A DSS approach with Fuzzy AHP to facilitate international multimodal transportation network

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ABSTRACT

International multimodal transport corridors connect one or more adjoining countries for delivering cargos with assurance of delivery reliability while minimizing transit time and costs. Since the economic standards of the countries in a particular international corridor vary from country to country, this can affect the overall performance of the routes due to the lack of interconnections, interoperability and legal framework while delivering cargos. The facilitation of a particular international route largely depends upon the decisions of commercial players who generally select an optimal multimodal transport route with respect to economic principles. Thus, it is important for the policy makers associated with an international route to understand what commercial players want and what kinds of barriers commercial players are facing. In this regard, it is highly justified to utilize analysis tools for systemically investigating the international routes in terms of interconnections, interoperability, legal framework, etc. However, the required data for the analysis is not only vast but also not easily obtained. Considering the complexity of logistics systems and the huge volume of data involved in international routes, this study proposes a decision-aid tool within a decision support system (DSS) using Fuzzy-AHP for the systemic analysis. This can assist countries to develop strategic policy decision making for the facilitation of international intermodal transport routes linking different countries.

Key words: Fuzzy-analytic hierarchy process, decision support system, multimodal transport network, policy decision makings.

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1. Introduction

As the world's economics are getting increasingly interconnected, an inefficient transport and logistics system plays an important role in facilitating international trade by integrating different transport modes of maritime shipping, railways or roads. Herein the seamless multimodal transportation system has been in increased demand by the trend of door-to-door delivery. In particular, the area of Eurasia has already entered a new era of greater economic development by strengthening economic integration especially in Russia, CIS, China, Korea, Japan and so on. This region is currently undertaking tremendous changes and occupies more than 60% of the world economy. Furthermore, it contains three major countries of BRICs such as China, India and Russia, which are the most promising countries to become large forces in the world economy. For example, China has seen spectacular growth over the last few years at the average annual growth rate of about 8.0%; India is becoming of prime interest to multinational companies and some see it as eventually rivaling China in terms of opportunities. In addition, the economic consolidation among Russia and CIS countries is promoted, where industrial diversification strategy is implemented on behalf of oil money for balance development.

For intra-regional trade, containerized cargo is the most dynamic sector of not only Eurasia but also world trade covering the entire global industrial structure. Consequently, a well-planned multimodal international transportation system in the area of Eurasia should play an important role in facilitating the movement of cargos. In addition to the flow of goods, it can provide many advantages to countries involved. This could lead to increased size of markets for companies, international economic bargaining power and so on. In particular, Northeast Asia is an area where economic growth has been increasing rapidly so that intra-regional trade is growing. For example, Korea, one of the Northeast Asian countries, is located on the far eastern side of Asia. Therefore, Korea is a land-bridge through Russia or China to Europe with respect to a multimodal transportation network as the Trans Korean Railway (TKR) is linked with northern corridors of TAR[1] such as TSR[2] and TCR[3]. Consequently, Korea can become a gateway to the Pacific for Europe. Cargo could be shipped to and from Busan by railway through Europe. In this regard, establishing a well functioning Korean multimodal international transportation system is an essential element to securing an efficient flow of cargos for the area of Eurasia.

The efficient, reliable and cost-effective services of international transportation and logistics systems facilitate smooth movement of cargoes so that the economic development of involved countries is secured. International multimodal transport corridors serve foreign trade between two or multiple countries, which have national and domestic routes. Hence

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[1] Trans-Asian Railway.

[2] Trans-Siberian Railway.

[3] Trans-Chinese Railway.

an international corridor connects one or more adjoining countries for delivering cargo between origin and destination with a high reliability of delivery with lower transit time and costs. With respect to the usage of international routes, they are competing with each other based on their overall performance. However, the economic standards of the countries in a particular international corridor vary from country to country. This can affect the overall performance of the corridor due to the lack of interconnections, interoperability and legal framework while delivering cargo.

The facilitation of a particular international route largely depends upon the decisions of commercial players who generally select an optimal multimodal transport route with respect to economic principles. In this regard, it is crucial for the policy makers of countries associated with an international route to understand what commercial players want and what kinds of barriers commercial players are facing. In addition to knowing the needs of commercial players, it is highly justified to utilize analysis tools for systemically investigating the international route in terms of interconnections, interoperability, legal framework, etc. However, the required data for the analysis are not only vast but also not easily obtained. Considering the complexity of logistics systems and the huge volume of data involved in international routes, this study proposes a decision-aid tool within a decision support system (DSS) using Fuzzy-AHP for the systemic analysis. This can assist countries in developing strategic policy decision making for the facilitation of international intermodal transport routes linking different countries.

2. Literature review

The international multimodal transport network can typically arise in a practical situation where either importers or exporters are located in Russia, China and Uzbekistan. Another situation that represents more common transportation scenarios is the transshipment of importing or exporting goods via transfer points to reach sources of supply or customer bases located in cities that are not directly inaccessible from major seaways (Banomyong & Beresford, 2001). Besides sea transport options in Eurasia, TAR was seen as a way to accommodate the increases in international trade between Europe and Asia and facilitate the movements of freight between countries. It also aimed to improve the economies and accessibility of landlocked countries like Laos, Afghanistan, Mongolia and the Central Asian countries (UNESCAP, 1996).

