Fuzzy AHP and Linear Programming Based Decision Support System for Logistics Service Providers Allocation

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Abstract

Supply chain Management is one of the most important factors in the success of businesses and their operations nowadays. In the petrochemicals industry, and with thousands of shipments yearly around the world, the allocation process of logistics service providers (LSP) is very critical to the company success in delivering products on time and with the required quality. In this paper, a Decision Support System DSS has been developed to help a petrochemical company optimize the allocation of shipments to Logistics Service Providers LSP's on a monthly and weekly basis. The Fuzzy Analytical Hierarchy Process FAHP was used to identify the different criteria and their corresponding weights that will be used for the LSP's ranking. After that, those weights were used to formulate a Linear Programming model that assigns the optimal number of shipments LSP's. After using the new decision support tool, the total cost has been significantly optimized, the LSP allocation process has been automated, which saves the decision makers time and help avoid errors.

Keywords

Logistics Service Provider(s), Analytic Hierarchy Process, Linear Programming, Decision Support System

1. Introduction

Saudi Arabia has a small-scale domestic petrochemical market and a significant volume of raw materials. The country's highly competitive petrochemical industry is therefore export-focused, and higher-value-added products are considered an important element in the maximization of profit. The industry has recently felt the impact of globalization, particularly as regards the rulings of the World Trade Organization (WTO) and a growing body of environmental regulation.

Under the leadership of the Saudi Arabian Basic Industries Corporation, set up in 1976 to spearhead development of the kingdom's petrochemical industries (Alfares, H., & Al-Amer, A.,2002), the sector is currently seeking ways to improve both effectiveness and efficiency. Principally, this entails cutting costs and focusing on an increase in profitability. The optimization techniques are being progressively adopted. Under optimization, all possible strategies to provide lowest cost of highest profit solutions are first generated, then evaluated (Alfares, H. K.,2009); this approach thus enables the best solution for given assumptions and data to be identified and implemented.

One significant challenge to the management of a business's supply chain is the allocation and distribution of orders to logistics service providers (LSPs), as this has a considerable effect on the business's longevity and the degree of competitiveness it can achieve.

One way of minimizing costs and, potentially, realizing savings, is to analyze and improve LSP allocation. In order for decision-makers to optimize order quantity per provider and ensure the smooth, timely, and correct transportation of goods, they must know the specific criteria required for optimum service (Petroni, A., & Bevilacqua, M.,2002). There is no consensus in the literature as to any single best way to select and evaluate LSPs; enterprises therefore need to choose from among various approaches according to their specific needs and overall aim, which may be, for example, minimizing cost or risk, or maximizing profit. In this research paper, a Decision Support System DSS will be developed to help a Saudi petrochemical company allocate shipments (a.k.a trips) to the 16 LSP's operating in the local Saudi market. First, Fuzzy AHP will be used to rank all the 16 LSP and calculate their overall scores according to the following criteria: Cost, Safety, On time delivery, capacity and "relationship". Then, these scores were used in a Linear Programming Model that will optimize the trips allocation to the different LSP's.

2 Literature review

Many supplier selection applications were suggested for the selection of LSPs. Ghodsypour et al (1998) was among the earliest scholars of this process, a linear programming (LP) was proposed to be integrated with analytical hierarchy process (AHP) so that intangible and tangible factors were both taken into account. Vaerma and Pulman (1998) experimented with discrete choice analysis (DCA) experiment and a Likert scale of questions to determine whether there was a difference between the managers' ranking of various potential suppliers and their ultimate choice. Some researchers, including Chan and Chan (2004), have suggested AHP, which is commonly used in multiple criteria decision-making in other areas, while others, including Bevilacqua and Petroni (2002) have experimented with the use of fuzzy logic and fuzzy expert systems.(T. N. Wong et al, 2000) combined scoring with fuzzy expert systems while Dulmin and Mininno (2003) are among many to suggest a multi-criteria decision aid (MCDA) approach, using a mid-sized Italian transportation firm as their case study. Chan and Chan (2004) likewise used a case study to introduce a supplier selection model combining quality management system principles and AHP, while Wu (2005) used rough sets theory to improve AHP, then multi-objective mixed integer programming according to multiple criteria. Kahraman et al. [10] experimented with fuzzy AHP in another Italian case study.

