Factors Impacting Transport Mode Choice in Egypt: An AHP Approach

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Abstract:

This paper identifies and prioritizes the criteria used for passengers' transportation mode choices using the Analytical Hierarchy Process (AHP). The four criteria that are considered are travel time, cost, comfort and reliability. The comfort criteria is subsequently divided into six sub criteria; noise, vibration, temperature, humidity, seat width and leg room. An empirical study for transportation passengers' choices using the analytic hierarchy process (AHP) is adopted to determine the relative weights and priorities of these criteria. The model is based on feedback received from 56 passengers through a structured interview process. The results of this study indicate that; for the main criteria, the criteria that influence on passengers' choices in the order of importance are as follows: reliability, travel time, travel cost and comfort. For the sub-criteria, the criteria that influence on passengers' choices addressing: humidity, leg-room, seat width, temperature, noise and vibration respectively. The results of the technique provide important insight into the preference of passengers in Egypt and is useful to better understand how new transportation modes might be received by Egyptian passengers.

Keywords: Analytical hierarchy process; passengers' choices; Multi-criteria decision making

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1. Introduction

Transportation service quality is based on "customer's satisfaction" which depends on "user's perception". Therefore, assuring the quality of the public transportation is an essential task for transportation engineers and authorities. Transit service providers need to rate the passenger's interests of their service to develop the competition among different transport modes. (Wang & Shieh, 2006)

Passengers' satisfaction is considered important for any service mode. In this paper, the authors investigate passengers' choices among different transportation modes such as; aviation, high speed rail and conventional rail. Their choices depend on several factors, which have a direct influence on their satisfaction (Chou et al. 2014).

In classifying the priority of the passenger's choices, this paper focuses on four main criteria that influence passengers' choices; travel time, travel cost, comfort and reliability. Due to the difficulty to directly measure comfort, this factor is further sub-divided into six sub-criteria; noise, vibration, temperature, humidity, seat width and leg-room. This paper starts by introducing these criteria and sub-criteria, and then presents an approach of multi criteria decision making an application based on analytical hierarchy process (AHP). Finally, the criteria are ranked after the consistency check.

2. Criteria affecting passengers' choices

2.1 Travel time

Travel time can be represented by the door-to-door time from the origin to destination, including travel to and from the station, waiting time in the station, actual travel time, and exit time from the station to last destination, as shown in Equation (1).

$$\boldsymbol{T_T^I} = (\boldsymbol{t_a^I} + \boldsymbol{t_w^I} + \boldsymbol{t_t^I} + \boldsymbol{t_e^I}) \qquad (1)$$

Where:

I: the transport mode; aviation services (AT), high speed rail services (HSR) or conventional rail services (CR),

t_a^I= arrival time from the origin to the departure station or airport of the mode I,

t_e^I= exit time from the arrival station or airport of the mode I to the final destination,

t_t^I= trip time from the departure station or airport to the arrival station or airport of mode I,

t_w^I= waiting time at departure station or airport for mode I

2.2 Travel cost

Travel cost is used to represent the total user cost for a journey (Adler et al. 2010). Travel cost is composed of the fare and arrival /exit costs, which depends on the distance and transport charges of different origin and destination cities, as shown in equation (2)

$$\boldsymbol{C^I = C_a^I + C_e^I + C_t^I} \qquad (2)$$

Where:

C_a^I= the costs of arrival trip from the origin to the departure station or airport of the mode I,

C_e^I= the costs of exit trip from the arrival station or airport of mode I to the last destination,

C_t^I= the trip fare or ticket price for the trip from the departure station or airport to the arrival station or airport for mode I

2.3 Comfort

Comfort factor is considered an important criterion that affects mode choice by passengers. Comfort is defined as the well-being of a person or absence of mechanical disturbance in relation to the induced environment. This well-being can be achieved through different factors, both physiological such as expectation and individual sensitivity. And by physical environment such as motions, temperature, noise, seating characteristics. (Lauriks, et al., 2003).

