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Passenger Transport Drawbacks: An Analysis of its “Disutilities” Applying the AHP Approach in a Case Study in Tokyo, Japan

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Abstract. Passenger transport is a key player in urban mobility. However, it imposes some disadvantages, such as: time wasting, cost of fares and other costs, insecurity, discomfort and damage to the environment. These disadvantages herein called disutilities affect passenger choices and therefore it is necessary to consider them encompassing all modes of transportation. In this study, an analysis of these disutilities was conducted with the purpose of measuring its drawbacks. To this end, a case study in the Greater Tokyo Area (Japan) was carried out and assessed using the Analytic Hierarchy Process. The results showed that from 0,000 to 1,000 automobiles produce the highest level of disutility (0.182) compared with seven other modes of transportation.

Keywords: urban mobility; transportation disadvantages; decision-making.

1 Introduction

People usually move from one place to another to meet their needs, as human activities occur in different areas of the city [1] [2]. Therefore, Passenger Transport (PT) is the main provider of access to work, leisure, education, etc. [3]. PT can be divided twofold: (i) private, such as automobiles and motorcycles; and (ii) public, where passengers pay a fare to ride, like on buses and trains. Even with PT being important for the economy, it imposes some disadvantages to the passengers and the society, given that it wastes time, costs money, is unsafe, uncomfortable and harms the environment, consuming non-renewable energy and urban space [4] [5]. These disadvantages, called disutilities, influence customer choices and transportation takes the character of a service of negative consumption, in other words, something that everyone needs, but nobody wants [6] [7]. Thus, there is not PT mode that does not present some issues. All modes of transport may present drawbacks; hence, it is important to minimize their levels of disutility [8].

The purpose of this study is to evaluate the levels of disutility in PT modes and classify them. To this end, a case study was conducted in the Greater Tokyo Area, Japan. This area was chosen due to the data access, high concentration of population and availability of all transportation modes. The evaluation was made applying the Analytic Hierarchy Process (AHP) approach.

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2 Methodology

The levels of disutilities can be measured or evaluated by specialists. The weights of each disutility are submitted to the AHP to calculate the "Total the Disutility" of each mode of transportation.

2.1 Analytic Hierarchy Process (AHP)

AHP is a structured technique for organizing and analyzing complex decisions based on mathematics and psychology, developed by Thomas L. Saaty in the 1970's. It is a multi-criterial decision-making approach that measures and establishes priority scales based on specialists' judgments about a given subject via the means of peer comparisons [9]. AHP is a methodology to calibrate the numeric scale for the measurement of quantitative as well as qualitative performances [10], and it has been used to solve several logistical, strategic and transport engineering problems.

AHP applications consist of breaking the problem into steps [11]: (i) define it; (ii) structure the decision hierarchy; (iii) construct a set of pairwise comparison matrices; and (iv) use the priorities obtained to weigh them.

In the present case, AHP is a means to determine the level of disutility of the PT modes, considering a displacement between two points. The criteria considered for the decision-making is related to "Passengers" and "Society" and the sub-criteria related to the disutilities is outlined in Section 3. To set the weights adopted, bibliographical references were selected, as can be seen in Table 1.

Table 1. Bibliographical references for weights adopted in pairwise comparisons

References	Criteria		Sub-criteria				
	Passenger	Society	Total Time of Displacement	Cost	Insecurity	Discomfort	Negative Impacts on Communities
Raymundo and Reis [12]	X	X	X	X	X	X	X
Vasconcellos [13]			X	X	X	X	X
ANTP [14]					X	X	X
Gibson et al. [15]							X

2.2 AHP Framework

The AHP method utilizes peer comparison between each one of the criteria, sub-criteria and alternatives, considering levels from a nominal scale [16], shown in Table 2, and, in this case, considering the bibliographical references previously cited in Table 1.

