Testing a New Methodology to Assess Urban Freight Systems through the Analytic Hierarchy Process

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Abstract- Decision-making models often deal with problems that involve multiple criteria analysis in order to assess alternatives in various decision-making settings. On the basis of a systematic process, the Analytic Hierarchy Process (AHP) has recently been recognized as a proven decision-making tool in a wide variety of fields. However, new methods to cope with evolving or scaled problems are emerging in the search of enhanced flexibility and accuracy. Under an AHP perspective, in this article a methodology to experimentally assess urban freight systems is proposed and tested. This approach is applied to validate an existing methodology, the Urban Freight Transport Index (UFTI), as a potential evaluation alternative. The statistic used to perform the testing procedure was the Pearson's correlation. Results indicating a good linearity between AHP and UFTI methodologies, suggesting that mathematical errors may reflect an accepted subjective situation, but that this is not due to the tested method itself. Therefore, it is concluded that the methodology used to design the Urban Freight Transport Index offers new assessing possibilities that might be extrapolated to multicriteria dynamic problems, as a way to produce useful general indexes in distinct disciplines.

Keywords- Decision-making; Analytic Hierarchy Process; Urban Freight Transport Index

I. INTRODUCTION

Decision makers often deal with problems that involve multi-criteria decision analysis. Available general-purpose methods have been accepted due to their simplicity and because they are used in a wide variety of situations (Liberatore and Nydick, 1997). In addition, the use of these methods has grown rapidly because of the development of more user-friendly computational tools, involving larger sets of variables.

In this context, new decision-making tools are also emerging to cope with dynamic problems. In that sense, the Urban Freight Transport Index (UFTI) version 1.0 (Betanzo, 2007; Betanzo and Romero, 2010) relies on a methodology composed of scales and corrective measures, producing a final quantitative value (an index). This new methodology is not expressed in terms of do or do not do something, but in terms of what to do and when to do it. Results from a preliminary application of such an index in the context of urban freight suggest that the embedded methodological frameworks could be used to assess other dynamic problems.

The purpose of this investigation is to test a single measure (UFTI) under the terms of the Analytic Hierarchy Process (AHP), establishing the methodological correlation of the urban freight transport index in the light of the AHP method. That comparison is made on the basis of the Pearson's correlation coefficient, which is expected to provide the degree of relationship between both methodological environments. The main motivation for carrying out this study was to find a direct method to validate the UFTI methodology, to identify its weaknesses and strengthens in the light of a well-known and proven method, so that new potential research applications could be explored for that index.

Most of the data presented herein were obtained from an investigation carried out in the Querétaro Metropolitan Area (QMA), in México, where UFTI was created and used (Betanzo, 2007). Betanzo et al., (2008; 2010; 2012) have reported both the approach and results for UFTI, therefore, the present paper analyzes UFTI in the light of the AHP method.

This paper is organized as shown in Fig. 1, considering descriptions of background information in the context of AHP and UFTI. In the introduction section some fundamental features of decision-making models are described, together with a brief review of the AHP experiences as reported in the scientific literature, including
some discussions on transportation case studies. The methodological section of the paper describes the Urban Freight Transport Index (UFTI), and its conversion into the AHP environment. That section also presents the analytical tools used to achieve the statistical comparison. The final step of the process consists of carrying out the comparative examination of the data collected from the case at hand.

