Methodology for Evaluating Service Quality of Public Transport: Case of Delhi, India

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Abstract

The harmful effects of air pollution, noise pollution, traffic congestion, and energy consumption can be minimised by more and more use of public transport system. But the service quality is an obstruction in use of public transport. Managing the service quality is crucial and more important factor for increasing the use of public transport. In this paper researchers used SERVQUAL for measuring service quality of one of the modes of public transport. Service quality is an amalgamation of a variety of criteria; among them some vague criteria are difficult to measure. This attribute introduces the problem for respondent to response to the survey. To conquer this issue, the researchers used Fuzzy TOPSIS for assess the service quality of public transport system. To measure the service quality, the researchers firstly developed a questionnaire based on SERVQUAL for collected the data. The respondents provided the linguistic assessment for rating the criteria of service quality and the various alternatives available. Then linguistic assessments are combined by Fuzzy TOPSIS for measurement of overall performance of each and every alternative. The better criterion is chosen on the basis of overall performance score and ranks them. The potency of the presented move toward is its convenient applicability and skill to endow with quantitative information. The utility of this proposed approach for assessment of service quality of public transport will be applicable in the capital city and neighboring townships i.e. Delhi & NCR.

Keywords: Service Quality, SERVQUAL, Fuzzy, TOPSIS, Transport System

Introduction

Service can be elaborated as an intangible commodity that is formed to meet up present requirements and currently consumed by consumers. Services act as intangible economic goods, offered by one to another consumer and engaged in time-based performances to fetch out the most wanted results in recipients themselves or in objects or other assets for which purchases have been done (Lovelock & Wirtz, 2007). To evaluate the service quality, the researcher measures this degree of satisfaction with service performance which consider as a set of relevant criteria. Service quality is one of the important characteristics which furnish the utility of public transport (Fujii & Van, 2009) and passengers are another important factor to determine and evaluate the service provided by the transport authorities (Freitas, 2013). The evaluation of service quality in transportation system in any economy is very important or vital to improve profits and productivity which may increase the customer satisfaction. Therefore, all the transport companies or organisations should assess their service quality regularly. To assess the worth of service quality, companies' measure this quality based on various parameters for example efficiency, reliability, safety, comfort etc. against required service by their customer. The proper knowledge and understanding of these quality parameters give a high quality level to the passengers and also fulfill their needs and expectations (Freitas, 2013). The assessment of the various characteristics can be done on timely basis, may be, on weekends, month-end etc. by transport expert, customers, service personnel. Ultimately the objective of organisations is to provide utmost level of service quality to satisfy customers which can be provided only after assessment of provided service quality.

Several models have been developed for measuring service quality of those organisations based on service parameter as SERVQUAL is acknowledged to be the base model compared to all the other models (Saravanan & Rao, 2007). To measure the dimensions of service quality, the criterion is based on both quantitative and qualitative approach (Awasthi *et al.*, 2011). To handle this issue, many researchers apply the multi-criteria decision making (MCDM) in their researches.

The researchers in this paper, focused on hybrid approaches which integrate the SEVQUAL and Fuzzy TOPSIS decision making technique for estimating the service quality of public transport system in an economy level. In the absence of quantitative information, fuzzy set is used to remove ambiguity and uncertainty in the process of decision making (Zadeh, 1965). For example, it is very easy to symbolize the service quality in organisations in linguistic terms as good, very good, poor, very poor, etc. rather than in numbers. The linguistic terms in fuzzy set theory signify decision maker preferences. Due to this reason, researchers have used linguistics terms in search of responses from experts.

Literature Review

Several researchers have investigated the dilemma of service quality in transportation system (Apostolopoulou *et al.*, 2000; DuPlessis, 1984; Iseki & Taylor, 2008; Miller, 1995; Pullen, 1993; Said, 2002; TRB, 1999). Various methods which were used by above researchers will be classified under interviews and survey studies, multi-criteria decision making, and statistical analysis of collected data. In initial survey studies, researchers introduced a questionnaire in front of respondents to consider their views on the dimensions of service quality. In interviews, participants are requested to answer the questions face to face. SERVQUAL is most commonly survey instrument used for assessing the worth of service quality of an organisation (Parasuraman *et al.*, 1988). SERVQUAL is established on 22 items which were used to measure five service quality dimensions those are tangibles, reliability, responsiveness, assurance, and empathy. Connection, convenience, and comfort are the three dimensions which were added in SERVQUAL by Robert *et al.*, (2007) to assess the service quality by railway passengers in New Zealand. SERVQUAL was used by Fick & Ritchie (1991) to evaluate the service quality in tour and travel industry. Three principal approaches to define service quality were the customer based approach, the philosophical approach, and technical approach (Paquette *et al.*, 2009). In the second type, research is situated on statistical analysis for measuring or assessing the service quality. It involves logit model (Hensher *et al.*, 2003; Tyrinopoulos & Antoniou, 2008); regression analysis (Agarwal, 2008); structural equation modeling (Swanson *et al*, 1997; Eboli & Mazzulla, 2008). Logit and regression analysis were used by the researchers to make a study on the causal relationship of service quality variable and service quality attributes or dimensions. In logit model uncertainty exists between the dependent and independent variable whereas some relationship exist between the variables in regression analysis. Factor analysis and logit analysis were used by Tyrinopoulos & Antoniou (2008) to assess satisfaction of public transit user. To analyse the impact of customers' perception on service quality performance, regression analysis and factor analysis were used as a statistical tool by Agrawal (2008) in Indian Railway. In the third category of research analysis based on multi-criteria decision making approach has been used for assessing service quality of public transport system which is based on overall weighted score. Performance of the bus companies asses by fuzzy multi-criteria decision making technique (Yeh *et al.*, 2000). For assortment of environmentally sustainable transport system, analytical hierarchy approach (AHP) utilised by Yedla & Shrestha (2003). Hensher *et al.*, (2003) recommended a service quality index in the prerequisite of commercial bus contracts. Eboli & Mazzulla (2009) suggested an index based on customer perspective for measuring transit service quality. Analytical hierarchy process (AHP) and analytical network process (ANP) will be used to assess the association and level of ranking of dimensions of service quality (Altuntas*etal.*, 2012). An approach based on SERVQUAL and fuzzy TOPSIS were proposed by Awasthi*etal.*, (2011) to evaluate service quality of the transport system. Awasthi *et al.* (2011) used three steps to assess the service quality starting from developing a questionnaire based on SERVQUAL for the purpose of collecting the data, then overall performance generated by linguistic ratings with combination of fuzzy TOPSIS method for each alternative and finally conducted the sensitivity analysis to measure and assess the influence of the criteria weights in service quality decision making process. Fuzzy weighted SERVQUAL model for measuring the service quality of airline has been proposed by Chou *et al.*, (2011). Efficiency of public transportation in larger cities has been measured by data envelopment analysis (DEA) based efficiency model by Hilmola (2011). Since it has been discussed by the researchers above, that dimensions used for assessing and evaluating service quality is not limited to quantitative because some dimensions of service quality are measured only qualitatively.

