A Decision Support System to Compare the Transportation Modes in Logistics

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ABSTRACT
The selection of an optimal transportation mode is one of the most important factors in supply chain and logistic planning. Furthermore, the selection transportation mode is a complex, multi-criteria decision problem. The decision makers have to face and take attention with a lot of criteria; such as cost, quality, delivery time, safety, accessibility and etc while choosing the best mode. Under these criteria, there must be a selection between motorway, seaway, airway, pipeline, railway and also intermodal modes. Selection the transportation mode is very promising issue because it affects about 60-65% of total logistic cake. There are some techniques which can be heuristics and logical approaches are used to reach the best option. The analytical hierarchy process (AHP) which is one of the mathematical methods can be very useful in involving several decision makers with different conflicting objectives to arrive at a consensus decision. In this paper, the selection of an optimal transportation mode using an AHP-based model was evaluated for logistic activities. To solve this transportation mode selection problem, we developed a decision support system based AHP. By using the developed decision support system, the best transportation modes is determined and discussed.

1. Introduction
Nowadays, having the best production system, producing with the best quality and selling the cheapest price are not enough to achieve competitiveness on the market. Besides them, enterprises have to reach end-products to end-customers at the right time with the optimum way. It is known that the logistics activities have a remarkable rate to accomplish this. Logistics is the management of the flow of goods, information and other resources, between the point of origin and the point of consumption in order to meet the requirements of consumers. Logistics includes the transportation, inventory, warehousing, material-handling, and packaging, insurances and customs etc. The most important component of logistics is transportation. To light the load of logistics costs and the other things, transportation has become a promising issue in the strategic plans of enterprises. The priority of transportation in logistics urges the decision makers choose the best transportation modes.
These modes could be motorway, seaway, airway, railway, pipeline and also intermodal transportation modes. Deciding on the appropriate transportation mode is very effective in minimizing the costs. Freight transport makes a vital contribution to the economy and society, and is at the heart of globalization. But its dramatic growth in the road sector is rapidly taking away the benefits, through impacts such as congestion, noise, pollution and infrastructure damage. Innovative policies and technologies can reduce these impacts by promoting the integrated transport chain for door-to-door services (European C., 2001).

Due to the trend of globalization and using the resources efficiency in recent decades, the importance of transportation modes in logistics management has been growing in various areas. The key element in a logistics chain is transportation system, which joins the separated activities. Transportation systems influence the performance of logistics system hugely. The purpose of this paper is to take attention the importance of transportation in logistics and help the decision makers choosing the optimum mode via developing a decision support system based on AHP. The paper started from this introducing part. Afterwards, a literature review which is deal with is given the AHP method is handled and all criteria are explained in detail. Nowadays, the research on the development of a Decision Support System (DSS) is directed at integrating technical knowledge in specific area with computer technologies for solving problems which neither man nor computer alone can address effectively.

In this study, we examine and explain all the transportation modes according to their criteria. Then after exposing the comparison matrices of each criterion with analytic hierarchic process (AHP) methodology, optimum transportation mode is determined. To solve this decision problem, we developed a decision support system based on AHP methodology.

2. Literature Review

Hwang and Mai 1990, tried to ascertain whether or not the profit-maximizing transport mode will be different from the welfare-maximizing one, and investigate the impact of endogenizing the choice of transport mode on the choice of location and input usage. It is shown that the results derived are critically dependent on the characteristics of the chosen production function as well as the specification of the transport cost structure. The model is particularly relevant in countries such as Taiwan, where transport regulation can play a crucial role in determining the location and output of certain industries. Five examples of applications of the Analytic Hierarchy Process (AHP) are made to illustrate the different uses of ratio scale multi-criteria decision method in transportation (Saaty, 1995). They include a commuter route selection hierarchy, a best mix of
routes to Pittsburgh’s new International Airport, a benefits/costs hierarchy to choose the best mode to cross a river, a planning hierarchy for a transport system and a simple dependence with feedback cycle to choose a car when criteria depend on the alternatives. For a better appreciation of the use and power of the method, the examples are followed by a resume of developments in research on the (AHP) in the last few years.

