Investigation of Stakeholders' View towards the introduction of ICT in Supply Chain using Analytic Hierarchy Process

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***Abstract*—Transportation of goods implies the management of complicated processes that affect many different users. Key stakeholders in freight transportation usually regard shippers, freight forwarders and receivers whereas local communities are also indirectly affected. The involvement of multiple actors leads to challenging decision-making processes due to the participation and involvement of several players with conflicting interests. The objective of this paper is to investigate shippers and receivers point of view on the introduction of ICT in supply chain for enhanced information provision, through Analytic Hierarchy Process method. This Multi-Criteria Analysis method allows clear prioritization of evaluation criteria for each stakeholder group and determines which stakeholder group takes advantage of the potential implementation of this concept. The result of this paper is to identify which quality criteria are more important for each stakeholder and the stakeholder group that takes benefit from this initiative.**

***Index Terms*—ICT, decision-making, key stakeholders, logistics, multi-criteria analysis**

I. Introduction

Cooperation between actors in supply chain is a key dimension of its operational performance. However, the involvement of different actors within such complicated context sometimes results in conflicting interests driven by the market competition. As such, decision-making is much more challenging. The interaction between stakeholders generates the need to devise ways to promote 'trading-off' of actors' interests aiming at win-win strategies without sacrificing the attainment of general objectives such as high level of service, environmental concerns, cost efficient operations, etc.

One of the salient instruments used in supply chains in order to achieve the above objectives are Information and Communication Technologies (ICT). In general, the use of ICT is getting wider in order to facilitate a range of people's needs. Households, businesses and administration take advantage of the ICT capacity to enhance efficiency whereas saving time and money. In particular, the relationship between ICT and transport has been growing since the 1970's [1].

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The aim of this paper is to present a multi-criteria analysis using Analytic Hierarchy Process (AHP) evaluating the key stakeholders' view regarding the use of ICT (like monitoring systems, transport mode tracking platforms, etc.) that offer enhanced supply chain visibility. In fact, AHP underpins this type of decision-making indicating which aspect is important to each stakeholder and which one of them could benefit most by the implementation of new-coming concepts.

First, the methodology of the data mining survey is described together with the evaluation tools that are used in this paper. Secondly, the scenarios are outlined including their objectives, involved stakeholders and criteria together with the alternatives proposed. Finally, the evaluation of their perspective is analyzed through AHP method and priorities to each criterion and alternative are assigned. A short discussion of the results then follows with views for potential use of the outcomes.

II. Methodological Approach

A. Methodological Approach of the Survey

The aforementioned survey is conducted within the context of STRAIGHTSOL project. STRAIGHTSOL (www.straightsol.eu) is a three-year EC co-funded project under the 7^{th} Framework Programme, which aims at proposing an array of urban logistics solutions for more efficient urban freight distribution. STRAIGHTSOL's objectives are attained through the implementation of a stakeholder-targeted impact assessment framework on urban-interurban logistics concepts that are fostered by establishing respective field demonstrations. The survey is part of a demonstration that foresees the use of monitoring systems in international rail freight transportation in order to strengthen information sharing and improve warehouse management and last-mile distribution. The demonstration was organized and run by Kuehne+Nagel (K+N).

In order to capture the views of stakeholders, personal interviews were conducted with experts of each stakeholders group in autumn-winter 2012. The questionnaire surveys that have taken place were addressed to key players of K+N's clientele, such as shippers and a receiver. The interviewees' location bases are within the wider area of Thessaloniki (Greece)

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agglomeration. The method followed in the survey was 'revealed and stated preferences' [2].

The salient aim of the survey was to evaluate the point of view of involved stakeholders towards the use of ICT and the criteria that they consider as over-arching when appraising such policies.

The specific shippers and receivers were selected pursuing certain criteria such as:

- Involving both types of shippers: large and smaller ones
- Focusing on companies that handle foods and beverages where delays are a substantial issue
- Mixed geographical coverage of activities
- Key actors that cooperate closely with K+N

The statistical analysis of the survey was conducted using the 'descriptive' method of statistical data analysis.