The TAR consists of four corridors such as the Northern Corridor, Southern Corridor, North-South Corridor and Subregional Network (UNESCAP, 2005). The Northern Corridor links Europe and the Pacific, via Korea, China, Mongolia, Kazakhstan, Russia, Belarus, Poland and Germany, with breaks of gauge at the Chinese-Mongolian border, Chinese-Kazakhstan border and the Belarus-Polish border. The Northern Corridor consists of five sections such as TKR, TSR, TCR, TMR[4] and TMGR[5]. In particular, TSR covers much of this route and carries large amounts of freight from East-Asia to Moscow and on to the rest of Europe. In contrast to other sections, TKR is not functioning up to this point due to political problems with South-North Koreas, but the reconnection efforts are on the way after the Joint South/North Declaration made on June 15, 2000. So, cargo from South Korea should be currently shipped by sea to Vladivostok port or Vostochny port to access the TAR.

The Southern Corridor goes from Europe to Southeast Asia, connecting Turkey, Iran, Pakistan, India, Bangladesh, Myanmar and Thailand, with links to China's Yunnan Province and, via Malaysia, to Singapore. Breaks of gauge occur, or will occur, at the Iran-Pakistan border, the India-Myanmar border and at the Thailand-China border. The North-South Corridor linking Northern Europe to the Persian Gulf. The main route starts at Helsinki in Finland and continues through Russia to the Caspian Sea, where it splits into three routes: a western route through Azerbaijan, Armenia and western Iran; a central route across the Caspian Sea to Iran via ferry; and an eastern route through Kazakhstan, Uzbekistan and Turkmenia to eastern Iran. The routes converge in the Iranian capital of Tehran and continue to the Iranian port of Bandar Abbas. A Subregional Network includes ASEAN and India-China subregions.

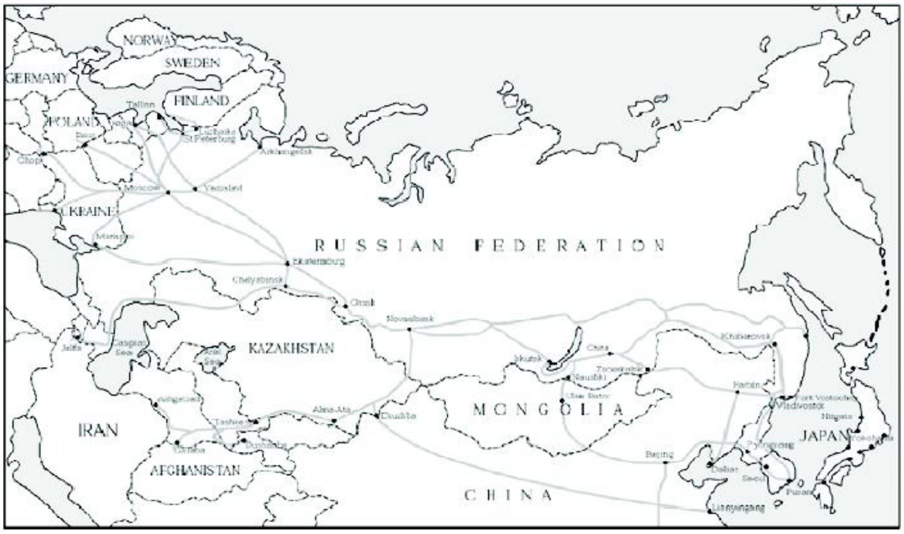

Figure 1. International multimodal transportation network

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[4] Trans-Manchurian Railway.

[5] Trans-Mongolian Railway.

Despite the practical significance of the intermodal transportation network design, a minimal amount of literature has been published on this topic. Min *et al.* (2007) is one of the researchers to look into a similar problem taking place in the Chinese logistics operations. However, they did not consider qualitative factors such as delivery reliability and transit risk influencing the global intermodal transportation network design. Moynihan *et al.* (2006) built an AHP-based DSS for supplier selection, but they did not address the global supply chain issues involving the multimodal logistics operations. Godwin *et al.* (2007) developed a mixed integer programming model to solve the passenger rail network design problem in India. However, their model was confined to a single-objective, single-modal routing and scheduling problem and was posed as a stand-alone model that could not be incorporated into the decision support framework. Similarly, Kumanan *et al.* (2007) proposed hybrid heuristics combining the merits of a genetic algorithm and a particle swarm search technique to solve the problem of designing a supply chain logistics network. The proposed heuristics was limited to a single objective production and distribution problem without the specific consideration of inland logistics issues. For recent advances in logistics modeling, the interested readers should refer to Min and Zhou (2002) and Barros and Hilmola (2007). Also, the interested readers should refer to Eom and Kim (2006) for the recent applications of DSS to logistics disciplines.

3. The framework of DSS

The framework of a decision support system (DSS) is depicted in Fig. 2 This framework aims to develop viable multimodal transportation strategies for route facilitation. Within the DSS framework suggested by Sprague and Carlson (1982) and Dotoli *et al.* (2003), the proposed DSS is comprised of three components:

- Database management enhancing the access of accurate, timely data necessary for model development
- Model base management system developing a computerized Fuzzy-AHP model to prioritize alternatives and investigate the characteristics of international multimodal routes
- Dialogue generation and management software generating a series of ‘if-then’ or ‘what-if’ rules for the changes of variables such as cost data, traffic data, reliability data and security data and so on

The proposed DSS can be used by policy makers for multimodal transportation route facilitation so as to develop cooperation strategies with associated countries with concrete data. The proposed DSS will help them to make strategic decisions as to which physical barriers on a route to be tackled, which institutional limitations to be resolved and which cost factors to be adjusted. The proposed DSS will be tested and validated with sample data gathered from Korean forwarders in section four. Unlike a standalone model which relies on the accuracy of available data for its efficiency, the proposed DSS allows for interfaces between databases and models and subsequently handles what-if scenarios in the case that model parameter values changed over time. The detailed descriptions of the proposed DSS are.