Forkenbrock 2001, estimated external costs for four representative modes of freight trains. For each mode of freight train, he estimated three general modes of external costs and compares them with the private costs experienced by railroad companies. The general modes of external costs include: accidents (fatalities, injuries, and property damage); emissions (air pollution and greenhouse gases); and noise. Rail external costs are 0.24 cent to 0.25 cent (US) per ton-mile, well less than the 1.11 cent for freight trucking, but external costs for rail generally constitute a larger amount relative to private costs, 9.3±22.6%, than is the case for trucking, 13.2%. Piantanakulchai and Saengkhao’ (2003) study applied Analytic Hierarchy Process (AHP) to transport decision making. Related social interest groups were modeled in the decision process to reflect social preference. Relative importance of each attribute in AHP was modeled by combining engineering model with decision model. A case study of alternative motorway alignments in Thailand was conducted. Impacts were estimated by the aid of Geographical Information System (GIS) and AHP model developed. Composite weighted AHP scored were used to generate AHP decision surface. Finally, the best alignment was proposed by generating a least cost path which is most socially preferable.

Punakivi and Hinkka 2006, took a closer look at the very basics of logistics and analyzed the selection criteria of transportation services from the industrial point of view as the main research problem. Their study also tries to establish a better understanding of which industrial sectors are using which mode of logistics services and why. According to the analysis, the high value and especially high price/kg ratio of products, short life cycles and worldwide markets are typical reasons to use rapid modes of transport. Based on the results, some of the future logistics needs were identified, and the aim is to help logistics service providers offer the exact services needed, providing better competitiveness for Finnish shipping companies operating in global markets. According to authors, logistics service providers should have compatible operating systems with different parties of various supply chains to enable deliveries to different customer groups according to their industry's required speed. Pogarcic et al.’ (2008) paper analyzed possibilities of applying AHP method in making decisions regarding planning and implementation of plans in
traffic and ensuring the qualitative business logistics. A case study examining the different modes for transportation of freight by a Turkish logistics-service provider company is presented by Tuzkaya and Önüt (2008). Qualitative criteria are often accompanied by ambiguity and vagueness. To cope with ambiguity and vagueness problem, the fuzzy analytic network process (ANP) method has been used. A large number of detailed criteria that interact with each other have been evaluated and synthesized to obtain the most suitable transportation mode. This evaluation has been carried out by a group of decision makers coming from different management levels and functional areas in the sector of logistics and from the service company with intent to provide a more accurate and mutually acceptable solution. Considered many no commensurable, nonlinear even conflicting criteria simultaneously, the transport mode selection in multimodal transportation is studied within the framework of multi-criteria decision making (MCDM). The theoretical basis for feed forward artificial neural network (FANN) to solve this MCDM problem is presented by Qu et al. (2008). With the initial topology predetermined by fuzzy analytic hierarchy process (AHP), an adaptive ANN system is proposed, in which the number of ANN input nodes, adapts the decision makers’ preference threshold and the initial input weights are determined by fuzzy AHP. Empirical results evidently showed this MCDM method is an accurate, flexible and efficient transport mode selection model.

Özkan and Başgil (2009), in their study, food, textile, and electronic, logistic, metal working and chemistry sectors will be analyzed to choose the most appropriate transportation mode. The goal of the study is to choose the best alternative for each sector according to main and sub-criteria. First of all, the weights of main criteria will be determined and then a multi-criteria decision making technique, TOPSIS will be applied on the problem to choose the best alternative for each sector. Lynn 2010, defined the transportation, explaining brainstorming in transportation, analyzed the modes of transportation, mentioned strengths and weaknesses of each mode and giving an example of UPS in his study.

3. Transportation Modes In Logistic

Transportation usually represents the most important single element in logistics cost for most firms. Freight movement has been observed to absorb between one-third and two-thirds of the total logistics costs (Figure 1). Thus, the logistician needs a good understanding of transportation matters (Ballou, 1999).
Without well developed transportation systems, logistics could not bring its advantages into full play. Besides, a good transport system in logistics activities could provide better logistics efficiency, reduce operation cost, and promote service quality. The improvement of transportation systems needs the effort from both public and private sectors. A well-operated logistics system could increase both the competitiveness of the government and enterprises (Tseng et al., 2005). However its costs are measured, the transportation industry operates more like a fractious gathering of shirrtail relatives than an integrated industry. Each mode of transportation (truck, train, ship, or plane) is a distinct entity with a unique culture, way of operating, and potential for growth. Further, some segments, trucking, for example, are significantly fragmented. The logistics sector, being the relatively new kid on the block as well as the one wearing the white collar, is even more differentiated from the rest of the industry. So, while the transportation industry as a whole may move in tandem with macro forces such as global economics, each segment marches to the beat of its own drum (Anonymous, 2010b).

