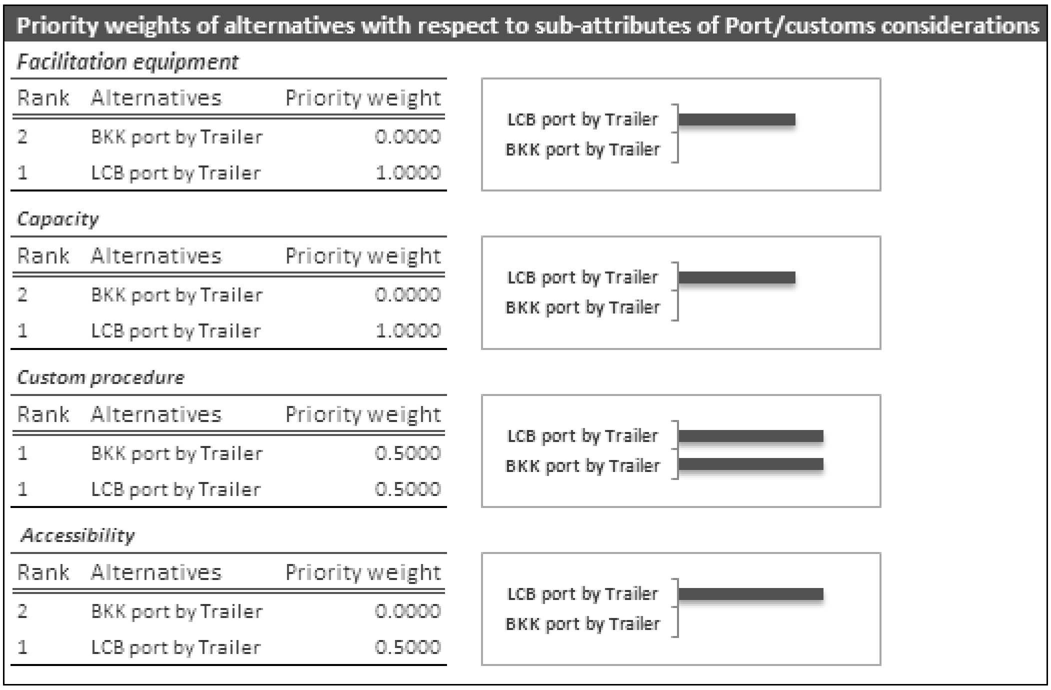
Figure 4.38 means that Laem Chabang port (LCB port) is the most appropriate alternative gateway for Nong Khai province. The transportation route starts from Nong Khai province. Exporter can transport to LCB port by using trailer. Then, rubber products are shiped to Hong Kong port by vessel. At Hong Kong port, these products are transited to mother vessel and are shiped to destination at Eastern China. The second appropriate alternative is Bangkok port (BKK port). Next is Mukdahan and Nakhon Phanom border respectively. For Bueng Kan border, this gateway has score is zero. It means that the route via Bueng Kan border is very low appropriate when compares with the other gateways. The zero score is a result of FAHP method of Chang’s extent analysis. This method neglects the alternatives which are less important than other. From the evaluation results, user can use the results as information support decision for selecting the most appropriate route.

The evaluation results of Nong Khai province, LCB port is the best alternative gateway. The results of this experiment correspond to the current situation of manufacturers in Nong Khai province. Due to LCB port is one of the most modern and advanced ports in Southeast Asia and the one of the most important gateway of Thailand. For Bangkok port, the port is situated on the left side of the Chao Phraya

River. But this port is limited by its access channel and traffic problems in the Bangkok area. In addition, Nong Khai province is near many important cross-border trades. These cross-border trades can connect with the highway road network for leading to Da Nang port in Vietnam. The highway road networks are built for supporting the Greater Mekong Sub-region Economic Corridor (GMS) project. The East-West Economic Corridor (EWEC) which is one of key routes linking the region stretches from Thailand to Eastern China via Laos. EWEC runs from Da Nang port in Vietnam, through Laos, Thailand, and to the Mawlamyine port in Myanmar. Economic corridors are meant to attract investment and generate economic activities along a region, usually with the aim toward development. They are meant to provide two fundamental attributes for development: lower distribution costs and improved land supply for economic activities. There is a bridge crossing Mekong River between Laos and Thailand at Mukdahan border. It is the Second Thai-Lao Friendship Mekong Bridge is part of Asia Highway No. 16 (or Road No. 9 in Laos). The bridge connects Mukdahan province (Thailand) to Savannaket province (Laos) for leading to Da Nang port in Vietnam. Currently, the Third Thai-Lao Mekong Bridge over the Mekong River has been constructed. This bridge connects the town of Nakhon Phanom province in Northeastern (Thailand) to Thakhek in Khammouane province (Laos). Construction is expected to be completed in 2011. For Da Nang port, the port is located in Da Nang City as socio economic center of mid-Vietnam and the biggest port in mid-Vietnam. It contains a total of 229.3 thousand square meters of storage area including 29.3 thousand square meters of warehouse space and 183.7 thousand square meters of yards. In EWEC, there are the issues on the transit transport in Laos. It is more difficult issues such as establishing bonded transport through third country. Now, there is no issue on the transit bonded transport in Laos. The development of transport operations along the new routes is hard to predict at this stage.

4.6.3.2 Result Visualization for Rayong Province

The result shows the priority weights of alternative gateways for Rayong province. Figures 4.39 - 4.42 present the results from evaluation under each sub-criteria. Then, overall scores of all alternative gateways are presented in Figure 4.43.



Priority weights of alternatives with respect to sub-attributes of Port/customs considerations

Facilitation equipment

Rank	Alternatives	Priority weight
2	BKK port by Trailer	0.0000
1	LCB port by Trailer	1.0000

Capacity

Rank	Alternatives	Priority weight
2	BKK port by Trailer	0.0000
1	LCB port by Trailer	1.0000

Custom procedure

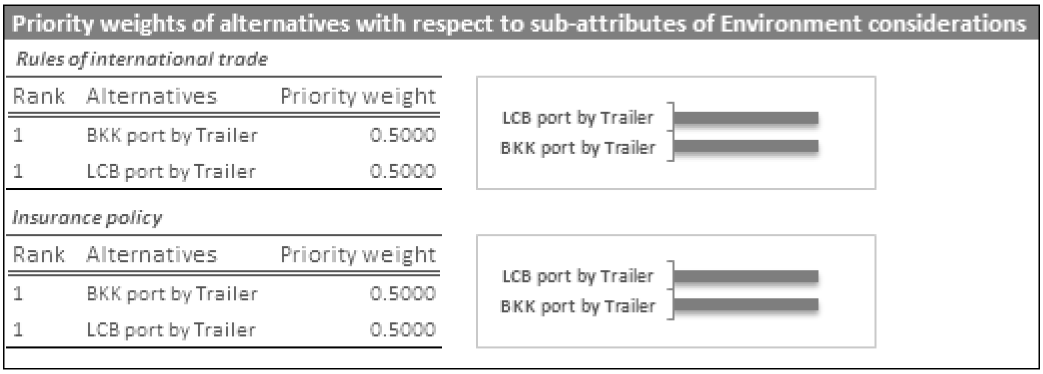
Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.5000
1	LCB port by Trailer	0.5000

Accessibility

Rank	Alternatives	Priority weight
2	BKK port by Trailer	0.0000
1	LCB port by Trailer	0.5000

Figure 4.39 The priorities of alternative gateways for Rayong province to Eastern China under port/customs considerations

From Figure 4.39, LCB port is more appropriated than BKK port when considers with facilitation equipment, capacity, and accessibility. For customs procedure, BKK and LCB ports have the priorities equally.



Priority weights of alternatives with respect to sub-attributes of Environment considerations

Rules of international trade

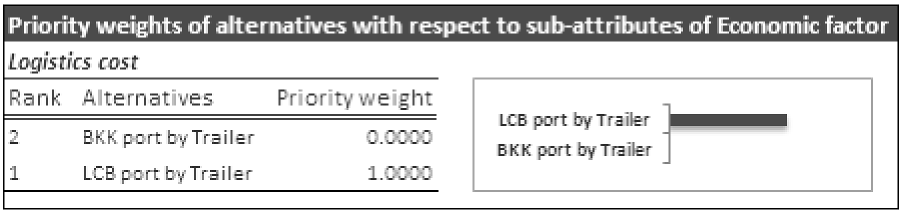
Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.5000
1	LCB port by Trailer	0.5000

Insurance policy

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.5000
1	LCB port by Trailer	0.5000

Figure 4.40 The priorities of alternative gateways for Rayong province to Eastern China under environment considerations

From Figure 4.40 presents that LCB and BKK port have the priorities equally when consider under environment considerations.

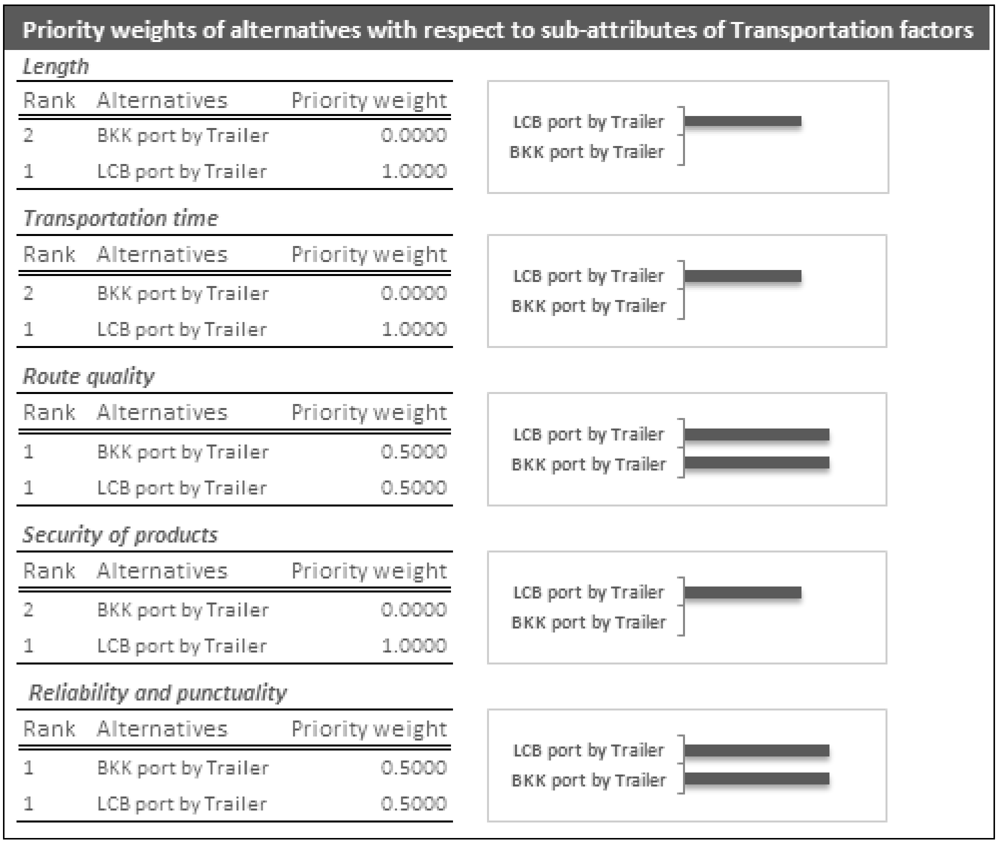

Priority weights of alternatives with respect to sub-attributes of Economic factor

Logistics cost

Rank	Alternatives	Priority weight
2	BKK port by Trailer	0.0000
1	LCB port by Trailer	1.0000

Figure 4.41 The priorities of alternative gateways for Rayong province to Eastern China under economic factor

Figure 4.41 shows that the transportation route from Rayong province to Eastern China via LCB port spend logistics cost less than via BKK port.


Priority weights of alternatives with respect to sub-attributes of Transportation factors

Length

Rank	Alternatives	Priority weight
2	BKK port by Trailer	0.0000
1	LCB port by Trailer	1.0000

Transportation time

Rank	Alternatives	Priority weight
2	BKK port by Trailer	0.0000
1	LCB port by Trailer	1.0000

Route quality

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.5000
1	LCB port by Trailer	0.5000

Security of products

Rank	Alternatives	Priority weight
2	BKK port by Trailer	0.0000
1	LCB port by Trailer	1.0000

Reliability and punctuality

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.5000
1	LCB port by Trailer	0.5000

Figure 4.42 The priorities of alternatives for Rayong province to Eastern China under transportation factors

From Figure 4.42, LCB port uses shorter time and shorter length than BKK port. LCB and BKK ports have the same priorities when consider with reliability and punctuality and route quality. LCB port is more appropriate than BKK port when considers with security of products.

The overall scores of alternative gateways for Rayong province to Eastern China are shown in Figure 4.43.

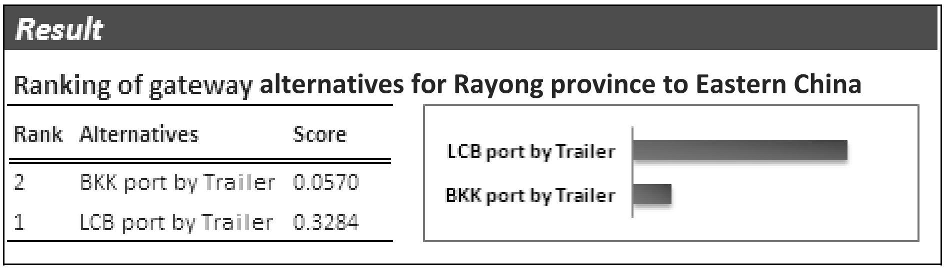


Figure 4.43 Overall scores of alternative gateways for Rayong province to Eastern China

Figure 4.43 means that Laem Chabang port (LCB port) is the most appropriate alternative gateways for Rayong province. Exporter can transport by using trailer into LCB port. Then, rubber products are shiped to Hong Kong port by vessel and transit to mother vessel at here. Next, these products are shipped to Eastern China.

The results for Rayong province, Laem Chabang port is recommended as the best alternative. Laem Chabang port is Thailand's premier deep-sea commercial port. It is one of the most modern and advanced ports in Southeast Asia and has positioned itself as the one of the most important gateway to Thailand and the greater Indochina region. For Bangkok port is situated on the left side of the Chao Phraya River. It has only narrow water width due to location along Chao Phraya River and the depth of water of 8.5 m. The big vessel over 10,000 tons cannot enter the port. Also, Rayong province is nearer LCB port than BKK port. Manufacuter can reduce cost and transportation time.

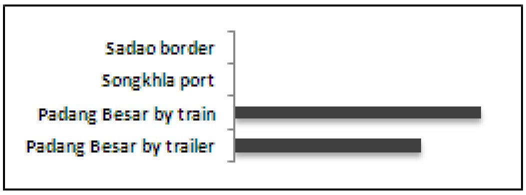
4.6.3.3 Result Visualization for Songkhla Province

The result shows the priority weights of alternative gateways for Songkhla province. Figures 4.44 - 4.47 present the results from evaluation under each sub-criteria. Then, overall scores of all alternatives are presented in Figure 4.48.