Proposed Methodology

In this paper researchers developed a questionnaire to take the responses of customer regarding the quality of services provided by Delhi Transport Corporation. For the development of questionnaire SERVQUAL (Parasuraman *et al.*, 1988) scale was used as base. On the basis of expert opinion all the 22 items were considered for collection of data from the respondents under five dimensions which were proposed by Parasuraman *et al.*, (1988) which was accepted in literature (Awasthi *et al.*, 2011; Tseng, 2011; Liou, 2011).

Table 1: Definitions of SERVQUAL Dimensions

Dimensions	Definition
Tangibles	It includes the physical appearance of the facility of the service, the personnel, equipments etc.
Reliability	It relates to ability of the service provider to perform the promised service accurately and dependably.
Responsiveness	It is the willingness of the service provider/ operator to be helpful and prompt in providing service.
Assurance	It refers to the knowledge and courtesy of employees and their ability to inspire trust and confidence.
Empathy	It refers to caring, individual attention to the customer.

To measure the gap between expectations and perceptions of customer, SERVQUAL is a useful instrument. Tangibles, Service Reliability, Responsiveness, Assurance and Empathy are the dimensions of SERVQUAL.

SERVQUAL Approach

SERVQUAL is an instrument which can be used for gaps analysis. Gap is the difference between expectations and perceptions of a customer. Tangibles, Reliability, Responsiveness, Assurance and Empathy are the dimensions of SERVQUAL scale. These dimensions are defined in Table 1 (Awasthi *et al.*, 2011, Erdoğan *et al.*, 2013).

Fuzzy TOPSIS

Technique for order performance by similarity to ideal solution is a multi-criteria decision-making technique which is used to rank or selecting the alternatives among various alternatives by the numerical evaluations and calculations with respect to certain attributes/criterion. In this technique, weights will be specified for each criterion for measuring the relative importance which is felt by the decision maker (Gamberini *et al.*, 2006; Kahraman *et al.*, 2009b). The method is based on the consideration that the selected alternative should have chosen alternative should nearest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS) (Chen, 2000; Chen *et al.*, 2006; Yong, 2006).

To represent the uncertainty and vagueness fuzzy set theory was designed. It generates the decisions in uncertainty. Fuzzy sets provide formalised tools for dealing with basic thought to many problems. The decision maker can specify preferences in the form of natural language expressions about the importance of each criterion (Kahraman *et al.*, 2004a). Fuzzy TOPSIS approached has been used to specify the alternative ranking in the current research.

Cheng & Hwang (1992), for the first time presented the Fuzzy TOPSIS with reference to Hwang & Yoon (1981). The chosen alternative showed the shortest distance and the farthest distance from the positive ideal solution and negative ideal solution in geometrical (i.e., Euclidean) sense respectively (Hwang & Yoon, 1981). For the present research using Fuzzy TOPSIS, the steps can be summarised as follows (Chen, 2000; Aydın *et al.*, 2012; Baysal *et al.*, 2013):

For example, if there are five fuzzy numbers in a fuzzy set $\tilde{A}$, namely x_1, x_2, x_3, x_4, x_5 and their membership values are defined, respectively, as 3, 4, 6, 7 and 2, then, we can write the fuzzy set as $\{(x_1, 3), (x_2, 4), (x_3, 6), (x_4, 7)$ and $(x_5, 2)\}$, where x_4 contributes mostly to the fuzzy set.

1. A fuzzy set $\tilde{A}$ is convex (Zimmermann, 2001) if:

$$\mu_{\tilde{A}}(\lambda x_1 + (1 - \lambda) x_2) \geq \min \{ \mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)\}, x_1, x_2 \in X, \lambda \in [0,10]$$

where $\mu_{\tilde{A}}(x_1)$, $\mu_{\tilde{A}}(x_2)$ are the membership values of x_1, x_2 belonging to fuzzy set $\tilde{A}$ and λ is a real number $\lambda \in [0,10]$.

