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Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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AN APPLICATION OF ANALYTIC NETWORK PROCESS FOR EVALUATING PUBLIC TRANSPORT SUPPLY QUALITY

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Abstract

For public transportation problem there are some analytic hierarchical processes for decision support, however there only very few applications which consider the interrelations between the public transport supply quality factors. Because, representing the problem by the analytic network process is more similar to real situations where the factors act in a non hierarchical way. The paper aims to analyze the interrelation and the importance of relevant factors in public transportation systems by using the analytic network process, that support the decision makers to evaluate the impacts of different criteria in the final result.

Keywords: analytic network process, public transport, decision maker, supply quality

1 Introduction

Public transportation has abundant problems like heavy traffic, parking problems, environmental problems and other phenomenon problems. Improving the quality of public transportation as efficiently as possible is important especially in big cities. Public transport supply quality improvement has a real impact on motivating the non passengers to use public transportation systems, it also increases the passenger's satisfaction. The aim of decision makers in the government and public transport companies is to find solutions for transportation problems and increase public transport's quality in order to achieve passengers satisfaction and encourage non passengers to utilize public transport. Multi criteria decision making applications have been applied by decision makers to deal with that [1-4]. In this study the multi criteria decision making approach has been suggested in determining public transport supply quality main criteria scores and ranking them based on experts' opinion. Sensitivity analysis has been tested to check the robustness of the results. The analytic hierarchal process is the favorite for decision makers and between different approaches of multi criteria decision making, it has been applied in a variety of fields [5, 6].
Using the analytic hierarchal process for hierarchal structured cases neglect the interrelations between the factors in different levels. Duleba had been applied the analytic hierarchal process to improve the supply quality for public transportation system in Japan depending on the constructed hierarchical structure [7], the research did not provide a comprehensive and complete view of the criteria's scores and interrelations, because of neglecting the interrelations between the factors.
To get a clear image for the interrelations between the factors and the scores of the factors the analytic network process has been applied by using Saaty's scale Table 1. for pairwise comparison, it is a general form of the analytic hierarchal process and one of the multi criteria decision making method [8]. The analytic network process modelled as network, while in the analytic hierarchal process as hierarchies. For non-hierarchal problems analytic network

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process had been applied in abundant studies, it makes possible to deal systematically with all kinds of dependence and feedback in a decision system.

Table 1 Judgment scale of relative importance for pairwise comparison (Saaty's 1-9 scale)

Numerical values	Verbal scale	Explanation
1	Equal importance of both factors	Two elements contribute equally
3	Moderate importance of one factor over another	Experience and judgment favour one factor over another
5	Strong importance of one factor over another	An factor is strongly favoured
7	Very strong importance of one factor over another	An factor is very strongly dominant
9	Extreme importance of one factor over another	An factor is favoured by at least an order of magnitude
2,4,6,8	Intermediate values	Used to compromise between two judgments

Fix cost is expected, so just supply quality issues are investigated. A reciprocal value is assigned to the inverse comparison; that is, aij=1/aji, where aij (aji) denotes the importance of the ith (jth) element. Like analytic hierarchal process, pairwise comparison in analytic network process is made in the framework of a matrix, and a local priority vector can be derived as an estimate of relative importance associated with the elements (or components) being compared by solving the following equation:

$$A \times w = \lambda_{max} \times w \tag{1}$$

where λ_{max} is the maximum eigenvalue of the matrix A. λ_{max} is the principal eigenvalue of the matrix A, and w is the eigenvector, considering A is a consistent matrix
The notation of public transport supply quality Criteria's [7].

Criteria	Explanation
C1	"Service Quality", Everything excluding transport it self
C2	"Transport Quality", for real time on vehicle
C3	"Tractability", getting information from every aspect
C4	"Physical comfort", comfort of seat, crowd, condition air
C5	"Mental comfort", contains environmental aspects, politeness of driver
C6	"Safety of travel", feeling in safe, accidents in the bus, security
C7	"Perspicuity", clear understanding for schedule and information
C8	"Information before travel", amount and quality of information
C9	"Information during travel", availability, quantity and quality of information
C10	"Approachability", of the service before beginning of travel
C11	"Directness" reaching the destination without shifting vehicles
C12	"Time availability" the time frame when using certain vehicle
C13	"Speed", speed for the time of whole travel process
C14	"Reliability", the quality of being trustworthy
C15	"Directness to stops", reaching the stops for travel
C16	"Safety of stops", subjective feeling,
C17	"Comfort in stops", heating and cooling systems, seats
C18	"Need of transfer", do passenger has to change or not
C19	"Fit connection", between bus lines or between other type of public transportation and bus lines, guarantee of transfer

C20	“Frequency of lines”, working hours based on schedule
C21	“Limited time of use”, a part of the whole travel process
C22	“Journey time”, related to speed of the vehicle, (get on_get off)
C23	“Awaiting time”, waiting for public transport
C24	“Time to reach stops” a part of the whole travel process

The analytic network process is mathematically proven application and have a nonlinear correlation, this make solving the problems more similar to real situations where the factors act in a non hierarchical way [8, 9]. This is the reason why the mode of thinking used in analytic network process is capable of mimicking human thinking more than analytic hierarchal process in decision making [10, 11]. However, the literature review about which decision-making methods have been used in practice to solve problems showed that the analytic hierarchal process method was used most, and the analytic network process was rarely used [12].