Priority weights of alternatives with respect to sub-attributes of Port/customs considerations

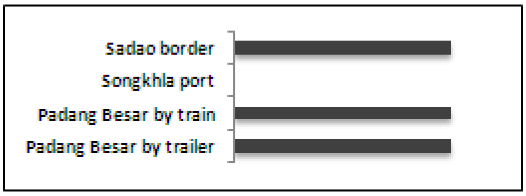
Facilitation equipment

Rank	Alternatives	Priority weight
2	Padang Besar by trailer	0.4317
1	Padang Besar by train	0.5683
3	Songkhla port	0.0000
3	Sadao border	0.0000



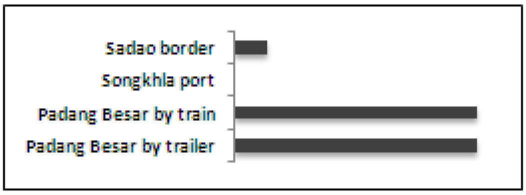
Capacity

Rank	Alternatives	Priority weight
1	Padang Besar by trailer	0.3333
1	Padang Besar by train	0.3333
4	Songkhla port	0.0000
1	Sadao border	0.3333



Custom procedure

Rank	Alternatives	Priority weight
1	Padang Besar by trailer	0.4694
1	Padang Besar by train	0.4694
4	Songkhla port	0.0000
3	Sadao border	0.0613



Accessibility

Rank	Alternatives	Priority weight
2	Padang Besar by trailer	0.3782
1	Padang Besar by train	0.5593
4	Songkhla port	0.0000
3	Sadao border	0.0626

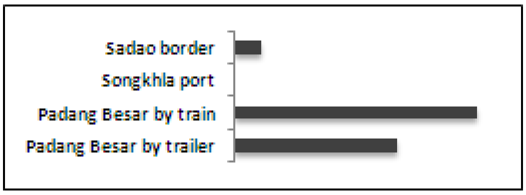


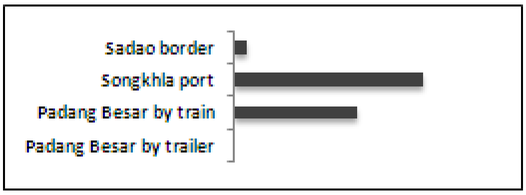
Figure 4.44 The priorities of alternatives for Songkhla province to Eastern China under port/customs considerations

From Figure 4.44, Padang Besar has facilitation equipment at border and port more facilitate than Songkhla port. Considering of capacity, Penang port can support volume of products is more than Songkhla port. For Padang Besar border, it can be accessed more comfortable than Sadao border and Songkhla port.

Priority weights of alternatives with respect to sub-attributes of Transportation factors

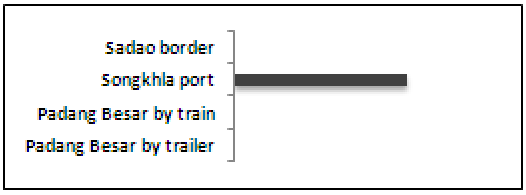
Length

Rank	Alternatives	Priority weight
4	Padang Besar by trailer	0.0000
2	Padang Besar by train	0.3802
1	Songkhla port	0.5807
3	Sadao border	0.0391



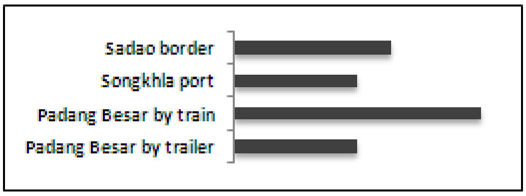
Transportation time

Rank	Alternatives	Priority weight
2	Padang Besar by trailer	0.0000
2	Padang Besar by train	0.0000
1	Songkhla port	1.0000
2	Sadao border	0.0000



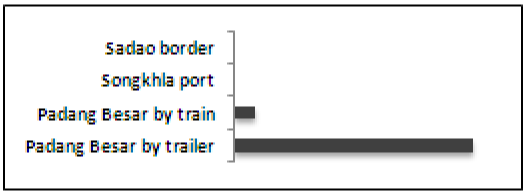
Route quality

Rank	Alternatives	Priority weight
3	Padang Besar by trailer	0.1891
1	Padang Besar by train	0.3790
3	Songkhla port	0.1891
2	Sadao border	0.2429



Security of products

Rank	Alternatives	Priority weight
1	Padang Besar by trailer	0.9230
2	Padang Besar by train	0.0770
3	Songkhla port	0.0000
3	Sadao border	0.0000



Reliability and punctuality

Rank	Alternatives	Priority weight
2	Padang Besar by trailer	0.4094
1	Padang Besar by train	0.5689
4	Songkhla port	0.0000
3	Sadao border	0.0217

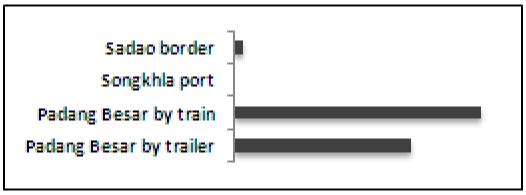


Figure 4.45 The priorities of alternatives for Songkhla province to Eastern China under transportation factors

Figure 4.45 presents the results from consideration under transportation factors. The transportation route via Songkhla port uses the shortest time and length. Considering of route quality, security, and reliability and punctuality, it is found that the best gateway is Padang Besar border.

Priority weights of alternatives with respect to sub-attributes of Economic factor

Logistics cost

Rank	Alternatives	Priority weight
2	Padang Besar by trailer	0.3249
3	Padang Besar by train	0.2766
1	Songkhla port	0.3985
4	Sadao border	0.0000

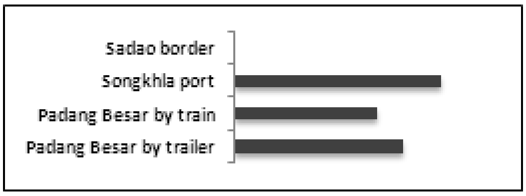


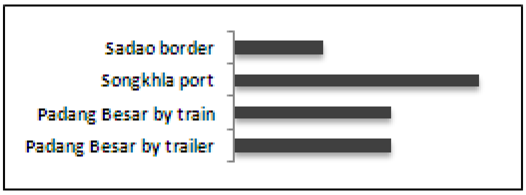
Figure 4.46 The priorities of alternatives for Songkhla province to Eastern China under economic factor

Figure 4.46 presents considering of logistics cost. The logistics cost considers from the origin to gateway. Songkhla port has the cheapest cost due to the port is located in Songkhla province.

Priority weights of alternatives with respect to sub-attributes of Environment considerations

Rules of international trade

Rank	Alternatives	Priority weight
2	Padang Besar by trailer	0.2427
2	Padang Besar by train	0.2427
1	Songkhla port	0.3777
4	Sadao border	0.1370



Insurance policy

Rank	Alternatives	Priority weight
1	Padang Besar by trailer	0.2500
1	Padang Besar by train	0.2500
1	Songkhla port	0.2500
1	Sadao border	0.2500

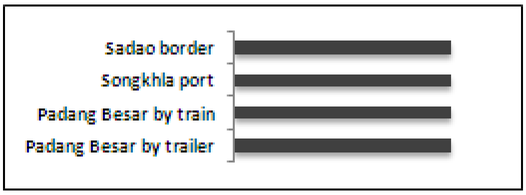


Figure 4.47 The priorities of alternatives for Songkhla province to Eastern China under environment considerations

Figure 4.47 presents that the rules of international trade of Songkhla port are more facilitate than Padang Besar and Sadao border border. And the priorities weights of gateways when are considered with insurance policy are not different.

The overall priorities of alternative gateways for Songkhla province to Eastern China are shown in Figure 4.48.

Result

Ranking of gateway alternatives for Songkhla province to Eastern China

Rank	Alternatives	Score
1	Padang Besar by trailer	0.1696
2	Padang Besar by train	0.1274
3	Songkhla port	0.0858
4	Sadao border	0.0032

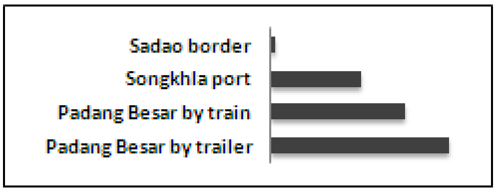


Figure 4.48 Overall priorities of alternatives for Songkhla province to Eastern China

Figure 4.48 means that Padang Besar border is the appropriate alternative for Songkhla province. Exporter transports by using trailer to Padang Besar border. Next, products are transited to train and then access Penang port at Malaysia. Then, rubber products are shipped to Eastern China via Penang port.

The results for Songkhla province, Padang Besar border is recommended as the best gateway. This gateway can access Penang port at Malaysia by train. Padang Besar is an important border-crossing between Perlis and Songkhla province Thailand. It is the location for both the road and rail crossing between Malaysia and Thailand. Transportation cargo by rail is more efficient compared to road. For Sadao border, this gateway can access Penang port. At the border, no container inspection area is provided. And traffic jam at the border is another issue. One problem for Thailand-Malaysia border trade is different time of work for Thai officer and Malaysian officer. Moreover, Malaysia is often close on Malalysia’s national holidays. Thus, the large amount of goods for export and import will be stayed at the border. As a result for using many time for goods inspection. For Penang port at Malaysia, It is the third biggest in terms of handling capacity of cargo in Malaysia and also adjacent to major industrial area of Prai and Butterworth. Penang port plays a vital role as logistics hub for freight collection and distribution in the Northern Malaysia. It holds container-handling capacity of around 1 million TEUs per year. For Songkhla port, the port is located on the Gulf of Thailand. The main issues of port are the lack of heavy handling equipment and un-availability for big ship due to light depth of water route. This route uses the shortest transportation time because it takes only 8 – 11 days. But, the route via Songkhla port has cost is higher than using Padang Besar border as a gateway to access Penang port. From the describe above, an evaluation of the results from using FAHP accord with fact of information.

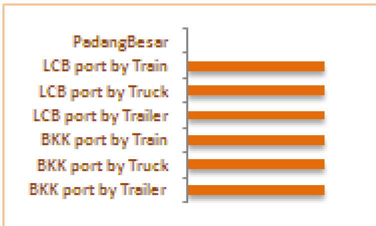
4.6.3.4 Result Visualization for Nakhon Si Thammarat province

The result shows the priority weights of alternative gateways for Nakhon Si Thammarat province. Figures 4.49 - 4.52 present the results from evaluation under each sub-criteria. Then, overall scores of all alternatives are presented in Figure 4.53.

Priority weights of alternatives with respect to sub-attributes of Environment considerations

Rules of international trade

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.1667
1	BKK port by Truck	0.1667
1	BKK port by Train	0.1667
1	LCB port by Trailer	0.1667
1	LCB port by Truck	0.1667
1	LCB port by Train	0.1667
7	PadangBesar	0.0000



Insurance policy

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.1667
1	BKK port by Truck	0.1667
1	BKK port by Train	0.1667
1	LCB port by Trailer	0.1667
1	LCB port by Truck	0.1667
1	LCB port by Train	0.1667
7	PadangBesar	0.0000

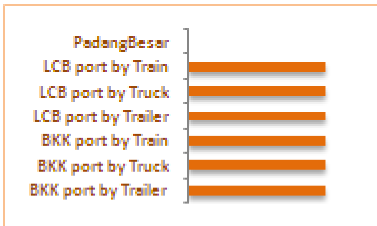


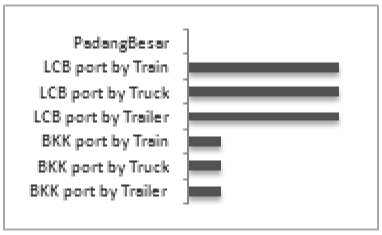
Figure 4.49 The priorities of alternative gateways for Nakhon Si Thammarat province to Eastern China under environment considerations

Figure 4.49 show that BKK and LCB ports are not different under considering of rules of international trade and insurance policy. the rules of international trade of LCB and BKK ports are more facilitate than Padang Besar border. And BKK and LCB ports have more priority than Padang Besar border when compare with insurance policy.

Priority weights of alternatives with respect to sub-attributes of Port/customs considerations

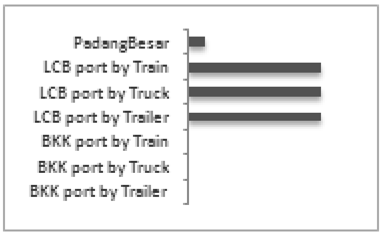
Facilitation equipment

Rank	Alternatives	Priority weight
4	BKK port by Trailer	0.0587
4	BKK port by Truck	0.0587
4	BKK port by Train	0.0587
1	LCB port by Trailer	0.2747
1	LCB port by Truck	0.2747
1	LCB port by Train	0.2747
7	PadangBesar	0.0000



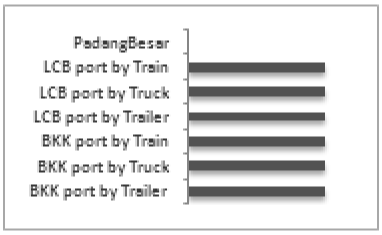
Capacity

Rank	Alternatives	Priority weight
5	BKK port by Trailer	0.0000
5	BKK port by Truck	0.0000
5	BKK port by Train	0.0000
1	LCB port by Trailer	0.3210
1	LCB port by Truck	0.3210
1	LCB port by Train	0.3210
4	PadangBesar	0.0371



Custom procedure

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.1667
1	BKK port by Truck	0.1667
1	BKK port by Train	0.1667
1	LCB port by Trailer	0.1667
1	LCB port by Truck	0.1667
1	LCB port by Train	0.1667
7	PadangBesar	0.0000



Accessibility

Rank	Alternatives	Priority weight
5	BKK port by Trailer	0.0000
5	BKK port by Truck	0.0000
5	BKK port by Train	0.0000
4	LCB port by Trailer	0.1991
2	LCB port by Truck	0.2523
1	LCB port by Train	0.3326
3	PadangBesar	0.2160

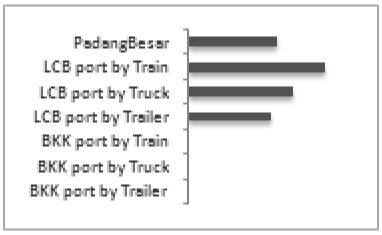


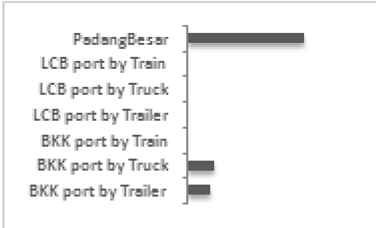
Figure 4.50 The priorities of alternatives for Nakhon Si Thammarat province to Eastern China under port/customs considerations

From Figure 4.50, considering of facilitation equipment and capacity, LCB port is better than the other alternative gateways. And BKK port has facility equipment is better than Penang port. But Penang port has capacity is better than BKK port. For custom procedure, BKK and LCB ports are more convenience than Padang Besar border. Accessing to LCB port by train is the first rank under accessibility.