Richards and Jacobson, (1977) were one of the first to study passenger comfort. They questioned 861 passengers. Their outcomes are still interesting because some results still remain valid. Rickenbacher & Freyenmuth, (2008) difined the most influenc factors of comfort; leg-room, seat characteristics, vibration, noise and air conditions. Peter & klaus (2011) and Zhang, et al. (2015), based on questionnaires, they found that discomfort is more related to physical characteristics of the environment, like noise, temperature and humidity.

According to above studies the set of factors which affect on passengers rest were adapted as follow:

2.3. 1 **Noise:** one of the factors which affect on passenger's comfort. Despite of some sounds gives us danger and causes a sense of discomfort, Vink (2005) stated that noise sources may come from engine motion, sounds of other passengers, etc.

Typical sound level in the environment adopted from (Howard & Angus, 1996), as shown in the table 1:

Table (1) Typical scale for noise

Decibel (dB)*	**Description**
> 100	Ouch
80 - 100	Very noisy
50 – 70	Noisy
20 – 40	Quiet
0 – 10	Just audible

* A unit for noise measurement

2.3. 2 **Vibration:** The unevenness of the transport's route will result in coupling vibration which is caused by the mode itself or the combined action of the mode and its route. . This kind of vibration is a part of low frequency with big amplitude, and has a big influence on people's feeling of comfort and may cause spinning sensation.

Scale of vibration comfort or discomfort adopted from (ISO2631, 2004), as shown in the table 2.

Table (2) Typical scale for vibration

r.m.s* Weighted Acceleration (m/s^2)	(Dis)Comfort Categories
< 0.315	Not uncomfortable
0.315 – 0.63	A little uncomfortable
0.5 – 1	Fairly uncomfortable
0.8 – 1.6	Uncomfortable
1.25 – 2.5	Very uncomfortable
> 2	Extremely uncomfortable

* Root Mean Square

2.3. 3 **Temperature and humidity:** Temperature and humidity are factors on climate conditions through the transport mode. The feelings of high or low temperature and humidity are unique and related to anthropometry. Vink and Brauer (2011) reported that air conditions, nowadays, solved this source of discomfort through taking them into consideration in designing of transport mode. Less than 5% of passengers, who were asked in their survey, mentioned the discomfort related to climate conditions. According to ISO 7730 standard the human's feeling about temperature and humidity adopted in table 3.

Table (3) Typical scale for temperature and humidity

Predicted Percentage of Dissatisfied (PPD)	Description
-3	Cold
-2	Cool
-1	A little cool
0	Thermal middle
1	A little warm
2	Warm
3	Hot

2.3. 4 **Leg room and seat width**: Most of the back pain comes from sitting in restricted posture for a long time. Giving the freedom in variation posture possibility is a kind of comfort in transport mode. In addition, increasing leg room has a positive effect on the comfort experience. A specified leg room size let the passenger stretch their legs in front and under the seats and move them in different positions. All of them reduce the musculoskeletal pain. (Nordin, 2005), (Parent-Thirion, et al., 2007) and (Hamberg-van Reenen, 2008).

Richards and Jacobson also found that there is a large increase in percentage of satisfied passengers when leg room is increased from 24 inches (61.0 cm) to 27 inches (68.6 cm). On the other hand, according to CAESAR data (2000), the satisfied width for the passenger is about 440 mm (17.3 in.).

2.4 Reliability

Reliability is an important concept for transportation services and has proved to be an essential component of their competitiveness. The reliability of transport service can be defined differently depending on the point of view. A transport operator is interested in reliability as the probability that a mode will follow a specific schedule, while a buyer of the transportation service is interested in the probability that the mode reaches its destination at a specific time. (Arcot, 2007). In other words; reliability measures the extent to which arrival time deviates from its planned arrival time (i.e. punctuality or service).

In each journey, there is an uncertainty related to the range of time delay from the start to the end of journey. This uncertainty in time is termed as reliability. There are different modes within transport process; each of them has their special causes of time delay. (Thorhauge, 2010).