2. For a triangular fuzzy number with member þ denoted by $\tilde{N}$ (þ$_1$, þ$_2$, þ$_3$), the membership function of the member þ is defined as (Zimmermann, 2001):

$$\mu_{\tilde{N}}(þ) = \begin{cases} 0, & þ \leq þ_1, \\ (þ - þ_1)/(þ_2 - þ_1), & \text{where } þ_1 \leq þ \leq þ_2, \\ (þ_3 - þ)/(þ_3 - þ_2), & \text{Where } þ_2 \leq þ \leq þ_3, \\ 0, & þ \geq þ_3 \end{cases}$$

Where þ_1, þ_2, þ_3 stand for the left bound value, mean value and right bound value, respectively, in the distribution of a triangular fuzzy number.

3. Let $\tilde{a} = [a_1, a_2, a_3]$ and $\tilde{n} = [n_1, n_2, n_3]$ be two triangular fuzzy numbers (Laarhoven, 1983), then:

(i) $\tilde{a} + \tilde{n} = [a_l + n_l, a_m + n_m, a_u + n_u]$

(ii) $\tilde{a} * \tilde{n} = [a_l n_l, a_m n_m, a_u n_u]$

(iii) $\mu\, \tilde{a} = [\mu x_l, \mu x_m, \mu x_u]$, $\mu > 0$

4. Let $\tilde{a} = [a_1, a_2, a_3]$ and $\tilde{n} = [n_1, n_2, n_3]$ be two triangular fuzzy numbers the distance between $\tilde{a}$ and $\tilde{n}$ is defined as :

$$d(\tilde{a}, \tilde{n}) = \begin{cases} \left(1/3\left(|a_l - n_l|^{\text{þ}} + |a_m - n_m|^{\text{þ}} + |a_u - n_u|^{\text{þ}}\right)\right)^{1/\text{þ}}, \\ \text{where } 1 \leq \text{þ} < \infty \\ \max\left(|a_l - n_l|, |a_m - n_m|, |a_u - n_u|\right), \quad \text{where } \text{þ} = \infty \end{cases}$$

Linguistic Variable Set

Most of the time, decision making problem is made under vagueness, fuzziness, uncertainties, risk, time pressure and sometime information is missing. For example, it is difficult for any decision makers to award correct value to convey their judgment on a company's capability. They generally describe their judgment in term of "good", "fair", or "poor", etc. which are the term of fuzzy sets. For criterion weighting, they can use fuzzy terms such as "very important", "important", "low", "very low", to express their views. The triangular fuzzy number (TFN) is the simplest form of and is mostly used in expressing the linguistic terms in research (Chen, 2000; Deng, 2006).

An appropriate linguistic variable set can help decision makers to give right judgments on decisions. The linguistic terms and corresponding membership functions can be elicited from expert assessment and past data, and can be modified to incorporate individual situations. In this paper the linguistic terms are defined for demonstration based on previous research (Chen, 2000; Lin & Chen, 2004; Li *et al*., 2007; Erdoğan *et al*., 2013). For example, if one decision maker/expert gives his/her opinion on the weighting of attribute "efficiency" as "high", his/her judgements can be expressed as a fuzzy number (7, 9, 10).

Selection of transport operator for public transport is based on the factors, which affect the services provided by the transport operator. Since the comparison between the services provided by various tour or transport operator is linked with uncertainty and complexity, fuzzy multiple criteria decision analysis is suitable for taking decisions under this situation and hence decision making model should be developed. With this many famous MCDM methods (Azadfallah, 2014), technique for order performance by similarity to ideal solution (TOPSIS) method is a practical and useful technique for ranking and selection of a number of possible alternatives through measuring distances (Ghadim and Nobarzad, 2012).

Analysis for Transport Operator Selection

Researchers have taken three public transport operators that are providing their transport services in NCR, India. These three transport operators are Delhi Transport Corporation (DTC), Haryana Roadways (HR) and Private Transport Operator (Private). For the rating purpose of these three transport operator; as suggested by Saaty & Varges (1994), five customers were selected on the following criteria:

1. Young generation lying in age group of 25 to 35 years.
2. Customers involved in use of public transport very frequently.
3. Customers are taking the services of all three types of transport operators.

This group of five customers was assigned to assess the three transport operator on 22 item scale under five dimensions based on SERVQUAL. For selecting one alternative with fuzzy TOPSIS, these were followed:

Step 1: Defining fuzzy decision matrix

Five experts are selected as the experts for assessing the selection of transport operator. Since Saaty & Varges (1994) suggest that three to seven experts are suitable.