2 Methodology

The analytic network process is the generalization of the analytic hierarchal process. It confines the analytic hierarchal process as a special case and can be used to deal with more emergency decision problems more than the analytic hierarchal process. In analytic network process questionnaire, pairwise comparison has been applied, it was constructed from 276 comparisons depending on 24 criteria that represent the supply quality in public transportation system Table 2. Experts in related field have been asked to perform pairwise comparison of the criteria based on the importance scale shown in Table 1. Eight experts have been participated to evaluate the questionnaire, the evaluation has been done be Judgment scale of relative importance for pairwise comparison (Saaty’s 1-9 scale). Based on study aim the analytic network analysis is designed in super decisions software.

$$
\mathbf{W} = \begin{array}{c} \\ \\ C_1 \\ \\ \\ C_2 \\ \vdots \\ C_n \end{array}
\begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1m_1} \\ e_{21} \\ e_{22} \\ \vdots \\ e_{2m_2} \\ \vdots \\ e_{n1} \\ e_{n2} \\ \vdots \\ e_{nm_n} \end{array}
\overset{\begin{array}{cccc} C_1 & C_2 & \cdots & C_n \\ e_{11}e_{12}\cdots e_{1m_1} & e_{21}e_{22}\cdots e_{2m_1} & \cdots & e_{n1}e_{n2}\cdots e_{nm_1} \end{array}}{\begin{bmatrix} \mathbf{W}_{11} & \mathbf{W}_{12} & \cdots & \mathbf{W}_{1n} \\ \mathbf{W}_{21} & \mathbf{W}_{22} & \cdots & \mathbf{W}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \mathbf{W}_{n1} & \mathbf{W}_{n2} & \cdots & \mathbf{W}_{nn} \end{bmatrix}}
$$

Figure 1 Supermatrix (source: [8]).

3 Results

The study has been made to evaluate the situation of Budapest's public transport system. As methodology, analytic network process has been applied based on created questionnaires that has been used regarding the network of quality criteria's. These criterions are ranked based on the experts' opinions using analytic network process pairwise comparison approach, where 276 pairwise comparisons have been evaluated, considering the network model Fig. 2. For the 1st criteria "Service Quality" the following question has been asked: "Decide if there is relation between Service Quality and other 23 criteria or not, if there is then, compare the importance by using Saaty's scale.

Table 2 Preference ranking for urban transport system criteria's

Rank	Criteria	Normalized Scores	Idealized Scores
1	C3	0,099318574	1
2	C1	0,075111638	0,756269801
3	C2	0,0736722	0,741776659
4	C8	0,060192025	0,606050027
5	C7	0,054193171	0,545649907
6	C23	0,053153161	0,535178453
7	C12	0,050342843	0,506882454
8	C11	0,045123964	0,454335598
9	C6	0,04483899	0,451466309
10	C16	0,041168056	0,414505103
11	C4	0,038746472	0,390123121
12	C20	0,038211198	0,38473366
13	C22	0,035720337	0,359654144
14	C19	0,034160844	0,34395222
15	C10	0,033079581	0,333065402
16	C9	0,03276281	0,329875956
17	C5	0,03117803	0,313919431
18	C13	0,030828966	0,310404836
19	C21	0,026397867	0,265789832
20	C24	0,024273387	0,244399275
21	C14	0,023484878	0,236460083
22	C18	0,019125931	0,192571542
23	C15	0,017946619	0,180697505
24	C17	0,016968459	0,170848795

The geometric mean has been applied to get super matrix Fig. 1 ([8]), geometric mean of decisions:

$$J_g\left(k,l\right)=\prod_{i=1}^{n}J_i\left(k,l\right)^{wi} \tag{2}$$

where: $J_g(k,l)$ refers to the group judgement of the relative importance of factors k and l, $J_i(k,l)$ refers to individual i's judgment of the relative importance of factors k and l,w_i is the weight of individual $i;\sum_{1}^{n}w_i=1$; and n the number of decision- makers.

$$P_g\left(A_j\right)=\sum_{i=1}^{n} w_i P_i\left(A_j\right) \quad (3)$$

where $P_g(A_j)$ refers to the group priority of alternative, j, $P_g(A_j)$ to individual i's priority of alternative j, w_i is the weight of individual i, $\sum_{i=1}^{n} w_i$, and n the number of decision-makers.