Table 2. Peer comparison nominal scale (Source: Adapt [11])

Scale	Meaning
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6 and 8	Intermediate values

These comparisons are established to determine the levels of importance of each criterion, comparing, for example, criterion “i” with criterion “j” [13] (Eq. 1).

$$A = \begin{pmatrix} 1 & a12 & \dots & a1n \\ a21 & 1 & \dots & a2n \\ \dots & \dots & \dots & \dots \\ an1 & an2 & \dots & 1 \end{pmatrix} \tag{1}$$

Thus, AHP correlates several criteria and performs by peer comparison, identifying inconsistencies in the analyses. If the specialist specifies that b > a and a > c, therefore it is expected that b > c, otherwise an inconsistency is pointed out by the software. Thus, AHP displays an inconsistency index (“II”) [17] [18], mathematically expressed by (Eq. 2). The maximum inconsistency allowed to guarantee the reliability of the chosen decision is II < 0.10. In the case of “II” being greater or equal to 0.10, it is necessary to adjust the comparisons before proceeding to the criteria analysis (Eq. 2):

$$II = \frac{\lambda max^{n}}{n^{1}} \tag{2}$$

where: “λmax” = auto maximum value; and “n” = matrix dimension or order of the matrix.

Then, the “consistency ratio” (“CR”) can be obtained by (Eq. 3) [19] [20]:

$$CR = \frac{II}{RI} \tag{3}$$

where “CR” corresponds to the “consistency ratio”, related to the answers given by specialists; “II” represents the inconsistency index and “RI” is the “random index”, calculated to square matrices of “n” order by the “Oak Ridge National Laboratory” – ORNL, being 1 = 0.00; 2 = 0.00; 3 = 0.58; 4 =0.90; 5 = 1.12; 6 = 1.24; and 7 = 1.32.

To determine the weights of each criterion, sub-criterion and alternatives, changes between the options should be compared, considering the preferred scenario and the less recommended one. Whenever possible, averages should override the judgments of specialists to avoid errors by the subjectivity of responses. To reduce the inconsistencies in the model, we opted to work with quantitative comparisons between the weights, using collected data from the case study and specialists’ opinions [21].

2.3 Decision Tree

A decision tree was adopted to solve the proposed problem [22], considering two criteria and five sub-criteria. A second layer of 11 sub-criteria was considered from the five sub-criteria. Peer comparisons were performed considering Table 1.

The decision tree (Figure 1) identifies the objective, criteria and respective sub-criteria (in two layers), indicating the alternatives considered. Once the decision model variables were determined, the data was inputted in the Expert Choice® version 11 (2014), generating the results shown in Section 4.

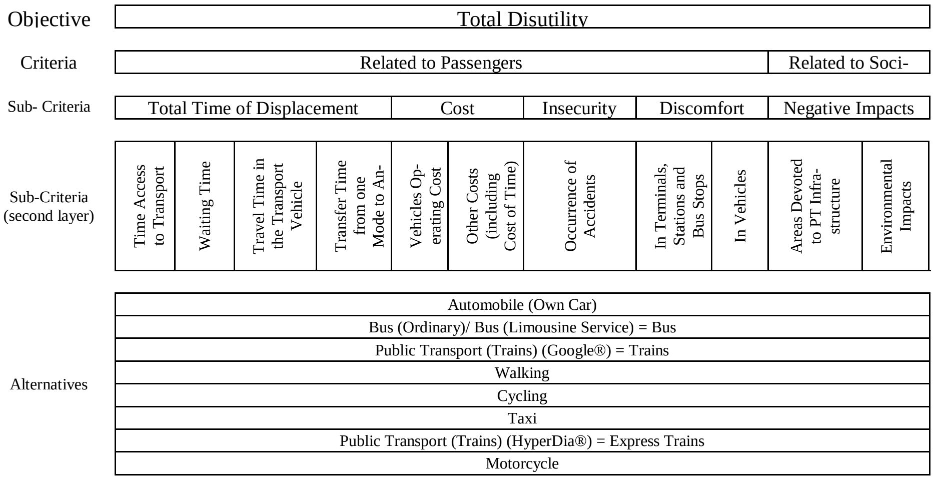

Fig. 1. Decision tree Case Study

2.4 Case Study

The case study refers to an experiment from Narita Airport to Tokyo Central Station, for the following PT modes: Automobile (own car); Taxi; Bus (Ordinary); Bus (Limousine Service); two Train options (Narita Skyaccess / Oedo Line and Narita Express), the first of them is a train with several stops and a compulsory transfer from one line to another, and the other is an express train, with few stops and no transfers; Cycling, Walking and Motorcycle, totalizing nine modes. Due to the AHP software limitation to eight alternatives, it was necessary to blend Bus (Ordinary) and Bus (Limousine Service) into a single alternative, simply called "Bus". However, this was a minor change that did not invalidate the analysis.