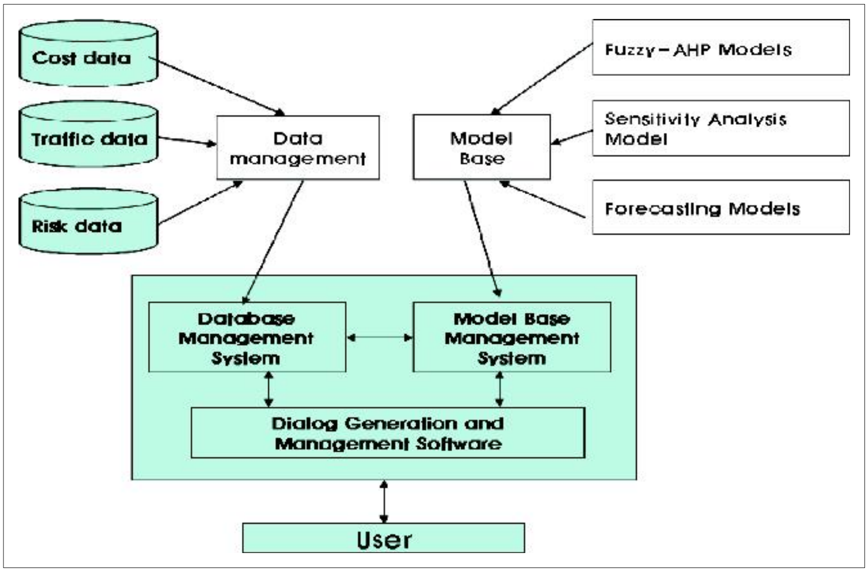

Figure 2. Architecture of decision support system for multimodal transport network

3.1 Database management system

To enhance data quality and avoid data redundancy, it is necessary to develop a database that contains two data sources: governmental and non-governmental. The database management system (DMS) is designed to supplement standard operating systems by allowing greater integration of data, complex file structure, quick retrieval and changes and better data security (Turban and Aronson, 2001). Governmental sources include regulatory guidelines and reports issued by federal and public transportation authorities and non-governmental sources include public data files such as published literature, websites and CD-ROMs and so on.

International multimodal transport corridors serve foreign trade between two or multiple countries, which have national and domestic routes. In this regard, international routes are competing with each other based on their overall performance. Most commercial players, in principle, make decisions on selecting a specific route according to the transport time, costs, volume of trade, on time delivery, supply chain security and so on. Thus, it is necessary for policy makers to understand in detail the key factors which affect the selection of routes for facilitation. The data categories in this study that are relevant to multimodal transportation analysis can be defined as traffic time, transport costs, on time delivery and supply chain security.

3.1.1 Cost data

Cost is one of the primary concerns of multimodal transportation selection. These costs include navigating fees, trans-anchoring fees, mooring/unmooring fees, harbor fees, groundage fees, demurrage fees, terminal handling charges, freight rates, freight surcharges, port charges, loading/unloading, transshipment costs, insurance costs, in-transit inventory carrying costs, taxes and customs duties. The more the cost data are broken down in detail, the better the analysis can be made.

3.1.2 Traffic data

Important concerns of multimodal transportation operations include proximity to inland river-ports, break-bulk terminals, paved roads, major road arteries, access to forwarders and common carriers, transit risks, ocean-carrier/barge/rail/truck schedules, ocean-carrier/barge/rail/truck transit time, loading/unloading time, shipment transfer time, carrier reliability, choke points and government traffic regulations and rules. In addition, the volume of trade is significant with respect to the discount of shipping charges from mass transport and the balance of inbound and outbound volume.

3.1.3 Reliability data

On time delivery can be affected by the availability of equipment, the coordination of sequential activity, labor productivity, level of equipment modernization, etc.

3.1.4 Security data

Supply chain security is measured by standardization of documents, efficiency of security checks, utilization of EDI systems, political risks, transit damage and conflict resolution of procedures, etc.

Table 1. Key factors for the network facilitation

Cost data	Traffic data	Reliability data	Security data
• Navigating fees • Trans-anchoring fee • Mooring/unmooring fee • Harbor fee • Groundage fee • Demurrage fee • Terminal handling charge • Freight rate • Freight surcharge • Port charge • Loading/unloading • Transshipment cost • Insurance cost • In-transit inventory carrying cost Taxes	• Proximity to ports • Border crossing time • Break-bulk terminals • Paved roads • Major road arteries • Access to forwarders and common carriers • ocean-carrier/barge/rail/truck schedules • ocean-carrier/barge/rail/truck transit time • Loading/unloading time • Shipment transfer time • Carrier reliability • Government traffic regulations and rules • Volume of trade	• Availability of equipment • Coordination of sequential activity • Labor productivity • Level of equipment Modernization	• Transit risks • Political risk • Transit damage • Conflict resolution procedure • Standardization of documents • Efficiency of security checks • Utilization of EDI system

3.2 Model management system

As a core of the model base within the DSS framework, the Fuzzy-AHP (FA) model is developed that considers multiple objective aspects of the multimodal transportation planning. The FA model is supported by the forecasting model that predicts any changes in the size of shipment between the port of entry and destinations, cost changes, infrastructure development, etc. in order to capture future updated information. The proposed FA model will determine which route should be selected to minimize the total transportation cost, transit time and transit risk, while maximizing the delivery reliability. This decision includes the consideration of either direct or indirect shipment via a transfer point and the optimal combination of the intermodal mix (Fig. 3).