Basically there are six transportation modes, these are: motorway, railway, seaway, airway, pipeline, and intermodal transportation.

**Motorway transportation:** This is one of the common use transportation modes. Transportation is made mostly with trucks and articulated lorries. In motorway transportation, fixed costs are low, but variable costs are high. One of the most advantages of motorway transportation is the availability to every point. It is a flexible transportation mode. Mostly, there is no need to another transportation mode to go to desired place. But, in motorway transportation accident rates are high than the other transportation modes (Özkan and Başlıgil, 2009). Road freight transport has advantages as cheaper investment funds, high accessibility, mobility and availability. Its disadvantages are low capacity, lower safety, and slow speed (Tseng et al., 2005).

The excessive usage of motorway transport also brings many problems, such as traffic jams, pollution and traffic crashes. In the future, to improve the land transport in transport efficiency and
reliability, a revolution of transport policies and management is required, e.g. pricing (Tseng et al., 2005).

Trucking is an transportation service of semi-finished and finished products with an average length of freight haul 646 miles for less than truckload (LTL) and 274 miles for truckload (TL). The inherent advantages of trucking are its door to door service such that loading or unloading is required between origin and destination, as is often true of rail and air modes; its frequency and availability of service; and its door to door speed and convenience (Ballou, 1999).

Railway transportation: In railway transportation, goods that have low value but have big volume and are heavy carried. Fixed costs are high because of the installation and maintenance costs. On the other hand variable costs are low. Because the goods are transported with high volume, the costs per unit are low, so it is a safe transportation mode. Transportation with railway is slow and transportation time is long. These are the disadvantages of this mode of transportation (Özkan and Başılıgil, 2009). Railway transport has advantages like high carrying capacity, lower influence by weather conditions, and lower energy consumption while disadvantages as high cost of essential facilities, difficult and expensive maintenance, lack of elasticity of urgent demands, and time consumption in organizing railway carriages (Tseng et al., 2005).

Rail service exists in two legal forms, common carrier or privately owned. A common carrier sells its transportation service to all shippers and is guided by the economic and the safety regulations of the appropriate government agencies. In contrast, private carriers are owned by the shipper with the usual intent of serving only the owner. Because of the limited scope of the private carrier’s operations, no economic regulation is needed. Virtually all rail movement is of the common carrier mode. Railroads offer a diversity of special services to the shipper, ranging from the movement of bulk commodities such as coal and grain to refrigerated products and new automobiles, which require special equipment. Other services included expedited service to guarantee arrival within a certain number of hours; various stop-off privileges, which permit partial loading and unloading between origin and destination points; pickup and delivery; and diversion and reconsignment, which allows circuitous routing and changes in the final destination of a shipment while en route (Ballou, 1999).

Airway transportation: The most important advantage of this mode transportation is its speed. It is used when the speed is important, when the products are valuable and when products should be transported urgently. Its cost is much higher than the other transportation modes. But because of its speed; store costs will decrease. A disadvantage of this mode transportation is the accessibility
problem. Mostly, only airway transportation is not enough to go to the desired point. Another transportation mode should be used with it (Özkan and Bağlıkıl, 2009).

Figure 2. Main transportation modes in logistic (Anonymous, 2010b)

Air freight logistics is necessary for many industries and services to complete their supply chain and functions. It provides the delivery with speed, lower risk of damage, security, flexibility, and good frequency for regular destinations, yet the disadvantage is high delivery fee. The characteristics of air freight logistics are that: (1) airplanes and airports are separated. Therefore, the industries only need to prepare planes for operation; (2) it allows to speed delivery at far destinations; (3) air freight transport is not affected by landforms. Given the trend of global markets, air freight logistics also has to change their services. The future tendencies of air freight development are integration with other transport modes and internationalization and alliance and merger between air transport companies. The future pattern of air freight logistics is cooperative with other transport modes, such as maritime and land transport, to provide a service base on Just-In-Time, and door-to-door (Tseng et al., 2005).