3. Analytic Hierarchy Process (AHP)

In the beginning of 1870, Thomas Saaty developed the Analytic Hierarchy Process method (AHP) which represents a tool in the decision making analysis. It was designed to assist the planners in resolving complex decision making problems where a large number of planners participate, and a number of criteria exist in a number of specific time periods. The area of application of the AHP method is the Multi-criteria decision making where, on the basis of a defined group of criteria and attribute values for each alternative, the selection of the most acceptable solution is done, i.e. the complete layout of alternative importance within the model is presented. Accordingly, in 1977, Saaty formally proposed his “theory of prioritized hierarchies”, and described the first full-scale application of his theory to 103 ranked air, road, rail, river, and port transport projects in Sudan. His published textbook, entitled The Analytical Hierarchy Process.

Worldwide, decision makers have used AHP to solve problems in more than 30 diverse areas including resource allocation, strategic planning, and public policy, and thousands of AHP applications have been reported (Wasil & Golden, 2003).As said it is a decision-making method for prioritizing alternatives when multiple criteria must be considered. Managerial judgments are used to drive the AHP approach by assigning weights to different criteria, and the alternative with the highest total weighted score is selected as the best (Saaty, 1994). It has also been used to rank, select, evaluate, and benchmark a wide variety of decision alternatives. Further, AHP has been used by organizations in both the public and private sectors to deal with complex problems.

Moreover, AHP provides a framework to cope with multiple criteria situations involving intuitive, rational, qualitative and quantitative aspects. Qualitatively, a complex decision problem is decomposed into a hierarchical structure. Quantitatively, it adopts pair-wise comparisons to rate decision elements (Cheng & Li, 2002). In the other hand, AHP employs redundant comparisons to ensure the validity of judgments and also provides a measure of inconsistency for discarding inconsistent judgments (Saaty, 2013).

In this research, AHP was adopted to prioritize the criteria that influence on passengers’ choices among different transportation modes.

4. The application of the AHP

The AHP aims at integrating different measures into a single overall score for ranking decision alternatives. Its main characteristic is based on pair-wise comparison judgments (Earl, et al., 2010). The AHP includes the following four steps. (Acuna, et al., 2009) (Omar & Abdullah, 2010):

- Developing a hierarchical structure of the decision problem in terms of overall objective, criteria, sub-criteria and decision alternatives.
- Data collection by pair-wise comparisons of the decision alternatives with respect to sub-criteria.
- Calculation of the normalized priority weights of criteria and sub-criteria, and check the consistency of judgments.
- Analyzing the priority weights and establish solutions to the problem.

5. Data collection

AHP In order to determine the relative importance of criteria, data was obtained from direct questions by experts who are effectively involved in the decision problem (Lee & Kim, 2013).

A questionnaire for both criteria and sub-criteria was addressed to be used during interviews. It contained clear questions to be answered in a way that helps to achieve the objectives of the study. It contained two parts, the first one included general information about interviewers, and the second one was specific about passengers' perceptions of the used services; users expressed importance and satisfaction, on a cardinal scale from 1 to 9, first about four service quality factors concerning travel time, travel cost, comfort and reliability. Then, about 6 factors that illustrate the comfort; noise, vibration, temperature and humidity, seat width and leg-room.

The survey was applied to a sample of 56 passengers. About 60% of the sample was interviewed on regional passenger trains and the remaining percentage on local air lines in Egypt. The users were interviewed in a weekday and a holiday. About 35% of the interviewed people travel for working, 50% for studying, and the remaining 15% travel for other purposes. The population part of the sampled people is students, but a considerable part is composed of employees. About 60% has a fixed income; people stated their income mainly belongs to a range between 700 LE and

20000 LE. 30% of people have an income ranges between7000 and 20000 LE, while 42% of them have an income ranges between 3000 and 6000 LE, and 28% of them have an income less than 3000 LE.