To perform the peer comparisons of the AHP method, the weight values of the disutilies per each mode of transportation were defined according to the bibliographical references shown in Table 1 and in transport specialist opinions. The purpose was created an overview of method application. Future studies intents to compare the judgments of specialist with the system users. Some restrictions of the AHP method, such as limited judgment scales and the consideration of which criteria are independent of each other, did not invalidate the results obtained.

3 Results and Discussion

The main objective of the study to measure the "Total Disutility". The results showed that an Automobile produces the highest level of disutility (0.182), followed by Bus, Taxi, Motorcycle, Trains, Walking, Cycling and Express Trains (0.083), as can be seen in Table 3. Apart from Bus, our result is close to that found in other studies, like Vasconcellos [13]. EMPLASA [7] could explain the second position occupied by Bus.

Table 3. General Result

Objective and Criteria	Alternative Weights (bold highest disutility - italic lowest disutility)							
	Automobile	Bus	Trains	Walking	Cycling	Taxi	Exp. Trains	Motorcycle
TOTAL DISUTILITY	**0.182**	0.148	0.119	0.107	0.098	0.140	*0.083*	0.125
Passenger	**0.169**	0.097	0.130	0.138	0.122	0.123	*0.092*	0.129
Society	0.216	**0.277**	0.093	*0.026*	0.029	0.185	0.060	0.114

Additionally, the criterion "Passenger" has a higher weight (0.667), compared with the criterion "Society" (0.333). In the case of the criterion "Passenger", Automobile (0.169) produces the highest disutility and the lowest is related to Express Trains (0.092). Concerning "Society, the highest disutility is represented by Bus (0.277) and the lowest by "Walking" (0.026).

3.1 Sub-criterion (two layers) and Alternatives

The results corresponding to each sub-criterion and the alternatives weights are represented in Tables 4 and 5 and discussed in the sub-items 3.2.1 to 3.2.5. The results are in general compatible with what is (currently) observed in the Greater Tokyo Area, concerning the level of supply of transportation modes (quality and quantity), the demand requirements and the equilibrium between these elements [12].

3.1.1 Total Time of Displacement - Walking is the mode with the highest level of disutility caused by its very long travel time. In second place is Trains (long waiting time, travel time and transfer time). Cycling comes in third place (long travel time), followed by Bus. The lowest levels are represented by Motorcycle, Automobile and Taxi, while Express Trains play an intermediate role. Our result is compatible with what is observed in Tokyo, where Motorcycle, Automobile and Taxi perform almost the same average speed [12].

3.1.2 Cost - Automobile shows the highest level of "Cost" due to its operating cost, followed by Walking (high time cost), Taxi, Trains and Cycling. In an intermediate position, there are the Express Trains and Motorcycle, while the lowest level is represented by Bus. Fares, and consequently their subsidies, influenced the performance of the public modes, determining their competitiveness. Vasconcellos [13] shows Automobile with a very high cost, while public transportation has the lowest values.

Table 4. Sub-criteria (first layer) and alternatives weights

Sub-criteria (first layer)	Alternative weights (bold highest disutility - italic lowest disutility)							
	Automobile	Bus	Trains	Walking	Cycling	Taxi	Exp. Trains	Motorcycle
Time of Displacement	0.077	0.136	0.156	**0.196**	0.147	0.081	0.141	*0.066*
Cost	**0.184**	*0.076*	0.121	0.152	0.121	0.129	0.119	0.091
Insecurity	0.224	0.067	0.050	0.135	0.102	0.143	*0.044*	**0,229**
Discomfort	0.116	0.172	**0.255**	0.059	0.117	0.106	*0.046*	0.129
Negative Inpacts on Communities	0.216	**0.277**	0.099	*0.026*	0.029	0.185	0.060	0.114