Priority weights of alternatives with respect to sub-attributes of Transportation factors

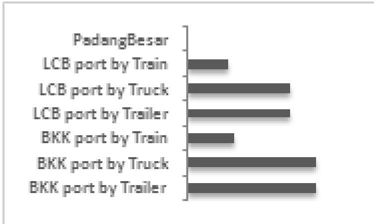
Length

Rank	Alternatives	Priority weight
3	BKK port by Trailer	0.1380
2	BKK port by Truck	0.1571
4	BKK port by Train	0.0000
4	LCB port by Trailer	0.0000
4	LCB port by Truck	0.0000
4	LCB port by Train	0.0000
1	PadangBesar	0.7049



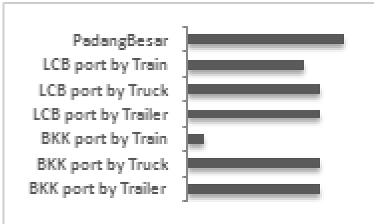
Transportation time

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.2355
1	BKK port by Truck	0.2355
5	BKK port by Train	0.0833
3	LCB port by Trailer	0.1858
3	LCB port by Truck	0.1858
6	LCB port by Train	0.0742
7	PadangBesar	0.0000



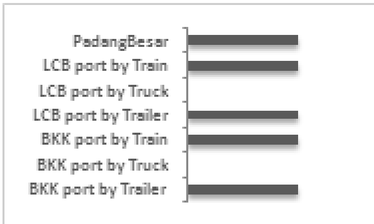
Route quality

Rank	Alternatives	Priority weight
2	BKK port by Trailer	0.1621
2	BKK port by Truck	0.1621
7	BKK port by Train	0.0207
2	LCB port by Trailer	0.1621
2	LCB port by Truck	0.1621
6	LCB port by Train	0.1416
1	PadangBesar	0.1894



Security of products

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.2000
6	BKK port by Truck	0.0000
1	BKK port by Train	0.2000
1	LCB port by Trailer	0.2000
6	LCB port by Truck	0.0000
1	LCB port by Train	0.2000
1	PadangBesar	0.2000



Reliability and punctuality

Rank	Alternatives	Priority weight
4	BKK port by Trailer	0.0000
4	BKK port by Truck	0.0000
2	BKK port by Train	0.3638
4	LCB port by Trailer	0.0000
4	LCB port by Truck	0.0000
1	LCB port by Train	0.4849
3	PadangBesar	0.1513

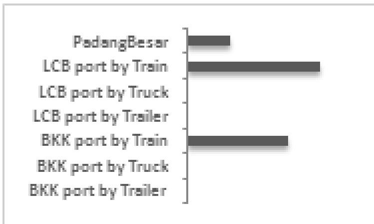


Figure 4.51 The priorities of alternative gateways for Nakhon Si Thammarat province to Eastern China under transportation factors

From Figure 4.51, for shipping via Padang Besar border by train uses the shortest distance but it is the longest shipment time. The transport routes via BKK port by trailer or truck uses shorter time than the other alternative gateways. LCB port is the best when compares with reliability and punctuality.

Priority weights of alternatives with respect to sub-attributes of Economic factor

Logistics cost

Rank	Alternatives	Priority weight
2	BKK port by Trailer	0.2238
6	BKK port by Truck	0.0000
4	BKK port by Train	0.1519
2	LCB port by Trailer	0.2238
6	LCB port by Truck	0.0000
4	LCB port by Train	0.1519
1	PadangBesar	0.2487

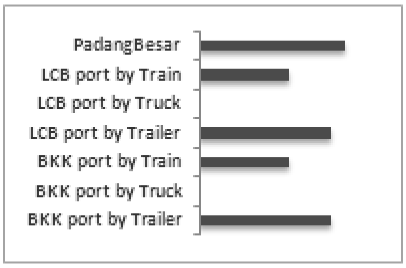


Figure 4.52 The priorities of alternative gateways for Nakhon Si Thammarat province to Eastern China under economic factor

From Figure 4.52, Padang Besar border as a gateway to Penang port is the route which spends the cheapest logistics cost.

The overall priorities of alternative gateways for Nakhon Si Thammarat province to Eastern China are shown in Figure 4.53.

Result

Ranking of gateway alternatives for Nakhon si Thammarat province to Eastern China

Rank	Alternatives	Score
5	BKK port by Trailer	0.0606
7	BKK port by Truck	0.0014
2	BKK port by Train	0.0838
4	LCB port by Trailer	0.0608
6	LCB port by Truck	0.0016
1	LCB port by Train	0.0970
3	PadangBesar	0.0808

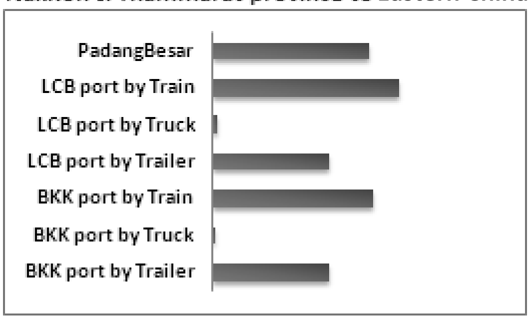


Figure 4.53 Overall scores of alternatives for Nakhon Si Thammarat province to Eastern China

Figure 4.53 means that LCB port is the most appropriate gateway alternative for Nakhon Si Thammarat province. Manufacturer can access LCB port by using train. Then, rubber products are shipped to Hong Kong port by vessel and transit to mother vessel at Hong Kong port to destination in Eastern China.

Nakhon Si Thammarat province is one of the main rubber planting areas in the Upper South of Thailand. From Nakhon Si Thammarat province, shipper can access LCB port by rail transport. Then, rubber products are exported to final destination in Eastern China. This route is recommended as a result of FAHP method. From the analysis on quantitative information, the route via Padang Besar border spends the cheapest logistics cost. But this route takes about 17 days of delivery time. The cost based on the railway transport services are cheaper than the road transport. The cost of railway service from Nakhon Si Thammarat to BKK and LCB ports is about 0.675 THB/kg. Thus, the results above correspond to the actual information of the routes. In current situation, all alternative gateways are uses as the gateway for exporting rubber products to Eastern China.

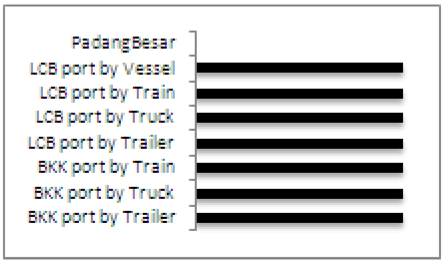
4.6.3.5 Result Visualization for Surat Thani province

The result shows the priority weights of alternative gateways for Surat Thani province. Figures 4.54 - 4.57 present the result from evaluation under each sub-criteria. Then, overall scores of all alternative gateways are presented in Figure 4.58.

Priority weights of alternatives with respect to sub-attributes of Environment considerations

Rules of international trade

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.1429
1	BKK port by Truck	0.1429
1	BKK port by Train	0.1429
1	LCB port by Trailer	0.1429
1	LCB port by Truck	0.1429
1	LCB port by Train	0.1429
1	LCB port by Vessel	0.1429
8	PadangBesar	0.0000



Insurance policy

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.1250
1	BKK port by Truck	0.1250
1	BKK port by Train	0.1250
1	LCB port by Trailer	0.1250
1	LCB port by Truck	0.1250
1	LCB port by Train	0.1250
1	LCB port by Vessel	0.1250
1	PadangBesar	0.1250

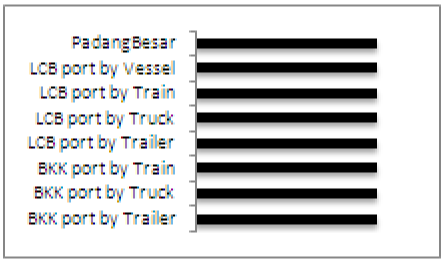


Figure 4.54 The priorities of alternatives for Surat Thani province to Eastern China under environment considerations

Figure 4.54 presents that the shipping via BKK port and LCB port is not different with rules of international trade and insurance policy. For consideration of rules of international trade, Padang Besar border has weight less than BKK and LCB ports.

Priority weights of alternatives with respect to sub-attributes of Economic factor

Logistics cost

Rank	Alternatives	Priority weight
2	BKK port by Trailer	0.2069
6	BKK port by Truck	0.0000
4	BKK port by Train	0.1215
2	LCB port by Trailer	0.2069
6	LCB port by Truck	0.0000
4	LCB port by Train	0.1215
6	LCB port by Vessel	0.0000
1	PadangBesar	0.3433

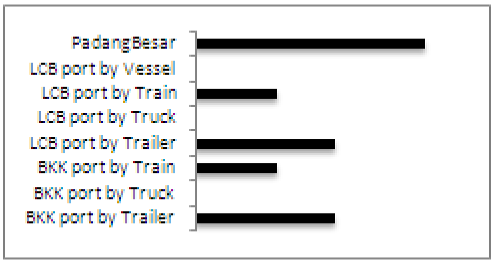


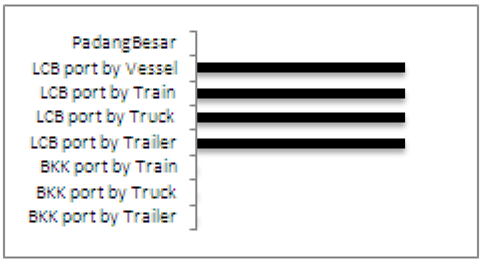
Figure 4.55 The priorities of alternatives for Surat Thani province to Eastern China under economic factor

And Figure 4.55 presents that Padang Besar border as a gateway to Penang port is route with the cheapest logistics cost.

Priority weights of alternatives with respect to sub-attributes of Port/customs considerations

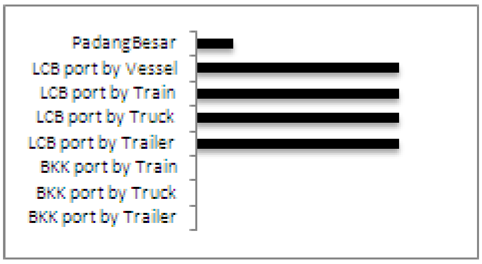
Facilitation equipment

Rank	Alternatives	Priority weight
5	BKK port by Trailer	0.0024
5	BKK port by Truck	0.0024
5	BKK port by Train	0.0024
1	LCB port by Trailer	0.2482
1	LCB port by Truck	0.2482
1	LCB port by Train	0.2482
1	LCB port by Vessel	0.2482
8	PadangBesar	0.0000



Capacity

Rank	Alternatives	Priority weight
6	BKK port by Trailer	0.0000
6	BKK port by Truck	0.0000
6	BKK port by Train	0.0000
1	LCB port by Trailer	0.2388
1	LCB port by Truck	0.2388
1	LCB port by Train	0.2388
1	LCB port by Vessel	0.2388
5	PadangBesar	0.0449



Custom procedure

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.1429
1	BKK port by Truck	0.1429
1	BKK port by Train	0.1429
1	LCB port by Trailer	0.1429
1	LCB port by Truck	0.1429
1	LCB port by Train	0.1429
1	LCB port by Vessel	0.1429
8	PadangBesar	0.0000

Accessibility

Rank	Alternatives	Priority weight
5	BKK port by Trailer	0.0000
5	BKK port by Truck	0.0000
3	BKK port by Train	0.1103
5	LCB port by Trailer	0.0000
5	LCB port by Truck	0.0000
4	LCB port by Train	0.0941
1	LCB port by Vessel	0.6743
2	PadangBesar	0.1213

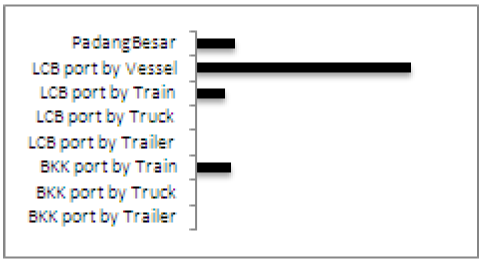


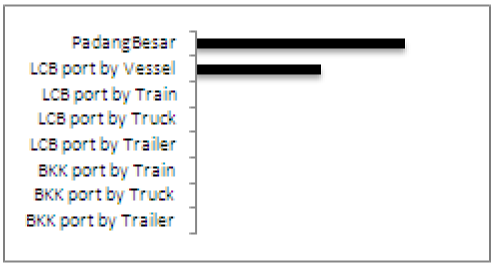
Figure 4.56 The priorities of alternatives for Surat Thani province to Eastern China under port/customs considerations

From Figure 4.56, LCB port is better than the other routes when consider with facility equipment and capacity. LCB and BKK ports is not different with customs procedure. From Surat Thani province, manufacuturer can access LCB port by using vessel. Overall under considering of port/customs, LCB and BKK ports is better than Penang port at Malaysia.

Priority weights of alternatives with respect to sub-attributes of Transportation factors

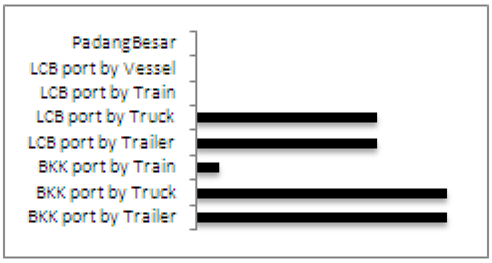
Length

Rank	Alternatives	Priority weight
3	BKK port by Trailer	0.0000
3	BKK port by Truck	0.0000
3	BKK port by Train	0.0000
3	LCB port by Trailer	0.0000
3	LCB port by Truck	0.0000
3	LCB port by Train	0.0000
2	LCB port by Vessel	0.3746
1	PadangBesar	0.6254



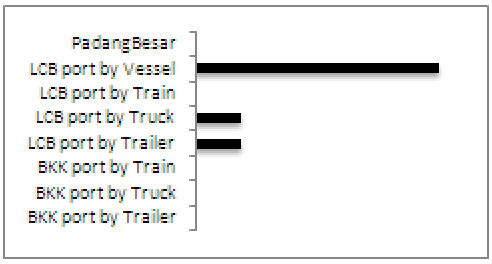
Transportation time

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.2832
1	BKK port by Truck	0.2832
5	BKK port by Train	0.0258
3	LCB port by Trailer	0.2038
3	LCB port by Truck	0.2038
6	LCB port by Train	0.0000
6	LCB port by Vessel	0.0000
6	PadangBesar	0.0000



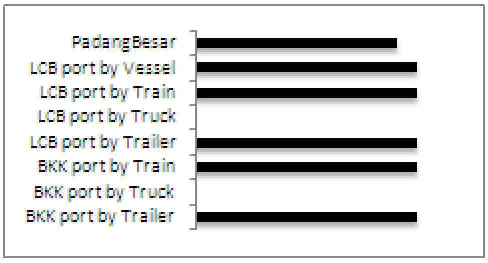
Route quality

Rank	Alternatives	Priority weight
4	BKK port by Trailer	0.0000
4	BKK port by Truck	0.0000
4	BKK port by Train	0.0000
2	LCB port by Trailer	0.1341
2	LCB port by Truck	0.1341
4	LCB port by Train	0.0000
1	LCB port by Vessel	0.7318
4	PadangBesar	0.0000