II. REVIEW OF THE LITERATURE

A. Decision Making Models

A brief comparative analysis of multi-criteria methods and systems is reported by Liberatore and Nydick (1997). The authors describe the methods and techniques that have been developed for the systematic evaluation of alternatives in various decision-making settings. According to the authors, the main assessing methods are the goal programming (GP) (Lee, 1972), the Multi-Attribute Utility Theory (MAUT) or scoring models (Keeney and Raiffa, 1976), and the analytic hierarchy process (AHP) (Saaty, 1977, 1980, 1982) (see Appendix I), with the later being applied since its early development, in a wide variety of decision making areas, where business or social concerns are involved. In this regard, some of the major applications of the AHP in operations management have been discussed by Partovi et al. (1990). In the case of small businesses, Armacost et al. (1999) illustrated one AHP application involving the evaluation of alternative products used by consumers, and the subsequent managerial implications, further suggesting the ways in which AHP approach could be used in many small-business applications as an implementation tool and guidance. Sun Hongcai (2003) reviewed applications of the AHP in China, especially for those matters concerning social, economic or technological decision-making problems. In education, Bahurmoz (2003) designed and implemented an AHP based multi-criteria group-decision making model aiming to recruit the best students to send them overseas for graduate studies so that they can eventually become teachers.

For modern organizations seeking to increase their global competitiveness, Albayrak and Erensal (2004) presented an AHP model illustrating the relationships between the human performance improvements and the style of management, further assessing the performance of the projects through the use of efficiency- or effectiveness-related measures. Hsu and Lin (2006) carried out a review of the applicability and ease of use of the AHP method, providing evidence not only that the integrated AHPs are better than the standalone ones, but also that such methods assist researchers and decision makers in applying the integrated AHPs effectively. In the light of recent experiences in the field of AHP, Timor and Tüzün (2006) demonstrated that such method gives decision makers an opportunity to move forward when facing complex decision making problems, especially when subjectivity is an issue.

AHP applications related to transportation systems have been performed. In the freight transport arena, Bagchi (1989) described a problem involving the rational selection of a carrier from among a large poll, in which all the criteria variables were not easily quantified. He demonstrated that the ranking models do not work well in general, further showing that the use of the AHP in carrier selection can provide the ranking of the alternative choices. Hsu (1999) uses a generalized means function to create a fuzzy Delphi scheme that conveys the aggregating fuzzy opinions of the expert group, considering the geometric mean to combine the fuzzy Delphi approach with a group decision model that the author calls Fuzzy Delphi Analytic Hierarchy Process (FDAHP).

Yeh et al. (2000) considers the operational integration of the mass rapid transit system (MRT) and the bus system in Kaohsiung, Taiwan, as an empirical case study of the use of an effective fuzzy multicriteria analysis (MA) approach to assess urban public transport systems involving multiple criteria of multilevel hierarchies, and subjective assessments of decision alternatives. Hsu, et al. (2006) analyzed the use of the membership grade of “possibility” and “significance” to conform an analysis matrix of travel risks, which can describe consumers’ differing cognitions regarding perceived-risk attributes. Changbing (2009) used the Data Envelopment Analysis (DEA) technique to evaluate the Transportation System Efficiency (TSE) in 31 major regions in China. For the planning of transport infrastructure, Duthie et al. (2010) evaluated the way that roadway investment decisions depend on whether uncertainty is recognized or not, finding that the ranking of improvement projects could indeed be different if uncertainty is considered, in comparison to treating all parameters and data as deterministic. Oswald and McNeil (2010) developed a methodology for rating systems in the context of transportation investments, specifically urban corridors, in which the multiple criteria evaluation approach is often used.

Islam and Saaty (2010) reported three case studies of implementation of AHP schemes in the transportation sector: (i) A governmental agency with jurisdiction over a certain area that must decide whether or not build a bridge over-, or a tunnel under- a river, whose pass was served at that time by a privately owned ferry; (ii) the use of the method of anticipatory scenario construction for planning alternative strategies for the future of the Sudan’s transport system; and (iii) The use of the dependence with a feedback system in deciding to buy a car made by an American, European, or Japanese company, on the basis of three criteria: cost, repair, and durability. Talbert et al. (1994) considered an AHP perspective to weigh indicators evaluating complex system designs involving software, hardware, and the human factor. In this case, as such a comprehensive design can easily include hundreds of quality system indicators, evaluators need a technique to ensure the identification and emphasis of salient indicators in determining design’s quality.

