APPLICATION OF AHP METHOD IN THE FIELD OF CITY LOGISTICS

Maja KIBA-JANIAK

Wroclaw University of Economics, Faculty of Economics, Management and Tourism in Jelenia Góra, Nowowiejska Street No 3, 58-500 Jelenia Góra , maja_kib@o2.pl

Abstract
City logistics plays an increasing role in many cities. The constant growth of traffic caused by passenger and freight transport in urban areas contributes to increasing congestion. The municipal authorities are faced with many other problems arising from these, such as: air pollution, noise, vibration. Society expects that the city representatives will undertake the roles of making imperative decisions to eliminate problems associated with city logistics in order to improve the quality of citizens’ lives. In this article an attempt to implement the AHP method will be used to select a solution in the field of urban logistics that would improve the quality of life.

Keywords:
city logistics, AHP analyses, city logistics’ solutions

INTRODUCTION
City logistics is a modern concept aimed at the integration of existing resources in order to solve problems arising from the growth rate of the automotive industry and the population in urban areas. Forecasts show, that activities of freight companies compared to 2005, will have grown by around 40% in 2030 and by over 80% in 2050. At the same time passenger transport may also increase by 34% in 2030 and 51% in 2050. Currently many large cities have a huge problem with congestion caused mainly by individual transport. The problem might be even greater in 2050 when passenger cars will contribute more than 60 percentage to total passenger transport [1]. As a result of these forecasts local governments are forced to look for solutions that will avoid high congestion in the future.

The aim of the study is an attempt of AHP method implementation for decision making in the field of city logistics. This method could be used as a tool supporting the municipalities in multicriteria decision making. In order to implement the research, the author has carried out five focus interviews with representatives of the city logistics stakeholders in one of the Polish medium sized city. The paper is the result of the research carried out within the grant under the title: ‘Reference Model of City Logistics versus Quality of Life of Citizens’ financed from funds for science in the years 2010-2013.

1. PROBLEMS OF THE DECISION MAKING PROCESS IN THE FIELD OF CITY LOGISTICS IN A MEDIUM-SIZED CITY

In the literature there are many different definitions of city logistics [2-11]. Some of them focus only on physical flows and some also include people's flows within the city. In the author’s opinion city logistics ‘focuses on planning, coordinating and controlling processes taking place within the boundary of a given urban area and is related to physical movement of goods (i.e. raw materials, semi-products, goods and waste, etc.), people and information in a manner that will optimise costs, minimise congestion and improve quality of life’ [12].

The main aim of city logistics is to improve citizens’ quality of life. There are many solutions which have already been implemented in some large and medium sized cities [13]. The advantage of a medium-sized town is that there are many low-effective solutions which could easily improve the citizens’ quality of life.
Although the logistics transportation does not require high capital expenditure involved in the case of medium-sized cities, the application of even the simplest solutions is preceded by many difficulties resulting from [14]:
1. Fragile strategic consensus – local authorities often expect advice or a guiding strategy from regional/provincial ones. These in turn count on local autonomy. Such inconsistent mutual expectations slow down work and reduce its effectiveness.
2. Intraregional conflicts – usually a conflict appears between the city and suburbs. These conflicts often result from the different administrative boundaries, separate budgets of individual regions and individual interest.
3. Lack of confidence and visionary power – for medium-sized cities it is more difficult to develop a visionary strategy than large urban agglomerations. This is due to limited funds and capacity, insufficient knowledge or lethargy of city managers, etc.
4. Gridlocked decision-making processes – lack of trust between local leaders, setting up relationships between decision-makers are not beneficial for making objective decisions.
5. The multiplicity of the city logistics stakeholders and conflicts of objectives between the authorities, commercial and manufacturing companies, carriers, contractors of municipal services and inhabitants of the cities.

2. THE ROLE OF THE AHP METHOD IN SUPPORTING THE DECISION PROCESS IN THE FIELD OF CITY LOGISTICS

Local governments need objective tools to make the right decisions in the field of city logistics. The Analytic Hierarchy Process (AHP) is a mathematical method used to solve multi-criteria decision-making problems. The method was developed in 1980 by Thomas L. Saaty and is used in many areas. The essence of the AHP method is to compare pairs of analysed decision variants toward all criteria. Comparisons are made with the use of special tables for each of the evaluation criteria based on the specific grading scale [15]. In the literature, many positions can be found which use the method of AHP for multi-criteria decision-making [16-19]. In both, foreign literature, as well as, to a lesser extent, in Polish literature can also be found application of this method in the field of city logistics [20-22];

The AHP method may be developed according to the following stages [18]:
1. Define the problem.
2. Expand the objectives of the dilemma or consider all subjects, objectives and its result.
3. Categorise the criteria that influence the activities.
4. Makeup of the problem of dissimilar levels constituting aims, criteria, sub-criteria and alternatives in hierarchy (figure 1).