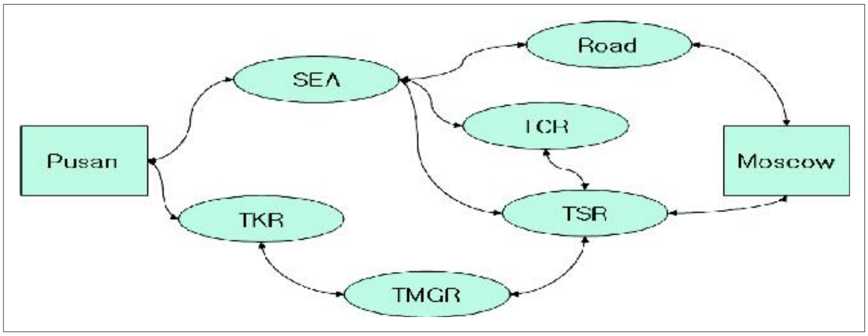

Figure 3. Various routing options between Busan and Moscow

Since the use of a cheaper mode of transportation requires a longer transit time, the goal of minimizing transportation costs inherently conflicts with the goal of minimizing transit time. The presence of these conflicting goals requires FA model that makes an optimal trade-off between cost, time, reliability and security. In general, FA is referred to as a multiple-criteria scoring method that was designed to synthesize the priorities of decision alternatives with each decision criterion into an overall priority score of each decision alternative (Saaty, 1980). Accordingly, FA helps the transportation planner not only to identify the best intermodal selection and routing option among various transportation alternatives, but to also to assess the pros and cons of each transportation alternative with respect to four conflicting decision-making criteria:

- The cost
- The time
- The reliability
- The security

In addition, FA permits the policy planner to investigate the sensitivity of the chosen transportation alternatives to changes in strategic importance of decision-making criteria. Furthermore, FA can enhance the transportation planner's ability to make tradeoffs among various quantitative and qualitative attributes (Saaty, 1988). The application of FA to multimodal transportation planning involves four major steps (Wind and Saaty, 1980; Zahedi, 1989):

- Step 1: Break down the process of selecting the most desirable multimodal transportation routes into a manageable set of criteria and alternatives and then structure these into a hierarchical form.
- Step 2: Estimate the relative weights of the decision criteria based on the transportation planner's perceived importance of those criteria.
- Step 3: Estimate the fuzzy numbers of the criteria in each route based on the information from government or non-government sources by the use of fuzzy concept.
- Step 4: Make computations of priority scores among the decision criteria and alternatives according to their given relative priorities. Then, determine ranks of the alternatives and identify the best transportation alternative. Finally based on the benchmarking analysis, provide strategic recommendations for the performance improvement of target routes.

3.2.1 Step 1

In step 1, the manageable set of criteria and alternatives are selected and then these are structured into a hierarchical form for evaluating multimodal transport alternatives, structured into four levels (Fig. 4). Since this hierarchical representation makes the complexity of analysis simplified through decomposition, it aids the transportation planner in understanding the interactions among transportation criteria. As shown in Fig. 4, the top level of a hierarchy represents the ultimate goal of determining the best multimodal transport option. At the second level of a hierarchy, the four distinctive decision criteria are placed which are generally considered important in evaluating the transportation alternatives. At the third level, the second level criteria were further broken down for more detailed analysis based on the transport planner's intention, as sub-criteria. At the fourth level, the third level criteria were connected to the bottom level of the hierarchy represented by multimodal routes under evaluation.

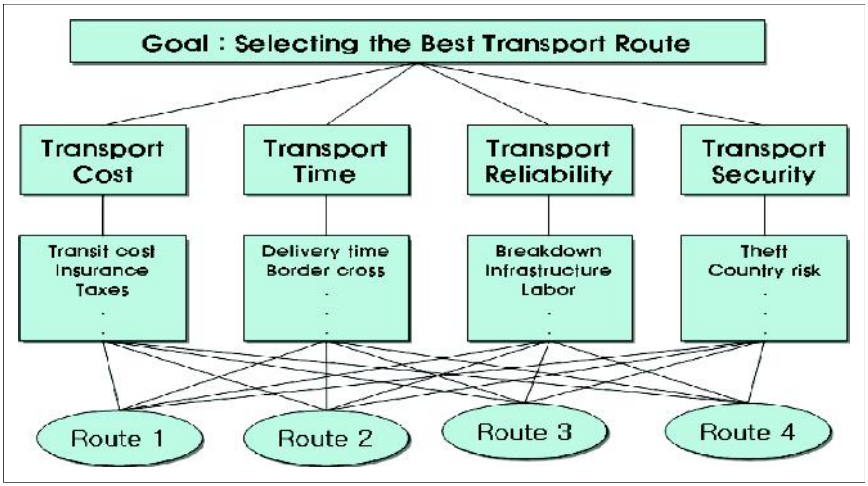

Figure 4. Hierarchy of selecting the best transport route

3.2.2 Step 2

Given the hierarchy of the problem, we need to estimate the relative weights of the decision criteria based on the transportation planner's perceived importance of those criteria. In this process, the sum of all the criteria belonging to the direct parent of the problem in the same hierarchy level must equal 100% or 1 so that each criterion has an absolute value between zero and one. For example, a transport time with priority 0.2 has twice the weight in reaching the goal as the transport cost with priority 0.1. As a result, an overall priority set, W_j, is computed for quantifying the relative importance of each criterion by multiplying the second level weight to the third level weight where j is an index for a criterion in the third level decision criteria. It is also true that W_j varies depending upon the transport strategies at hand. The transport planer then has the transport reliability in some business situations and can be the highest priority compared to other factors and vice versa.