Under AHP, a hierarchy is created of factors which affect a given system and possible decisions are evaluated at all levels, with scores calculated from the results. Complex hierarchies incorporating multiple persons and attributes can thus be created, and it is possible to analyze each level individually. Two possible drawbacks can be identified: decision-makers may not be able to give precise numerical values to human judgments; and lack of information, or inaccurate information about potential suppliers, will affect the completeness of the results, as will subjective evaluations. However, it has been proved that AHP prevents decision-makers from incorporating personal preferences (Mikhailov, L., & Tsvetinov, P.,2004) and can thus eliminate many elements of uncertainty.

2.1 Supply Chain Logistics

With the fast growth of business, involving the development of customers, several organizations have realized that it is important to create effective, relevant, and efficient service or product solutions to fulfill the different requirements of supply chain associates (Bowersox, D., & Stank, T.,2000). Issues associated with the logistics operations of a company have in particular become increasingly a business bottleneck. In some circumstances, a self-built logistics system, including functions such as warehousing or simple delivery, is incapable of meeting the market's changing distribution needs.

Companies need to have long-term plans and manage their operations and logistics efficiently to remain competitive in a global marketplace. As a result, coordination between production and transportation scheduling and distribution planning has received increased attention in global companies. To minimize total costs, manufacturing firms should integrate their production and logistics decisions, especially given the rising costs of transporting and distributing their products. Transportation planning has often been considered with the allocation of service providers from the plants to the customers (Benotmane, Z. et al, 2017). Due to efficiency considerations, non-core activities have been outsourced to several industries in the last decades (Bokor, Z.,2012). One of the biggest misconceptions about outsourcing is the simple make-or-buy decision. In fact, outsourcing is a wide concept that involves a spectrum of arrangements, each with unique risks and advantages. Understanding the virtual benefits and risks of each of the potential alternatives is critical in making the right decision Kalinzi, C. (2016).

Some case studies adduce cost reduction, together with simultaneous enhancements in customer service. Consequently, the enhancement in customer service would increase cost levels; this effect can be seen as an example of the shift happening in the existing logistics thinking (Alvarado, U., & Kotzab, H.,2001).

2.2 Logistics Outsourcing

Outsourcing has become a trend in many industries, especially in supply chain management and logistics (Lynch, C.F.,2000). The overall extent of outsourcing is growing gradually, as organizations focus on their core business and shed functions perceived as noncore activities (Chaabouni, F., & Dhiaf, M. M.,2013).

Managers are under pressure to make the right outsourcing decision, as the business effects will be significant (McGovern, G.J., & Quelch, J.A.,2005).Good outsourcing decisions could minimize costs and give competitive advantage; in contrast, poor outsourcing decisions could lead to several problems, for example, business failure due to increased costs (Barthelemy, J.,2003).

Logistics is among the activities commonly considered for outsourcing by various companies. These logistics responsibilities are performed by service providers who operate independently from their client and offer complex logistics packages (Bokor, Z.,2012). Reducing logistics costs is one of the core areas to show huge opportunities. Manufacturing companies delegate professional LSPs by signing contracts with the best logistics companies offering the best services at the lowest cost.

Jharkharia and Shankar (2007) emphasized that outsourcing logistics functions brings professional experience and expertise to the company; thus, it is better to concentrate on the core business and outsource the logistics operations, as this will reduce cost and improve customer service levels. Therefore, many companies nowadays cooperate with LSPs to enhance their competitive benefits by long-term consideration. Andersson and Norrman (2002) realized that there was a remarkable business-to-business relationship between LSPs and their users in the whole supply chain. The users would not just play the role of a critical stakeholder to get benefits but the quality of these LSPs also affects the supply chain's users.