As it can be seen, AHP is a method that has been applied to deal with problems in diverse areas, matching judgments of intangible qualitative criteria with tangible quantitative criteria. Given the experiences reported in the literature, it was determined in this study that a comparative test using the UFTI methodology could be feasible, as discussed in the next section.
B. The Analytic Hierarchy Process (AHP)

The AHP was initially developed by Saaty (1980), with the objective of determining the relative importance of a set of alternatives in a multi-criteria decision problem. AHP is classed as a multicriteria decision making approach, in which “certain judgment factors are arranged in a hierarchic structure” (Saaty, 1990, as quoted by Talbert et al. 1994). According to this approach, judgment factors were used to evaluate sets of alternatives, which were ranked with the aid of judgment matrices designed by decision making analysts (Sun, 2003). There are three principal steps in the AHP: design of the hierarchy, a prioritization procedure, and the calculation of the results.

Taking into account that UFTI is currently in an experimental state, a widespread-use tool such as AHP was chosen to perform the comparative testing aiming to reduce uncertainty, instead of initially working with other related methods. Given that UFTI is characterized as having a linear hierarchy and two scales of measurement, the authors were compelled to use a basic AHP version as a good primary choice to perform comparative testing, as AHP has the same functional structure of any general decision models. In that sense, it is assumed in this research that UFTI has the flexibility to be consistent with decision-making models, in this case, with the AHP. Furthermore, UFTI does not need to relate variables between different nodes, as it is the case, for instance, when using AHP Fuzzy

III. METHODOLOGY

A. Methodological Structure of the Urban Freight Transport Index

A brief description of the basics of UFTI method, Version 1, is presented, which was developed with the goal of assessing the performance of urban freight transport systems. UFTI’s hierarchical morphology and its elements are listed in Table 1, representing structural relationship between reagents and indicators, within the context of a certain thematic group that finally will take the form of an index.

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>NUMBER OF ELEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index</td>
<td>1</td>
</tr>
<tr>
<td>n.n.Group</td>
<td>4</td>
</tr>
<tr>
<td>n.n.n.Indicator</td>
<td>34</td>
</tr>
<tr>
<td>n.n.n. Reagents</td>
<td>234</td>
</tr>
</tbody>
</table>

Basic definitions of UFTI method are as follows:

1. An Index formulates the aggregation of groups aiming at assessing the overall performance of the system.

2. A Group represents a collection of indicators pertaining to the same group (for example, political and institutional levels)

3. An Indicator includes sets of reagents.

4. A Reagent is considered as evidence-based signs of implemented actions concerning urban freight transport. In UFTI, a reagent is the most basic component of an indicator. A reagent is going to be translated into a quantitative value assessing groups, until reaching the Index level.

The main features of the UFTI generic methodology consist of:

- A five-level scale that identifies the severity of a given problem that is being studied.
- A five-stage scale of common measures undertaken to alleviate such a problem.
- A set of 34 specialized indicators reflecting the current situation of the system.
- A set of 234 reagents used for an in-depth evaluation.
- An evaluation scale, assigning a weighted value to a number of selected reagents, according to the problem studied.
- A computational tool that is capable of managing data producing outputs in a systematized manner.
- A chart that will be used to benchmark the situation of the evaluated subject with respect to others cases.