Air transportation service exists in common, contract, and private legal forms. Direct air service is offered in seven types: (1) regular domestic trunk-line carriers, (2) all cargo carriers, (3) local-service airlines, (4) supplemental carriers, (5) air taxis, (6) commuter airlines, (7) international carriers (Ballou, 1999).
Seaway transportation: This is the cheapest mode of explained transportation modes. Products with large quantity (dry cargo, liquid, gas and goods with low value) and products in containers can be transported. It is 22 times cheaper than airway, 7 times cheaper than motorway and 3.5 times cheaper than railway transportation. For that reason it is the most used transportation mode all over the world. It is considered as most secure mode of transportation. But the speed of transport is low and distribution time is longer compared to other transportation modes (Özkan and Başlugil, 2009).

Seaway transportation plays an important role in international freight. But its schedule is strongly affected by the weather factors. To save costs and enhance competitiveness, current maritime logistics firms tend to use large scaled ships and cooperative operation techniques. Moreover, current maritime customers care about service quality more than the delivery price. Thus, it is necessary to build new logistics concepts in order to increase service satisfaction, e.g. real-time information, accurate time windows and goods tracking systems. The operation of maritime transport industry can be divided into three main types: (1) Liner Shipping: The business is based on the same ships, routes, price, and regular voyages. (2) Tramp Shipping: The characters of this kind of shipping are irregular transport price, unsteady transport routes, and schedule. It usually delivers particular goods, such as Dry Bulk Cargo and crude oil. (3) Industry Shipping: The main purpose of industry shipping is to ensure the supply of raw materials. This sometimes needs specialized containers, such as the high-pressure containers for natural gas (Tseng et al., 2005).

Loss and damage costs resulting from transporting by water are considered low relative to other modes because damage is not much of a concern with low valued bulk products, and losses due to delays are not serious (large inventories are often maintained by buyers). Claims involving transport of high valued goods, as in ocean service, are much higher. Substantial packaging is needed to protect goods, mainly against rough handling during the loading unloading operation (Ballou, 1999).

Pipeline transportation: The advantages of pipeline transport are high capacity, less effect by weather conditions, cheaper operation fee, and continuous conveyance; the disadvantages are expensive infrastructures, harder supervision, goods specialization, and regular maintenance needs (Tseng et al., 2005).

The most economically feasible products to move by pipeline are crude oil and refined petroleum products. However there is some experimentation with moving solid products suspended in a liquid or containing the solid products in cylinders that in turn move in a liquid. If
these innovations prove to be economical, pipeline service could be greatly expanded. In regard to transit time, pipeline service is the most dependable of all modes, because there are few interruptions to cause transit time variability. Weather is not a significant factor, and pumping equipment is highly reliable. Also, the availability of pipeline capacity is limited only by the use that other shippers may be making of the facilities at the time capacity is desired (Ballou, 1999).

Intermodal transportation: The 21st century will see a renewed focus on intermodal freight transportation driven by the changing requirements of global supply chains. Each of the transportation modes (air, inland water, ocean, pipeline, rail, and road) has gone through technological evolution and has functioned separately under a modally based regulatory structure for most of the 20th century. With the development of containerization in the mid-1900s, the reorientation toward deregulation near the end of the century, and a new focus on logistics and global supply chain requirements, the stage is set for continued intermodal transportation growth (Dewitt and Clinger, 2010).

As new intermodal transportation hubs are constructed and as existing ports, airports, rail terminals, and trucking and distribution complexes expand to provide intermodal transportation services, the potential environmental impacts associated with each type of transportation can be multiplied and compounded (Rondinelli and Berry, 2000). Intermodal transport is the set of technologies that facilitates the transfer of loading units from one mode of transport to another. Intermodal transfer allows en route change from a given transport mode (such as road transport) to another (such as train or ship) in order to carry larger volumes in one transport operation.