Lately, most LSPs have raised their capabilities to offer multiple functions involving value-added services, information-related services, and material management to achieve long-term cooperation with their clients (Jayaram, J., & Tan, K.,2010). It is important for companies to specify and identify exactly which operations they demand from LSPs. Many researchers have discussed the performance of outsourcing logistics as mentioned earlier; nevertheless, the selection criteria for LSPs has been little written about.

LSP allocation is a complex decision-making problem. The complexity comes from the qualitative and quantitative factors that influence LSPs as well as making various trade-offs among these factors.

According to a study by consulting company Accenture and Northeastern University, more than 65% of manufacturing firms in the U.S. outsource a part of their logistics. Therefore, the LSP selecting process is common, and often handled like a routine purchasing decision. For a company such as Huber Engineering Materials, which considers outsourcing as a strategic process, selecting the right LSP is an exact process that focuses more on operations, technology, and management skills than on the cost (Foster, J.,2003).

In the field of logistics services, researchers have shown interest mainly in three areas; first area focuses on the primary reasons for outsourcing logistics functions; second area concerned with measuring the contribution of logistics outsourcing to a firm's capabilities; and lastly , the process of selecting LSP for outsourcing relationship (Boyson, S. et al, 1999). This research focuses on a new area, which is the allocation and selection of the service provider that comes after the contracting with LSP companies.

However, finding the right partner needs careful assessment and could be a time-consuming process; moreover, developing a relationship with understanding of the partners' objectives and expectations will take time. Many relationships are formed through previous experience or by chance meetings with the partners. Very few researches have mentioned this issue; therefore, this research will focus on the analytical approach and decision support system for LSPs.

2.3 LSP Evaluation and Selection Methods

In recent years, many researchers have proposed different methods to evaluate LSPs. Jayant et al. (2012) used 29 indices to sort and evaluate different logistics corporations, such as evaluating their performance, transportation costs, and integrated capabilities by Pareto diagram. Furthermore, Data Envelopment Analysis (DEA) is proposed to evaluate logistics service providers. The literature shows that the efficiency of the DEA model has not completed the sorting ability (Feng, C. et al, 2011). In general, the indices, evaluations, and weights play an important role in determining a reasonable and scientific way to select logistics providers. There are different qualitative and quantitative methods to determine weights, such as the Analytical Hierarchy Process (AHP), the Delphi method, and the expert prediction method (Felix T. S. Chan and Hing Kai Chan.,2010). However, choosing the method depends on expert knowledge. Sajjad (1991) studied the AHP of a decision judgments matrix in uncertainly interval. In particular, Haih and Kwong (2002) presented fuzzy AHP, and considered operating performance, such as delivery costs, to solve the selected problem of industrial supply chains adapting to rapid market reaction by means of expert decision software in the apparel industry; nonetheless, it is not suitable for critical issues in the expert decision.

Analytic Hierarchy Process (AHP) was introduced in 1971 by Saaty to solve the limitation of allocation resources and planning needs for the military (Saaty, R.,1987). AHP has become one of the most commonly used multiple criteria decision-making (MCDM) methods and has been applied to unstructured problems in different areas, such as economic, political, healthcare, and management sciences. AHP facilitates decision-making by organizing judgments, perceptions, and feelings into a framework that presents the factors that influence a decision (Saaty, T. L.,1994).

Since the AHP problem is structured as a hierarchy, once it is constructed the decision-maker initiates the periodization process to determine the relative importance of the elements in each level. Prioritization involves educing judgments in response to questions about the domination of one element over another with respect to criteria. The scale that is used for comparison in AHP enables the decision-maker to integrate knowledge and experience instinctively and indicate how many times one element dominates another with consideration to the criterion (Millet, I., & Wedley, W.C., 2002).

Table A in the appendix shows the scale that is used for the comparison matrix of AHP.