3.2.3 Step 3

The sub-criteria estimation of each alternative was investigated in this step. The concept of fuzzy sets was applied. In fact, an international multimodal transport route passes through a number of cities in different countries so that it is hard to get qualified data along the route since they have their own transport regulations, infrastructure conditions, configurations of logistics systems and so on. Therefore, there is a limitation of data acquisition and a high uncertainty on data quality. In pursuit of such consideration, the concept of fuzzy sets[6] was used to calculate the sub-criteria estimation that is represented as the type of a triangular membership function. The triangular membership function in this study can be defined as (a, b, c) or $\mu_G(x)$ with a fuzzy set G where a and c are lower bond and upper bound respectively. In addition, b is a real number with fuzzy quantity between a and c (e.g. b = {x| a≤=x≤c and x∈G}). Fig. 5 represents the graphical description of $\mu_G(x)$ which increases from a to b and then decreases up to c. For example, if a person has information on the transport risk to a particular route, it is very hard for him or her to quantify the information. In this case, the information can be scaled easily as a fuzzy number like (4, 8, 9) using the interval scale of 0 and 10 (e.g. the higher the worse), which means the level of transport risk lies between 4 and 9 but the effect of the transport risk is considerably serious because the average number of eight is located near ten.

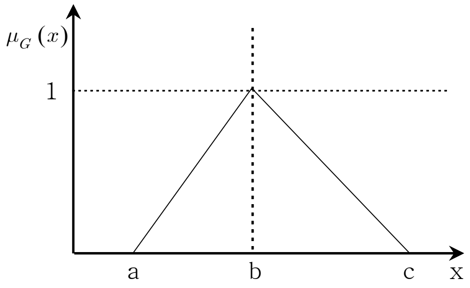

Figure 5. Triangular membership function

3.2.4 Step 4

In order to compute the priority scores of each alternative, it is first required to calculate the centers of gravity of fuzzy numbers of criteria obtained from Step 3. The center of a gravity of a fuzzy number is defined as G_j^i where j is an index for the criterion of the third level criteria mentioned in Step 2 and is an index for an alternative. Then, G_j^i is calculated as follows:

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[6] Zadeh, L.A (1965), Fuzzy sets, *Information and Control* 8:338~353.

$$G_j^i = c_j^i - \sqrt{\frac{(c_j^i - a_j^i)(c_j^i - b_j^i)}{2}} \text{ or } a_j^i - \sqrt{\frac{(c_j^i - a_j^i)(b_j^i - a_j^i)}{2}}$$

For example, when the second criterion of the first alternative is (0.074, 0.230, 0.487), its center of gravity is 0.256.

$$G_{2j}^1 = 0.487 - \sqrt{\frac{(0.487 - 0.174)(0.487 - 0.230)}{2}}$$

Therefore, the overall priority score of an alternative, $Score^i$, is obtained from the formula
$\sum_j W_j \times G_j^i$ and then the alternatives are ranked according to the priority scores. Finally the best transportation alternative is identified.

3.3 Dialogue generation and management software

At best, the model is an abstraction of real-world situations. Consequently, it cannot capture reality without running it more than once (Dyer and Mulvey, 1983). Thus, the model should enable policy planners to evaluate ‘what-if’ scenarios associated with changes in the transportation strategy (e.g., a shift from cost savings to prompt delivery services or vice versa), accessibility to transportation infrastructure (e.g., inland transportation hubs, terminals, rail sidings) and government regulations and rules. In other words, the model’s robustness needs to be tested by examining its sensitivity to contingency planning. Thus, the outcomes of a model can be different according to the changes in the relative importance of transport time and cost, whereas it is insensitive to changes in the relative importance of delivery reliability and transit risk.

4. Fuzzy-AHP DSS application and results

4.1 Model application

The proposed Fuzzy-AHP DSS is applied to an international multimodal network linking Busan in Korea to Moscow in Russia in which there are four possible routes (Table 2). Route 1 is a popular corridor at present where cargo are shipped from Busan to Vostochny by way of sea route and then are transported to Moscow through TSR. The distance is 10,280 km from Busan to Moscow. Route 2 is a route of using both TCR and TSR in which cargoes are shipped from Busan to Liayungang in China and then are transported from Liayungang to Moscow via Zhengzhou, Alasankou, Druzhba. Transshipment is required at the Alashankou/Druzuba border crossing. Route 3 is connecting from the Korean Peninsula to Moscow by railway. This route runs from Busan to Moscow, connecting the Gyungui Line, TMGR, TSR via Sinuiju, Shenyang, Beijing, Brenhot, ZamynUud, Ulanbaatar. Transshipment works are required at the Erenhot/ ZamynUud border crossing. Route 4 is one of the sea routes where cargo is shipped from Busan to the port of St. Petersburg and then transported to Moscow by road. Therefore, the success of routes for international trade will depend on whether it would be economically or efficiently competitive with other routes available such as maritime shipping and combined marine-railways. In addition, each route consists of two or more countries and they have different standards of logistics and transportation systems based on their economic development.