Table 5. Sub-criteria (second layer) and alternatives weights

Sub-criteria (first layer)	Sub-criteria (second layer)	Alternative weights (bold highest disutility - italic lowest disutility)							
		Automobile	Bus	Trains	Walking	Cycling	Taxi	Exp. Trains	Motorcycle
Time of Displacement	Access	**0.207**	0.142	0.086	*0.015*	0.179	0.122	0.062	0.187
	Waiting	*0.022*	0.286	**0.309**	*0.022*	*0.022*	0.139	0.177	*0.022*
	Travel	0.027	0.053	0.077	**0.461**	0.238	*0.022*	0.095	0.027
	Transfer	0.177	*0.066*	**0.487**	*0.066*	*0.066*	*0.066*	*0.066*	*0.066*
Cost	Vehicles	0.262	0.086	0.092	*0.020*	*0.020*	**0.301**	0.074	0.145
	Other)	0.158	*0,073*	0.130	**0.195**	0.162	0.074	0.134	0.074
Insecurity	Accidents	0.224	0.067	0.050	0.135	0.102	0.143	*0.044*	**0.236**
Discomfort	Infrastructure	0.094	0.068	**0.232**	0.204	0.133	0.094	**0.037**	0.137
	Vehicles	0.124	0.211	**0.263**	*0.031*	0.084	0.110	0.050	0.126
Negative Impacts on Communities	Infrastructure	*0.284*	0.144	0.080	**0.030**	0.040	0.233	0.066	0.123
	Environmental Impacts	0.190	*0.328*	0.098	**0.025**	**0.025**	0.167	0.058	0.110

3.1.3 Insecurity - Motorcycle represents the highest level of "Insecurity", followed by Automobile, Taxi, Walking, Cycling, Bus, Trains and Express Trains. Even in Japan, non-motorized modes (Walking and Cycling) are subjected to a high risk and are relatively less protected from traffic threats shared between Automobile, Motorcycle, Taxi and Bus, not to mention trucks. The data collected by Raymundo and Reis [12] related to Tokyo confirms our result, where Motorcycle is the most unsafe, followed by Automobile, Walking and Cycling, Trains and Bus.

3.1.4 Discomfort - A trade-off occurs due to Trains showing the highest level of "Discomfort" and Express Trains the lowest. In Trains, compared to Express Trains, passengers in Tokyo face worse conditions concerning infrastructure (terminals and stations) and worse conditions in vehicle comfort. From the higher levels to the lower ones, we have Bus, Motorcycle, Cycling, Automobile and Walking. ANTP [14] reached similar conclusions when analyzing the discomfort of PT modes in São Paulo, Brazil.

3.1.5 Negative Impacts on Communities - The highest position is occupied by Bus, followed by Automobile, Taxi, Motorcycle, Trains and Express Trains, while the lowest level is represented by Walking and Cycling. Bus has the highest position in "Environmental Impacts" because most of them are still diesel powered, polluting much more than the other modes. Gibson et al. [15], studying most of cities in the European Union countries, arrived at a similar result to ours.

4 Conclusions

The measurement of disutilities of the selected PT modes in the Greater Tokyo Area and the establishment of priorities among them allowed us to identify the reasons that influence the performance of these transportation systems.

When it is known that, on a scale from 0,000 to 1,000, where the values are complementary, the Automobile produces the highest level of disutility (0.182), followed by Bus (0.148), Taxi (0,140), Motorcycle (0.125), Trains (0.119), Walking (0.107), Cycling (0.098) and Express Trains (0.083), it is not difficult to suppose that similar situations are happening in most metropolitan areas of the world, requiring the minimization of total disutility produced by PT.

The results show that it is worthwhile for public transportation to invest in better trains, subsidize fares and substitute the bus fleet by vehicles that pollute less. For private transportation, it is worth protecting walking and cycling from the shared traffic threats. Finally, it is important to highlight in a more transparent way the harmful effects of automobiles, taxis and motorcycles. From this, it could be possible to improve them and then to integrate them to the non-motorized individual modes and to the public and collective modes in a more effective manner.

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