3. Case Study

3.1 Company Overview and Current Challenges

The petrochemical company for which the DSS is developed is a global leader company that manufactures diversified chemicals. Their supply chain management and planning are undertaking complex tasks associated with decision making at all levels: from chain design stage to planning operational and logistics functions.

It produces around 2.4 million different petrochemical products, shipped to 84 different destinations, making around 100,000 trips yearly. The company wanted a suitable decision procedure to know how to best allocate customers' orders to various LSPs to maintain reliable performance and minimize the total cost of transportation. In this work, an LP optimization model has been developed to jointly optimize the allocation plan on a monthly and yearly basis.

3.2 Problem Definition

LSP allocation is a complex multi-criteria problem including many factors. In order to optimize the allocation, it is necessary to make a tradeoff between these factors. In this problem, if LSPs have capacity or other different constraints, such as good performance, two problems will exist: which LSPs are the best in terms of performance, and how many trips to allocate for each.

The company has used to allocate them using a manual decision method based on experience, which could lead to a higher cost, higher risk, and lower performance due to non-optimized allocation. Therefore, the integrated approach of Fuzzy AHP and LP is proposed for allocating trips to different LSPs.

3.3 Proposed Solution

First step began by understanding the company's operations through rotations and meetings with various units in the supply chain department. It has been realized that the department is allocating customers' orders to transporters manually, based on their experience following the process illustrated in figure 1.

The new suggested DSS will allocate the LSPs with the lowest cost, highest performance, and shortest time while taking into consideration the forecasted demand, LSP capacity and their corresponding performance and cost.

To develop this new process, the fuzzy AHP was applied to rank, evaluate, and find the weight for each LSP according to multiple criteria. The procurement and logistics manager at a petrochemical company manager at the company has been chosen to be the decision-maker in the case company, as he is the one in charge of selecting and allocating the LSPs in the logistics unit.

The criteria for comparison that have been used for the model to compare the LSPs are safety, cost, on time lifting (OTL), capacity, and relationship. The criteria definitions are detailed in Table 1.

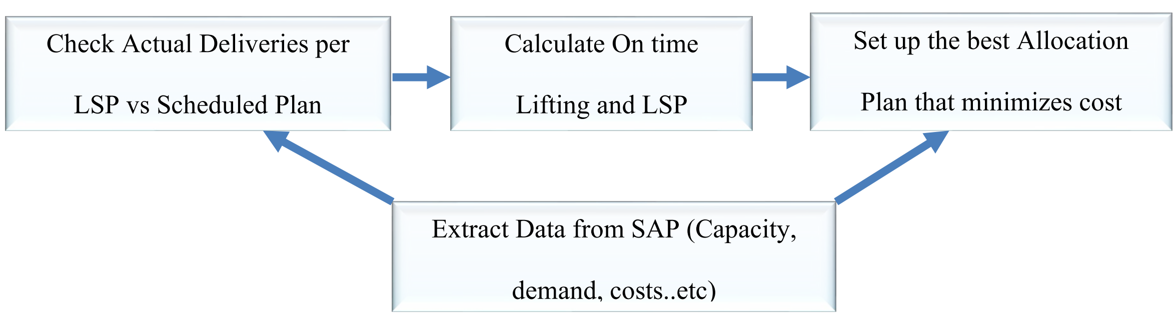

Figure 1:Old Decision-Making Process

After conducting AHP, the calculated overall score of each LSP was used in the objective function for Linear Programming Model for the optimal shipment allocation. Data for the optimization model, such as production and demand, were obtained from SAP as well as costs and capacity that were extracted from contracts signed with the transportation companies. These quantitative data were mainly collected by the decision-maker, who is experienced in the field of logistics and can thus ensure the allocation criteria and give valid and efficient judgments and evaluations in the process of fuzzy AHP.

The new process is shown in figure 2.