Security of products

Rank	Alternatives	Priority weight
1	BKK port by Trailer	0.1690
7	BKK port by Truck	0.0000
1	BKK port by Train	0.1690
1	LCB port by Trailer	0.1690
7	LCB port by Truck	0.0000
1	LCB port by Train	0.1690
1	LCB port by Vessel	0.1690
6	PadangBesar	0.1548



Reliability and punctuality

Rank	Alternatives	Priority weight
6	BKK port by Trailer	0.0341
6	BKK port by Truck	0.0341
6	BKK port by Train	0.0341
1	LCB port by Trailer	0.1919
1	LCB port by Truck	0.1919
1	LCB port by Train	0.1919
1	LCB port by Vessel	0.1919
5	PadangBesar	0.1300

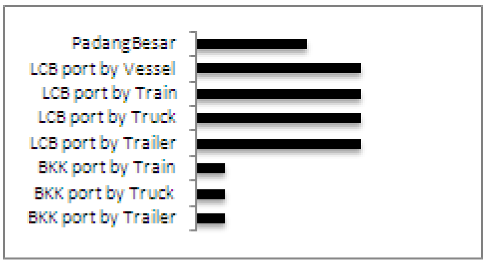
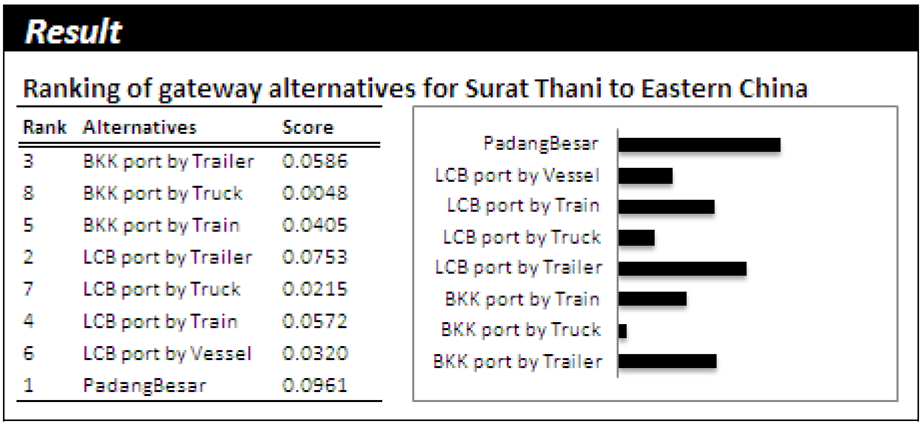


Figure 4.57 The priorities of alternatives for Surat Thani province to Eastern China under transportation factors

From Figure 4.57, for shipping via Padang Besar border by using train is the shortest distance but it is the longest shipment time. The transportation routes via BKK port by using trailer or truck is shorter time than the other routes. For considering of route quality, shipping to LCB port by using vessel is the best under security of products. LCB port is the best when is compared with reliability and punctuality.

The overall priorities of alternative gateways for Surat Thani province to Eastern China are shown in Figure 4.58.



Rank	Alternatives	Score
3	BKK port by Trailer	0.0586
8	BKK port by Truck	0.0048
5	BKK port by Train	0.0405
2	LCB port by Trailer	0.0753
7	LCB port by Truck	0.0215
4	LCB port by Train	0.0572
6	LCB port by Vessel	0.0320
1	PadangBesar	0.0961

Figure 4.58 Overall priorities of alternative gateways for Surat Thani province to Eastern China

Figure 4.58 means that Padang besar is the appropriate gateway alternative for Surat Thani province. Exporter transports by using train into Penang port via Padang Besar border. Then, rubber products are shiped to Eastern China via Penang port at Malaysia. This route spend the cheapest logistics cost. The route takes 18 days to Eastern China. For the other routes, shipper takes time shorter. It uses time about 12-13 days. Due to all alternative gateways are uses as the gateway for exporting rubber products to Eastern China. Thus, the results may change when evaluate by other user.

From the results above, it demonstrates that the model can provide a framework to support decision makers in analyzing route alternatives. User can view the results by graphic and data grid which bring out the appropriate route of the origin from this evaluation. The results of the FAHP approach are satisfactory. These results are comparable with fact of information and user's experience. However, the result that optimal route and choice cannot be identified since the selection may change upon different circumstances. This decision support system was developed for appropriate route selection for each case.

CHAPTER V
DISCUSSION

The objectives of this research are to analyze criteria and alternative route for Thailand rubber export and to develop the decision support system for evaluating an appropriate alternative route in a case study for Thailand rubber export. This chapter discusses the current situation of Thailand rubber industry, evaluation the criteria for Thailand rubber export, and a decision support system. Finally, the limitations of the system are described.

5.1 The Current Situation of Thailand Rubber Industry

Thailand has been the first rank of rubber exporting in the world. The amount of rubber products will be rapidly increased as a result of the one million rais project in year 2011. This one million rais project had been launched in year 2004 in the new planting area, the Northeastern region of Thailand. This will make the exporting value to be 570,362 million THB in year 2012 (Kritchanchai *et al*., 2009). It can be expected when these volume blooms, logistics system in Thailand for rubber exporting will become a major concern. Exporters still lack information about alternative routes. Apart from this, the new planting area may require a new route for exporting. Decision support information about alternative routes has not been provided. A decision support technique is a helpful tool for this problem.

All routes for Thailand rubber export were considered in this decision support system varied by origins to the target destinations. In this research, study areas were selected by amount of rubber planting areas and manufacturers. From literature and focus group, this study has been divided into four regions of Thailand namely the Upper Southern, Lower Southern, Eastern, and Northeastern regions. Afterward, five main areas were selected to be the origins of case study as follows: Nakorn Si Thammarat, Surat Thani, Songkhla, Rayong, and Nong Khai provinces. These areas are major planting area in each region. Mostly, natural rubbers from Thailand are shipped to Eastern China at Shanghai and Qingdao ports (Wasusri and Chichomphoo, 2008). Thus, Eastern China can be considered as the representing destination for route selection. The alternative routes are also considered along with mode of transportation depending on the origin and destination. The alternative routes in this study are Laem Chabang port, Bangkok port, Songkhla port, Padang Besar border, Sadao border, Mukdahan border, Nakhon Phanom border, and Bueng Kan border. The alternative gateways are pair-wise compared under all criteria which must be considered. The appropriate route can be provided from decision analysis under criteria which are considered.

5.2 A Decision Support System for Thailand Rubber Export by Using Fuzzy Analytic Hierarchy Process

This study presents a case of rubber supply chain in Thailand. Route selection is a major concern for exporters. Necessary thing for the appropriate route selection, the criteria must be determined and included in the decision analysis. The main criteria adopted in this study are based on reviewing relevant literature and logistics experts' opinion. From literature survey and interview with experts, this research proposed four main criteria for alternative selection. These are transportation factor, economic factor, port/customs consideration, and environment consideration. These criteria and sub-criteria were evaluated by logistics and multimodal transportation experts.

Due to route selection is a multi-criterion problem on strategic decision making. One popular method for solving multi-criteria analysis problem is Analytic Hierarchy Process (AHP). AHP can consider both qualitative and quantitative criteria in the decision analysis. It is to provide choices from among several alternatives which does comparison for the considered options. However, the traditional AHP still cannot reflect the human thinking. The traditional AHP method is problematic in that it uses exact values to express the decision maker's opinion in the comparison of alternatives.

Therefore, Fuzzy Analytic Hierarchy Process (FAHP) was applied in this study. FAHP is originally based on the concept of the fuzzy set theory, introduced by Zadeh (1965). Analysis of hierarchical structures in fuzzy environment, initially proposed by Buckley (1985), who examined pair-wise comparisons while utilizing fuzzy ratios instead of crisp values (Celik *et al.*, 2009). There are many FAHP methods and applications in the literature proposed by various authors. This study selected Chang's extent analysis method (Chang, 1996). Chang (1996) introduced a new approach for handling FAHP, with the use of triangular fuzzy numbers for pair-wise comparison scale of FAHP and the use of the extent analysis method for the synthetic extent values of the pair-wise comparisons. The proposed method with extent analysis is simple and easy to prioritize decision variables, compared with the conventional AHP. The steps of Chang's extent analysis method are easier than other FAHP approaches. The reason for using a triangular fuzzy number is that it is intuitively easy for decision makers to use and calculate. In addition, modeling using triangular fuzzy numbers has been proven to be an effective way for formulating decision problems where the information available is subjective and imprecise (Dağdeviren and Yüksel, 2008).

From the evaluation found that economic factor is the most important main criteria. The transportation factor was more important than port/customs consideration and environmental consideration was the least of all. After prioritize these main criteria, the sub-criteria under each criteria were compared. Five sub-criteria under transportation factors, reliability and punctuality and security of products were more important than length, transportation time, and route quality. Under port/customs factors composed of four sub-criteria. The convenience of customs process for exporting and the accessibility of inland transportation to port were more important than other sub-criteria under port/customs considerations. The most important sub-criteria under environment considerations was rule of international trade. This also shows that insurance policy was significant but less important than the international trade regulations.

Furthermore, some sub-criteria namely length, transportation time, route quality, facilitation equipment, and capacity were not important for route selections. These sub-criteria had weight was zero. It was a result from FAHP method. This means that decision criteria with zero weight have less important or no important when compared with others. Chang's FAHP extents analysis neglects the criteria which less important than others. The decision maker can focus on the more important criteria. Hence, seven sub-criteria should be concerned in the decision analysis.

However, these are weights of criteria as a result from evaluating by only one group of experts (ten experts' opinion). The geometric mean is preferable to the arithmetic one. Thus, weights of criteria may be changed when the criteria are evaluated by another group of experts. After the weights are determined, weights of each criteria based on the opinions of a group of experts are integrated to a decision support system. Therefore, alternative gateways will be ranked by FAHP algorithm behind the system based on these weights of criteria. If some weights are changed, it can affect to user's result.

Next, a decision support system was developed. A decision support system can be defined as computer technology solutions that can be used to support complex decision making and problem solving (Shim *et al*., 2002). Salewicz and Nakayama (2004) depict that the decision support system as a set of computer-based tools that provide decision maker with interactive capabilities to enhance his understanding and information basis about considered decision problem through usage of models and data processing, which in turn allows reaching decisions by combining personal judgment with information provided by these tools. Classic decision support system tool design is comprised of the components for:

- Database management capabilities with access to internal and external data, information and knowledge.
- Powerful modeling functions accessed by a model management system.
- User interfaces that enable interactive communication between the user and system.

This application was composed of three components: user interface, database of gateway information under each criteria, and FAHP model behind the interface. For system design, the concept module development was used in this system. From this concept, many modules could be developed at the same times. The decision support system allows for interfaces between databases and FAHP model. User can use this application for decision making via user interface. Image object were used to get values from user evaluation. This system was designed for only one user to use in one time.

For system implementation, this study used Excel in combination with Visual Basic for Application (VBA) to write macros, user interface, and model processing. VBA greatly simplifies the process of passing the model to a solver and presenting the solution in a user friendly format (LeBlanc and Galbreth, 2007). VBA has three distinct advantages. It is very easy to learn and use. It has extensive capabilities. It is seamlessly integrated into Microsoft Excel. In addition, it provides platform for the user interface (Tse, Forrest, and Briggs, 1998). Decision makers who use this application can enter data quickly and accurately by checking or clicking the object buttons that are integrated the code list (see Appendix D). Then, the application executes and reveals the data analysis to decision maker with FAHP model behind the interface. In addition, developer may change the appearance of information easily.

From previous chapter, we tested the decision support system by evaluating gateway alternatives of all case studies. With the evaluation results, it demonstrates that the model can provide a framework to support decision makers in analyzing alternative routes. The corresponding results were calculated based on weights of criteria in Table 4.18. In alternative pair-wise comparison, we assessment based on the information of gateways under the criteria which support in the system. For result visualization, the result will be shown overall priorities of gateway alternatives as summary result with overall score and priorities under each sub-criteria.

In Chang’s extent analysis method, it cannot find a consistency process. Ozdagoglu and Ozdagoglu (2007) describe that the consistency index method is not appropriate because of the fuzziness. In fact, Chang's FAHP comprises such a mechanism during the pair-wise calculations when the membership values or possibilities are compared and the intersections are obtained. Furthermore the fuzziness concept has some bias including decision maker's inconsistency.

Disadvantage of Chang’s FAHP extent analysis method is about the zero weights. Fuzzy pair-wise comparisons provide that if a criteria is less important than all of others, then this criteria has very less importance or no importance and weight is zero. Thus, this FAHP method may assign a zero weight to a decision criteria or alternative. Decision criteria with zero weight will not be considered in decision analysis. FAHP totally neglects the criteria which is less important than the others. The decision maker can evaluate gateway alternatives by focusing on more important criteria only. This is unacceptable because some criteria will not be considered in the evaluation of gateway alternatives.

5.3 Limitations of the System

1) The corresponding weights of evaluation are obtained from this decision support system may be changed. Due to the final result was integrated by the weight of criteria which are evaluated by one group of experts only. Thus, the weights of criteria may be changed when the criteria are evaluated by another group of experts.

2) All criteria that are considered in this study as the important factor for route selection problem. But some criteria are not considered in a decision analysis. Because FAHP method neglects the criteria which is very less important than the others. FAHP method gives weights to these criteria are zero. Some criteria that are not important may be neglected in decision analysis.

3) This application was developed by using Microsoft Excel 2007. Microsoft Excel 2007 is the latest version of Excel. Excel 2007 has a new look, a new user interface, and can be supported more than a million rows. If this application file is distributed to other users, people using an older version won’t be able to take advantage of features in later versions. Users with an older version of Excel will get an error when they run this macro.

CHAPTER VI
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Currently, the amount of natural rubbers will be rapidly increased as a result of rubber planting areas expanding to the Northeast of Thailand. Consequently, it can be expected when volume blooms, a decision support system for route selection will be needed. The aim of this study is to investigate the route selection problem by using Fuzzy Analytic Hierarchy Process (FAHP) method. FAHP method provides additional support to the decision makers for assigning the judgments on related pair-wise comparisons.

Literature and fieldwork identified alternative routes for current and future exporting channels. This study proposed alternative routes from five origin areas for Thailand rubber export to Eastern China. The exporting route selection problem is multi-criteria problem. This study considered four main criteria for decision making namely transportation factor, economic factor, port/customs consideration, and environment consideration. With the criteria weight under relevant experts' opinion found by using FAHP, logistics cost under economic factor was the most important criteria for selection. Some sub-criteria such as length, transportation time, route quality, facilitation equipment, and capacity were less important than cost.

This research presents a fuzzy decision support system development and demonstration. A decision support program is simplicity with FAHP algorithm behind the interface. In addition, the information of sub-criteria and weight of criteria based on rubber situation in Thailand were integrated in application.

However, the result that appropriate route and choice cannot be identified since the selection may change upon different circumstances. This decision support system was developed for appropriate route selection for each case.