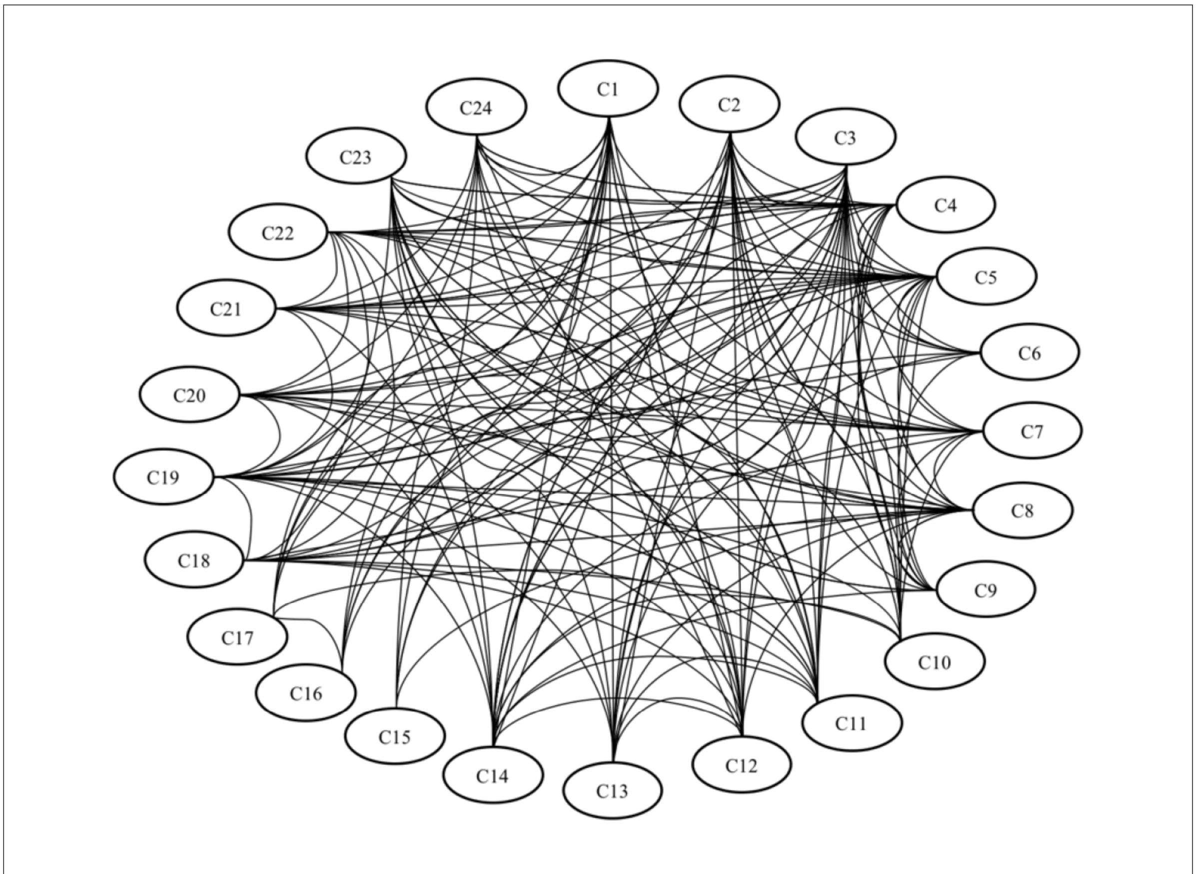

Figure 2 The interdependent relationship among the public transport supply quality criteria (source: research by the authors)

151 Interrelations between different criteria have been detected, The network model contains (276-125 = 151 interrelations). Super decisions software has been applied to get preference ranking for public transport system criteria's Table 3. Tractability was the most important criteria depending on the applied analysis, the second important criteria was Service quality, after that the Transport quality. The preferences make decisions more flexible to solve the variety of transportation problem [13, 14]. During the analytic network process, the consistency of answers has been examined by Saaty's Consistency Index (CI) and Consistency Ratio (CR) ‹ 0.1, [5, 6], The results of the ranking of the main criteria are presented in Table 3.

4 Conclusion

The paper has been proposed a model for ranking the supply quality of public transport in Budapest used as a case study. Due to the complexity of the problem, the multi criteria decision making tool (analytic network process) has been applied. The application enables the decision-makers to better understand the complex relationships of the relevant criteria in the decision-making, that subsequently improve the reliability of the decision. Applying the analytic network process is quite complicated than other approaches, because of it's large number of comparisons, and the inconsistency check also difficult due to the super matrix. Participated experts have been stated that the analytic network process questionnaire is quite complicated and require long time to evaluate the criteria., due to the large number of comparisons "276". For further researches, authors recommend to apply another approach regarding the detected interrelation between the criteria.

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