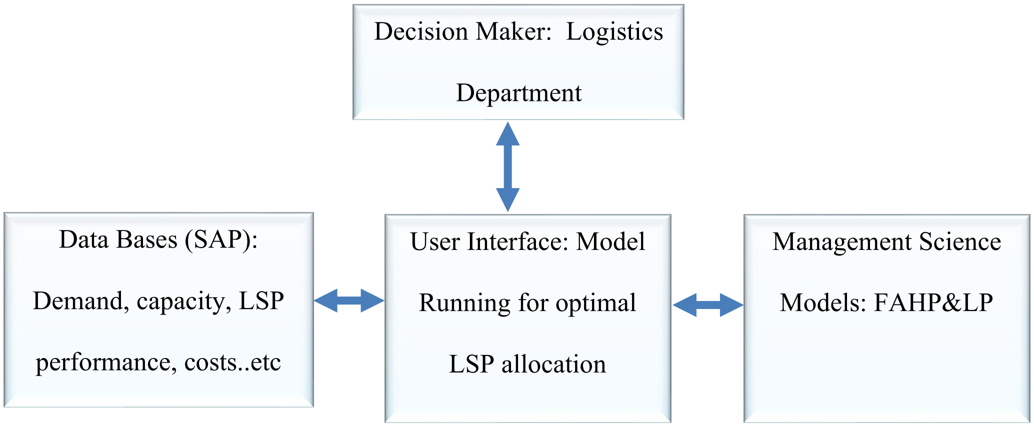

Figure 2: New Decision-Making System

Table 1: Criteria Definition

Criteria	**Definition**
Safety	The ability of LSP to meet safety rules and policies.
Cost	The ability of LSP to provide services at the target rate price of the company.
OTL	On Time Lifting: The ability to fulfill the customers' orders and deliver on time without loss or damage.
Capacity	The ability and willingness to offer flexible capacity options.
Relationship	The ability to build good relation and collaboration.

3.3.1 Fuzzy AHP

Given that the AHP is always structured as a hierarchy, a prioritization process is initiated by the decision-makers to define the relative importance of the criterion at each level. Since simple AHP does not involve vagueness for personal judgments, it has been developed to benefit from fuzzy logic approach. In Fuzzy AHP, the pair wise comparisons of the alternatives and criteria are performed through the linguistic variables, where they represented by triangular numbers. The Fuzzy AHP scale is detailed in Table A, in the appendix.

- **Criteria Weight Calculation**

In order to calculate the weight of each criteria, the following steps were performed (Buckly, 1985).

- Step 1: Convert the decision maker's (the procurement and logistics manager) perspective through a questionnaire to fuzzy AHP scale.

In this step, The pairwise comparisons are translated into a matrix as shown in Eq.1, where $\tilde{d}_{ij}^{k}$ indicates the kth decision maker's (the procurement and logistics manager) preference of ith criterion over jth criterion, via fuzzy triangular numbers. The result of Step 1 is represented in Table 2.

$$\text{Eq. 1}\quad \widetilde{A}^{k} = \begin{bmatrix} \tilde{d}_{11}^{k} & \tilde{d}_{12}^{k} & \dots & \tilde{d}_{1n}^{k} \\ \tilde{d}_{21}^{k} & \dots & \dots & \tilde{d}_{2n}^{k} \\ \dots & \dots & \dots & \dots \\ \tilde{d}_{n1}^{k} & \tilde{d}_{n2}^{k} & \dots & \tilde{d}_{nn}^{k} \end{bmatrix}$$

Table 2: Pair wise comparison matrix between criteria

	Safety	Cost	OTL	Capacity	Relationship
Safety	(1,1,1)	(1,2,3)	(3,4,5)	(4,5,6)	(6,7,8)
Cost	(1,2,3)	(1,1,1)	(3,4,5)	(4,5,6)	(6,7,8)
OTL	(1/5,1/4,1/3)	(1/5,1/4,1/3)	(1,1,1)	(2,3,4)	(4,5,6)
Capacity	(1/6,1/5,1/4)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1,1,1)	(3,4,5)
Relationship	(1/8,1/7,1/6)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/5,1/4,1/3)	(1,1,1)

Table 3:The geometric mean of fuzzy comparison values

Criteria		ri	
Safety	14.40	56.00	144.00
Cost	14.40	56.00	144.00
OTL	0.06	0.19	0.53
Capacity	0.00	0.02	0.03
Relationship	0.00	0.00	0.00
Total	28.87	112.20	288.56
Reverse(^-1)	0.03	0.08	0.04
Increasing Order	0.03	0.04	0.08

After acquiring the comparison evaluations from the decision makers, consistency was checked using the consistency ratio (CR = CI/RI), which was around 0 and CR<0.1, and it was concluded that the evaluation matrix was consistent.