B. *Evaluation Tools and Methods*

Decision-making in supply chain should not undermine the cordial cooperation between actors. In the operational research there are plenty of tools that support balanced strategic planning and decision-making.

Multicriteria-analysis (MCA) is a decision-making method that is intertwined with operations research and its main objective is to perform comparisons between a number of alternatives in terms of specific criteria [3]. The general methodological steps that are pursued when using multi-criteria analysis method are:

- a) model structuring and objective(s) definition,
- b) determining of the alternatives that each one of them meets the objectives of the problem,
- c) conception of the criteria in terms of which the evaluation of each one of the alternatives will take place, d) building of the evaluation matrix and finally
- e) evaluation of the alternatives through the criteria shaped.

The criteria reflect the dimensions of a decision-making problem that is governed by the number of objectives. The fact that multiple criteria of multiple stakeholders are used seems very useful especially within the context of ICT applications, where multiple stakeholders, conflicting interests and criteria represent the common nature of such problems [4].

Global bibliography contains almost 40 approaches of multi-criteria decision-making methods, some of them more complex whereas other are identified as simple prioritization methods [3], [5].

The techniques offer the capability of including the evaluation of both qualitative and quantitative indicators in the same model and the structuring of criteria that their difference is not so clear facilitating the complicating decision-making process.

One of the most used methods of multi-criteria analysis is Analytic Hierarch Process (AHP). The AHP is a multi-criteria decision making method. It was conceived by Saaty and it is considered as one of the most practical methods of Multi-Criteria Decision-Making [6], [7]. The method has been widely used in site selection [8], strategy selection [9], [10], in sustainability evaluation [11], energy selection [12] and many others.

One of the advantages of AHP is that it allows a hierarchical structure of the criteria. This provides better view on objectives, alternatives, criteria and sub-criteria and wiser allocation of weights. The structure issue is of utmost importance as different types of structure may lead to a different final ranking. As an example, many authors argue that criteria with a large number of sub-criteria tend to receive more weight than the rest ones that are less detailed [13], [14].

In a simple multi-criteria decision making problem all the above elements of the matrix are expressed in the same unit (e.g. euros). Sometimes, though, in a more complex problem some criteria may be expressed in different units reflecting time, environmental indices, qualitative indicators on political criteria, etc. However, AHP facilitates decision-making problems through the quantification and normalization of values.

The structure of a typical decision problem regards a number of i.e. M alternatives and N criteria. The pair-wise comparison matrices consist of MxN elements. The performance value of the i-th alternative in terms of the j criterion is denoted with a_{ij}. Wj denotes the weight of criterion C j. As such, the decision matrix below represents a typical multi-criteria decision making problem:

$$A = \begin{array}{c} \begin{array}{ccc} C_1 & \cdots & C_N \end{array} \\ \begin{bmatrix} a_{11} & \cdots & a_{1N} \\ \vdots & \ddots & \vdots \\ a_{M1} & \cdots & a_{MN} \end{bmatrix} \end{array} \quad \text{for i=1 to M and j=1 to N}$$

The core of the problem is to decide which alternative of M ones is the best to opt for in order to fully meet the problem's objectives. A slightly similar approach of the problem is to determine the relative significance of each of the alternatives comparing them each other in combination with N criteria [15].

Due to the fact that for the decision maker it is not always feasible to assign absolute values to certain qualitative indicators, the determination of relative importance of the alternatives in terms of certain criteria facilitates decision making. This is exactly the role of pair-wise comparison; to determine the relative importance of each alternative in terms of each criterion. Practically the statements that reflect the choices in the pair-wise comparison are "A is more important than B" or "A is of the same importance as B" or "A is less important than B" [15].

In this regard, AHP would run more smoothly using ratio scales. This type of scale represents a set of discrete choices available to the decision maker and a set of discrete numbers representing the choices that express the relative importance of one choice upon the other in terms of criterion studied. Verbal statements as the "A is of the same importance as B" are 'converted' into integers. This scale is proposed by Saaty [16]. According to Saaty the numbers that are used in pair-wise comparisons and form the scale are: {9,7,5,3,1,1/3,1/5,1/7,1/9}. Also, even numbers could be used together with the odd ones expressing an intermediate evaluation. The used structure of scales and the numbers that was generated based on psychological theories [15].