Figure 1. AHP process decision

5. Define the decision makers’ preferences, in the form of a pairwise comparison matrix on a scale from 1 to 9 points (1 - equal importance, 9 - Extreme importance; for inverse comparison reciprocals are used; see
more [17] and [24]) and calculating the absolute validity of standardised assessments of all elements of the hierarchy.
6. Perform the coherence test of the comparison matrices at all levels of the hierarchy by calculating the coherence indexes CI of the matrices and comparing them with the limit value (CI < 0.1);
7. Generate the final variants’ ranking based on aggregate utility measure, obtained by aggregating the absolute standardised assessments of elements’ validity in hierarchy, using an additive utility function.
The final outcome of the AHP method algorithm is a ranking, which prioritises the variants from the best to the worst according to the calculated values of their utility from largest to smallest. (see more [17, 21]).

3. DEFINITION OF THE DECISION PROBLEM AND RESULTS OF THE RESEARCH

The main objective of the city logistics is to improve the quality of life by: improvement of freight and passenger movement, reduction in CO2 emissions and reduction of noise in the city. It is not easy to make the right decisions in order to implement solutions enabling the achievement of these objectives. They are often very large and expensive projects whose value is difficult to calculate, let alone the predicted effect in the form of improving the quality of life. One of the methods enabling multi-criteria decision-making by local authorities is the AHP method. The author has made an attempt to exploit AHP method for ranking solutions in the field of urban logistics in the context of improving the quality of life of residents in a city of medium-size in Poland. In order to implement the study eight alternative solutions were identified (A1 - A8), that affect the residents quality of life through: improving traffic in the city - C1, reducing CO2 emissions – C2 and reducing noise - C3 (figure 2).

Figure 2. Best solutions in the city logistics field decision process

Source: own research

The criteria were selected by experts. They also had decided that the study would not have included the cost criterion due to the nature of the public administration sector.
Figure 3 presents the scheme of the calculation procedure leading to the final rankings based on the method of AHP. After determining the three main criteria and eight alternative solutions, five city logistics
stakeholders from Gorzow Wielkopolski were selected, such as: Vice President of the City, the Director of the Municipal Department of Communications, a resident, a representative of the shipping company and a representative of the trade and services company. The study was conducted through the focus interview with the use of questionnaires. The experts were asked to compare all pairs of elements in the hierarchy, and granting them with the appropriate level of importance on a scale from 1 to 9 points. These comparisons were performed for criteria and alternative solutions. Then obtained data were entered into the AHP Excel Template [26], where resulting from the calculation 24 preferences matrices were obtained. For the consolidated matrices (as a geometric mean for all stakeholders), after six iterates, normalised principal eigenvectors were obtained, which also took the form of absolute, standardised weights of criteria / alternative solutions – $w_{ij}^b$.

![Figure 3. Scheme of the calculation procedure leading to the final rankings based on the method of AHP](source: own study [based on 21])

Table 2 presents consolidated pairwise matrix with normalised weights for the criteria. According to the respondends criterium 1 – *improvement of freight and passanger movement* ist the most important (weight: 66,8%). Table 3 shows consolidated pairwise matrix with normalised weights for alternative solutions for the criterium – C1. In this case the alternative solution – A2 has been recognised as the most preferable with respect to the criterion *improvement of freight and passanger movement*. The least preferred alternative solutions for the criterium C1 are A6 (*Prohibition on the movement of all vehicles through the city center*) and A7 (*The introduction of some places for bicycles to hire in the city*).