- Step 2: Calculating the geometric mean of fuzzy comparison values of each criterion is calculated as shown in Eq. 2. Here $\tilde{r}_i$ still represents triangular values

$$\text{Eq2.}\ \tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{d}_{ij}\right)^{1/n} \text{‘}\ i = 1, 2, \dots, n$$

Step 2 results are depicted in Table 3.

- Step 3: Computing the fuzzy weights of each criterion (Eq.3), by incorporating next 3 sub steps (results are depicted in Table 4). Step 3.a: Find the vector summation of each $\tilde{r}_i$. Step 3.b: Find the (-1) power o summation vector. Replace the fuzzy triangular number, to make it in an increasing order. Step 3.c: To find the fuzzy weight of criterion I ($\widetilde{w}_i$), multiply each $\tilde{r}_i$ with this reverse vector.

$$\text{Eq3. } \widetilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \dots \oplus \tilde{r}_n)^{-1} = (lw_i, mw_i, uw_i)$$

Table 4:Relative fuzzy weights of each criterion

Criteria	Wi		
Safety	0.43	2.24	11.52
Cost	0.43	2.24	11.52
OTL	0.00	0.01	0.04
Capacity	0.00	0.00	0.00
Relationship	0.00	0.00	0.00

Table 5:Average relative weights of criteria

Criteria	Mi
Safety	4.73
Cost	4.73
OTL	0.02
Capacity	0.00
Relationship	0.00
Sum	1.43

- Step 4: Since are $\widetilde{w}_i$ still fuzzy triangular numbers, they need to de-fuzzified by center of area method, via applying the Eq. 4. Step 4 results are depicted in Table 5.

$$\text{Eq 4. } M_i = \frac{lw_i + mw_i + uw_i}{3}$$

- Step 5: M_i is non-fuzzy number and needs to be normalized using Eq. 5. The Criteria normalized weights are presented in Table 6.

$$Eq.5 \quad N_i = \frac{M_i}{\sum_{i=1}^{n} M_i}$$

Table 6:Normalized relative weights of criteria

Criteria	Ni
Safety	3.31
Cost	3.31
OTL	0.01
Capacity	0.00
Relationship	0.00

According to Table 6 above, the most important criteria are safety and cost.

➢ LSP's Relative Score Calculation

The same procedure used in section 4.7 was applied in the calculation of the relative scores of the LSP alternatives. The decision makers utilized both their expertise and existing information that the petrochemical company has collected during previous interactions with the 16 LSPs. For example, the cost pairwise comparison Matrix between the different LSP's was developed using the data (cost is in SR=0.26$US) from Table 7.

The relative scores of each LSPs according to the different criteria are depicted in Table 8.

After that Table 6 and Table 8 were used to calculate the overall score or rate Q_i of each LSP which is equal to the sum of relative score multiplied by the corresponding criterion weight.