The generic methodology that has produced this index can be described as follows:

\[(UFTI) : \text{Urban Freight Transport Index}\]

\[(N) : \text{National policies decision reagent } j \text{ in the stage } s_i (i=1, 2, \ldots, 5)\]

\[(R) : \text{Local or regional policies decision reagent } j \text{ in the stage } s_i (i=1, 2, \ldots, 5)\]

\[(D) : \text{Decision making capabilities } j \text{ in the stage } s_i (i=1, 2, \ldots, 5)\]

\[(P) : \text{Private sector decision reagent } j \text{ in the stage } s_i (i=1, 2, \ldots, 5)\]

At a national policy decision level:

\[N = \sum_{i=1}^{5} \sum_{j=1}^{n} (N) \geq 0\]  \hspace{1cm} (1)

For local or regional policies decision level:

\[R = \sum_{i=1}^{5} \sum_{j=1}^{n} (R) \geq 0\]  \hspace{1cm} (2)

For decision making capabilities level:

\[D = \sum_{i=1}^{5} \sum_{j=1}^{n} (D) \geq 0\]  \hspace{1cm} (3)

For private sector decision level:

\[P = \sum_{i=1}^{5} \sum_{j=1}^{n} (P) \geq 0\]  \hspace{1cm} (4)

The Urban Freight Transport Index (UFTI) can be calculated at reagent or level echelons, using the following Equations (5) and (6).
By reagent:

\[ (UFTI) = \sum_{j=1}^{m_j} \sum_{i=1}^{m_i} \left( N_j \right)_{iz} + \sum_{j=1}^{m_j} \sum_{i=1}^{m_i} \left( R_j \right)_{iz} + \sum_{j=1}^{m_j} \sum_{i=1}^{m_i} \left( D_j \right)_{iz} + \sum_{j=1}^{m_j} \sum_{i=1}^{m_i} \left( P_j \right)_{iz} \]  

(5)

\[ j = 1, 2, \ldots, m_j \]

\[ m_i = m_{i1}, m_{i2}, \ldots, m_{iM} \]

By level:

\[ (UFTI) = \sum_{i=1}^{4} L_i \]

(6)

Where:

\[ L_i : \text{Level } z \ (z=N,R,D,P) \]

The structure of this method allows decision makers to assess the current state of an urban freight system, whether as a whole, or separately by levels \((N, R, D \text{ or } P)\).

The UFTI operation does lie in the implementation of reagents or running surveys. It is noteworthy that during the establishment of the evaluation scale, the research group defined the weight of each reagent. In addition, the research group also agreed on the value assigned to each reagent during the evaluation process for the study at hand.

B. Statistical Tool

A statistical test was utilized as a means to prove the consistency of the UFTI methodology in the light of AHP principles. To assess the relationship between these two methods, it was taken into consideration that results from such methodologies must comply with the condition of a statistical correlation. For this case, correlation is going to refer to a specialized type of relationship between mean values of both UFTI and UFTI when AHP procedures are used. The correlation between these two variables will reflect the way these variables are related in both methodologies.

Pearson’s correlation coefficient can reflect the degree of linear relationship between the two variables analyzed. Such metric could be sensitive to a linear relationship between these two variables, which remains even if one of the variables keeps a nonlinear relationship with the other.

In this respect, it is well known that the Pearson correlation is +1, in the case of a perfect positive, increasing, linear relationship or correlation; −1 in the case of a perfect decreasing, negative, linear relationship, also known as an anticorrelation; and a value between −1 and 1 in all other cases, which measures the degree of linear dependence between the two variables (Halperin, 1986, Wilcox, 2003, Genest and Lévesque, 2009).

- -1.0 to -0.7 strong negative association
- -0.7 to -0.3 weak negative association
- -0.3 to +0.3 little or no association
- +0.3 to +0.7 weak positive association
- +0.7 to +1.0 strong positive association

C. Performing the Comparative Test

Fig. 2 depicts the methodology applied to achieve the comparative methodological test, consisting of the following three steps: (i) adapting UFTI to the AHP methodology; (ii) setting of pairs ranking; and (iii) testing UFTI under AHP method.

Step 1: Adapting UFTI to the AHP methodology

First of all, the UFTI method was converted into the hierarchical structure of the AHP method. The UFTI methodology was tailored according the AHP steps stated by Saaty (1980; 1990). As the AHP methodology suggests, each indicator in UFTI was nested in a corresponding hierarchical level nest. In addition, a set of pair assessment indicators was analyzed, in order to obtain the ratio scale of measurement. An example of this step is illustrated in Table II. UFTI version 1.0 was tested using a well-known commercial software (Expert Choice).