Table 2: Linguistic Variable Set

Linguistic Terms		Triangular Fuzzy Numbers (TFN)
Weightings	**Ratings**	
Very low (VL)	Very Poor (VP)	(0,0,1)
Low (L)	Poor (P)	(0,1,3)
Medium Low (ML)	Medium poor (MP)	(1,3,5)
Medium (M)	Fair (F)	(3,5,7)
Medium high (MH)	Medium good (MG)	(5,7,9)
High (H)	Good (G)	(7,9,10)
Very high (VH)	Very Good (VG)	(9,10,10)

Table 3: Decision Makers' Judgment on Items Weightings

	T1	**T2**	**T3**	**T4**	**R1**	**R2**	**R3**	**R4**	**R5**
DM_1	5,7,9	3,5,7	3,5,7	5,7,9	3,5,7	7,9,10	3,5,7	5,7,9	5,7,9
DM_2	3,5,7	7,9,10	7,9,10	7,9,10	7,9,10	5,7,9	7,9,10	7,9,10	7,9,10
DM_3	7,9,10	5,7,9	3,5,7	5,7,9	7,9,10	7,9,10	7,9,10	3,5,7	5,7,9
DM_4	5,7,9	7,9,10	5,7,9	7,9,10	5,7,9	3,5,7	5,7,9	7,9,10	7,9,10
DM_5	7,9,10	3,5,7	3,5,7	7,9,10	7,9,10	7,9,10	7,9,10	5,7,9	7,9,10
	RE1	RE2	RE3	RE4	A1	A2	A3	A4	E1
DM_1	3,5,7	7,9,10	7,9,10	3,5,7	3,5,7	5,7,9	5,7,9	3,5,7	7,9,10
DM_2	7,9,10	5,7,9	7,9,10	5,7,9	7,9,10	7,9,10	3,5,7	7,9,10	5,7,9
DM_3	5,7,9	7,9,10	7,9,10	7,9,10	5,7,9	3,5,7	7,9,10	3,5,7	3,5,7
DM_4	3,5,7	7,9,10	5,7,9	7,9,10	3,5,7	3,5,7	7,9,10	5,7,9	7,9,10
DM_5	5,7,9	5,7,9	5,7,9	3,5,7	7,9,10	7,9,10	7,9,10	7,9,10	7,9,10
	E2	**E3**	**E4**	**E5**					
DM_1	5,7,9	7,9,10	5,7,9	7,9,10					
DM_2	7,9,10	5,7,9	7,9,10	5,7,9					
DM_3	7,9,10	7,9,10	3,5,7	5,7,9					
DM_4	3,5,7	5,7,9	7,9,10	5,7,9					
DM_5	3,5,7	5,7,9	7,9,10	7,9,10					

Table 4: Decision Maker Judgements on Rating for Alternative (Transport Operators)

		T1	**T2**	**T3**	**T4**	**R1**	**R2**	**R3**	**R4**
	HR	5,7,9	7,9,10	5,7,9	5,7,9	5,7,9	3,5,7	1,3,5	3,5,7
	PRIVATE	1,3,5	3,5,7	5,7,9	5,7,9	3,5,7	7,9,10	5,7,9	5,7,9
	DTC	5,7,9	5,7,9	7,9,10	7,9,10	3,5,7	5,7,9	7,9,10	5,7,9
		R5	RE1	RE2	RE3	RE4	A1	A2	A3
	HR	7,9,10	7,9,10	7,9,10	5,7,9	1,3,5	7,9,10	7,9,10	1,3,5
DM_1	**PRIVATE**	7,9,10	7,9,10	5,7,9	1,3,5	3,5,7	7,9,10	7,9,10	3,5,7
	DTC	1,3,5	5,7,9	7,9,10	7,9,10	1,3,5	1,3,5	7,9,10	7,9,10
		A4	**E1**	**E2**	**E3**	**E4**	**E5**		
	HR	3,5,7	3,5,7	3,5,7	5,7,9	1,3,5	3,5,7		
	PRIVATE	5,7,9	3,5,7	1,3,5	7,9,10	7,9,10	7,9,10		
	DTC	5,7,9	3,5,7	1,3,5	1,3,5	1,3,5	7,9,10		
		T1	**T2**	**T3**	**T4**	**R1**	**R2**	**R3**	**R4**
	HR	7,9,10	5,7,9	5,7,9	7,9,10	5,7,9	3,5,7	3,5,7	5,7,9
	PRIVATE	3,5,7	3,5,7	7,9,10	1,3,5	7,9,10	7,9,10	3,5,7	5,7,9
	DTC	5,7,9	3,5,7	5,7,9	7,9,10	1,3,5	1,3,5	7,9,10	3,5,7
		R5	RE1	RE2	RE3	RE4	A1	A2	**A3**
	HR	5,7,9	5,7,9	5,7,9	7,9,10	3,5,7	5,7,9	3,5,7	1,3,5
DM_2	**PRIVATE**	5,7,9	1,3,5	1,3,5	3,5,7	1,3,5	3,5,7	1,3,5	1,3,5
	DTC	3,5,7	5,7,9	7,9,10	7,9,10	5,7,9	5,7,9	7,9,10	5,7,9
		A4	**E1**	**E2**	**E3**	**E4**	**E5**		
	HR	5,7,9	3,5,7	5,7,9	3,5,7	3,5,7	3,5,7		
	PRIVATE	5,7,9	1,3,5	7,9,10	3,5,7	1,3,5	1,3,5		
	DTC	5,7,9	3,5,7	1,3,5	1,3,5	3,5,7	1,3,5		