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>$w_{ij}^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>6 4/9</td>
<td>3</td>
<td>66,8%</td>
</tr>
<tr>
<td>C2</td>
<td>1/6</td>
<td>1</td>
<td>1 1/2</td>
<td>13,9%</td>
</tr>
<tr>
<td>C3</td>
<td>1/3</td>
<td>2/3</td>
<td>1</td>
<td>19,3%</td>
</tr>
</tbody>
</table>

Source: Own study

The final results of the research are presented in the figure 4. According to stakeholders’ representatives the best alternative solution, which would improve the quality of life in the city is - *Prohibition on the movement of trucks through the city centre* (0,342). The second group of alternative solutions, which were assessed on the similar level are: *Prohibition on the movement of all vehicles through the city center* (0,168), *Restrictions for heavy goods vehicles* (0,122) and *Restrictions on the movement of vehicles in the city center* (0,120). At the end of the ranking is solution such as *The introduction in the city of some places to hire bicycles from (0,43).*
Table 3. Consolidated pairwise matrix with normalised weights for alternative solutions for the criterium – C1

<table>
<thead>
<tr>
<th></th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
<th>A7</th>
<th>A8</th>
<th>Wij</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>1</td>
<td>2/7</td>
<td>1 ½</td>
<td>7/8</td>
<td>2</td>
<td>4 1/9</td>
<td>5 1/9</td>
<td>1 ½</td>
<td>12,5%</td>
</tr>
<tr>
<td>A2</td>
<td>3 4/7</td>
<td>1</td>
<td>4 1/9</td>
<td>4 2/3</td>
<td>5 4/9</td>
<td>6</td>
<td>6 1/7</td>
<td>3 1/3</td>
<td>39,6%</td>
</tr>
<tr>
<td>A3</td>
<td>2/3</td>
<td>1/4</td>
<td>1</td>
<td>½</td>
<td>6/7</td>
<td>2 1/8</td>
<td>2 1/6</td>
<td>1 1/9</td>
<td>8,6%</td>
</tr>
<tr>
<td>A4</td>
<td>1 1/7</td>
<td>2/9</td>
<td>1 5/6</td>
<td>1</td>
<td>1 8/9</td>
<td>5 4/9</td>
<td>5 2/9</td>
<td>2</td>
<td>12,8%</td>
</tr>
<tr>
<td>A5</td>
<td>1/2</td>
<td>1/5</td>
<td>1 1/6</td>
<td>1/2</td>
<td>1</td>
<td>3 2/3</td>
<td>3</td>
<td>1 1/4</td>
<td>8,2%</td>
</tr>
<tr>
<td>A6</td>
<td>1/4</td>
<td>1/6</td>
<td>1/2</td>
<td>1/5</td>
<td>2/7</td>
<td>1</td>
<td>1 3/5</td>
<td>2/3</td>
<td>4,8%</td>
</tr>
<tr>
<td>A7</td>
<td>1/5</td>
<td>1/6</td>
<td>1/2</td>
<td>1/5</td>
<td>1 1/2</td>
<td>5/8</td>
<td>1</td>
<td>2/3</td>
<td>4,5%</td>
</tr>
<tr>
<td>A8</td>
<td>2/3</td>
<td>1/3</td>
<td>1</td>
<td>1/2</td>
<td>4/5</td>
<td>1 4/7</td>
<td>1 1/2</td>
<td>1</td>
<td>9,1%</td>
</tr>
</tbody>
</table>

Source: Own study

Figure 4. The final ranking of alternative solutions

<table>
<thead>
<tr>
<th>Alternative solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
</tr>
<tr>
<td>A2</td>
</tr>
<tr>
<td>A3</td>
</tr>
<tr>
<td>A4</td>
</tr>
<tr>
<td>A5</td>
</tr>
<tr>
<td>A6</td>
</tr>
<tr>
<td>A7</td>
</tr>
<tr>
<td>A8</td>
</tr>
</tbody>
</table>

Source: own study

CONCLUSION

The paper presents an attempt to exploit AHP method to multi-criteria and group decision making in the selection of alternative solutions in the area of city logistics. The expectations of city logistics’ stakeholders are different. With the methods of group decision-making it is possible to take into account opinions of all stakeholders. The observations made during the research show that all stakeholders agreed on the fact that the most important criterion in the field of urban logistics, affecting the quality of life, is efficient movement within the city. Among the most desirable solution, according to experts, is: - prohibition on the movement of trucks through the city centre.

The AHP method is still relatively unknown and seldom used by local authorities in Poland. None of the experts who participated in the survey had ever come across this method before. Furthermore, the AHP method appeared to be difficult to the respondents who admitted that if the survey had not been conducted in the form of interviews they would not have been able to assign the utility to each criterion and alternative solutions. The respondents also noticed the positive side of the AHP method, such as taking into account the views of all stakeholders and the multiplicity of criteria in the decision making process. The AHP method is one among many tools (UTA, ELECTRE I-IV, Promethee, Oreste itp. , see more: Zak 2005 [27]) that allows policy makers to make multi-criteria decisions. Certainly this is the method that is worth using in city logistics.
ACKNOWLEDGEMENTS

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LITERATURE


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