There are ten possible intermodal service combinations: (1) rail and truck, (2) rail and water, (3) rail and air (Fig. 3), (4) rail and pipeline, (5) truck and air, (6) truck and water, (7) truck and pipeline, (8) water and pipeline, (9) water and air, and (10) air and pipeline. Not all of these combinations are practical. Some that are feasible have gained little acceptance (Ballou, 1999).
4. Selection the Best Transportation Mode

In the paper, the most appropriate transportation mode will be chosen from six different modes. The transportation modes are motorway, railway, seaway, airway, pipeline, and intermodal transportation, respectively. In our model, we have and determined cost, travel time, safety, air pollution, energy consumption, noise, and accessibility criteria that affect transportation modes. We originated from Balluo’s (1999) transportation modes comparison table while determining the criteria. But the comparisons of the transportation alternatives according these criteria are made by experts.

For determining the most appropriate alternative, we use Analytic Hierarchy Process (AHP), a multi criteria decision making technique. In this section, first we emphasized the AHP method and then each criterion is explained. After the explanations of method, criteria and alternatives, we create the comparison matrixes of each alternative for each criterion. The created matrixes are solved by the developed and implemented decision support system, and get the results.

4.1 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP), Saaty (1980), is a powerful tool that may be used to make decisions when multiple and conflicting objectives/criteria are present, and both qualitative and quantitative aspects of a decision need to be considered. The AHP considers a set of evaluation criteria, and a set of alternative scenarios among which the best decision is to be made. It generates a weight for each evaluation criterion and scenario according to the information provided by the

Figure 3. Some intermodal transportation modes (Anciaux and Yuan, 2007)
decision maker (DM). The AHP combines the objective and scenario evaluations determining a ranking of the scenarios (Anonymous, 2010a).

AHP is effective in dealing with complex decision making because it reduces complex decisions to a series of pairwise comparisons. AHP reduces the bias in the decision making process because it also checks the consistency of the DM’s evaluations. AHP may be considered as a tool that is able to translate the pairwise relative evaluations (both qualitative and quantitative) made by the DM into a multicriteria ranking. The AHP is simple because there is no need of building a complex expert system with the DM’s knowledge embedded in it.

The AHP-based model is used to evaluate the objectives above together. Al-Harbi (2001) developed the following steps for applying the AHP.

1. Define the problem and determine its goal.
2. Structure the hierarchy from the top (the objectives from a decision-maker's viewpoint) through the intermediate levels (criteria on which sub-sequent levels depend) to the lowest level which usually contains the list of alternatives.
3. Construct a set of pair-wise comparison matrices (size n x n) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement shown in Table 1. The pair-wise comparisons are done in terms of which element dominates the other.

<table>
<thead>
<tr>
<th>Numerical rating</th>
<th>Verbal judgments of preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Extremely preferred</td>
</tr>
<tr>
<td>8</td>
<td>Very strongly to extremely</td>
</tr>
<tr>
<td>7</td>
<td>Very strongly preferred</td>
</tr>
<tr>
<td>6</td>
<td>Strongly to very strongly</td>
</tr>
<tr>
<td>5</td>
<td>Strongly preferred</td>
</tr>
<tr>
<td>4</td>
<td>Moderately to strongly</td>
</tr>
<tr>
<td>3</td>
<td>Moderately preferred</td>
</tr>
<tr>
<td>2</td>
<td>Equally to moderately</td>
</tr>
<tr>
<td>1</td>
<td>Equally preferred</td>
</tr>
</tbody>
</table>

4. There are n x (n-1) judgments required to develop the set of matrices in step 3. Reciprocals are automatically assigned in each pair-wise comparison.
5. Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.
6. Having made all the pair-wise comparisons, the consistency is determined by using the Eigen value, $\lambda_{\text{max}}$, to calculate the consistency index, CI as follows: $CI = (\lambda_{\text{max}} - n)/(n-1)$, where $n$ is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table 2. The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.