Table 2. Possible routes from Busan to Moscow

Mode	Route	Distance (km)	Transshipment
Route 1 : Sea+TSR	Busan-Vostochny-Moscow	9,833	None
Route 2 : Sea+TCR+TSR	Busan-Liayungang-Zhengzhou-Alasankou-Druzhba-TSR-Moscow	9,200	Alashankou/Druzhba
Route 3 : TKR+TMGR+TSR	Busan-Sinuiju-Shenyang-Beijing-Erenhot-ZamynUud-Ulanbaatar-TSR-Moscow	9,000	Erenhot/ZamynUud
Route 4 : Sea+Road	Busan-St.Petersburg-Moscow	23,000	None

In order to identify key factors of network facilitation in a particular route for getting competitive, we first construct a hierarchical form for evaluating multimodal transport alternatives, which was structured into four levels (Fig. 4). The top level of a hierarchy is set as finding the best alternative; the second level consists of the four distinctive decision criteria such as cost, time, reliability and security; the third level sub-criteria is set with nine factors such as transit costs, insurance costs, transit time, border crossing, equipment breakdown, infrastructure level, labor productivity, theft and country risk (Table 3); the fourth level consists of the four alternatives mentioned above. Given the hierarchical structure, we need to investigate the relative weights of criteria for which DSS searches the required information from the module of a database management system (Fig. 2). Unlike a standalone model, the database management system can provide more accurate information about evaluation criteria such as costs, times, reliability and security with updated sources from government or non-government organizations. Then, a policy planner interacts with the database management system by the use of dialogue generation and management software. In doing so, he or she can finalize the relative weight of decision criteria (Table 3).

Table 3. Relative weights of decision criteria

Criteria	Weight	Sub-criteria	Weight	Combined weight
Cost	0.286	Transit cost	0.90	0.257
		Insurance	0.10	0.029
Time	0.357	Transit time	0.80	0.286
		Border crossing	0.20	0.071
Reliability	0.214	Equipment breakdown	0.30	0.064
		Infrastructure level	0.40	0.086
		Labor productivity	0.30	0.064
Security	0.143	Theft	0.70	0.100
		Country risk	0.30	0.043

After setting up the relative weights, a policy planner needs to decide the performance of each route according to the sub-criteria. A particular international route generally passes a number of cities in the different countries so that it is hard to get qualified data due to the limitation of data availability and reliability. To overcome the difficulty, the concept of fuzzy sets is applied in this study in which the triangular membership function is adopted and then the fuzzy numbers are also extracted by the use of the database management system and dialogue generation and management software. By doing so, Table 4 is the summary of the fuzzy numbers and their gravity centers in each route (Section 3.2).

Table 4. Fuzzy number and gravity center of each route

j	Criteria	W_j	Route1		Route2		Route3		Route4	
			Fuzzy No. (a, b, c)	G_j	Fuzzy No. (a, b, c)	G_j	Fuzzy No. (a, b, c)	G_j	Fuzzy No. (a, b, c)	G_j
1	Transit cost	0.257	(0.70,0.72,0.73)	0.718	(0.71,0.74,0.77)	0.744	(0.67,0.69,0.72)	0.692	(0.95,0.97,1.00)	0.974
2	Insurance	0.029	(0.70,0.71,0.73)	0.714	(0.86,0.89,0.92)	0.888	(0.93,0.94,1.00)	0.964	(0.94,0.97,0.99)	0.969
3	Transit time	0.286	(0.51,0.57,0.62)	0.568	(0.62,0.68,0.73)	0.676	(0.54,0.60,0.65)	0.595	(0.89,0.95,1.00)	0.946
4	Border crossing	0.071	(0.14,0.29,0.43)	0.286	(0.43,0.57,0.86)	0.610	(0.29,0.71.1.00)	0.681	(0.143,0.29,0.43)	0.286
5	Equipment breakdown	0.064	(0.29,0.43,0.57)	0.429	(0.57,0.71,0.86)	0.714	(0.71,0.86,1.00)	0.857	(0.29,0.43,0.57)	0.429
6	Infrastructure level	0.086	(0.43,0.50,0.60)	0.507	(0.50,0.60,0.75)	0.613	(0.60,0.75,1.00)	0.776	(0.38,0.43,0.50)	0.433
7	Labor productivity	0.064	(0.43,0.50,0.60)	0.507	(0.50,0.60,0.75)	0.613	(0.60,0.75,1.00)	0.776	(0.43,0.50,0.60)	0.507
8	Theft	0.100	(0.29,0.43,0.57)	0.429	(0.43,0.57,0.71)	0.571	(0.57,0.71,1.00)	0753	(0.29,0.43,0.57)	0.429
9	Country risk	0.043	(0.25,0.38,0.50)	0.375	(0.75,0.86,1.00)	0.875	(0.50,0.75,1.0)	0.750	(0.25,0.38,0.50)	0.375

In the end, we need to calculate the overall priority score of each alternative. It is important to check the characteristics of sub-criteria which means that for some criteria the higher the better but in other cases the lower the better. For example, the lower the transit cost, the better the alternative, but the higher the labor productive, the better the alternative. In order to unify such conflict factors of the criteria, it is useful to take the reciprocal of the fuzzy numbers with respect to a single standard. In this case, we set the objective function as to minimize the overall score so that the rule of evaluation is that the lower the overall score, the better the alternative. Table 5 shows the performance of alternatives according to the criteria.