Table 7:Cost per trip of each LSP from Dammam to other cities

Destination	STR	ARS	BTT	FNS	GMS
Riyadh	1,100	1,100	1,100	1,100	1,249
Jeddah	2,344	2,344	2,344	2,344	2,699
Dammam	459	759	559	459	499
Jubail	276	501	301	276	299
Qassim	1,432	1,782	1,432	1,432	1,649
Hafof	627	877	627	627	979
Haradh	739	1,139	739	739	1,129
Kharj	1,107	1,107	1,107	1,107	1,359
Rabigh	1,947	2,747	1,947	1,947	2,199

Table 8: LSP's scores

	Safety Ni		Cost Ni		OTL Ni		Relationship Ni
ARS	0.03	ARS	0.01	ARS	0.08	ARS	0.09
BTT	0.08	BTT	0.09	BTT	0.02	BTT	0.04
FNS	0.08	FNS	0.09	FNS	0.08	FNS	0.04
GMS	0.03	GMS	0.01	GMS	0.08	GMS	0.09
GST	0.03	GST	0.01	GST	0.02	GST	0.04
ATE	0.08	ATE	0.09	ATE	0.01	ATE	0.04
IMM	0.17	IMM	0.21	IMM	0.12	IMM	0.13
LSC	0.03	LSC	0.01	LSC	0.08	LSC	0.04
MFQ	0.08	MFQ	0.09	MFQ	0.08	MFQ	0.04
MSL	0.08	MSL	0.09	MSL	0.08	MSL	0.09
MNS	0.03	MNS	0.01	MNS	0.08	MNS	0.09
MTE	0.03	MTE	0.01	MTE	0.02	MTE	0.04
SAH	0.08	SAH	0.09	SAH	0.08	SAH	0.09
ARE&RTE	0.10	ARE&RTE	0.09	ARE&RTE	0.08	ARE&RTE	0.07
SKT	0.08	SKT	0.09	SKT	0.08	SKT	0.09
TMS	0.01	TMS	0.02	TMS	0.02	TMS	0.01

3.3.2 Model Formulation

The model applies Fuzzy AHP that measures an LSP's performance along with linear programming. In fact, the obtained rates Qi from the fuzzy AHP will be used as coefficients for the objective function of the proposed LP model. The solution obtained from the maximum total additive utility of the LP model provides the optimal allocation plan.

Maximize: $\sum_{i=1}^{n} \mathrm{Q}\, i \ * \mathrm{U}pxy$ (1)

Subject to

$\sum \mathrm{U}pxy \ = \ Dxy$ (2)

$for\ each\ \mathrm{p}, \mathrm{U}pxy \ \leq \ Npxy$ (3)

$for\ each\ \mathrm{p}, \mathrm{U}pxy \ \leq \ Rpxy$ (4)

$\sum \mathrm{Lxy} \ \geq \ TLxy$ (5)

Notations and Decision Variables

Qi	=Utility rate of ith LSP,
X	= Loading point,
Y	= Discharge point,
P	= LSP,
Upxy	= Allocated shipments to LSP p from loading point (x) to discharge point (y),
Dxy	= Forecasted demand from loading point (x) to discharge point (y),
C*pxy*	= Cost corresponding to LSP (p) from loading point (x) to discharge point (y), sample Data can be found in Table 9.
R*pxy*	= Maximum allowed number of shipments for LSP (p) from loading point (x) to discharge point (y). Actually, and for risk mitigation reasons, the company doesn't allocate the full capacity agreed on the contract with the LSP, in fear that the LSP may not be able to commit to the full capacity level. R*pxy* is usually 10-20% of full capacity depending on the LSP performance.
N*pxy*	= Maximum capacity of LSP (p) from loading point (x) to discharge point (y), Sample Data can be found in Table 10.
L pxy	= Number of projected on time shipments corresponding to LSP p from loading point (x) to discharge point (y), this is calculated based on delivery history and it is equal to the mean of on time shipments.
TL*xy*	= Target number of on time shipments from loading point (x) to discharge point (y),

(1) represents the **Objective Function**: the objective function maximizes performance, by allocating more shipments to the highly rated LSP's.

(2) represents the **Demand Constraint**: ensures that the sum of allocated shipments to all LSP's from loading point (x) to discharge point (y) is equal the forecasted demand from loading point (x) to discharge point (y)

(3) represents the **capacity constraint**: it implies that the allocated shipments to LSP (p) should be less than or equal to its maximum capacity,

(4) represents **Risk Mitigation**: requires the allocated units (number of trucks) of LSP (p) from loading point (x) to discharge point (y) to be less than or equal to the maximum number of trips R*pxy* allowed for LSP.