		T1	T2	T3	T4	R1	R2	R3	R4
	HR	1,3,5	5,7,9	7,9,10	7,9,10	5,7,9	3,5,7	1,3,5	3,5,7
	PRIVATE	3,5,7	1,3,5	3,5,7	3,5,7	1,3,5	7,9,10	1,3,5	3,5,7
	DTC	1,3,5	5,7,9	3,5,7	1,3,5	1,3,5	7,9,10	1,3,5	7,9,10
		R5	RE1	RE2	RE3	RE4	A1	A2	A3
	HR	1,3,5	1,3,5	7,9,10	3,5,7	3,5,7	5,7,9	5,7,9	5,7,9
DM_3	PRIVATE	7,9,10	5,7,9	3,5,7	7,9,10	3,5,7	1,3,5	3,5,7	3,5,7
	DTC	1,3,5	3,5,7	5,7,9	7,9,10	7,9,10	3,5,7	1,3,5	1,3,5
		A4	E1	E2	E3	E4	E5		
	HR	7,9,10	7,9,10	5,7,9	1,3,5	3,5,7	7,9,10		
	PRIVATE	1,3,5	1,3,5	3,5,7	3,5,7	5,7,9	5,7,9		
	DTC	3,5,7	3,5,7	3,5,7	5,7,9	3,5,7	5,7,9		
		T1	T2	T3	T4	R1	R2	R3	R4
	HR	1,3,5	3,5,7	1,3,5	5,7,9	1,3,5	1,3,5	3,5,7	1,3,5
	PRIVATE	5,7,9	7,9,10	7,9,10	3,5,7	7,9,10	5,7,9	1,3,5	3,5,7
	DTC	1,3,5	1,3,5	1,3,5	7,9,10	5,7,9	7,9,10	1,3,5	5,7,9
		R5	RE1	RE2	RE3	RE4	A1	A2	A3
	HR	3,5,7	3,5,7	5,7,9	3,5,7	7,9,10	1,3,5	3,5,7	5,7,9
DM_4	PRIVATE	7,9,10	5,7,9	7,9,10	5,7,9	3,5,7	7,9,10	3,5,7	3,5,7
	DTC	7,9,10	1,3,5	3,5,7	5,7,9	3,5,7	7,9,10	3,5,7	7,9,10
		A4	E1	E2	E3	E4	E5		
	HR	1,3,5	7,9,10	7,9,10	3,5,7	3,5,7	7,9,10		
	PRIVATE	1,3,5	7,9,10	7,9,10	1,3,5	5,7,9	3,5,7		
	DTC	3,5,7	5,7,9	3,5,7	7,9,10	3,5,7	3,5,7		
		T1	T2	T3	T4	R1	R2	R3	R4
	HR	1,3,5	1,3,5	7,9,10	5,7,9	3,5,7	5,7,9	3,5,7	1,3,5
	PRIVATE	1,3,5	1,3,5	7,9,10	1,3,5	5,7,9	1,3,5	7,9,10	3,5,7
	DTC	5,7,9	7,9,10	1,3,5	7,9,10	5,7,9	1,3,5	3,5,7	1,3,5
		R5	RE1	RE2	RE3	RE4	A1	A2	A3
	HR	5,7,9	7,9,10	7,9,10	7,9,10	3,5,7	1,3,5	5,7,9	1,3,5
DM_5	PRIVATE	5,7,9	5,7,9	7,9,10	1,3,5	3,5,7	5,7,9	3,5,7	5,7,9
	DTC	3,5,7	1,3,5	5,7,9	1,3,5	7,9,10	3,5,7	1,3,5	5,7,9
		A4	E1	E2	E3	E4	E5		
	HR	3,5,7	7,9,10	5,7,9	3,5,7	1,3,5	5,7,9		
	PRIVATE	5,7,9	7,9,10	7,9,10	1,3,5	5,7,9	3,5,7		
	DTC	1,3,5	5,7,9	3,5,7	1,3,5	7,9,10	7,9,10		

In the linguistic language, the items weightings are assessed from Table 2 by the team of decision makers and convert that in to TFN (shown in Table 3).

The linguistic ratings and values (Table 4) are expressed in exact numerical values (Chen & Hwang, 1992; Liang, 1999; Tsaur *et al.*, 2002; Chu, 2002; Chu & Lin, 2003; Chen & Tzeng, 2004). This rating of alternatives is formulated based on decision makers' judgements as shown in Table 4 after conversion of linguistic terms into TFN:

Step 2: Formulating the complex fuzzy decision matrix

The fuzzy items weightings and fuzzy decision matrix are formulated by the converting the linguistic terms into TFN (Table 3 and Table 4). After TFN, convert this into complex decision matrix (Table 5) by using following formulas:

$\tilde{a}_{ij} = 1/t\,[\tilde{a}_{ij}^{1} + \tilde{a}_{ij}^{2} + \ldots\ldots + \tilde{a}_{ij}^{t}]$,

$i = 1,2,\ldots\ldots,s;\ j = 1,2,\ldots$

$\tilde{w} = 1/t\,[\tilde{w}_{i}^{1} + \tilde{w}_{i}^{2} + \ldots\ldots + \tilde{w}_{i}^{t}]$,

$i = 1,2,\ldots,s$

Table 5: Averaged Frequency Weightings and Ratings of Three Public Transport Operators