TABLE II EXAMPLE PAIR WISE COMPARISONS.

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Adapting UFTI to the AHP methodology</td>
<td>Development of indicators under AHP structure</td>
</tr>
<tr>
<td>2</td>
<td>Pairs ranking</td>
<td>Weights of each indicator</td>
</tr>
<tr>
<td>3</td>
<td>Testing UFTI under AHP method</td>
<td>Application of UFTI-AHP to a case study</td>
</tr>
</tbody>
</table>

Fig. 2 Steps followed in the comparative test

On the basis of a comparative methodological test, it was assumed that the processing of data according to the AHP method should respect the weight assigned in UFTI environments. In that sense, the conversion was carried out in Step 2.

Step 2: Setting of pairs ranking

The original weights of UFTI version 1.0, ranging from 1 to 5, were rescaled according to AHP methodology, followed by assessing the comparison of pairs, as follows: 1 = equal, 3 = moderate, 5 = strong, 7 = very strong, 9 = extreme. Final computations should reach the “ultimate
goal” that equals to 1, or 100%. Assessment of both indicators and pair of nodes is achieved from the resulting AHP weight for each pair. It is noteworthy that any inconsistency was not higher than 0.05 for any level.

Step 3: Testing UFTI under AHP method

Once the test was done using AHP principles, UFTI model showed variations of the weight of some indicators with respect to the original version. The new weights oscillated from 0.001 to 0.013, while UFTI ranged from 0.00125 to 0.00624.

As a result of having a different weight ranges, the original stages $S_i$ to $S_j$ pertaining to the original UFTI were subject to a new calculation method and a distinct conceptual consideration, meaning that the UFTI method under AHP perspective has been modified to be equivalent. The new UFTI computing, by reagent or level, is shown in Equations (7) and (8).

$$(UFTI) = \sum_{i=1}^{N} N_i + \sum_{i=1}^{R} R_i + \sum_{i=1}^{D} D_i + \sum_{i=1}^{P} P_i$$

Where:

- $N_i$: National policies decision, reagent $i$
- $R_i$: Local or regional policies decision, reagent $i$
- $D_i$: Decision making capabilities, reagent $i$
- $P_i$: Private sector decision, reagent $i$

By level:

$$\text{(UFTI)} = \sum_{i=1}^{L_j} l_j$$

Depending on whether the answer is: yes or no, the corresponding weights assigned to each reagent are:

- A negative answer assigns zero points;
- A positive answer assigns the points corresponding for the reagent.

IV. RESULTS

The following results contain comparative assessments between UFTI version 1.0 and UFTI within AHP: Pearson correlation, mean values, statistical paired contrasts, equal variances test, and the overall results of the test in terms of specific measures.

Results from both methods show a high correlation when contrasting each one of the regents at the four levels. This fact indicates a strong statistical correlation, higher than 0.821, as depicted in Table III.

In the same manner, it was noted that the mean values between the two versions are also very similar. However, the reagents that measure the dispersion range of each variable with respect to the mean (SDDev) show a greater dispersion in the UFTI with AHP, as it was aforementioned.