**Table 2. Average random consistency (Al-Harbi, 2001)**

<table>
<thead>
<tr>
<th>Size of Matrix</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Consistency</td>
<td>0</td>
<td>0</td>
<td>0.58</td>
<td>0.9</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
<td>1.49</td>
</tr>
</tbody>
</table>

7. Steps 3-6 are performed for all levels in the hierarchy.

4.2 Main Criteria with Descriptions

The user selects a service or a combination of services that provides the best balance between the quality of service offered and the cost of that service. The task of service choice selection is not as forbidding as it first appears because the circumstances surrounding a particular shipping situation often reduce the choice to only a few reasonable possibilities (Ballou, 1999). To aid in solving the problem of transportation service choice, transportation service may be viewed in terms of characteristics that are basic to all services: cost, travel time, safety, air pollution, energy consumption, noise, and accessibility. These factors seem to be the most important to decision makers.

The criteria which are taken into consideration in the structure are below:

*Cost:* The cost criterion is important for companies to choose the transportation mode. First installation cost, fixed cost, variable cost, usage costs and maintenance costs affect cost criteria. Generally, companies want to transport maximum loads with minimum costs (Özkan and Başlugil, 2009).

Cost of modes varies greatly from one type of transport service to another. Table 4 gives the approximate cost per ton-mile for the five modes of transportation. Notice that airway is the most expensive, sea and pipe carriages are the least costly. Trucking is about seven times more expensive than the rail, and rail is about four times as expensive as sea and pipeline movement (Ballou, 1999).
Table 4. Average Freight Ton-Mile Transportation Price by Mode (Ballou, 1999)

<table>
<thead>
<tr>
<th>Mode</th>
<th>Price (cent/ton-mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Railway</td>
<td>2.50</td>
</tr>
<tr>
<td>Motorway</td>
<td>25.08</td>
</tr>
<tr>
<td>Seaway</td>
<td>0.73</td>
</tr>
<tr>
<td>Pipeline</td>
<td>1.40</td>
</tr>
<tr>
<td>Airway</td>
<td>58.75</td>
</tr>
</tbody>
</table>

Traveling Time: Traveling time is usually referred to as the average time it takes for a shipment to move from its point of origin to its destination. The traveling time is one of the promising criteria that affect choosing the optimum transportation mode. There are also a lot of things which affect the distribution time from one point to another point. Especially, the weather, goods, roads, and the other things are directly related with the time. While airway is the fastest way, seaway is the slowest (Figure 4). The other transportation modes traveling times are between the sea and airway modes.

Figure 4. Average traveling times of different transportation modes (Ballou, 1999)

Safety: This criterion evaluates the risk of being damaged and lost of products during the transportation period. Because transportation modes differ in their ability to move freight without loss and damage, loss and damage experience becomes a factor in selection transportation mode.

Air Pollution: As new multimodal transportation hubs are constructed and as existing ports, airports, rail terminals, and trucking and distribution complexes expand to provide intermodal transportation services, the potential environmental impacts associated with each type of transportation can be multiplied and compounded (Rodinelli and Berry, 2000).
Table 5. Ranking of Modes by Emissions per tonne-km (Khan, 1991)

<table>
<thead>
<tr>
<th>Rank</th>
<th>NO</th>
<th>VOC</th>
<th>PM</th>
<th>CO</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Most efficient</td>
<td>Railway</td>
<td>Railway</td>
<td>Airway</td>
<td>Railway</td>
<td>Railway</td>
</tr>
<tr>
<td>2</td>
<td>Seaway</td>
<td>Seaway</td>
<td>Railway</td>
<td>Seaway</td>
<td>Seaway</td>
</tr>
<tr>
<td>3</td>
<td>Motorway</td>
<td>Airway</td>
<td>Seaway</td>
<td>Airway</td>
<td>Motorway</td>
</tr>
<tr>
<td>4-Least efficient</td>
<td>Airway</td>
<td>Motorway</td>
<td>Motorway</td>
<td>Motorway</td>
<td>Airway</td>
</tr>
</tbody>
</table>

Transportation is a major source of air pollution. The following charts show the relative contribution of transportation and all other sources (other forms of transport, energy production, industry and domestic sources) to emissions of five key pollutants: particulates (PM, fine dust and soot particles), carbon monoxide (CO), nitrogen oxides (NO), benzene, volatile organic compounds (VOC) and hydrocarbons (Table 5, Figure 5).