	T1	T2	T3	T4	R1	R2	R3	R4	R5
WEIGHTS	5.4, 7.4, 9	5, 7, 8.6	4.2, 6.2, 8	6.2, 8.2, 9.6	5.8, 7.8, 9.2	5.8, 7.8, 9.2	5.8, 7.8, 9.2	5.4, 7.4, 9	6.2, 8.2, 9.6
HR	3, 5, 6.8	4.2, 6.2, 8	5, 7, 8.6	5.8, 7.8, 9.4	3.8, 5.8, 7.8	3, 5, 7	2.2, 4.2, 6.2	2.6, 4.6, 6.6	4.2, 6.2, 8
PRIVATE	2.6, 4.6, 6.6	3, 5, 6.8	5.8, 7.8, 9.2	2.6, 4.6, 6.6	4.6, 6.6, 8.2	5.4, 7.4, 8.8	3.4, 5.4, 7.2	3.8, 5.8, 7.8	6.2, 8.2, 9.6
DTC	3.4, 5.4, 7.4	4.2, 6.2, 8	3.4, 5.4, 7.2	5.8, 7.8, 9	3, 5, 7	4.2, 6.2, 7.8	3.8, 5.8, 7.4	4.2, 6.2, 8	3, 5, 6.8
	RE1	**RE2**	**RE3**	**RE4**	**A1**	**A2**	**A3**	**A4**	**E1**
WEIGHTS	4.6, 6.6, 8.4	6.2, 8.2, 9.6	6.2, 8.2, 9.6	5, 7, 8.6	5, 7, 8.6	5, 7, 8.6	5.8, 7.8, 9.2	5, 7, 8.6	5.8, 7.8, 9.2
HR	4.6, 6.6, 8.2	6.2, 8.2, 9.6	5, 7, 8.6	3.4, 5.4, 7.2	3.8, 5.8, 7.6	4.6, 6.6, 8.4	2.6, 4.6, 6.6	3.8, 5.8, 7.6	5.4, 7.4, 8.8
PRIVATE	4.6, 6.6, 8.4	4.6, 6.6, 8.2	3.4, 5.4, 7.2	2.6, 4.6, 6.6	4.6, 6.6, 8.2	3.4, 5.4, 7.2	3, 5, 7	3.4, 5.4, 7.4	3.8, 5.8, 7.4
DTC	3, 5, 7	5.4, 7.4, 9	5.4, 7.4, 8.8	4.6, 6.6, 8.2	3.8, 5.8, 7.6	3.8, 5.8, 7.4	5, 7, 8.6	3.4, 5.4, 7.4	3.8, 5.8, 7.8
	E2	**E3**	**E4**	**E5**					
WEIGHTS	5, 7, 8.6	5.8, 7.8, 9.4	5.8, 7.8, 9.2	5.8, 7.8, 9.4					
HR	5, 7, 8.8	3, 5, 7	2.2, 4.2, 6.2	5, 7, 8.6					
PRIVATE	5, 7, 8.4	3, 5, 6.8	4.6, 6.6, 8.4	3.8, 5.8, 7.6					
DTC	2.2, 4.2, 6.2	3, 5, 6.8	3.4, 5.4, 7.2	4.6, 6.6, 8.2					

Table 6: Normalised Fuzzy Decision Matrix

	T1	T2	T3	T4	R1	R2	R3	R4	R5
HR	0.3125, 0.5208, 0.7083	0.4375, 0.6458, 0.8333	0.5208, 0.7292, 0.8958	0.6042, 0.8125, 0.9792	0.3958, 0.6042, 0.8125	0.3125, 0.5208, 0.7292	0.2292, 0.4375, 0.6458	0.2708, 0.4792, 0.6875	0.4375, 0.6458, 0.8333
PRIVATE	0.2708, 0.4792, 0.6875	0.3125, 0.5208, 0.7083	0.6042, 0.8125, 0.9583	0.2708, 0.4792, 0.6875	0.4792, 0.6875, 0.8542	0.5625, 0.7708, 0.9167	0.3542, 0.5625, 0.75	0.3958, 0.6042, 0.8125	0.6458, 0.8542, 1
DTC	0.3778, 0.6, 0.8222	0.4667, 0.6889, 0.8889	0.3778, 0.6, 0.8	0.6444, 0.8667, 1	0.3333, 0.5556, 0.7778	0.4667, 0.6889, 0.8667	0.4222, 0.6444, 0.8222	0.4667, 0.6889, 0.8889	0.3333, 0.5556, 0.7556
	RE1	**RE2**	**RE3**	**RE4**	**A1**	**A2**	**A3**	**A4**	**E1**
HR	0.4792, 0.6875, 0.8542	0.6458, 0.8542, 1	0.5208, 0.7292, 0.8958	0.3542, 0.5625, 0.75	0.3958, 0.6042, 0.7917	0.4792, 0.6875, 0.875	0.2708, 0.4792, 0.6875	0.3958, 0.6042, 0.7917	0.5625, 0.7708, 0.9167
PRIVATE	0.4792, 0.6875, 0.875	0.4792, 0.6875, 0.8542	0.3542, 0.5625, 0.75	0.2708, 0.4792, 0.6875	0.4792, 0.6875, 0.8542	0.3542, 0.5625, 0.75	0.3125, 0.5208, 0.7292	0.3542, 0.5625, 0.7708	0.3958, 0.6042, 0.7708
DTC	0.3333, 0.5556, 0.7778	0.6, 0.8222, 1	0.6, 0.8222, 0.9778	0.5111, 0.7333, 0.9111	0.4222, 0.6444, 0.8444	0.4222, 0.6444, 0.8222	0.5556, 0.7778, 0.9556	0.3778, 0.6, 0.8222	0.4222, 0.6444, 0.8667
	E2	**E3**	**E4**	**E5**					
HR	0.5208, 0.7292, 0.9167	0.3125, 0.5208, 0.7292	0.2292, 0.4375, 0.6458	0.5208, 0.7292, 0.8958					
PRIVATE	0.5208, 0.7292, 0.875	0.3125, 0.5208, 0.7083	0.4792, 0.6875, 0.875	0.3958, 0.6042, 0.7917					
DTC	0.2444, 0.4667, 0.6889	0.3333, 0.5556, 0.7556	0.3778, 0.6, 0.8	0.5111, 0.7333, 0.9111					