### Table III: Paired Statistical Contrasts, by Level.

<table>
<thead>
<tr>
<th>Level</th>
<th>UFTI Version</th>
<th>N</th>
<th>Mean</th>
<th>StDev</th>
<th>SE Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>UFTI-AHP</td>
<td>53</td>
<td>0.004190</td>
<td>0.000274</td>
<td>0.000179</td>
<td></td>
</tr>
<tr>
<td>UFTI ver. 1</td>
<td>53</td>
<td>0.004406</td>
<td>0.000106</td>
<td>0.000147</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>53</td>
<td>0.000216</td>
<td>0.000270</td>
<td>0.000286</td>
<td></td>
</tr>
<tr>
<td>Pearson correlation = 0.925</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UFTI-AHP</td>
<td>117</td>
<td>0.003895</td>
<td>0.000270</td>
<td>0.000205</td>
<td></td>
</tr>
<tr>
<td>UFTI ver. 1</td>
<td>117</td>
<td>0.004098</td>
<td>0.000106</td>
<td>0.000157</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>117</td>
<td>-0.000201</td>
<td>0.000155</td>
<td>0.000146</td>
<td></td>
</tr>
<tr>
<td>Pearson correlation = 0.947</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UFTI-AHP</td>
<td>35</td>
<td>0.003857</td>
<td>0.000264</td>
<td>0.000044</td>
<td></td>
</tr>
<tr>
<td>UFTI ver. 1</td>
<td>35</td>
<td>0.003924</td>
<td>0.000106</td>
<td>0.000185</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>35</td>
<td>-0.000267</td>
<td>0.000155</td>
<td>0.000312</td>
<td></td>
</tr>
<tr>
<td>Pearson correlation = 0.930</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UFTI-AHP</td>
<td>27</td>
<td>0.005296</td>
<td>0.003220</td>
<td>0.000620</td>
<td></td>
</tr>
<tr>
<td>UFTI ver. 1</td>
<td>27</td>
<td>0.005309</td>
<td>0.000111</td>
<td>0.000215</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>27</td>
<td>-0.000013</td>
<td>0.000218</td>
<td>0.000464</td>
<td></td>
</tr>
<tr>
<td>Pearson correlation = 0.921</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The F-test for each level depicted in Table IV, doesn’t show significant differences between the means at a 95% confidence, at each level, between each version of UFTI.

Tables V and VI show a statistical comparison of all reagents (234). While the descriptive statistics show a high correlation, the variances test does not reflect significant differences between the means by version; their behavior is similar to that already described in the analysis by level. From the contrasts exposed, the positive validation of UFTI under AHP is established.

### Table VI: Test for Equal Variances, UFTI Versions.

<table>
<thead>
<tr>
<th>UFTI Version</th>
<th>N</th>
<th>Lower</th>
<th>StDev</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>UFTI-AHP</td>
<td>234</td>
<td>0.004284</td>
<td>0.002835</td>
<td>0.000186</td>
</tr>
<tr>
<td>UFTI ver. 1</td>
<td>234</td>
<td>0.004310</td>
<td>0.000147</td>
<td>0.000097</td>
</tr>
<tr>
<td>Difference</td>
<td>234</td>
<td>-0.000026</td>
<td>0.000183</td>
<td>0.000121</td>
</tr>
<tr>
<td>Pearson correlation = 0.819</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table IV: Test for Equal Variances, by Level.