Figure 5. Comparison of gas emissions by transportation modes (Anonymous, 2010c)

_Energy Consumption:_ Energy efficiency is an important economic consideration for transportation. To minimize negative impacts on the environment, transportation companies must increase the efficiency of energy consumption. Of the petroleum used by the various transportation modes, rail’s share is very small relative to that of trucking. The estimates of total (aggregate) energy presented in Figure 6 were derived from both direct and indirect energy consumption. It is evident that nationally, at the aggregate level, rail freight is the most efficient user of energy (in tonne-kilometre terms) (Khan, 1991).
Noise: Because large numbers of people are impacted by transportation noise, and because the impacts are significant, noise levels are important concerns in the design and operation of all modes of transportation. Transportation noise is frequently the dominant environmental concern voiced by the logistic about the development and expansion of transportation systems. Transportation noise is the main source of environmental pollution, including; road traffic, railway traffic, air traffic, sea traffic. As a general rule, larger and heavier vehicles emit more noise than smaller and lighter vehicles (Waitz et al., 2007).

Motorway accounts for approximately 70% of total noise emissions by transportation. It must be noted that different road transportation modes have different scales of noise emissions. Main sources of noise come from the engine and the friction of the wheels over the road surface. Further, travel speed and the intensity of traffic are directly linked with its intensity of noise. For instance, one truck moving at 90 km/hr makes as much noise as 28 cars moving at the same speed. Noise level grows arithmetically with speed. For instance a car traveling at 20 km/hr emits 55 db of rolling noise, at 40 km/hr 65 db, at 80 km/hr 75 db and at 100 km/hr 80 db. Rail accounts for 10% of total noise emissions by transportation. Noise comes from the engine (mostly diesel), the friction of wheels over the rails, and whistle blowing. The most important noise impacts of rail operations are in urban areas where the majority transshipment functions are performed. Furthermore, rail terminals are often located in the central and high density areas of cities. Air transportation accounts for 20% of total noise emissions by transportation. As air transportation took a growing importance in inter-city transportation and that jet engines were predominantly used, noise
emissions have increased significantly to the point of becoming a major concern near airports. The establishment of heavily used flight paths between major cities creates noise corridors where ambient noise is almost prevalent (Figure 7). This is particularly noted when those corridors are over densely populated areas. Even it does not widely take place in literature; the noise from sea traffic is not negligible. Ships, ferryboats, jet skis, sea motors cause different types of noise most of all emitting high noise levels (Rodrique, 2010).

![Figure 7. Percentage of highly annoyed people correlated with day-night average sound level (Ldn) for three modes of transportation (Waitz et al., 2007)](image)

Accessibility: Transport is a demand derived from the need for access. By better addressing directly the accessibility needs of decision makers, the need for transportation might be reduced. This criterion is related to the potential to transport the goods exactly to the same point that is arranged before (Özkan and Başeğil, 2009). While the motorway has the highest accessibility in logistic, second is airway, third one is railway and the last one is pipe and seaway.

4.3 Application of Developed Decision Support System

In this part, in order to selection of the best transportation modes for the decision makers, the developed decision support system (DSS) based on AHP was used. First step of the application of DSS is construction of the hierarchy. Criteria and alternatives’ hierarchy for this study to make a decision is showed in Figure 8.
The above mentioned criteria and alternatives help in deciding the best transportation mode selection. After the construction of the hierarchy, at the second step, the different priority weights of each criteria and alternatives are calculated by using AHP approach. The decision matrices which are created by developed decision support system for the sample problem are shown below:

**Figure 7.** Hierarchical structure of the application

**Figure 8.** Entrance interface of the developed DSS
Figure 9. Evaluation interface of each alternative

The decision maker fills the matrix according to his/her evaluation by using rates (1-9). For instance, if motorway is more costly than railway, so the user has to click below of the scale (near the railway).

After filling the all cells of matrix, the new interface is shown like Figure 10.

Figure 10. Evaluation of the alternative with respect to cost criteria
According to priorities value of each alternative (Figure 10), the comparison matrix is calculated. The calculated consistency ratio is 0.035, and then this matrix is consistent because of smaller then 0.1. The weight vector (total is 1) is shown below of the Figure 10. According to cost criteria, the most suitable transportation mode is found seaway (0.42), and respectively, pipeline, railway, intermodal, motorway and airway.