6.2 Recommendation

This study is concentrated on Thailand rubber products exports from five plantation areas to Eastern China. The same methodology can be applied considering another product and another area.

A decision support system is a stand-alone application. Only one decision maker and one computer can use for decision making. For further development, this technique can be used to develop as a web-based decision support system. One of the main advantages of internet is ability to provide almost unlimited access to the system. Several decision makers can use the online application at the same time. Moreover, decision maker may change the weight of criteria. Due to some decision maker may consider with different between own opinion and experts' opinion.

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APPENDICES

APPENDIX A
RESEARCH QUESTIONAIRE

แบบสอบถามงานวิจัย

โครงการออกแบบระบบสนับสนุนการตัดสินใจ
เลือกระบบการขนส่งต่อเนื่องหลายรูปแบบ สำหรับการส่งออกยางพาราของประเทศไทย

วันที่……..เดือน……………….พ.ศ………

ชื่อ/สกุล……………………………………………………………………………………………...…..…..

แผนก……………………………………………..ตำแหน่ง……………………………………...……………

ประสบการณ์ในการทำงานในตำแหน่งนี้…………………………………………………..…………………….

แบบสอบถามนี้ได้นำมาเพื่อเป็นส่วนหนึ่งของงานวิจัย โดยแบบสอบถามจะมีจุดประสงค์เพื่อสำรวจปัจจัยที่มีความสำคัญต่อการเลือกช่องทางการขนส่งยางพาราของประเทศไทย

วัตถุประสงค์

แบบสอบถามนี้มีเป้าหมายเพื่อให้ผู้กรอกแบบสอบถามพิจารณาเปรียบเทียบปัจจัยที่มีผลต่อการเลือกช่องทางการขนส่งยางพาราของประเทศไทย

แบบประเมิน แบ่งออกเป็น 4 ส่วน ดังนี้

ส่วนที่ 1: ประเมินระดับความสำคัญของปัจจัยหลักของการเลือกเส้นทางการขนส่งยางพาราของประเทศไทย

ส่วนที่ 2: ประเมินระดับความสำคัญของปัจจัยย่อยของปัจจัยด้านการขนส่ง

ส่วนที่ 3: ประเมินระดับความสำคัญของปัจจัยย่อยของปัจจัยด้านสิ่งแวดล้อมอื่นๆ ที่เกี่ยวข้อง

ส่วนที่ 4: ประเมินระดับความสำคัญของปัจจัยย่อยของปัจจัยเกี่ยวกับท่าเรือ/ด่านการค้าชายแดน

ปัจจัยที่มีผลต่อการตัดสินใจเลือกเส้นทางการขนส่งยางพารา

ปัจจัยหลัก	ปัจจัยย่อย	คำจำกัดความ
ปัจจัยด้านการขนส่ง	**ระยะทาง**	พิจารณาระยะทางในการขนส่งยางพาราระหว่างจุดต้นทาง ประเทศไทย จนถึงช่องทางการส่งออกยางพาราจุดสุดท้าย สำหรับการขนส่งไปยังประเทศจีนตะวันออก
	ระยะเวลาในการเดินทาง	พิจารณาระยะเวลาที่ใช้ในการขนส่งยางพาราระหว่างจุดต้นทาง ประเทศไทย จนถึงช่องทางการส่งออกยางพาราจุดสุดท้าย สำหรับการส่งออกยางพาราไปยังประเทศจีนตะวันออก
	คุณภาพเส้นทางที่ใช้ในการขนส่ง	พิจารณาคุณภาพเส้นทางที่ใช้ในการขนส่ง ระหว่างจุดต้นทาง ประเทศไทย จนถึงช่องทางการส่งออกยางพาราจุดสุดท้ายสำหรับการส่งออกยางพาราไปยังประเทศจีนตะวันออก
	คุณภาพและความปลอดภัยของสินค้า	คุณภาพของสินค้า พิจารณาจากสภาพของสินค้าเมื่อถึงปลายทาง เกิดความเสียหายเนื่องจากการขนส่งบนเส้นทางมากน้อยเพียงใด
	ความน่าเชื่อถือและความตรงต่อเวลาในการขนส่งสินค้า	ความน่าเชื่อถือ พิจารณาจากความตรงต่อเวลาในการขนส่ง ความสามารถที่จะขนส่งสินค้าได้อย่างสม่ำเสมอ
ปัจจัยด้านเศรษฐศาสตร์	**ต้นทุนโลจิสติกส์**	ค่าใช้จ่ายในการขนส่งต่อหน่วย โดยประมาณการค่าใช้จ่ายรวมทั้งหมดที่เกิดขึ้นจากการขนส่งสินค้าจากจุดต้นทาง ประเทศไทย จนสินค้าไปถึงประเทศจีนตะวันออก
ปัจจัยเกี่ยวกับท่าเรือ/ด่านการค้าชายแดน	**อุปกรณ์อำนวยความสะดวก**	พิจารณาที่เครื่องมืออุปกรณ์ที่มีอยู่ ของท่าเรือ หรือด่านการค้าชายแดนที่มีการเดินทางผ่านในเส้นทางการขนส่ง ที่สามารถเอื้อประโยชน์ต่อการขนส่งสินค้ามากน้อยเพียงใด
	ความสามารถในการรองรับสินค้า	พิจารณาที่ความสามารถในการรองรับสินค้าของท่าเรือ หรือด่านการค้าชายแดน มีความสามารถที่จะรองรับสินค้าตามปริมาณที่มีการขนส่งได้หรือไม่
	พิธีการด้านศุลกากร	พิจารณาจากขั้นตอนการดำเนินการทางด้านศุลกากร ขั้นตอนในการส่งออก การตรวจสอบคุณภาพสินค้าผ่านแดน สามารถอำนวยความสะดวกต่อการขนส่งได้มากน้อยเพียงใด
	ความสะดวกในการเข้าถึงท่าเรือ/ด่านการค้าชายแดน	พิจารณาถึงรูปแบบที่ทำให้สามารถเข้าถึงบริเวณท่าเรือ หรือด่านการค้าชายแดน
ปัจจัยด้านสิ่งแวดล้อมอื่นๆ ที่เกี่ยวข้อง	**กฎระเบียบว่าด้วยการค้าระหว่างประเทศ**	พิจารณาในกรณีที่รูปแบบการขนส่งมีการขนส่งต่อเนื่องในพื้นที่หลายประเทศ ซึ่งข้อกำหนดต่างๆ ของในแต่ละประเทศ สามารถเอื้อประโยชน์ต่อการขนส่ง หรือเป็นปัญหามากน้อยเพียงใด
	นโยบายด้านการประกันภัยสินค้า	พิจารณาที่เส้นทางการขนส่งที่ใช้สามารถกำหนดผู้ที่เป็นผู้รับผิดชอบในกรณีที่เกิดปัญหาต่างๆ จากการขนส่งสินค้าได้ชัดเจนมากน้อยเพียงใด

ส่วนที่ 1: ประเมินระดับความสำคัญของปัจจัยหลักของการเลือกเส้นทางการขนส่งยางพาราของประเทศไทย

คำถามที่ 1: **ปัจจัยด้านการขนส่ง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ปัจจัยด้านเศรษฐศาสตร์**

คำถามที่ 2: **ปัจจัยด้านการขนส่ง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ปัจจัยเกี่ยวกับท่าเรือ/ด่านการค้าชายแดน**

คำถามที่ 3: **ปัจจัยด้านการขนส่ง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ปัจจัยด้านสิ่งแวดล้อมอื่นๆ ที่เกี่ยวข้อง**

คำถามที่ 4: **ปัจจัยด้านเศรษฐศาสตร์** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ปัจจัยเกี่ยวกับท่าเรือ/ด่านการค้าชายแดน**

คำถามที่ 5: **ปัจจัยด้านเศรษฐศาสตร์** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ปัจจัยด้านสิ่งแวดล้อมอื่นๆ ที่เกี่ยวข้อง**

คำถามที่ 6: **ปัจจัยเกี่ยวกับท่าเรือ/ด่านการค้าชายแดน** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ปัจจัยด้านสิ่งแวดล้อมอื่นๆ ที่เกี่ยวข้อง**

คำถาม	ระดับความสำคัญของปัจจัยหลัก										
	ปัจจัยหลัก	**มากที่สุด**	**มาก**	**ค่อนข้างมาก**	**ปานกลาง**	**เท่ากัน**	**ปานกลาง**	**ค่อนข้างมาก**	**มาก**	**มากที่สุด**	**ปัจจัยหลัก**
1	ปัจจัยด้านการขนส่ง										ปัจจัยด้านเศรษฐศาสตร์
2	ปัจจัยด้านการขนส่ง										ปัจจัยเกี่ยวกับท่าเรือ/ด่านการค้าชายแดน
3	ปัจจัยด้านการขนส่ง										ปัจจัยด้านสิ่งแวดล้อมอื่นๆ ที่เกี่ยวข้อง
4	ปัจจัยด้านเศรษฐศาสตร์										ปัจจัยเกี่ยวกับท่าเรือ/ด่านการค้าชายแดน
5	ปัจจัยด้านเศรษฐศาสตร์										ปัจจัยด้านสิ่งแวดล้อมอื่นๆ ที่เกี่ยวข้อง
6	ปัจจัยเกี่ยวกับท่าเรือ/ด่านการค้าชายแดน										ปัจจัยด้านสิ่งแวดล้อมอื่นๆ ที่เกี่ยวข้อง

ส่วนที่ 2: ประเมินระดับความสำคัญของปัจจัยย่อยของปัจจัยด้านการขนส่ง

คำถามที่ 1: **ระยะทาง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ระยะเวลาในการเดินทาง**

คำถามที่ 2: **ระยะทาง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **คุณภาพเส้นทางที่ใช้ในการขนส่ง**

คำถามที่ 3: **ระยะทาง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **คุณภาพและความปลอดภัยของสินค้า**

คำถามที่ 4: **ระยะทาง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ความน่าเชื่อถือและความตรงต่อเวลาในการขนส่งสินค้า**

คำถามที่ 5: **ระยะเวลาในการเดินทาง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **คุณภาพเส้นทางที่ใช้ในการขนส่ง**

คำถามที่ 6: **ระยะเวลาในการเดินทาง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **คุณภาพและความปลอดภัยของสินค้า**

คำถามที่ 7: **ระยะเวลาในการเดินทาง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ความน่าเชื่อถือและความตรงต่อเวลาในการขนส่งสินค้า**

คำถามที่ 8: **คุณภาพเส้นทางที่ใช้ในการขนส่ง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **คุณภาพและความปลอดภัยของสินค้า**

คำถามที่ 9: **คุณภาพเส้นทางที่ใช้ในการขนส่ง** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ความน่าเชื่อถือและความตรงต่อเวลาในการขนส่งสินค้า**

คำถามที่ 10: **คุณภาพและความปลอดภัยของสินค้า** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ความน่าเชื่อถือและความตรงต่อเวลาในการขนส่งสินค้า**

คำถาม	**ระดับความสำคัญของปัจจัยย่อย**										
	ปัจจัยย่อย	**มากที่สุด**	**มาก**	**ค่อนข้างมาก**	**ปานกลาง**	**เท่ากัน**	**ปานกลาง**	**ค่อนข้างมาก**	**มาก**	**มากที่สุด**	**ปัจจัยย่อย**
1	ระยะทาง										ระยะเวลาในการเดินทาง
2	ระยะทาง										คุณภาพเส้นทางที่ใช้ในการขนส่ง
3	ระยะทาง										คุณภาพและความปลอดภัยของสินค้า
4	ระยะทาง										ความน่าเชื่อถือและความตรงต่อเวลาในการขนส่งสินค้า
5	ระยะเวลาในการเดินทาง										คุณภาพเส้นทางที่ใช้ใน

คำถาม	ระดับความสำคัญของปัจจัยย่อย										
	ปัจจัยย่อย	**มากที่สุด**	**มาก**	**ค่อนข้างมาก**	**ปานกลาง**	**เท่ากัน**	**ปานกลาง**	**ค่อนข้ามาก**	**มาก**	**มากที่สุด**	**ปัจจัยย่อย**
6	ระยะเวลาในการเดินทาง										คุณภาพและความปลอดภัยของสินค้า
7	ระยะเวลาในการเดินทาง										ความน่าเชื่อถือและความตรงต่อเวลาในการขนส่งสินค้า
8	คุณภาพเส้นทางที่ใช้ในการขนส่ง										คุณภาพและความปลอดภัยของสินค้า
9	คุณภาพเส้นทางที่ใช้ในการขนส่ง										ความน่าเชื่อถือและความตรงต่อเวลาในการขนส่งสินค้า
10	คุณภาพและความปลอดภัยของสินค้า										ความน่าเชื่อถือและความตรงต่อเวลาในการขนส่งสินค้า

ส่วนที่ 3: ประเมินระดับความสำคัญของปัจจัยย่อยของปัจจัยด้านสิ่งแวดล้อมอื่นๆ ที่เกี่ยวข้อง

คำถามที่ 1: **กฎระเบียบว่าด้วยการค้าระหว่างประเทศ** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **นโยบายด้านการประกันภัยสินค้า**

คำถาม	ระดับความสำคัญของปัจจัยย่อย										
	ปัจจัยย่อย	**มากที่สุด**	**มาก**	**ค่อนข้างมาก**	**ปานกลาง**	**เท่ากัน**	**ปานกลาง**	**ค่อนข้ามาก**	**มาก**	**มากที่สุด**	**ปัจจัยหลัก**
1	กฎระเบียบว่าด้วยการค้าระหว่างประเทศ										นโยบายด้านการประกันภัยสินค้า

ส่วนที่ 4: ประเมินระดับความสำคัญของปัจจัยย่อยของปัจจัยเกี่ยวกับท่าเรือ/ด่านการค้าชายแดน

คำถามที่ 1: **อุปกรณ์อำนวยความสะดวก** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ความสามารถในการรองรับสินค้า**

คำถามที่ 2: **อุปกรณ์อำนวยความสะดวก** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **พิธีการด้านศุลกากร**

คำถามที่ 3: **อุปกรณ์อำนวยความสะดวก** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ความสะดวกในการเข้าถึงท่าเรือ/ด่านการค้าชายแดน**

คำถามที่ 4: **ความสามารถในการรองรับสินค้า** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **พิธีการด้านศุลกากร**

คำถามที่ 5: **ความสามารถในการรองรับสินค้า** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ความสะดวกในการเข้าถึงท่าเรือ/ด่านการค้าชายแดน**

คำถามที่ 6: **พิธีการด้านศุลกากร** มีความสำคัญอย่างไรเมื่อเปรียบเทียบกับ **ความสะดวกในการเข้าถึงท่าเรือ/ด่านการค้าชายแดน**