Table 5. The overall performance of alternatives

Criteria	Route1	Route2	Route3	Route4	Benchmark
Transit cost	0.18	0.19	0.18	0.25	Route 1, 3
Insurance	0.02	0.03	0.03	0.03	Route 1
Transit time	0.16	0.19	0.17	0.27	Route 1
Border crossing time	0.02	0.04	0.05	0.02	Route 1, 4
Equipment breakdown	0.03	0.05	0.06	0.03	Route 1, 4
Infrastructure level*	0.04	0.05	0.07	0.04	Route 1, 4
Labor productivity*	0.03	0.04	0.05	0.03	Route 1, 4
Theft	0.04	0.06	0.08	0.04	Route 1, 4
Country risk	0.02	0.04	0.03	0.02	Route 1, 4
Total	0.55	0.69	0.70	0.73	
Rank	1	2	3	4	

* The scores of infrastructure level and labor productivity are transformed into the lower the better standards

4.2 Results

The outcomes of model application shown in Table 5 indicate Route 1 that combines the intermodal mix of the ocean carrier and the railways is very competitive at present with the overall score of 0.55. Alternate Route 2 is the second most favorable option with an overall priority score of 0.69. Route 3 is followed by Route 2 which generates an overall priority score of 0.70. Among the four alternate routes, Route 4 is the least favorable route with on overall priority 0.73. The superiority of Route 1 over other alternatives shows that the priority scores of criteria are higher than those of alternative routes. On the other hand, Route 4 is less competitive in transit time and cost since cargo is shipped from the port of Busan to the port of St. Petersburg and then delivered by road. Road transport is very expensive and ocean transport is low cost.

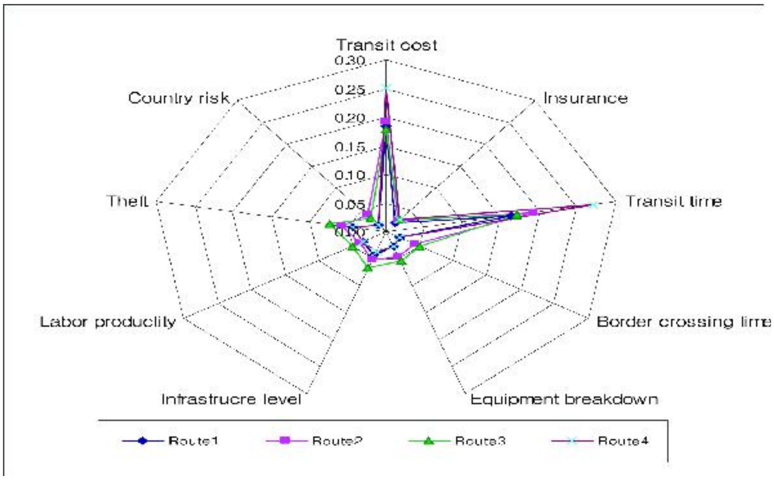

Figure 6. The graphical description of comparisons of the routes

The cargo in Route 1 is shipped from the port of Busan in S. Korea and sent to the port of Fareast Russia and then transshipped by TSR up to Moscow. The competitive advantages of Route 1 partly can be explained by the fact that it has been used for a long time by numerous shippers and carriers so that the efficiency of the logistics systems is effectively improved. That is why Route 1 shows the highest scores in all the criteria, but the policy makers of the two countries need to continuously pay attention to the criterion of transit cost. The reason is that the gap of cost factors compared with other routes is relatively small so it is necessary for the two countries to cooperate to reduce the unnecessary cost in order to remain competitive.

The second rank is Route 2 where cargo is shipped by sea at the port of Busan and then arrives at Lianyungang port in China for the transshipment by the TCR up to the border of China-Russia (Alasnnkou-Druzhha). At the border, transshipment operations of cargo are required due to the different size of rail gauge and then delivered to Moscow. This corridor involves three countries such as Korea, China and Russia so that the efforts of coordination operations are important to improve the overall performance of the corridor with respect to interconnections, interoperability and legal framework. The outcomes of DSS show that there are high gap differences in the criteria of border crossing times, equipment breakdown, infrastructure levels, labor productivity, theft, country risk and so on. This indicates that the policy makers of three countries need to make efforts to cooperate for facilitating this route. First of all, the lack of efficiency in transit customs clearance should be overcome. In fact, many commercial players point out some weak points of Route 2. These are that the wagon supply in China is not sufficient to meet the need of logistics companies and the weight limitation of trains at TCR.

The third rank is Route 3 where cargo is shipped by railway connecting South

Korea, North Korea, Mongolia and Russia so that four countries are involved in moving cargo through the corridor. In this corridor, the transshipment operations are required at the border of China-Mongolia (Eranhot-Zamin Uud) through Beijing due to the different size of rail gauge. At Ulanbaatar, cargo is transported by the use of TMGR up to the border of Mongolia-Russia and then delivered by TSR to Moscow. Route 3 and Route 4 have similar overall scores with 0.69 and 0.70 respectively. Although the transit costs and time and country risks of Route 3 are more competitive than Route 2, other criteria of Route 3 such as border crossing time, equipment breakdown, infrastructure, labor productivity and theft are less competitive. The economic standards of the countries involved in Route 3 vary from country to country. This can affect the overall performance of the corridor due to the lack of interconnections, interoperability and legal framework while delivering cargo from origin to destination.