6. Results and analysis

To obtain the overall prioritization of the four criteria and six sub-criteria with respect to the goal of passenger's choices, global weights for the criteria were calculated as follow:

1. Structuring the hierarchy:

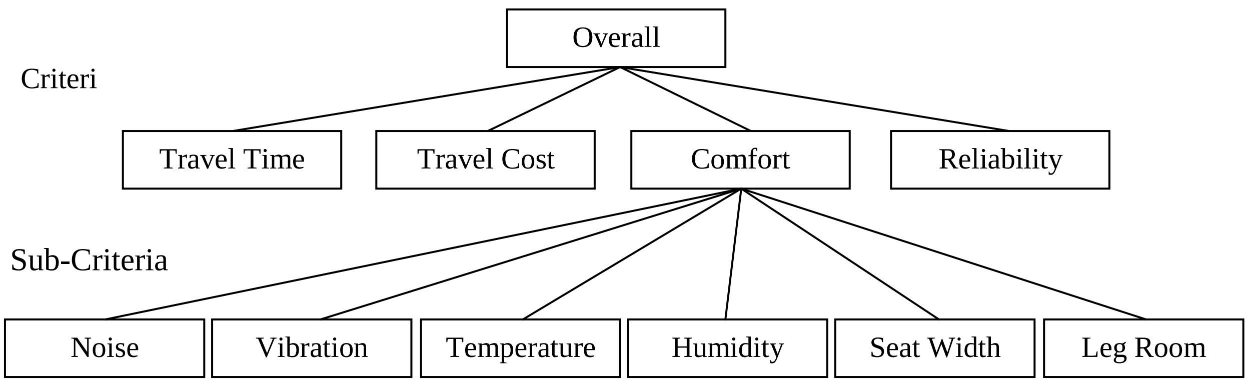

Figure (1) The hierarchical structure of a decision problem

2. Constructing a pair-wise comparison matrix (size n _ n) for each level by using the relative scale measurement, We have used the widely accepted nine-point scale which is the original scale suggested by Saaty, as shown in Table 4.
   The pair-wise comparisons are done in terms of which element dominates the other. Table 5 shows the preference for the decision-makers for each criterion.

Table (4) Pair-wise comparison scale for AHP preferences by (Saaty, 1977), (Saaty, 2013)

Intensity of importance	**Definition**	**Explanation**
1	Equal importance	Two factors contribute equally to the objective

3	Moderate importance	Experience and judgment slightly favor one over the other
5	Strong importance	Experience and judgment strongly favor one over the other
7	Very strong importance	Experience and judgment very strongly favor one over the other
9	Extreme importance	The evidence favoring one over the other is of the highest possible validity
2,4,6,8	Intermediate values	When compromise is needed

Table (5): Pair-wise comparison matrix

	Time	Cost	Comfort	Reliability
Time	1	3	5	0.333
Cost	0.333	1	3	0.143
Comfort	0.2	0.333	1	0.2
Reliability	3	7	5	1

3. Synthesizing the pair-wise comparison matrix and calculate the priority for a criterion. Synthesizing the pair-wise comparison matrix is performed by dividing each element of the matrix by its column total.

The priority in Table 6 can be obtained by finding the row averages.

Table (6): Synthesized matrix

	Time	Cost	Comfort	Reliability	Priority
Time	0.221	0.265	0.357	0.199	0.260
Cost	0.074	0.088	0.214	0.085	0.115
Comfort	0.044	0.029	0.071	0.119	0.066
Reliability	0.662	0.618	0.357	0.597	0.558

4. Determining the consistency by using the Eigen-value (λ_{max}) to calculate the consistency index (CI) as given in Equation (3):

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad (3)$$

Where:

CI: is the consistency index

λ_{max}: is the Eigen-value

n: is the matrix size

The calculations for these items will be explained next for illustration purposes.

First the weighted sum matrices were found by multiplying the pair-wise comparison matrix by the computed priority. Then, all the elements of the weighted sum matrices were divided into their respective priority. After that, the average of these values was computed to obtain Eigen-value (λ_{max}). Finally, the consistency index (CI) was found as shown in Table 7:

Table (7): Consistency Index

Number of criteria (n)	Eigen-value (λ_{max})	Consistency Index (CI)
4	4.243	0.081

5. Calculating the consistency ratio:

Judgment consistency can be checked by taking the consistency ratio (CR) of the consistency index (CI) with the appropriate value of the random consistency ratio (RI) illustrated in Table 8. (Saaty, 1980) and (Saaty, 2013). The CR is acceptable, if it less than 0.10. If it is more, the judgment matrix is inconsistent.

Table (8) Average random consistency (RI)

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

In this paper, the matrix size for the criteria is four, so the value of random consistency ratio (RI=0.9) by using Table 5.