Step 3: Normalising the complex fuzzy decision matrix

The fuzzy decision matrix now normalised (Table 6) by using the formulas

$$\tilde{r}_{ij} = \left(\frac{a_{lij}}{a^*_{uij}}, \frac{a_{mij}}{a^*_{uij}}, \frac{a_{uij}}{a^*_{uij}}\right) \quad i \in B$$

$$\tilde{r}_{ij} = \left(\frac{a^-_{li}}{a_{uij}}, \frac{a^-_{li}}{a_{mij}}, \frac{a^-_{li}}{a_{lij}}\right) \quad i \in C$$

Step 4: Construction of weighted normalised fuzzy decision matrix

With the normalised fuzzy numbers now construct the weighted normalised fuzzy decision matrix (Table 7) by using the formula

$$\tilde{v}_{ij} = \tilde{w}_{I*} \tilde{r}_{ij},$$

i = 1, 2, 3 -----s,

j = 1,2,3,……………,n

Step 5: Calculate the FPIS and FNIS

A* = [(1,1,1), (1,1,1), (1,1,1), (1,1,1), (1,1,1), (1,1,1), (1,1,1)]

A^- = [(0,0,0), (0,0,0), (0,0,0), (0,0,0), (0,0,0), (0,0,0), (0,0,0)]

Step 6: Calculate the distance

The distance for each alternative form FNIS and FPIS can be calculated according to the following formulas:

Table 7: Weighted Normalised Fuzzy Decision Matrix

	T1	T2	T3	T4	R1	R2	R3	R4	R5
HR	1.6875, 3.8542, 6.375	2.1875, 4.5208, 7.1667	2.1875, 4.5208, 7.1667	3.7458, 6.6625, 9.4	2.2958, 4.7125, 7.475	1.8125, 4.0625, 6.7083	1.3292, 3.4125, 5.9417	1.4625, 3.5458, 6.1875	2.7125, 5.2958, 8
PRIVATE	1.4625, 3.5458, 6.1875	1.5625, 3.6458, 6.0917	2.5375, 5.0375, 7.6667	1.6792, 3.9292, 6.6	2.7792, 5.3625, 7.8583	3.2625, 6.0125, 8.4333	2.0542, 4.3875, 6.9	2.1375, 4.4708, 7.3125	4.0042, 7.0042, 9.6
DTC	2.04, 4.44, 7.4	2.3333, 4.8222, 7.6444	1.5867, 3.72, 6.4	3.9956, 7.1067, 9.6	1.9333, 4.3333, 7.1556	2.7067, 5.3733, 7.9733	2.4489, 5.0267, 7.5644	2.52, 5.0978, 8	2.0667, 4.5556, 7.2533
	RE1	**RE2**	**RE3**	**RE4**	**A1**	**A2**	**A3**	**A4**	**E1**
HR	2.2042, 4.5375, 7.175	4.0042, 7.0042, 9.6	3.2292, 5.9792, 8.6	1.7708, 3.9375, 6.45	1.9792, 4.2292, 6.8083	2.3958, 4.8125, 7.525	1.5708, 3.7375, 6.325	1.9792, 4.2292, 6.8083	3.2625, 6.0125, 8.4333
PRIVATE	2.2042, 4.5375, 7.35	2.9708, 5.6375, 8.2	2.1958, 4.6125, 7.2	1.3542, 3.3542, 5.9125	2.3958, 4.8125, 7.3458	1.7708, 3.9375, 6.45	1.8125, 4.0625, 6.7083	1.7708, 3.9375, 6.6292	2.2958, 4.7125, 7.0917
DTC	1.5333, 3.6667, 6.5333	3.72, 6.7422, 9.6	3.72, 6.7422, 9.3867	2.5556, 5.1333, 7.8356	2.1111, 4.5111, 7.2622	2.1111, 4.5111, 7.0711	3.2222, 6.0667, 8.7911	1.8889, 4.2, 7.0711	2.4489, 5.0267, 7.9733
	E2	**E3**	**E4**	**E5**					
HR	2.6042, 5.1042, 7.8833	1.8125, 4.0625, 6.8542	1.3292, 3.4125, 5.9417	3.0208, 5.6875, 8.4208					
PRIVATE	2.6042, 5.1042, 7.525	1.8125, 4.0625, 6.6583	2.7792, 5.3625, 8.05	2.2958, 4.7125, 7.4417					
DTC	1.2222, 3.2667, 5.9244	1.9333, 4.3333, 7.1022	2.1911, 4.68, 7.36	2.9644, 5.72, 8.5644					

$$d_j^* = \sum_{i=1}^{s} d\left(\tilde{v}_{ij}\tilde{v}_i^*\right) \quad j = 1,2,\ldots\ldots s$$

$$d_j^- = \sum_{i=1}^{s} d\left(\tilde{v}_{ij}\tilde{v}_i^-\right) \quad j = 1,2,\ldots\ldots s$$

Table 8: Distance Measurement of Alternatives

Alternative	d*	d-
HR	123.3554	113.9301
Private	124.2437	112.501
DTC	119.1257	119.8863

Step 7: Calculate the closeness coefficient of each alternative using the following formula

$$CC_i = \frac{d_j^-}{d_j^* + d_j^-} \quad j = 1, 2 \ldots.n$$

Table 9: Closeness Coefficient (CC) of Transport Operators

Alternative	CC
HR	0.48014
Private	0.4752
DTC	0.50159

According to the closeness coefficient the three transport operators can be ranked as DTC>HR> Private, from highest to the lowest. The results indicate that DTC is outstanding one. HR performs worse than DTC in terms of T_1, T_2, T_4, R_2, R_3, RE_3, RE_4, E_3, E_4 and E_5. So HR has some more gaps to improve these four factors to improve the service quality to their customers.