<table>
<thead>
<tr>
<th>Level</th>
<th>UFTI Version</th>
<th>N</th>
<th>Lower</th>
<th>StDev</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>UFTI-AHP</td>
<td>53</td>
<td>0.002351</td>
<td>0.000287</td>
<td>0.000663</td>
<td></td>
</tr>
<tr>
<td>UFTI ver. 1</td>
<td>53</td>
<td>0.000875</td>
<td>0.000068</td>
<td>0.000365</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>53</td>
<td>0.000076</td>
<td>0.000019</td>
<td>0.000282</td>
<td></td>
</tr>
<tr>
<td>Pearson correlation = 0.819</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UFTI-AHP</td>
<td>117</td>
<td>0.002357</td>
<td>0.000275</td>
<td>0.000316</td>
<td></td>
</tr>
<tr>
<td>UFTI ver. 1</td>
<td>117</td>
<td>0.001481</td>
<td>0.000170</td>
<td>0.000192</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>117</td>
<td>0.000876</td>
<td>0.000105</td>
<td>0.000124</td>
<td></td>
</tr>
<tr>
<td>Pearson correlation = 0.804</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UFTI-AHP</td>
<td>35</td>
<td>0.002079</td>
<td>0.000264</td>
<td>0.000314</td>
<td></td>
</tr>
<tr>
<td>UFTI ver. 1</td>
<td>35</td>
<td>0.000886</td>
<td>0.000104</td>
<td>0.000146</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>35</td>
<td>0.000193</td>
<td>0.000160</td>
<td>0.000168</td>
<td></td>
</tr>
<tr>
<td>Pearson correlation = 0.855</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UFTI-AHP</td>
<td>27</td>
<td>0.002453</td>
<td>0.000322</td>
<td>0.000632</td>
<td></td>
</tr>
<tr>
<td>UFTI ver. 1</td>
<td>27</td>
<td>0.000852</td>
<td>0.000118</td>
<td>0.000160</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>27</td>
<td>0.001601</td>
<td>0.000204</td>
<td>0.000472</td>
<td></td>
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<tr>
<td>Pearson correlation = 0.804</td>
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Finally, the overall results of the case study using a combined UFTI-AHP are presented in Fig. 3, while results by level are shown in Fig. 4. As it was noted above, similarity in the results can be seen as it was previously demonstrated using the statistical tests. It should be noted that the right side charts in Fig. 3 and Fig. 4 are expressed in term of points, whereas charts at the left side corresponding to the AHP method, are expressed as absolute values.

Fig. 3 Comparative global results of the test

1.1 Definition of national policies on urban freight transport
1.2 Standardization of applied measures
1.3 Restrictions for truck access
1.4 Restrictions for truck parking
1.5 Location of loading/unloading zones
1.6 Creation of urban distribution centers
1.7 Traffic bypasses
1.8 Measures to reduce noise pollution
1.9 Taxes
1.10 Subsidies or economic incentives
1.11 Support for research and development
1.12 Support for undertaking pilot projects
1.13 Information dissemination

2.1 Definition of a local policy (state and municipal) on urban freight
2.2 Access restrictions
2.3 Parking restrictions
2.4 Loading and Unloading areas
2.5 Urban distribution centers supported by local authorities
2.6 Pilot projects
2.7 Dedicated corridors for trucks
2.8 Intermodal options within urban scale
2.9 Integration of freight transport in urban planning
2.10 Traffic
2.11 Pavements
2.12 Pollution

3.1 Perception of the importance of the urban freight transport in the society
3.2 Consultation and discussion forums on urban freight transport
3.3 Lack of awareness and technical knowledge
3.4 Lack of instruments for evaluation before and after

4.1 Carriers: Reduction of fees
4.2 Carriers: Use of intelligent transportation systems
4.3 Producers and retailers: Processes
4.4 Indicators of logistic performance
4.5 Automotive industry: Technology innovation
V. DISCUSSION

As it was noted above, due to the linearity of both methods, it was considered appropriate to use the Pearson correlation. Keeping in mind the methodological considerations of the test, the resulting Pearson correlation value of 0.819 means that there is a strong positive association between both methods.

In fact, the hierarchical structure of UFTI arranged in groups, indicators and reagents, matches well with the AHP software used. In the light of the results of this article, UFTI appears to be a flexible and compatible assessing method, capable of being combined with AHP methods.

As part of this article, the experience from dealing with the two versions of UFTI, generically and under the AHP ambient, has permitted the authors to acquire some sensitivity regarding the manageability to change the evaluated reagents, involving adding, removing or changing the sense of the assessed element. In terms of the flexibility of the generic UFTI version, if any change in the reagents is required, simply proceed by utilizing the appropriate weight established by the scale.

One of the advantages of UFTI under the AHP environment is that changes will be included in the corresponding group (node), while the comparison is made directly between pairs at a certain node. For this situation, the software automatically rescales the corresponding weights. It should be noted that the above changes do not loose the conditions of linearity of the studied method.