คำถาม	ระดับความสำคัญของปัจจัยย่อย										
	ปัจจัยย่อย	**มากที่สุด**	**มาก**	**ค่อนข้างมาก**	**ปานกลาง**	**เท่ากัน**	**ปานกลาง**	**ค่อนข้างมาก**	**มาก**	**มากที่สุด**	**ปัจจัยย่อย**
1	อุปกรณ์อำนวยความสะดวก										ความสามารถในการรองรับสินค้า
2	อุปกรณ์อำนวยความสะดวก										พิธีการด้านศุลกากร
3	อุปกรณ์อำนวยความสะดวก										ความสะดวกในการเข้าถึงท่าเรือ/ด่านการค้าชายแดน
4	ความสามารถในการรองรับสินค้า										พิธีการด้านศุลกากร
5	ความสามารถในการรองรับสินค้า										ความสะดวกในการเข้าถึงท่าเรือ/ด่านการค้าชายแดน
6	พิธีการด้านศุลกากร										ความสะดวกในการเข้าถึงท่าเรือ/ด่านการค้าชายแดน

APPENDIX B
THE INFORMATION OF GATEWAYS UNDER SUB-CRITERIA

Transportation factors

Length

Length (Origin to gateway)	**Surat Thani**	**Nakhon Si Thammarat**	**Songkhla**	**Rayong**	**Nong Khai**
Bangkok port by trailer	647 km	748 km		190 km	615 km
Bangkok port by truck	647 km	748 km			
Bangkok port by train	685 km	769 km			
Laem Chabang port by trailer	761 km	861 km		142 km	696 km
Laem Chabang port by truck	761 km	861 km			
Laem Chabang port by train	802 km	900 km			
Laem Chabang port by vessel	491 km				
Padang Besar border - Penang port (MY) by train	474 km	415 km	138 km		
Padang Besar border by trailer - Penang (MY) by train			237 km		
Sadao border - Penang port (MY) by trailer			201 km		
Songkhla port			39 km		
Mukdahan border - Da Nang port (VT)					822 km
Nakhon Phanom border - Da Nang port (VT)					856 km
Bueng Kan border - Da Nang port (VT)					747 km

Source: Google™ Earth 5.0.11

Transportation time

Transportation time (Origin to Eastern China)	Surat Thani[1]	Nakhon Si Thammarat[1]	Songkhla[1]	Rayong[2]	Nong Khai
Bangkok port by trailer	12 days 10 hrs	12 days 12 hrs		12 days 3 hrs	12 days 10 hrs
Bangkok port by truck	12 days 10 hrs	12 days 12 hrs			
Bangkok port by train	12 days 18 hrs	13 days			
Laem Chabang port by trailer	12 days 12 hrs	12 days 15 hrs		12days 1.5hrs	12 days 12 hrs
Laem Chabang port by truck	12 days 12 hrs	12 days 15 hrs			
Laem Chabang port by train	13 days	13 days 6 hrs			
Laem Chabang port by vessel	13 days				
Padang Besar border - Penang port (MY) by train	17 days 9 hrs	17 days 6 hrs	17 days 2 hrs		
Padang Besar border by trailer - Penang MY by train			17 days 2 hrs		
Sadao border - Penang port (MY) by trailer			17 days 2 hrs		
Songkhla port			8 days 2 hrs		
Mukdahan border - Da Nang port (VT)					12 days 16 hrs[3]
Nakhon Phanom border - Da Nang port (VT)					12 days 18 hrs[3]
Bueng Kan border - Da Nang port (VT)					12 days 15 hrs[3]

[1] Khompatraporn, C., Somboonwiwat, T., Ruktanonchai, C., Atthirawong, W., and Wasusri, T. (2009). A study to enhance the Thai - Chinese trade logistics system in the context of ASEAN-China free trade agreement: case study of selected export items. *Final report*, Thailand Research Fund (TRF), Thailand.

[2] Manufacturer interviewing at Rayong

[3] Transportation time from Da Nang port to border trade in Thailand for 12 days (ASEAN-US Technical Assistance and training Facility, “Toward a Roadmap for Integration of the ASEAN Logistics Sector: Rapid Assessment & Concept Paper Executive Summary”.

Route quality

Route quality	Thailand	Malaysia	Laos	Vietnam
Road evaluation	Road and its maintenance condition as a whole are in favorable condition. The road connecting to all neighboring Myanmar, Laos, Cambodia, and Malaysia is designated to Asian Highway and well developed. More than 60% of all sections are high-spec, road with more than 4 lanes.	Total length of road is about 78 thousand km. The ratio of paved road in Borneo island is low. But the pavement condition in peninsula is quite favorable. The North-South Express Way as an international logistics bone and its connected sections are well developed with no noticeable bottlenecks. Thailand border area is also well developed at the Malaysian side. Since the by-pass road is available for Kuala Lumpur and Johor Bahru, the traffic congestion and control are not serious bottlenecks for freight transportation in 2007	The main cross border routes pass through Laos are designated to Asian Highway and connect to neighboring countries. Recently, the government placed high priority for road development. Thus, the largest share of its public investment was towards the development of road network under assistance from international organization. Out of total road network, only 15% of total length was paved. Even above-mentioned cross boarder routes, 15% of were remained un-paved. On the other hand, road surface conditions of main routes including No.9 in south recently developed are generally better.	The total length of the road is 221,115 km in 2004. The road network carried 84% of passengers and 66% of freight in 2004. Main trunk routes are designated to Asian Highway.
Surface condition				
% of good	78.70%	52.80%	47.60%	86.00%
% of poor	1.30%	0.00%	22.60%	0.00%
Number of lanes				
% of 2 Lanes	36.70%	46.00%	98.60%	84.40%
% of 4 Lanes	58.30%	44.70%	0%	6.70%
% of 8 Lanes	4.00%	0.00%	0%	0.00%
Maximum total vehicle weight (tons)				
truck	21.00	-	12.00	16.00
Tractor/trailer	39.20	-	32.80	38.00

Source: Japan External Trade Organization (JETRO), "ASEAN Logistics Network Map", 2nd Edition, 2009

Reliability and punctuality

Reliability and punctuality	Bangkok port	Laem Chabang port	Songkhla port	Penang port (MY)	Da Nang port (VT)
Port	Bangkok port (Klong Toey port) has acted as the major marine gateway to Thailand. It is situated on the left side of the Chao Phraya River, the distance of 26-19 km from the entrance of the river and was developed as base of transport from/to Bangkok.	Laem Chabang port is Thailand's premier deep-sea commercial port, under the management of The port Authority of Thailand (PAT). LCB is one of the most modern and advanced ports in Southeast Asia and has positioned itself as the one of the most important gateway to Thailand and the greater Indochina region	The port is located on the Gulf of Thailand about 100 km north of the Thai-Malaysia border. After the opening in 1988, this port meets the demands of local shippers in the south of Thailand. The port is leased to a private operator and fall under the responsibility of the Harbor Department, Ministry of Commerce and Communications. Its future expansion of port facility is under regional economic development plan and hoped to spur southern exporters and industries.	Penang port is the third biggest in terms of handling capacity of cargo in Peninsular Malaysia and located between the Peninsular Malaysia and Penang Island, and also adjacent to major industrial area of Prai and Butterworth. Penang port plays a vital role as logistics hub for freight collection and distribution in the northern Malaysia.	Da Nang port is located in Da Nang City as socio economic center of mid Vietnam and biggest port in mid-Vietnam after over 100 years development and consists of two areas of Tien Sa terminal and Song Han terminal.

Source: Japan External Trade Organization (JETRO), "ASEAN Logistics Network Map", 2nd Edition, 2009

Economics factors

Transportation cost

Logistics cost	Surat Thani[1]	Nakhon Si Thammarat[1]	Songkhla[1]	Rayong[2]	Nong Khai[3]
Bangkok port by trailer	0.525 THB/kg	0.931 THB/kg		1.00 THB/kg	1.58 THB/kg
Bangkok port by truck	0.667 THB/kg	0.903 THB/kg			
Bangkok port by train	0.558 THB/kg	0.675 THB/kg			
Laem Chabang port by trailer	0.525 THB/kg	0.931 THB/kg		0.6 THB/kg	1.73 THB/kg
Laem Chabang port by truck	0.667 THB/kg	0.903 THB/kg			
Laem Chabang port by train	0.558 THB/kg	0.675 THB/kg			
Laem Chabang port by vessel	0.567 THB/kg				
Padang Besar border - Penang port (MY) by train	0.414 THB/kg	0.414 THB/kg	1.853 THB/kg		
Padang Besar border by trailer - Penang MY by train			0.978 THB/kg		
Sadao border - Penang port (MY) by trailer			1.34 THB/kg		
Songkhla port			0.86 THB/kg		
Mukdahan border - Da Nang port (VT)					3.71 THB/kg
Nakhon Phanom border - Da Nang port (VT)					3.77 THB/kg
Bueng Kan border - Da Nang port (VT)					3.56 THB/kg

1 Khompatraporn, C., Somboonwiwat, T., Ruktanonchai, C., Atthirawong, W., and Wasusri, T. (2009). A study to enhance the Thai - Chinese trade logistics system in the context of ASEAN-China free trade agreement: case study of selected export items. *Final report*, Thailand Research Fund (TRF), Thailand.

2 Manufacturer interviewing at Rayong

3 Door-to-door cost estimation method. (Japan External Trade Organization (JETRO), Current Status and Issues of Logistics Network in ASEAN, Outline of “ASEAN Logistics Network Map” Project, Workshop on Statistics of Asian Traffic and Transportation.)

Port /Customs Considerations

Capacity

Capacity	Bangkok port	Laem Chabang port	Songkhla port	Penang port (MY)	Da Nang port (VT)
No. of Container Berth	0	11	3	5	n.a.
Terminal Facilities (m^2)	363,168	3,329,265	41,300	828,000	267,456
Container Freight Station (m^2)	498,063	74,792	6,726	20,292	n.a.
Cargo Handling Volume (1000 tons)	16,031	35,736	1,242	28,222	2,256
Container Throughput (1000 TEUs)	1,349	3,766	125	849	32

Source: Japan External Trade Organization (JETRO), "ASEAN Logistics Network Map", 2nd Edition, 2009

Accessibility to port

Accessibility	Bangkok port	Laem Chabang port	Songkhla port	Penang port (MY)	Da Nang port (VT)
High way	Yes	Yes	Yes	Yes	Yes
Railway	Yes	Yes	No	Yes	No
Inland Water Transport (IWT)	Yes	No	No	No	No

Source: Japan External Trade Organization (JETRO), "ASEAN Logistics Network Map", 2nd Edition, 2009

Accessibility to border trade

Accessibility	Sadao Customs	Padang Besar Customs	Beuang Kan Customs	Mukdahan Customs	Nakhon Phanom Customs
High way	Yes	Yes	Yes	Yes	Yes
Railway	No	Yes	No	No	No
Inland Water Transport (IWT)	No	No	No	No	No

Source: Japan External Trade Organization (JETRO), "ASEAN Logistics Network Map", 2nd Edition, 2009

Facilitation equipment

Facilitation equipment	Bangkok port	Laem Chabang port	Songkhla port	Penang port (MY)	Da Nang port (VT)
No.of Sea-shore container Gantries	14	26	n.a.	9	1
No. of Yard Gantries	34	68	n.a.	32	2

Source: Japan External Trade Organization (JETRO), "ASEAN Logistics Network Map", 2nd Edition, 2009

Customs procedure

Customs procedure	Thailand	Malaysia	Vietnam	Laos
Charge for customs service in non-office hours	250 - 400 TH baht	Not set. Open for 24 hours for all year around, excluding the budget day	n.a.	n.a.
Standard hours of customs clearance : Export	It takes around half day to acquire an export permit by declaring through EDI system. And it takes several from half day to one day for the process from document check to the completion of cargo inspection.	1 - 2 days	One day for document processing. Two days including physical inspection from notice to approval	As for customs clearance at the border with Vietnam, goods are cleared with around twenty minutes due to the single window system. The single window system with Thailand is planned
Bar code use	Global Location Numbers (GLN) is used by 142 forwarders 335 distributors and the 5,984 members of GS1 Thailand. For a total of 6,476 companies	EAN Malaysia promotes the use of bar-code system	Vietnam Article Numbering and Bar-coding Organization (EAN-VN) contracts with nearly 8,000 member companies in the whole country.	No GS1 organization in Laos
Customs clearance EDI	EDI system including Trade Siam and CAT is introduced for customs clearance	Customs clearance is processed through EDI system. DaganNet.	Vietnamese government plans to establish the customs system by 2010 with loan from the World Bank	EDI system is not yet introduced to customs clearance

Source: Japan External Trade Organization (JETRO), "ASEAN Logistics Network Map", 2nd Edition, 2009

Environment Considerations

Rules of international trade

Rules of International Trade	Thailand	Malaysia	Vietnam	Laos
Standards on Logistics	Maximum load capacity is 12 tons for six wheeler, 21 tons for 10 wheeler, and 37.4 tons for full trailers. There are TISI standards for freight containers: designation (TIS 587-2528), wooden flat pallets (TIS 588-2528), transport packages: designation (TIS 589-2528)	Attention needs to be paid on a lack of rule on the liability of carriers in the event of damage, loss, or delay of cargo. Gross vehicle mass is 35 tons for ocean containers and 25 tons for trucks.	Maximum gross deadweight is 25 tons for twenty foot container. 38 tons for forty foot container. 18 tons for two-axis truck and 24 tons for three-axis truck.	n.a.
Licenses approvals on logistics service	According to Thailand Foreign Business Act of 1999, domestic land, waterway or air transportation, including domestic airline business is included in List Two. Foreign businesses may apply for an Alien Business License if they wish to engage in an activity covered by List Two provided that they have been granted approval by the Minister along with the approval of the Cabinet. The foreigners may operate the business under List Two only	Customs broker / agent should be licensed by Ministry of Finance, and participate in the forwarders association at the ports in service. Foreign equity portion is limited up to 30%, but allowed up to 49% in case of partnering with Bumi capital.	Following business are limited to a business co-operation contract or joint venture for foreign companies : Air, rail, and ocean freight transportation, public transportation, ocean port and airport construction (concluding investments in the form of BOT, BTO, BY). Following business are limited a business co-operation contract : International / domestic delivery service. When a foreign company starts a forwarding business. the	Foreign investments are approved with provision for the following businesses; 1) Land transportation, railway transportation, other scheduled passenger transportation, other non-scheduled passenger transportation, road cargo transportation, pipeline transportation. 2) Ocean / coastal transportation, inland water transportation. 3) Auxiliary supportive transport businesses: freight agencies, storage and warehouse business,

Rules of International Trade	Thailand	Malaysia	Vietnam	Laos
	if Thai nationals or justice persons that are not foreigners under this Act hold the shares of not less than 40% of the capital of those foreign juristic persons.		participation to the Vietnam Freight Forwarders' Association is required. For international forwarding, the maximum foreign capital participation is 49%, and for domestic forwarding 100% participation of foreign capital is possible.	other supportive transportation businesses
Special Traffic Control area	In Bangkok, trucks and trailer of over 6 wheels are restricted during 6:00 - 9:00 and 16:00 -20:00. Maximum load capacity is 12 tons for six wheeler, 21 tons for six wheeler, 37.4 tons for semi-trailer, and 39.4 tons for full trailers.	In some area of KL, commercial vehicles more than 3 tons are prohibited during 7:30 - 9:00 and 16:00 - 19:00. Gross vehicle mass is 35 tons for ocean containers and 25 tons for trucks.	Maximum gross deadweight is 25 tons for twenty foot container. 38 tons for forty foot container. 18 tons for two-axis truck and 24 tons for three-axis truck.	n.a.