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1N} \\ \vdots & \ddots & \vdots \\ a_{M1} & \cdots & a_{MN} \end{bmatrix} \quad \text{for i=1 to M and j=1 to N}$$

The preliminary priorities of the alternatives are calculated with the use of the geometric mean of the rows:

$$P_i = \sqrt[N]{\prod_{j=1}^{N} a_{ij}} \qquad (1)$$

After the calculation of each priority P_i, i=1 to M, normalization is achieved through dividing priorities with their sum.

$$p_i = P_i / \sum P \qquad (2)$$

The final priorities vector for each comparing option is then produced, $\vec{p} = (p_1, p_2, \ldots, p_N)$.

The next step is the estimation of the consistency level of statements, namely a consistency test of the outcomes of pair-wise comparisons. AHP methodology could allow for slightly non-consistent pair-wise comparisons. In Ref. [7] Saaty suggested a Consistency Index (CI) which is estimated by adding the columns in the pair-wise matrix (judgment matrix) and multiply the resulting vector with the vector of priorities $\vec{p}$. The value which is yielded is the λ_{max}. The CI is calculated by the formula [15] :

$$CI = (\lambda_{max} - N)/(N - 1) \qquad (3)$$

where N is the dimension of the matrix.

Finally, the Consistency Ration is estimated through:

$$CR = CI/RCI \qquad (4)$$

RCI is the Random Consistency Index, which represents that average CI of 500 randomly filled matrices. Saaty calculated the RCIs according to the dimension of the pair-wise comparison matrix [7].

TABLE I. RCI VALUES FOR DIFFERENT VALUES OF INDICATOR N

N	1	2	3	4	5	6	7	8
RCI	0	0	0.58	0.9	1.12	1.24	1.32	1.41

In the light of synthesis, if a problem consists of M alternatives and N criteria, then there should be N judgment matrices (one for each criterion) of MxM elements and one M judgment matrices (one for each alternative) of NxN criteria. In this respect, the final priorities of the alternatives evaluated in terms of the investigated criteria are determined through the following formula [15]:

$$A_{AHP}^{i} = \sum_{j=1}^{N} a_{ij} w_j \quad (5) \qquad i=1,2,3\ldots,M$$

III. SCENARIOS

The alternative scenarios that are tested are the following:

- Do nothing
- Do something

The 'Do nothing' scenario regards the use of the existing monitoring mechanisms for this specific transport system. In the international rail freight itinerary that is tested within STRAIGHTSOL demonstration, such mechanisms regard manual recording of cargo location and information via phone to the interested stakeholders. As such, information provision to interested stakeholders flows according to the availability of involved staff. Information sharing is not automated and seems more complex as each stakeholder is facing delays while trying to retrieve updates.

The 'Do something' scenario fits better the concept of enhanced visibility of supply chain as automated monitoring systems that enable cargo (wagon) tracking along the international rail trip offer opportunities for up-to-date information provision. In particular, K+N uses GPS systems with devices affixed on train wagons, emitting signal to the destination (K+N warehouse/freight center) stimulating efficient and timely preparation of next transport leg and organization of warehousing. In parallel, the information is provided to shippers, receivers and rest stakeholders acknowledging them of any delays or new ETA (estimated time of arrival) of goods. Then, each actor is responsible for further actions that address to customers, to suppliers of raw materials, etc.

IV. STAKEHOLDERS

The 'stakeholders' concept was firstly introduced by Williamson in the field of 'strategic management' [17]. In Ref. [18] Freeman refers to 'a stakeholder' as an individual or group of individuals that can affect or be affected by the attainment of the organization's objectives. Another point of view is defined in Ref. [19] by Grimble & Wellard who argue that stakeholders are deemed as an organized group of people who share common interests under a certain issue or a wider system.

