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A methodology for evaluating transit service quality based on subjective and objective measures from the passenger's point of view

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ABSTRACT

In this paper a methodology for measuring transit service quality is proposed. The methodology is based on the use of both passenger perceptions and transit agency performance measures involving the main aspects characterizing a transit service. The combination of these two types of service quality measurement fulfils the need to provide a reliable as possible measurement tool of the transit performance. Considering passenger perceptions is fundamental because the customer's point of view is very relevant for evaluating the performance of a transit service. At the same time, the use of a more objective measurement provided by the transit agency can be a useful solution for obtaining a more comprehensive service quality measurement. The proposed procedure is applied to a real case study of a suburban bus line; a series of subjective and objective indicators are calculated on the basis of users' perception about the service and measurements provided by the transit agency.

1. Introduction

The measurement of transit performance has been, and will continue to be, an important concern for allocating resources among competing transit agencies. Performance measurement is fundamental for assessing management performance of the transit service in relation to community expectations, for assessing management problems regarding costs of the service, and as a monitoring tool for improving the service (Transportation Research Board, 1994). In addition, the measure of performance allows the behaviour of organizations to be compared over time or/and across space (De Borger et al., 2002). A transit performance measure is defined as a quantitative or qualitative factor used to evaluate a particular aspect of a transit service (Transportation Research Board, 2003b). Each performance measure has its own series of indicators. Indeed, scientific research is ever more oriented towards the establishment of appropriate transit performance measures and indicators. Fielding (1987) explores the concept of performance indicators to monitor performance, asserting that "these indicators may not capture every activity of an agency, but they do indicate progress in key areas". In fact, specific measures defining transit performance include efficiency, effectiveness, impact, productivity, and service quality. There is an extensive literature (Fielding et al., 1985) on measuring the efficiency and effectiveness of transit services. Efficiency can be considered as the production of the realized service compared to the invested resources, while effectiveness can be defined as the correspondence of the service to the goal achievement. In addition, efficiency is the relationship of inputs to the produced service (e.g., vehicle kilometres), while effectiveness is the relationship of inputs to the consumed service (e.g., passenger kilometres) (Hensher, 2007). What is important and vital in the performance and delivery of a transit service depends significantly upon perspective (Transportation Research Board, 2003a). As an example, traditional cost efficiency indicators (e.g., operating expense per vehicle revenue kilometre and/or hour) and cost-effectiveness indicators (e.g., operating expense per passenger kilometre and/or passenger trip) can be considered as performance measures from the transit agency perspective, while they are not linked to customer-oriented and community issues, which are fundamental perspectives (Transportation Research Board, 2003a). Passengers evaluate services in many ways that may not be systematically associated with the amount of use of the service, because the measures of efficiency and effectiveness, as aggregate indicators of total output, implicitly assume homogeneity of service quality (Hensher, 2007), which is the overall measured or perceived transit performance from the passenger's point of view (Transportation Research Board, 2003b). It should be added that many researchers consider the customer's point of view the most relevant for evaluating transit performance; as an example, Berry et al. (1990) pointed out that "customers are the sole judge of service quality".

Service quality can be evaluated by considering customer perceptions and expectations, or by a range of simple disaggregate performance measures which can be used for measuring the ability of the transit agency to offer services that meet customer

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expectations (Transportation Research Board, 1999). These performance measures are quantitative measures expressed as a numerical value, which provides no information by itself about how "good" or "bad" a specific result is, and for this reason it must be compared with a fixed standard or past performance. Instead passengers' perceptions are qualitative measures of transit service quality. These measures generally derive from the well-known Customer Satisfaction Surveys (CSS), which help transit operators to identify which service quality factors are considered the most important by their customers. Indeed, CSS can also be used to help prioritize future quality of service improvement initiatives, measure the degree of success of past initiatives, and track changes in service quality over time (Transportation Research Board, 2003b). Through the CSS, passengers express their judgments about some attributes describing the service according to a pre-defined scale of evaluation. Actually these judgements can be considered a subjective measure of service quality, while the performance measures provided by transit operators can be considered an objective measure of service quality.