Source: Japan External Trade Organization (JETRO), "ASEAN Logistics Network Map", 2nd Edition, 2009

APPENDIX C
AN EXAMPLE OF FUZZY SCORE AND PAIR-WISE COMPARISON MATRICES FROM USER EVALUATION

An Example of Fuzzy Score from User Evaluation

Fuzzy scores from user evaluation				
Q	**Description**	***Fuzzy score***		
		l	***m***	***u***
Q11	**Length**			
1	BKK port is more appropriate length than LCB port WEAKLY	0.67	1.00	1.50
2	BKK port is more appropriate length than Mukdahan border VERY STRONG	2.50	3.00	3.50
3	BKK port is more appropriate length than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
4	BKK port is more appropriate length than Bueng Kan border ABSOLUTELY	3.50	4.00	4.50
5	LCB port is more appropriate length than Mukdahan border VERY STRONG	2.50	3.00	3.50
6	LCB port is more appropriate length than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
7	LCB port is more appropriate length than Bueng Kan border ABSOLUTELY	3.50	4.00	4.50
8	Mukdahan border is more appropriate length than Nakhon Phanom border WEAKLY	0.67	1.00	1.50
9	Bueng Kan border is more appropriate length than Mukdahan border WEAKLY	0.67	1.00	1.50
10	Bueng Kan border is more appropriate length than Nakhon Phanom border FAIRLY STRONG	0.40	0.50	0.67
Q12	**Transportation time**			
1	BKK port is more appropriate transportation time than LCB port WEAKLY	0.67	1.00	1.50
2	BKK port is more appropriate transportation time than Mukdahan border FAIRLY STRONG	1.50	2.00	2.50
3	BKK port is more appropriate transportation time than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
4	BKK port is more appropriate transportation time than Bueng Kan border FAIRLY STRONG	1.50	2.00	2.50
5	LCB port is more appropriate transportation time than Mukdahan border WEAKLY	0.67	1.00	1.50
6	LCB port is more appropriate transportation time than Nakhon Phanom border FAIRLY STRONG	1.50	2.00	2.50
7	LCB port is more appropriate transportation time than Bueng Kan border VERY STRONG	2.50	3.00	3.50
8	Mukdahan border appropriate transportation time EQUAL with Nakhon Phanom border	1.00	1.00	1.00
9	Mukdahan border is more appropriate transportation time than Bueng Kan border FAIRLY STRONG	1.50	2.00	2.50
10	Nakhon Phanom border is more appropriate transportation time than Bueng Kan border WEAKLY	0.67	1.00	1.50
Q13	**Route quality**			
1	BKK port is appropriate transportation time EQUAL with LCB port	1.00	1.00	1.00
2	BKK port is more appropriate route quality than Mukdahan border FAIRLY STRONG	1.50	2.00	2.50
3	BKK port is more appropriate route quality than Nakhon Phanom border FAIRLY STRONG	1.50	2.00	2.50
4	BKK port is more appropriate route quality than Bueng Kan border VERY STRONG	2.50	3.00	3.50
5	LCB port is more appropriate route quality than Mukdahan border FAIRLY STRONG	1.50	2.00	2.50
6	LCB port is more appropriate route quality than Nakhon Phanom border FAIRLY STRONG	1.50	2.00	2.50
7	LCB port is more appropriate route quality than Bueng Kan border VERY STRONG	2.50	3.00	3.50
8	Mukdahan border appropriate route quality EQUAL with Nakhon Phanom border	1.00	1.00	1.00
9	Mukdahan border is more appropriate route quality than Bueng Kan border FAIRLY STRONG	1.50	2.00	2.50
10	Nakhon Phanom border is more appropriate route quality than Bueng Kan border WEAKLY	0.67	1.00	1.50

Fuzzy scores from user evaluation				
Q	**Description**	***Fuzzy score***		
		l	***m***	***u***
Q14	**Security of product**			
1	BKK port is appropriate security of product EQUAL with LCB port	1.00	1.00	1.00
2	BKK port is more appropriate security of product than Mukdahan border FAIRLY STRONG	1.50	2.00	2.50
3	BKK port is more appropriate security of product than Nakhon Phanom border FAIRLY STRONG	1.50	2.00	2.50
4	BKK port is more appropriate security of product than Bueng Kan border VERY STRONG	2.50	3.00	3.50
5	LCB port is more appropriate security of product than Mukdahan border VERY STRONG	2.50	3.00	3.50
6	LCB port is more appropriate security of product than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
7	LCB port is more appropriate security of product than Bueng Kan border ABSOLUTELY	3.50	4.00	4.50
8	Mukdahan border appropriate security of product EQUAL with Nakhon Phanom border	1.00	1.00	1.00
9	Mukdahan border is more appropriate security of product than Bueng Kan border FAIRLY STRONG	1.50	2.00	2.50
10	Nakhon Phanom border is more appropriate security of product than Bueng Kan border FAIRLY STRONG	1.50	2.00	2.50
Q15	**Reliability and punctuality**			
1	BKK port is appropriate reliability and punctuality EQUAL with LCB port	1.00	1.00	1.00
2	BKK port is more appropriate reliability and punctuality than Mukdahan border WEAKLY	0.67	1.00	1.50
3	BKK port is more appropriate reliability and punctuality than Nakhon Phanom border WEAKLY	0.67	1.00	1.50
4	BKK port is more appropriate reliability and punctuality than Bueng Kan border FAIRLY STRONG	1.50	2.00	2.50
5	LCB port is more appropriate reliability and punctuality than Mukdahan border VERY STRONG	2.50	3.00	3.50
6	LCB port is more appropriate reliability and punctuality than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
7	LCB port is more appropriate reliability and punctuality than Bueng Kan border ABSOLUTELY	3.50	4.00	4.50
8	Mukdahan border appropriate reliability and punctuality EQUAL with Nakhon Phanom border	1.00	1.00	1.00
9	Mukdahan border is more appropriate reliability and punctuality than Bueng Kan border FAIRLY STRONG	1.50	2.00	2.50
10	Nakhon Phanom border is more appropriate reliability and punctuality than Bueng Kan border FAIRLY STRONG	1.50	2.00	2.50
Q21	**Logistics cost**			
1	BKK port is appropriate logistics cost EQUAL with LCB port	1.00	1.00	1.00
2	BKK port is more appropriate logistics cost than Mukdahan border VERY STRONG	2.50	3.00	3.50
3	BKK port is more appropriate logistics cost than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
4	BKK port is more appropriate logistics cost than Bueng Kan border ABSOLUTELY	3.50	4.00	4.50
5	LCB port is more appropriate logistics cost than Mukdahan border VERY STRONG	2.50	3.00	3.50
6	LCB port is more appropriate logistics cost than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
7	LCB port is more appropriate logistics cost than Bueng Kan border ABSOLUTELY	3.50	4.00	4.50
8	Mukdahan border appropriate logistics cost EQUAL with Nakhon Phanom border	1.00	1.00	1.00
9	Mukdahan border is more appropriate logistics cost than Bueng Kan border VERY STRONG	2.50	3.00	3.50
10	Nakhon Phanom border is more appropriate logistics cost than Bueng Kan border FAIRLY STRONG	1.50	2.00	2.50
Q31	**Facilitation equipment**			
1	LCB port is more appropriate facilitation equipment than BKK port FAIRLY STRONG	0.40	0.50	0.67
2	BKK port is more appropriate facilitation equipment than Mukdahan border VERY STRONG	2.50	3.00	3.50
3	BKK port is more appropriate facilitation equipment than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
4	BKK port is more appropriate facilitation equipment than Bueng Kan border VERY STRONG	2.50	3.00	3.50
5	LCB port is more appropriate facilitation equipment than Mukdahan border ABSOLUTELY	3.50	4.00	4.50
6	LCB port is more appropriate facilitation equipment than Nakhon Phanom border ABSOLUTELY	3.50	4.00	4.50
7	LCB port is more appropriate facilitation equipment than Bueng Kan border ABSOLUTELY	3.50	4.00	4.50
8	Mukdahan border appropriate facilitation equipment EQUAL with Nakhon Phanom border	1.00	1.00	1.00
9	Mukdahan border is appropriate facilitation equipment EQUAL with Bueng Kan border	1.00	1.00	1.00
10	Nakhon Phanom border is appropriate facilitation equipment EQUAL with Bueng Kan border	1.00	1.00	1.00
Q32	**Capacity**			
1	LCB port is more appropriate capacity than BKK port FAIRLY STRONG	0.40	0.50	0.67
2	BKK port is more appropriate capacity than Mukdahan border FAIRLY STRONG	1.50	2.00	2.50

Fuzzy scores from user evaluation				
Q	Description	*Fuzzy score*		
		l	*m*	*u*
3	BKK port is more appropriate capacity than Nakhon Phanom border FAIRLY STRONG	1.50	2.00	2.50
4	BKK port is more appropriate capacity than Bueng Kan border FAIRLY STRONG	1.50	2.00	2.50
5	LCB port is more appropriate capacity than Mukdahan border ABSOLUTELY	3.50	4.00	4.50
6	LCB port is more appropriate capacity than Nakhon Phanom border ABSOLUTELY	3.50	4.00	4.50
7	LCB port is more appropriate capacity than Bueng Kan border ABSOLUTELY	3.50	4.00	4.50
8	Mukdahan border appropriate capacity EQUAL with Nakhon Phanom border	1.00	1.00	1.00
9	Mukdahan border is appropriate capacity EQUAL with Bueng Kan border	1.00	1.00	1.00
10	Nakhon Phanom border is appropriate capacity EQUAL with Bueng Kan border	1.00	1.00	1.00
Q33	**Custom procedure**			
1	BKK port is appropriate custom procedure EQUAL with LCB port	1.00	1.00	1.00
2	BKK port is more appropriate custom procedure than Mukdahan border VERY STRONG	2.50	3.00	3.50
3	BKK port is more appropriate custom procedure than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
4	BKK port is more appropriate custom procedure than Bueng Kan border VERY STRONG	2.50	3.00	3.50
5	LCB port is more appropriate custom procedure than Mukdahan border VERY STRONG	2.50	3.00	3.50
6	LCB port is more appropriate custom procedure than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
7	LCB port is more appropriate custom procedure than Bueng Kan border ABSOLUTELY	3.50	4.00	4.50
8	Mukdahan border appropriate custom procedure EQUAL with Nakhon Phanom border	1.00	1.00	1.00
9	Mukdahan border is appropriate custom procedure EQUAL with Bueng Kan border	1.00	1.00	1.00
10	Nakhon Phanom border is appropriate custom procedure EQUAL with Bueng Kan border	1.00	1.00	1.00
Q34	**Accessibility**			
1	BKK port is more appropriate accessibility than LCB port WEAKLY	0.67	1.00	1.50
2	BKK port is more appropriate accessibility than Mukdahan border ABSOLUTELY	3.50	4.00	4.50
3	BKK port is more appropriate accessibility than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
4	BKK port is more appropriate accessibility than Bueng Kan border VERY STRONG	2.50	3.00	3.50
5	LCB port is more appropriate accessibility than Mukdahan border VERY STRONG	2.50	3.00	3.50
6	LCB port is more appropriate accessibility than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
7	LCB port is more appropriate accessibility than Bueng Kan border VERY STRONG	2.50	3.00	3.50
8	Mukdahan border appropriate accessibility EQUAL with Nakhon Phanom border	1.00	1.00	1.00
9	Mukdahan border is appropriate accessibility EQUAL with Bueng Kan border	1.00	1.00	1.00
10	Nakhon Phanom border is appropriate accessibility EQUAL with Bueng Kan border	1.00	1.00	1.00
Q41	**Rules of international trade**			
1	BKK port is appropriate rules of international trade EQUAL with LCB port	1.00	1.00	1.00
2	BKK port is more appropriate rules of international trade than Mukdahan border VERY STRONG	2.50	3.00	3.50
3	BKK port is more appropriate rules of international trade than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
4	BKK port is more appropriate rules of international trade than Bueng Kan border VERY STRONG	2.50	3.00	3.50
5	LCB port is more appropriate rules of international trade than Mukdahan border VERY STRONG	2.50	3.00	3.50
6	LCB port is more appropriate rules of international trade than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
7	LCB port is more appropriate rules of international trade than Bueng Kan border VERY STRONG	2.50	3.00	3.50
8	Mukdahan border appropriate rules of international trade EQUAL with Nakhon Phanom border	1.00	1.00	1.00
9	Mukdahan border is appropriate rules of international trade EQUAL with Bueng Kan border	1.00	1.00	1.00
10	Nakhon Phanom border is appropriate rules of international trade EQUAL with Bueng Kan border	1.00	1.00	1.00
Q42	**Insurance policy**			
1	BKK port is appropriate insurance policy EQUAL with LCB port	1.00	1.00	1.00
2	BKK port is more appropriate insurance policy than Mukdahan border VERY STRONG	2.50	3.00	3.50
3	BKK port is more appropriate insurance policy than Nakhon Phanom border VERY STRONG	2.50	3.00	3.50
4	BKK port is more appropriate insurance policy than Bueng Kan border WEAKLY	0.67	1.00	1.50
5	LCB port is more appropriate insurance policy than Mukdahan border WEAKLY	0.67	1.00	1.50

Fuzzy scores from user evaluation				
Q	**Description**	***Fuzzy score***		
		l	***m***	***u***
6	LCB port is more appropriate insurance policy than Nakhon Phanom border WEAKLY	0.67	1.00	1.50
7	LCB port is more appropriate insurance policy than Bueng Kan border VERY STRONG	2.50	3.00	3.50
8	Mukdahan border appropriate insurance policy EQUAL with Nakhon Phanom border	1.00	1.00	1.00
9	Mukdahan border is appropriate insurance policy EQUAL with Bueng Kan border	1.00	1.00	1.00
10	Nakhon Phanom border is appropriate insurance policy EQUAL with Bueng Kan border	1.00	1.00	1.00

An Example of Pair-wise Comparison Matrices from User Evaluation

Evaluation of the gateway alternatives with respect to length

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	0.67	1.00	1.50	2.50	3.00	3.50	2.50	3.00	3.50	3.50	4.00	4.50
LCB port	0.6667	1	1.5	1	1	1	2.50	3.00	3.50	2.50	3.00	3.50	3.50	4.00	4.50
Mukdahan border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	1	1	1	0.67	1.00	1.50	0.67	1.00	1.50
Nakhon Phanom border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	0.6667	1	1.5	1	1	1	0.40	0.50	0.67
Bueng Kan border	0.2222	0.25	0.2857	0.2222	0.25	0.2857	0.6667	1	1.5	1.5	2	2.5	1	1	1