Stakeholders in supply chain usually constitute of shippers, logistics service providers (or freight forwarders), receivers of goods, and sometimes local authorities and citizens that are indirectly or directly affected. The role of each stakeholder is outlined in the following table [20]:

TABLE II. OVERVIEW OF STAKEHOLDER GROUPS AND THEIR ROLES

Stakeholder category	**Role in urban freight transport**
Shipper	Gives order to send the goods
Logistic Service Provider	Assures and supports the transportation service
Receiver	Receives the goods
Citizen	Lives and consumes in the city
Local Authority	Regulation and infrastructure provider

Although all actors practically interact in the supply chain context, there are not all of them who actually take decisions and deploy strategies. These are primarily the logistics service providers and secondarily the shippers. Besides this, shippers and receivers are the stakeholder groups who directly interact with the transport operator (logistics service provider). Consequently, costs that stem from logistics service provider's operations are borne by them, likewise any monetary benefits.

The receiver commences a supply chain by ordering something from his supplier (who is usually also the shipper of the goods).

Shippers on the other side send the goods ordered by the receiver and serve as the customer of the logistic service provider. The shipper can be the producer of the goods or a wholesaler [20].

The shippers that participated in this survey comprise two private companies, one small that commercializes automobile spare parts and a bigger one that supplies food products for supermarkets. The receiver is a supermarket company that receives foodstuff and beverages by suppliers and producers.

V. CASE-STUDY

The problem in this case regards the introduction of systems that enhance supply chain visibility as for the transportation of goods in interurban and urban areas. The information system is managed by the freight forwarder, which is the logistics service provider and mostly affects shippers and receivers cooperating with the logistics service provider. Information provided by the monitoring systems is filtered and channeled to interested customers (shippers or receivers). This service is firstly investigated as free of charge. An alternative for future research could entail the charge of this service.

A. Shippers

The important issue for this case was to investigate whether direct stakeholders such as shippers and receivers are willing to uptake such services. However, each shipper may use different criteria to evaluate the feasibility of business models. The evaluation criteria which were determined for shippers are: costs, environment, level of service, company image, safety and security and supply chain visibility. The matrix below reflects the opinion of shipper #1:

TABLE III. PAIR-WISE COMPARISON OF CRITERIA FOR SHIPPER #1

CRITERIA	TC	LOS	CI	EI	S	SCV
Total costs (TC)	1	3	3	5	1/9	3
Level of service (LOS)	1/3	1	1/5	5	1/9	3
Company image (CI)	1/3	5	1	5	1/9	3
Environmental impacts (EI)	1/5	1/5	1/5	1	1/9	1/5
Safety (S)	9	9	9	9	1	9
Supply chain visibility (SCV)	1/3	1/3	1/3	5	1/9	1

Shipper #2 stated his own preference in the following matrix (Table IV).

Merging the two matrices is a simple process, which is achieved by multiplying each element of one matrix with the same element (aij) of the other matrix and calculates the n^{th} root of the product, where n is the number of matrices/decision-makers [21]:

TABLE IV. PAIR-WISE COMPARISON OF CRITERIA FOR SHIPPER #2

CRITERIA	TC	LOS	CI	EI	S	SCV
Total costs (TC)	1	7	5	5	7	5
Level of service (LOS)	1/7	1	3	5	5	3
Company image (CI)	1/5	1/3	1	3	3	1/3
Environmental impacts (EI)	1/5	1/5	1/3	1	1	1/3
Safety (S)	1/7	1/5	1/3	1	1	1
Supply chain visibility (SCV)	1/5	3	3	3	1	1

TABLE V. GROUPING OF PAIR-WISE COMPARISONS OF INDIVIDUAL SHIPPERS (FINAL JUDGMENT MATRIX)

CRITERIA	TC	LOS	CI	EI	S	SCV
Total costs (TC)	1	4.58	3.87	5.00	0.88	3.87
Level of service (LOS)	0.22	1	0.77	5	0.74	3
Company image (CI)	0.26	1.29	1	3.87	0.58	0.99
Environmental impacts (EI)	0.2	0.2	0.26	1	0.33	0.26
Safety (S)	1.13	1.34	1.73	3	1	3
Supply chain visibility (SCV)	0.26	0.99	0.99	3.87	0.33	1

The priority vector for the matrix above, calculated through formulas (1) and (2):

TABLE VI. PRIORITIES MATRIX FOR THE DECISION-CRITERIA

CRITERIA	PRIORITIES (WEIGHTS)
Total costs	0.345
Level of service	0.148
Company image	0.127
Environmental impacts	0.041
Safety	0.226
Supply chain visibility	0.111

In order to test the consistency level, the Consistency Index is estimated through the formula (3). The indicator λmax is estimated as follows: the sum of each column elements from the final judgment matrix is multiplied to the weight of each criterion and then the components are aggregated, according to the formula:

$$\lambda_{max} = \sum \sum_{i=1}^{n} a_{ij} * P_i \tag{6}$$

As such, λmax = 6.678 and CI = 0.136.