Table 6. The gaps between Route 2 and Route 3

Criteria	Route2	Route3	Gap(Route2 – Route3)
Transit cost	0.19	0.18	0.01
Insurance	0.03	0.03	0
Transit time	0.19	0.17	0.02
Border crossing time	0.04	0.05	-0.01
Equipment breakdown	0.05	0.06	-0.01
Infrastructure level*	0.05	0.07	-0.02
Labor productivity*	0.04	0.05	-0.01
Theft	0.06	0.08	-0.02
Country risk	0.04	0.03	0.01
Total	0.69	0.70	-0.01

In fact, commercial players have expressed that Route 3 has some issues to be improved for the efficient movement of cargo. First, there is delay at the border between Mongolia and Russia. Commercial players felt that the transshipment system in Mongolia lagged behind compared to international standards. In particular, they think that Mongolian transport companies don’t have enough experience or knowledge in up to date logistics operations. Second, the availability of wagons in China and Mongolia is not sufficient to meet the needs of logistics companies. Third, the dispatch schedule which allocates wagons to railways is not predictable in China especially in peak seasons like Christmas. Fourth, while transferring cargo at Zamin Uud in Mongolia, frequent breakdowns of transshipment equipment takes place due to outdated machinery. This indicates that the improvement of these weak factors would allow Route 3 to have a competitive portion so that the policy makers of the four countries need to cooperate to make this happen.

5. Conclusions

The efficient, reliable and cost-effective services of international transportation and logistics systems facilitate smooth movement of cargo so that the economic development of associated countries is secured. With respect to the usage of international routes in a particular region, they are competing with alternate routes based on their overall performance. Since the economic standards of the countries along a particular international corridor vary from country to country, this can affect the overall performance of the corridor due to the lack of interconnections, interoperability and legal framework while delivering cargo. In fact, the facilitation of a particular international route largely depends upon the decisions of commercial players who generally select an optimal multimodal transport route with respect to economic principles. In this regard, it is crucial for the policy makers of associated countries in an international route to understand what commercial players want and what kinds of barriers commercial players are facing for the corridor facilitation. However, in order to investigate the characteristics of a particular route, it is required to have an analysis tool that can handle a large amount of data from multiple countries concerning not only physical and institutional factors but also the reliability of data. Thus, this study proposes a decision-aid tool within a decision support system (DSS) using Fuzzy-AHP for systemic analysis, which can assist countries in developing strategic policy decision making for the facilitation of international intermodal transport routes linking different countries.

The proposed decision support system is comprised of three components that are database management, model base management system with Fuzzy-AHP and dialogue generation and management software. The database management is to enhance the access of necessary data. For example, the input data for the model are physical and institutional factors. On the physical side, these are inadequate existing infrastructure such as poor rail and road access to ports, poor coordination of loading and unloading activities and different rail gauges resulting in costly methods of moving cargos from one country to another and so on. On the institutional side, conflicting customs and immigration procedures resulting in delays and prevention of cargos movement from one country to another, institutional blockage to the free flow of transit vehicles and cargo in the hinterland and a lack of coordination between different levels of government, etc. should be considered. A model base management system is developed to prioritize alternatives and investigate the characteristics of routes. The dialogue generation management software handles a series of ‘if-then’ or ‘what-if’ rules for the changes of variables.

The proposed Fuzzy-AHP DSS is applied to the case example of an international multimodal network linking Busan in Korea to Moscow in Russia in which four possible routes are considered. Route 1 is a popular corridor at present by which cargo is shipped from Busan to Vostochny by way of sea route and then are transported to Moscow through

TSR. The distance is 10,280 km from Busan to Moscow. Route 2 is a route of using both TCR and TSR. On Route 2 cargo is shipped from Busan to Liayungang in China and then transported from Liayungang to Moscow via Zhengzhou, Alasankou, Druzhba. Transshipment is required at the Alashankou/ Druzuba border crossing. Route 3 is connecting from the Korean Peninsula to Moscow by railway. This route runs from Busan to Moscow, connecting Gyungui Line, TMGR, TSR via Sinuiju, Shenyang, Beijing, Brenhot, ZamynUud, Ulanbaatar. Transshipment works are required at the Erenhot/ZamynUud border crossing. Route 4 is one of the sea routes where cargo is shipped from Busan to the port of St. Petersburg and then transported to Moscow by road.

As a result, the outcomes indicate that Route 1 is the most competitive route but for further facilitation, it is necessary for the two countries to cooperate to reduce the unnecessary cost in order to remain competitive; second ranked is Route 2 where three countries such as South Korea, China and Russia are involved. Facilitating the route is to have the efforts of coordination operations in the reduction of border crossing times, equipment breakdown, theft, country risks, as well as the improvement of infrastructure level and labor productivity; the third rank is Route 3 where South Korea, North Korea, Mongolia and Russia are involved. The cooperation efforts are placed at the border between Mongolia and Russia for removing delays, the improvement of Mongolia's logistics systems, the availability of wagons in China and Mongolia, the systems of dispatching and scheduling of wagons and the reduction of frequent breakdowns of transshipment equipment. Therefore, the proposed model can assist policy makers of the associated countries to develop cooperation strategies of route facilitation based on the mutual benefits with the outcomes of analysis. Finally, the proposed DSS can be extended for future work: i) The DSS can be expanded to include the knowledge base so that it can be evolved into an intelligent DSS that can learn from a series of model experiments and sensitivity analyses with changing parameters, ii) The theme of future research is to include dynamic design of the multimodal transport network which reflects the time-sensitivity of cost and risk parameters over a multiple planning horizon.

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