Evaluation of the gateway alternatives with respect to transportation time

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	0.67	1.00	1.50	1.50	2.00	2.50	2.50	3.00	3.50	1.50	2.00	2.50
LCB port	0.6667	1	1.5	1	1	1	0.67	1.00	1.50	1.50	2.00	2.50	2.50	3.00	3.50
Mukdahan border	0.4	0.5	0.6667	0.6667	1	1.5	1	1	1	1.00	1.00	1.00	1.50	2.00	2.50
Nakhon Phanom border	0.2857	0.3333	0.4	0.4	0.5	0.6667	1	1	1	1	1	1	0.67	1.00	1.50
Bueng Kan border	0.4	0.5	0.6667	0.2857	0.3333	0.4	0.4	0.5	0.6667	0.6667	1	1.5	1	1	1

Evaluation of the gateway alternatives with respect to route quality

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	1.00	1.00	1.00	1.50	2.00	2.50	1.50	2.00	2.50	2.50	3.00	3.50
LCB port	1	1	1	1	1	1	1.50	2.00	2.50	1.50	2.00	2.50	2.50	3.00	3.50
Mukdahan border	0.4	0.5	0.6667	0.4	0.5	0.6667	1	1	1	1.00	1.00	1.00	1.50	2.00	2.50
Nakhon Phanom border	0.4	0.5	0.6667	0.4	0.5	0.6667	1	1	1	1	1	1	0.67	1.00	1.50
Bueng Kan border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	0.4	0.5	0.6667	0.6667	1	1.5	1	1	1

Evaluation of the gateway alternatives with respect to security of products

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	1.00	1.00	1.00	1.50	2.00	2.50	1.50	2.00	2.50	2.50	3.00	3.50
LCB port	1	1	1	1	1	1	2.50	3.00	3.50	2.50	3.00	3.50	3.50	4.00	4.50
Mukdahan border	0.4	0.5	0.6667	0.2857	0.3333	0.4	1	1	1	1.00	1.00	1.00	1.50	2.00	2.50
Nakhon Phanom border	0.4	0.5	0.6667	0.2857	0.3333	0.4	1	1	1	1	1	1	1.50	2.00	2.50
Bueng Kan border	0.2857	0.3333	0.4	0.2222	0.25	0.2857	0.4	0.5	0.6667	0.4	0.5	0.6667	1	1	1

Evaluation of the gateway alternatives with respect to reliability and punctuality

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	1.00	1.00	1.00	0.67	1.00	1.50	0.67	2.00	3.50	1.50	2.00	2.50
LCB port	1	1	1	1	1	1	2.50	3.00	3.50	2.50	3.00	3.50	3.50	4.00	4.50
Mukdahan border	0.6667	1	1.5	0.2857	0.3333	0.4	1	1	1	1.00	1.00	1.00	1.50	2.00	2.50
Nakhon Phanom border	0.2857	0.5	1.5	0.2857	0.3333	0.4	1	1	1	1	1	1	1.50	2.00	2.50
Bueng Kan border	0.4	0.5	0.6667	0.2222	0.25	0.2857	0.4	0.5	0.6667	0.4	0.5	0.6667	1	1	1

Evaluation of the gateway alternatives with respect to logistics cost

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	1.00	1.00	1.00	2.50	3.00	3.50	2.50	3.00	3.50	3.50	4.00	4.50
LCB port	1	1	1	1	1	1	2.50	3.00	3.50	2.50	3.00	3.50	3.50	4.00	4.50
Mukdahan border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	1	1	1	1.00	1.00	1.00	2.50	3.00	3.50
Nakhon Phanom border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	1	1	1	1	1	1	1.50	2.00	2.50
Bueng Kan border	0.2222	0.25	0.2857	0.2222	0.25	0.2857	0.2857	0.3333	0.4	0.4	0.5	0.6667	1	1	1

Evaluation of the gateway alternatives with respect to facilitation equipment

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	0.40	0.50	0.67	2.50	3.00	3.50	2.50	3.00	3.50	2.50	3.00	3.50
LCB port	1.5	2	2.5	1	1	1	3.50	4.00	4.50	3.50	4.00	4.50	3.50	4.00	4.50
Mukdahan border	0.2857	0.3333	0.4	0.2222	0.25	0.2857	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00
Nakhon Phanom border	0.2857	0.3333	0.4	0.2222	0.25	0.2857	1	1	1	1	1	1	1.00	1.00	1.00
Bueng Kan border	0.2857	0.3333	0.4	0.2222	0.25	0.2857	1	1	1	1	1	1	1	1	1

Evaluation of the gateway alternatives with respect to capacity

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	0.40	0.50	0.67	1.50	2.00	2.50	1.50	2.00	2.50	1.50	2.00	2.50
LCB port	1.5	2	2.5	1	1	1	3.50	4.00	4.50	3.50	4.00	4.50	3.50	4.00	4.50
Mukdahan border	0.4	0.5	0.6667	0.2222	0.25	0.2857	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00
Nakhon Phanom border	0.4	0.5	0.6667	0.2222	0.25	0.2857	1	1	1	1	1	1	1.00	1.00	1.00
Bueng Kan border	0.4	0.5	0.6667	0.2222	0.25	0.2857	1	1	1	1	1	1	1	1	1

Evaluation of the gateway alternatives with respect to custom procedure

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	1.00	1.00	1.00	2.50	3.00	3.50	2.50	3.00	3.50	2.50	3.00	3.50
LCB port	1	1	1	1	1	1	2.50	3.00	3.50	2.50	3.00	3.50	3.50	4.00	4.50
Mukdahan border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00
Nakhon Phanom border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	1	1	1	1	1	1	1.00	1.00	1.00
Bueng Kan border	0.2857	0.3333	0.4	0.2222	0.25	0.2857	1	1	1	1	1	1	1	1	1

Evaluation of the gateway alternatives with respect to accessibility

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	0.67	1.00	1.50	3.50	4.00	4.50	2.50	3.00	3.50	2.50	3.00	3.50
LCB port	0.6667	1	1.5	1	1	1	2.50	3.00	3.50	2.50	3.00	3.50	2.50	3.00	3.50
Mukdahan border	0.2222	0.25	0.2857	0.2857	0.3333	0.4	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00
Nakhon Phanom border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	1	1	1	1	1	1	1.00	1.00	1.00
Bueng Kan border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	1	1	1	1	1	1	1	1	1

Evaluation of the gateway alternatives with respect to rules of international trade

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	1.00	1.00	1.00	2.50	3.00	3.50	2.50	3.00	3.50	2.50	3.00	3.50
LCB port	1	1	1	1	1	1	2.50	3.00	3.50	2.50	3.00	3.50	2.50	3.00	3.50
Mukdahan border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00
Nakhon Phanom border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	1	1	1	1	1	1	1.00	1.00	1.00
Bueng Kan border	0.2857	0.3333	0.4	0.2857	0.3333	0.4	1	1	1	1	1	1	1	1	1

Evaluation of the gateway alternatives with respect to rules of insurance policy

	BKK port			LCB port			Mukdahan border			Nakhon Phanom border			Bueng Kan border		
BKK port	1	1	1	1.00	1.00	1.00	2.50	3.00	3.50	2.50	3.00	3.50	0.67	1.00	1.50
LCB port	1	1	1	1	1	1	0.67	1.00	1.50	0.67	1.00	1.50	2.50	3.00	3.50
Mukdahan border	0.2857	0.3333	0.4	0.6667	1	1.5	1	1	1	1.00	1.00	1.00	1.00	1.00	1.00
Nakhon Phanom border	0.2857	0.3333	0.4	0.6667	1	1.5	1	1	1	1	1	1	1.00	1.00	1.00
Bueng Kan border	0.6667	1	1.5	0.2857	0.3333	0.4	1	1	1	1	1	1	1	1	1

APPENDIX D
VISUAL BASIC FOR APPLICATION (VBA) CODE LISTED

```
Private Sub BKKtrailBKKtrain1_Click()
Range("M17").Value = "BKK port by trailer is more appropriate Facilitation equipment than BKK port by train ABSOLUTELY"
Range("O17").Value = 7 / 2
Range("P17").Value = 4
Range("Q17").Value = 9 / 2
BKKtrailBKKtrain1.BackColor = RGB(213, 228, 255)
BKKtrailBKKtrain1.ForeColor = RGB(213, 228, 255)
End Sub
#Check radio button name BKKtrailBKKtrain1 then show linguistics context in cell M17 and add fuzzy score 3.5,4,4.5  in to cell O17 P17 and Q17 respectively

Private Sub BKKtrailBKKtrain2_Click()
Range("M17").Value = "BKK port by trailer is more appropriate Facilitation equipment than BKK port by train VERY STRONG"
Range("O17").Value = 5 / 2
Range("P17").Value = 3
Range("Q17").Value = 7 / 2
BKKtrailBKKtrain2.BackColor = RGB(221, 233, 255)
BKKtrailBKKtrain2.ForeColor = RGB(221, 233, 255)
End Sub
#Check radio button name BKKtrailBKKtrain2 then show linguistics context in cell M17 and add fuzzy score 2.5,3,3.5 in to cell O17 P17 and Q17 respectively

Private Sub BKKtrailBKKtrain3_Click()
Range("M17").Value = "BKK port by trailer is more appropriate Facilitation equipment than BKK port by train FAIRLY STRONG"
Range("O17") = "3/2"
Range("P17") = "2"
Range("Q17") = "5/2"
BKKtrailBKKtrain3.BackColor = RGB(229, 238, 255)
BKKtrailBKKtrain3.ForeColor = RGB(229, 238, 255)
End Sub
#Check radio button name BKKtrailBKKtrain3 then show linguistics context in cell M17 and add fuzzy score 1.5,2,2.5 in to cell O17 P17 and Q17 respectively
```

```
Private Sub BKKtrailBKKtrain4_Click()
Range("M17").Value = "BKK port by trailer is more appropriate Facilitation equipment than BKK port by train WEAKLY"
Range("O17") = "2/3"
Range("P17") = "1"
Range("Q17") = "3/2"
BKKtrailBKKtrain4.BackColor = RGB(243, 247, 255)
BKKtrailBKKtrain4.ForeColor = RGB(243, 247, 255)
End Sub
```

#Check radio button name BKKtrailBKKtrain4 then show linguistics context in cell M17 and add fuzzy score 0.67,1,1.5 in to cell O17 P17 and Q17 respectively

```
Private Sub BKKtrailBKKtrain5_Click()
Range("M17").Value = "BKK port by trailer is appropriate Facilitation equipment EQUAL with BKK port by train"
Range("O17") = "1"
Range("P17") = "1"
Range("Q17") = "1"
BKKtrailBKKtrain5.BackColor = RGB(255, 255, 255)
BKKtrailBKKtrain5.ForeColor = RGB(255, 255, 255)
End Sub
```

#Check radio button name BKKtrailBKKtrain5 then show linguistics context in cell M17 and add fuzzy score 1,1,1 in to cell O17 P17 and Q17 respectively

```
Private Sub BKKtrailBKKtrain6_Click()
Range("M17").Value = "BKK port by train is more appropriate Facilitation equipment than BKK port by trailer WEAKLY"
Range("O17") = "2/3"
Range("P17") = "1"
Range("Q17") = "3/2"
BKKtrailBKKtrain6.BackColor = RGB(243, 247, 255)
BKKtrailBKKtrain6.ForeColor = RGB(243, 247, 255)
End Sub
```

#Check radio button name BKKtrailBKKtrain6 then show linguistics context in cell M17 and add fuzzy score 0.67,1,1.5 in to cell O17 P17 and Q17 respectively

```
Private Sub BKKtrailBKKtrain7_Click()
Range("M17").Value = "BKK port by train is more appropriate Facilitation equipment than BKK port by trailer FAIRLY STRONG"
Range("O17") = "2/5"
Range("P17") = "1/2"
Range("Q17") = "2/3"
BKKtrailBKKtrain7.BackColor = RGB(229, 238, 255)
BKKtrailBKKtrain7.ForeColor = RGB(229, 238, 255)
End Sub
```

#Check radio button name BKKtrailBKKtrain7 then show linguistics context in cell M17 and add fuzzy score 0.4,0.5,0.67 in to cell O17 P17 and Q17 respectively

```
Private Sub BKKtrailBKKtrain8_Click()
Range("M17").Value = "BKK port by train is more appropriate Facilitation equipment than BKK port by trailer VERY STRONG"
Range("O17") = "2/7"
Range("P17") = "1/3"
Range("Q17") = "2/5"
BKKtrailBKKtrain8.BackColor = RGB(221, 233, 255)
BKKtrailBKKtrain8.ForeColor = RGB(221, 233, 255)
End Sub
```
#Check radio button name BKKtrailBKKtrain8 then show linguistics context in cell M17 and add fuzzy score 0.29,0.33,0,4 into cell O17 P17 and Q17 respectively

```
Private Sub BKKtrailBKKtrain9_Click()
Range("M17").Value = "BKK port by train is more appropriate Facilitation equipment than BKK port by trailer ABSOLUTELY"
Range("O17") = "2/9"
Range("P17") = "1/4"
Range("Q17") = "2/7"
BKKtrailBKKtrain9.BackColor = RGB(213, 228, 255)
BKKtrailBKKtrain9.ForeColor = RGB(213, 228, 255)
End Sub
```
#Check radio button name BKKtrailBKKtrain9 then show linguistics context in cell M17 and add fuzzy score 0.22,0.25,0.29 into cell O17 P17 and Q17 respectively

```
Private Sub NexttoQ32_Click()
Dim i As Long
   i = 1 'desired row for this button
    Worksheets(ActiveSheet.Index + 1).Activate 'desired sheet for this button
   With ActiveWindow 'bring desired row to the top
      .ScrollRow = i
      .ScrollColumn = 1 'optional to ensure first column in view
   End With
    Range(Cells(i, 1), Cells(i, 256).End(xlToLeft)).Interior.Color = RGB(49, 132, 155)
End Sub
```
#Click Next button for change to next sheet

```
Private Sub PrevioustoQ21_Click()
Dim i As Long
   i = 1 'desired row for this button
    Worksheets(ActiveSheet.Index - 1).Activate 'desired sheet for this button
   With ActiveWindow 'bring desired row to the top
      .ScrollRow = i
      .ScrollColumn = 1 'optional to ensure first column in view
   End With
    Range(Cells(i, 1), Cells(i, 256).End(xlToLeft)).Interior.Color = RGB(49, 132, 155)
End Sub
```
#Click Previous button for change to previous sheet

BIOGRAPHY

NAME	Miss Wirachchaya Chanpuypetch
DATE OF BIRTH	11 May 1984
PLACE OF BIRTH	Chonburi, Thailand
INSTITUTIONS ATTENDED	Burapha University, 2001-2005
	Bachelor of Science (Food Science)
	Ramkhamhaeng University, 2002-2009
	Bachelor of Arts (Political Science)
	Mahidol University, 2006-2009
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PUBLICATIONS	Chanpuypetch, W. and Kritchanchai, D. (2009). Gateway selection for Thailand rubber export. Proceedings of the 10th Asia Pacific Industrial Engineering & Management Systems Conference 2009, Dec 14-16, Kitakyushu, Japan, pp. 582-590.
	Kritchanchai, D. and Chanpuypetch, W. (2009). A framework for decision support systems in logistics: a case study for Thailand rubber exports. International Journal of Logistics and SCM Systems, Vol.3(1), pp. 24-31.