(5) represents the **on-time delivery performance constraint:** implies that the number of projected on time shipments from loading point (x) to discharge point (y) should be more than or equal to the target number of on time units from allocated unit (U).

Table 9: LSP's capacity

Capacity	299	113	334	55
LSP	FNS	GMS	BTT	ARS

Table 10: Average number of trips from Dammam to each

Destination	Avg. Trips
Riyadh	1320
Jeddah	920
Dammam	430
Jubail	270
Qassim	180
Hafof	130
Haradh	140
Kharj	300
Rabigh	210

4. Results and Conclusions

In this research paper, the analytical hierarchy process AHP is used to rate each of the 16^{th} logistics service provider in the local Saudi Market. According to the results obtained by the AHP method, the most important criteria are cost and safety with scores equal to 3.31 each. LSPs were then rated according to criteria, and the overall score or rate of each LSP was calculated. That rating was then used as coefficient in the objective function of an integer programming model, that assigns the optimal number of trips to LSP's. After formulation, the model has been run using Excel Solver and results were compared with the company historical data of year 2017. Compared to 2017, when the total cost was 5,783,084 SR (around $1.542 Million), the use of the decision support tool minimized the cost to SR4,883,163($1.302 Million). Thus, the saved cost is 899,921 SR ($239,978), which is around 15%.

In conclusion, the development of the Decision Support System DSS achieved the following:

- Facilitate the assignment process and make it automated, which will help save time and avoid errors in the future. Other than time, the DSS shows significant improvements in the LSP assignments like cost decrease.
- The DSS offers flexibility to the decision maker to change criteria weights and LSP scores whenever it is necessary like the addition of a new LSP or a change in the LSP's performance.
- The DSS will serve as an evaluation tool of the LSP's and will help the decision makers to continuously evaluate the LSP's performance which will help the company better negotiate future contracts.
- This DSS will be a good starting point to streamline the company global logistics and adopt it in other markets where the company is operating.

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Appendix

Table A: FAHP Scale

<table>
<tr><th>AHP Scale</th><th>Definition</th><th>Fuzzy triangle scale</th></tr>
<tr><td>1</td><td>Equally Important</td><td>(1,1,1)</td></tr>
<tr><td>3</td><td>Weakly Important</td><td>(2,3,4)</td></tr>
<tr><td>5</td><td>Fairly Important</td><td>(4,5,6)</td></tr>
<tr><td>7</td><td>Strongly Important</td><td>(6,7,8)</td></tr>
<tr><td>9</td><td>Absolutely Important</td><td>(6,7,8)</td></tr>
<tr><td>2</td><td rowspan="4">Intermittent values between the tables</td><td>(1,2,3)</td></tr>
<tr><td>4</td><td>(3,4,5)</td></tr>
<tr><td>6</td><td>(5,6,7)</td></tr>
<tr><td>8</td><td>(9,9,9)</td></tr>
<tr><td colspan="2">For inverse comparison</td><td>Reciprocals of the above numbers</td></tr>
</table>

Biographies:

Sobhi Mejjaouli is currently an Assistant Professor in the Industrial Engineering Department at Alfaisal University, Riyadh. Dr. Mejjaouli had a Bachelor and a Master Degree in Industrial Engineering from the National School of Engineers of Tunis in Tunisia before working for Johnson Controls as a Manufacturing Quality Engineer. After that, he joined University of Arkansas at Little Rock, USA, where he got his PhD in Systems Engineering while teaching and conducting Research. Dr. Mejjaouli's work was published in venues such as Journal of Manufacturing Systems, well-known IEEE and ISERC conference proceedings, as well as in book chapter format in the Springer Book Series: Studies in Computational Intelligence. His major research areas are: Supply Chain Engineering and Management, Manufacturing, Transportation Systems, and Applications of RFID and Sensor Networks.

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