For each criterion, the decision maker evaluates all alternatives pairwise. For each criterion, every possible combination of two alternatives is judged in this way (Figure 11). The other criteria or characteristics of an alternative should not be considered in making the pairwise comparisons with respect to one particular criterion.

![Alternative Priorities and Consistency Ratios](image)

**Figure 11.** Priority weights of each criterion

After entered the judgments of cost criteria, we have entered the judgments provided through the questionnaires for the rest of criteria (Appendix). According to traveling time criteria, airway is the best option of selecting the best transportation mode with a priority of 0.46. Pipeline is also a major factor with an importance priority of 0.20. Seaway is the most unsuitable option with a priority of 0.032. According to safety criteria, motorway is the safest option for selecting the best transportation mode with a priority of 0.43. Airway is also a major factor with an importance priority of 0.24. Railway is the most unsuitable option with a priority of 0.039. For the air pollution criteria, railway received the highest priority, 0.38. Seaway turned out to be the most important one, 0.27, and airway is least weight with 0.067. According to energy consumption criteria, railway is the best option with the priority of 0.41 whereas the priority of airway is 0.156. According to noise criteria, pipeline is the best option for selecting the best transportation mode with a priority of 0.38. Railway is also a major factor with an importance priority of 0.24. Airway is the most unsuitable option with a priority of 0.039. For the accessibility criteria, motorway received the highest priority, 0.38. Airway turned out to be the most important one, 0.25, and pipeline is least
weight with 0.040 (Figure 11). After evaluating all alternatives for each criterion, finally, the evaluation criteria matrix is calculated via program (Figure 12).

![Evaluation Matrix](image)

**Figure 12.** The evaluation matrix of each criterion

For this example, we used an evaluation method, AHP method for the comparison purpose. We developed the computer programs and applied it in the given example problem. Appendix summarizes these results for the comparative purpose. By the results of AHP ranking method, the reasonable transportation mode is known to be seaway (0.21), while the railway is the second suitable option (0.18). According the criteria, the most unsuitable transportation mode is intermodal (0.096). All the results are shown at Figure 13.
Planning business activities is of vital importance for realizing business goals completely, on time, while meeting the required standards of quality at the same time. Decision-making is an activity which should adequately be incorporated in the process of realization of the accepted plan. Planning and organization in a business system which deals with transport and/or logistics because of specific demands of the business processes could be a very demanding job. The above mentioned activities by complexity are proportionally dependent on the size and structure of the business system, but their seriousness and importance are constant (Pogarcic et al., 2008).

When an organization is confronted with choosing the best transportation mode to deliver or supply a good or service, the decision can often be very complex. Transportation mode selection problems are multi-objective problems which have many qualitative and quantitative concerns in logistics. This paper has presented the AHP as a decision analysis tool in transportation mode selection problems. We proposed and developed a decision support system based on a comprehensive AHP model to select the best transportation mode. The AHP models a decision making framework using a hierarchical relationship among decision levels. It is capable of handling multiple criteria and enabled us to incorporate seven different criteria factors, when assessing the transportation modes. We concluded that seaway is the best transportation mode with an overall priority score of 0.2118.
In general, because decision-makers fail to rank correctly the relative accuracy of elicitation methods, there seems to be a need to direct decision-makers toward better choice of techniques. This is a new area of research to explore. We were able to acquire the cooperation of the decision making team to structure the model, and solve it. We attribute our success mainly ease of use of AHP and developed an easy-to-use decision support system software. This study showed the researchers that the AHP can be used to manage complex problems in transportation mode selection. For the academic users and the companies, we would provide this software and user manual. For the future searchers, the criteria and alternatives should be increased; problem should be solved based different multi criteria decision techniques (TOPSIS, PROMETHEE, and ELECTRE etc.) with fuzzy logic.

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Appendix

Figure 14. Evaluation of the alternative with respect to traveling time criteria

Figure 15. Evaluation of the alternative with respect to safety criteria
Figure 16. Evaluation of the alternative with respect to air pollution criteria

Figure 17. Evaluation of the alternative with respect to energy consumption criteria
Figure 18. Evaluation of the alternative with respect to noise criteria

Figure 19. Evaluation of the alternative with respect to accessibility criteria