The consistency ratio was calculated by dividing consistency index into the random index, as shown in Equation (4):

$$CR = \frac{CI}{RI} \qquad (4)$$

Where:

CR: is the consistency ratio

CI: is the consistency index

RI: is the random index

The value of CR is 0.08, it is less than 0.01, then the decision-maker's comparisons were consistent

On the other hand, the previous steps were applied on the sub-criteria that explained previously. The following results were obtained:

Table (9): Pair-wise comparison matrix for the sub-criteria

	Noise	Vibration	Temperature	Humidity	Seat Width	Leg Room
Noise	1	5	1	0.143	0.333	0.143
Vibration	0.2	1	0.333	0.111	0.2	0.143
Temperature	1	3	1	0.333	0.333	0.2
Humidity	7	9	3	1	3	3
Seat Width	3	5	3	0.333	1	0.333
Leg Room	7	7	5	0.333	3	1

Table (10): Synthesized matrix for the sub-criteria

	Noise	Vibration	Temperature	Humidity	Seat Width	Leg Room	Local Weight
Noise	0.052	0.167	0.075	0.063	0.042	0.030	0.0715
Vibration	0.010	0.033	0.025	0.049	0.025	0.030	0.0289
Temperature	0.052	0.100	0.075	0.148	0.042	0.042	0.0765
Humidity	0.365	0.300	0.225	0.444	0.381	0.623	0.3895
Seat Width	0.15	0.167	0.225	0.148	0.12	0.06	0.148

	6				7	9	7
Leg Room	0.36 5	0.233	0.375	0.148	0.38 1	0.20 8	0.284 9

Table (11): Consistency ratio

Number of criteria (n)	Eigen-value (λ_{max})	Consistency Index (CI)	Random Index (RI)	Consistency Ratio (CR)
6	6.464	0.093	1.24	0.075

The value of CR is 0.075, it is less than 0.01, then the decision-maker's comparisons were consistent.

After that, the global weights-based the criteria that influence on passenger's choices were ranked. They have been calculated by multiplying the local weights of each sub-criteria by the priority of each criteria. The computed global weights were presented in Table 12.

Table (12): The criteria that influence on passenger's choices ranking with global weights

Criteria	Time	Cost	Comfort						Reliability
Priority (%)	26.03	11.53	6.61						55.83
Sub-criteria	Time	Cost	Noise	Vibration	Temperature	Humidity	Seat Width	Leg Room	Reliability
Local Weight (%)	26.03	11.53	7.15	2.89	7.65	38.95	14.87	28.49	55.83
Global weight (%)	26.03	11.53	0.47	0.19	0.51	2.57	0.98	1.88	55.83

The global weights-based the criteria that influence on passenger's choices ranking are illustrated in Table 13.

Table (13): the global weights

Ranking	Criteria	Global Weights	Category

1	Reliability	55.83%	Reliability
2	Time	26.03%	Time
3	Cost	11.53%	Cost
4	Humidity	2.57%	Comfort
5	Leg Room	1.88%	Comfort
6	Seat Width	0.98%	Comfort
7	Temperature	0.51%	Comfort
8	Noise	0.47%	Comfort
9	Vibration	0.19%	Comfort

7. Conclusion:

This paper provides a method for ranking the criteria and it also allows a consistency measure of results. Thus, it was proposed using the analytic hierarchy process to rank the different criteria related with passenger's choices among several transportation modes. The technique seems to perform better than the results based purely on the experts' assignation of the absolute priorities of each criterion. However, by using this technique, the level of importance of each attribute is compared to the others.

The study is accounted for the travel time, travel costs, comfort and reliability as the most criteria that influence on passenger's choices; in addition to dividing the comfort into; noise, vibration, temperature, humidity, seat width and leg-room. Then the factors are compared using the analytic hierarchy process. The results showed that the most significant category for level 1 is reliability, the second is time, the third is cost and the fourth is comfort. On the other hand, in level 2, reliability has a relatively high-global weight, followed by time and cost. The remaining items are humidity, leg-room, seat width, temperature, noise and vibration respectively.

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