The Random Index, according to Table I, supposing that n=6 is RI=1.24. Finally, the consistency ratio (CR) is estimated with formula (4). Consequently, CR = 0.109. CR should be below 0.1 and under no circumstances more than 0.3[15], [20].

The next step is to compare the alternatives with each other in terms of each evaluation criterion. This step will show how relatively preferable is each alternative compared to the other. Practically, the 'do-nothing' scenario is compared to 'do-something' scenario. After merging the judgment matrices of each decision-maker the final matrices and priority vectors become:

TABLES VII, VIII, IX, X, XI, XII. PAIR-WISE COMPARISON MATRICES OF THE ALTERNATIVES IN TERMS OF EACH CRITERION (SHIPPERS)

Total costs	With GPS	Without GPS	Weights
With GPS	1	5.916	0.855
Without GPS	0.168	1	0.145

Level of service	With GPS	Without GPS	Weights
With GPS	1	4.582	0.821
Without GPS	0.217	1	0.179

Company image	With GPS	Without GPS	Weights
With GPS	1	1.732	0.634
Without GPS	0.577	1	0.366

Environmental impacts	With GPS	Without GPS	Weights
With GPS	1	3	0.75
Without GPS	0.333	1	0.25

Safety	With GPS	Without GPS	Weights
With GPS	1	6.708	0.87
Without GPS	0.149	1	0.13

Supply chain visibility	With GPS	Without GPS	Weights
With GPS	1	4.582	0.821
Without GPS	0.217	1	0.179

CI=0 and RI(n=2)=0 and this stands for all the matrices above.

As it was aforementioned, the priorities of the tables above are used to form the elements of the decision matrix. The final decision matrix and the final priorities (which are calculated according to formula (5) are:

TABLE XIII. FINAL DECISION MATRIX (SHIPPER)

	TC	LOS	CI	EI	S	SCV	Final priorities
Criteria weights	0.346	0.148	0.127	0.041	0.226	0.111	
With GPS	0.855	0.821	0.634	0.75	0.870	0.821	0.817
Without GPS	0.145	0.179	0.366	0.25	0.130	0.179	0.183

Therefore, shippers' opinion is that the adoption of GPS systems for enhanced visibility is much more preferable than the do-nothing scenario that entails the use of the existing systems for information provision. According to the table above, the monitoring service might contribute mostly in cost savings and upgrade safety and security level of personnel and goods.

Interpreting the pair-wise comparison matrix of shippers, they both think that the less important field is the environmental impacts. This argument corresponds to the local tough economic environment and the fact that cost mitigation stills remain the principal priority for entrepreneurs. It should also be denoted that the criterion 'company image' is considered as of medium relevant importance. This could be explained by the fact that 'level of service' and 'company image' represent two different criteria. In fact, 'level of service' includes time accuracy and punctuality whereas 'company image' reflects company's market and society uptake, which is mostly intertwined with the company's performance.

B. Receiver

Receivers are also directly involved as they could be impacted by the enhanced supply chain visibility in terms of time punctuality of deliveries and improved information provision. As such, better stock management, customer information and higher satisfaction and cost savings are achieved aiming at offering better potential in three sectors: costs (expenses), level of service and visibility of supply. These are the criteria that were used for the decision-making process. A key stakeholder was requested to prioritize the criteria used for receiver's evaluation in AHP. The pair-wise comparison matrix is the following:

TABLE XIV. JUDGMENT MATRIX OF RECEIVER'S PAIR-WISE COMPARISON

CRITERIA	Total costs	Level of service	Supply chain visibility
Total costs	1	5	3
Level of service	1/5	1	1
Supply chain visibility	1/3	1	1

Then, processing with the aforementioned methodology the priorities' vector is derived presenting the weights of each criterion according to judgment matrix.