However, one of the disadvantages observed in applying the AHP was the difference in the cumulative relative weight obtained during the computing process. Two aspects are implied in this situation: one refers to the values in the AHP scales, in such a way that the total sum of weights must be 1 (one), and the other one because the software uses a three decimal system. It was taken into consideration that numerical losses were produced in small-scale reagents. Conversely, as the original version of UFTI uses exclusively integers numbers, a greater number of reagents has no influence on the loss of accuracy of the reagents.

VI. CONCLUSIONS

The current literature review revealed that there are distinct decision-making methods, to deal with specific problems. That is the case of the urban freight transport index (UFTI) which needed an objective assessing of its qualities as a performance measure. In order to do that, a correlation test was carried out utilizing AHP principles.

The results of this research show that the hypothesis is true, that is, that the UFTI methodology has flexible and consistent features compared to a well-known decision-making model (AHP). The results show that the UFTI methodology is reliable with respect to a proven method. Consequently, it is concluded that this methodology could be considered useful from the perspective of a new generic widespread tool for the decision-making in dynamical environments.

In other evaluation contexts, different from those related to urban freight, the methodological structure of the UFTI can remain intact; therefore, the generic methodology can be used as a reliable tool to create indexes, and to establish a systematic form of intervention with progressive measures. For that, it will be necessary to establish an evolutionary scale of the problem and a range of progressive intervention measures, creating specific indicators and reagents, while designating specific assessment groups addressed to the specific case.

However, the UFTI method is not intended to substitute other existing methods, rather, it can complement the decision-making process in cases where a yes or not decision is not needed. The same holds true when complex systems can not be physically measured; therefore, subjective scopes could be required.

Finally, the authors foresee the development of computer programs based upon the UFTI approach, to create useful indices that complement outputs from the computational AHP tools available today.

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### Appendix I: Methods and Systems in the Presence of Multiple Criteria

<table>
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<tr>
<th>Method</th>
<th>Description</th>
<th>Advantages</th>
<th>Weakness</th>
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<tr>
<td>Goal programming (GP)</td>
<td>Mathematical procedure for evaluating a set of alternatives in the presence of limited resources.</td>
<td>It is an improvement over standard mathematical programming techniques that consider only one criterion or objective.</td>
<td>It is a model and not a process, and thus provides no methods for ensuring that the goals selected adequately reflect the factors related to the group making the decision, and can only incorporate criteria that can be measured quantitatively.</td>
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<td>(Lee, 1972)</td>
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<td>Multi-attribute utility theory (MAUT) (Keeney and Raiffa, 1976)</td>
<td>It can be used to model the unique preferences of a decision-making group using utility functions that must be derived.</td>
<td>These scoring models are easy to use and construct, but their results are often misinterpreted.</td>
<td>Practical applications have been limited due to difficulties in constructing utility functions for an individual or group. More specifically, individuals must evaluate a sequence of artificially constructed lotteries to calibrate the utility functions for each criterion.</td>
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<td>Analytic hierarchy process (AHP) (Saaty, 1977, 1980, 1982)</td>
<td>Decision-making method for prioritizing alternatives when multiple criteria must be considered. Use pairwise comparisons to obtain a ratio scale of measurement.</td>
<td>It can compare alternatives among measure both tangible and intangible factors. Make use of pairwise comparisons to measure the impact of items on one level of the hierarchy on the next higher level. Permits the identification of inconsistency in judgments, establishes an acceptable tolerance level for the degree of inconsistency.</td>
<td>Liberatore and Nydick (1997) exposes that the primarily MAUT advocates, believe that permitting inconsistency of judgment and the possibility that the rankings of alternatives can change if new alternatives are added into the analysis. Rank reversals are a disadvantage of using the AHP.</td>
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*Source: Adapted from Liberatore and Nydick (1997)*