Limitations

Following are the limitations of the present work.

1. The researchers had taken 22 items for solving the problem. These items and factors/criteria can be varying in developed and underdeveloped economies. The referred scale is confined to the developed economy. Hence, there may be variation in number of items or factors in other less developed economies.
2. Limited categorisation of the transport operators were considered for the present study. More specific categorisation of operators can be done to have more accurate result.
3. The experts (customers) approached for the present work was restricted to five only. This may affect the result of the research.

Future Research

As, this case had been solved by taking SERVQUAL items developed for different set of context. So, future research can be conducted by developing a new scale for measuring service quality provided by transport operators.

Since, Fuzzy TOPSIS approach was used, so the same work can be replicated by using some other MCDM method or by statistical methods. Future research may also be conducted by categorizing transport operators on different parameters like affiliation, type of service provided etc.

Furthermore, the research can also be conducted to explore that how operators can improve the gaps in each items and factors based on Network Relationship Map (NRM) and capture the complex relationships among these items.

Conclusion

The result of present work had broken a common myth that public services are not at par in comparison to private service provider, specifically in transport sector. In the present research expert opinion or judgment on service items/factors given in SERVQUAL were collected and MCDM technique under fuzzy environment was applied since service quality may be affected by several different factors and perception of the customers may be subjective. The analysis reveals that improved service quality can reduce number of problems associated with traffic congestion, pollution etc.

From Table 9 it can be concluded that DTC is the best service provider for the passengers as compared to Haryana Roadways and private transport operators. Thus, this research submits an idea for comparing the service quality of the public transport operators in NCR for daily passengers depending on several service quality factors/items.

The proposed model provides a great opportunity to the transport operators or decision makers for comparing the performance of their company with other on service quality factors/items.

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Appendix 1

Following questions had been asked for the rating of three operators i.e. Haryana Roadways, Private Operators and Delhi Transport Corporation from the decision expert on the basis of ratings as given the tables below.

Table for Responses

For bus service provider

1	2	3	4	5	6	7
Very poor	Poor	Medium poor	Fair	Medium good	Good	Very good

Haryana Roadways _______________

Private Operator ____________________

Delhi Transport Corporations __________

For the items

1	2	3	4	5	6	7
Very low	low	Medium low	Medium	Medium high	High	Very high

Questions Asked

S.No	Dimensions/ items	1	2	3	4	5	6	7
Tangibles: *It includes the physical appearance of the facility of the service, the personnel, equipment etc.*								
T1	Operator has up to date equipment.	1	2	3	4	5	6	7
T2	Operator's physical facilities are visually appealing.	1	2	3	4	5	6	7
T3	Operator's employees are well dressed and appear neat.	1	2	3	4	5	6	7
T4	The appearance of the physical facilities of operator is in keeping with the type of service provided.	1	2	3	4	5	6	7
Reliability:*It relates to ability of the service provider to perform the promised service accurately and dependably.*								
R1	Operator promises to do something by a certain time, it does so.	1	2	3	4	5	6	7
R2	When you have problems, operator is sympathetic and reassuring.	1	2	3	4	5	6	7
R3	Operator is dependable.	1	2	3	4	5	6	7
R4	Operator provides its services at the time it promises to do so.	1	2	3	4	5	6	7
R5	Operator keep its records accurately.	1	2	3	4	5	6	7
Responsiveness: *It is the willingness of the service provider/ operator to be helpful and prompt in providing service.*								
RE1	Operator's does not tell customers exactly when services will be performed.	1	2	3	4	5	6	7
RE2	You do not receive prompt service from operator's employees.	1	2	3	4	5	6	7
RE3	Employees are not always willing to help customers.	1	2	3	4	5	6	7
RE4	Employees of operators are too busy to respond to customer requests promptly.	1	2	3	4	5	6	7
Assurance: *It refers to the knowledge and courtesy of employees and their ability to inspire trust and confidence.*								
A1	You can trust employees of operator.	1	2	3	4	5	6	7
A2	You feel safe in your transaction with operator's employees.	1	2	3	4	5	6	7
A3	Employees of operators are polite.	1	2	3	4	5	6	7

S.No	Dimensions/ items	1	2	3	4	5	6	7
A4	Employees get adequate support from operator to do their jobs well.	1	2	3	4	5	6	7
Empathy: *It refers to caring, individual attention to the customer.*								
E1	Employees do not give you personal attention.	1	2	3	4	5	6	7
E2	Employees of operator do not know what you needs are.	1	2	3	4	5	6	7
E3	Operator does not give you individual attention.	1	2	3	4	5	6	7
E4	Operator does not have your best interest at heart.	1	2	3	4	5	6	7
E5	Operator does not have operating hours convenient to all the customers.	1	2	3	4	5	6	7