TABLE XV. PRIORITY VECTOR OF CRITERIA

CRITERIA	PRIORITIES (WEIGHTS)
Total costs	0.659
Level of service	0.156
Supply chain visibility	0.185

The next step is to exact the Consistency Index and Consistency Ratio. In order to estimate these indicators λmax should be calculated. The values for λmax, CI and CR are: $\lambda max = 3.029$, CI = 0.014, CR = 0.025.

The indicator RI, for n=3, has been RI=0.58 (Table I). As there is only one decision-maker and the number of criteria and alternatives is small, the value of the indicator CR is reasonably low.

The next step is the comparison of the alternatives in terms of each criterion. This step reflects the actual impact of each alternative in the field of each criterion, according to decision-maker's opinion.

TABLES XVI, XVII, XVIII. PAIR-WISE COMPARISON MATRICES OF THE ALTERNATIVES IN TERMS OF EACH CRITERION (RECEIVER)

Total costs	With GPS	Without GPS	Weights
With GPS	1	3	0.75
Without GPS	1/3	1	0.25

Level of service	With GPS	Without GPS	Weights
With GPS	1	5	0.83
Without GPS	1/5	1	0.17

Supply chain visibility	With GPS	Without GPS	Weights
With GPS	1	3	0.75
Without GPS	1/3	1	0.25

For all the above matrices, CI=0 and RI (n=2) =0.

The priorities of the Tables XV, XVI and XVII are used to form the elements of the decision matrix. The final decision matrix and the resulted final priorities (which are calculated according to formula (5) are:

TABLE XIX. FINAL DECISION MATRIX

Criteria	Total costs	Level of service	Supply chain visibility	Final priorities
Alternatives	0.659	0.156	0.185	
With GPS	0.750	0.833	0.750	0.763
Without GPS	0.250	0.167	0.250	0.237

The above table could express that the receiver believes that the introduction of GPS monitoring could have greater impacts in the 'level of service' field. However, the adoption of GPS system could probably facilitate cost mitigation and enhancing supply chain visibility. In general, it is evident that the 'total costs' criterion is by far the most important one. The rest two score almost equal weight values. The receiver considers that ICT usage would mainly raise the level of service in conjunction with cost reduction and enhanced visibility of supply chain.

VI. DISCUSSION

AHP serves as a valuable tool to facilitate decision-making process especially under complex circumstances where several actors represent conflicting interests. By stating their opinions, the stakeholders empower strategic decision taking clarifying their needs by the assignment of weights to certain criteria.

In the survey, the stakeholder groups that participated were shippers and receivers. With respect to transportation and logistics, shippers and receivers are among the key players and sometimes they participate actively in the decision-making process of the logistics operations that is mostly a freight forwarder's task. Shippers stated that costs and safety are the two most important criteria, whereas the environment is not treated as a vital one, probably due to the emerging global focus on cost-effectiveness. It is also expected that shippers would support the introduction of enhanced supply chain visibility through GPS especially as a new asset to improve level of service, cost reduction and to monitor safety and security levels of their personnel and goods.

Another point that should be stressed out is that although both shippers and receivers consider that the introduction of GPS may contribute in upgrading the level of service, shippers seem to be more keen on its introduction because probably of their more active participation in the supply chain. Nevertheless, receivers also believe that supply chain visibility is a key added-value that could help their activities too (inventory management, communication with customers, up-to-date information provision, etc.). The outcomes produced by AHP also prove that the use of ICT for enhanced supply chain visibility could benefit mainly shippers and also be beneficial for receivers.

An alternative research direction could include the economic assessment of the benefits and costs that incurred to each stakeholder while identifying the amount of money that each actor could pay in order to take advantage of enhanced information provision and generally the value that this service should be charged. Practically, this would be a willingness-to-pay study that could foster efficient budget allocation for the investment and ensure that the one who pays for the investment, enjoys the benefits derived from this.

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