Both these different kinds of transit performance measures support transit agencies for monitoring, evaluating, and implementing improvements in service. For this purpose transit agencies might be interested in collecting a wide array of information, but the cost of collecting and analysing a large amount of transit performance and service quality data presents a constraint to transit agencies. As a result, data collection and analysis activities should be concentrated on those aspects of transit service that are crucial and that more accurately reflect the needs of customers and potential customers. The objective is to match the most important perceptions to specific aspects of transit service and to identify one or more corresponding service performance indicators (Transportation Research Board, 1999).

Ultimately, both passenger perceptions and objective measures provided by transit agencies are fundamental for evaluating the performance of a transit service, even if they provide service quality measures from different points of view. Therefore, the combination of these two types of service quality measure could provide a useful and reliable measurement tool of transit performance. The aim of this research is to propose a methodology which provides a way for evaluating transit service quality by considering both subjective and objective measures of service performance.

2. Literature review

In the literature, there is an amount of studies regarding user perceptions about the different transit service aspects or performance measurement by indicators; whereas few studies deal with the topic of transit service quality by considering both subjective and objective measures of transit performance.

In the following, some examples of the most recent studies regarding the subjective measures are briefly described.

Some studies propose qualitative or quantitative analyses based on simple statistical techniques.

As an example, Friman (2004) examined whether quality improvements have effects on satisfaction with public transport services and frequency of perceived negative critical incidents. Respondents evaluated Swedish transit services by checking a nine-point scale from 'very dissatisfied' to 'very satisfied'. The most important finding of the study is that the satisfaction people experience when using public transport services is influenced by quality improvements only to a limited extent. Moreover, Beirão and Sarsfield-Cabral (2007) propose a qualitative study of public transport users and car drivers in order to obtain a deeper understanding of travellers' attitudes towards transport and to explore perceptions of public transport users. 24 in-depth interviews were addressed to regular and occasional users of public transport and car users. This qualitative study highlighted some key factors influencing mode choice. In fact, the key findings indicate that in order to increase public transport usage, the service should be designed in a way that accommodates the levels of service required by customers and by doing so attract potential users.

Subsequently, Tyrinopoulos and Antoniou (2008) propose a methodology based on the application of two different statistical methods, factor analysis and ordered logit modelling, for analysing the variability of the users' behaviour and their level of satisfaction from the use of diverse transit systems. This methodology is applied to five different transit systems in Greece; survey respondents were asked to rate 23 selected attributes according to importance and satisfaction criteria. The data collected from the first set of questions were used as input for the factor analysis, while the second set of data was used as input for the ordered logit models. The objective of the factor analysis is to try to discern and recognize the underlying unobserved factors that the respondents perceive.

Also, Iseki and Taylor (2008) examined transit users' perceptions of the quality of service and infrastructure at bus stops and train stations around metropolitan Los Angeles. In this study, an importance–satisfaction analysis was effected to examine which stop and station attributes matter most in transit users' experience. To this purpose, satisfaction and importance rates were expressed by a four-point Likert scale and verbal scale, respectively. Ordered logistic regression models were proposed for measuring the influence of 16 stop/station attributes on users' overall satisfaction with their wait/walk/transfer experience.

Other studies adopted more advanced statistical techniques, like path analysis, latent variable and structural equation models. Some examples are reported in Joewono and Kubota (2007), Stuart et al. (2000), Eboli and Mazzulla (2007), and Nurul-Habib et al. (2009).

Specifically, Joewono and Kubota (2007) examine the condition of private paratransit in Indonesia from the user's point of view in order to balance the judgment from other stakeholders. This research employs the path analysis and binomial regression method to reveal and explore the data. Path analysis was employed to reveal the relationship among variables and to examine the predictive power of several variables on overall satisfaction with paratransit. Analysis using the binomial logistic regression is able to distinguish the loyal users by exploring their characteristics.

In Stuart et al. (2000), and in Eboli and Mazzulla (2007) structural equation models are formulated in order to explore the impact of the relationship between global customer satisfaction and transit service quality aspects. In this approach, users expressed a judgement in terms of rate according to a numerical scale from 1 to 10 about some service aspects and the overall service. Through this type of model the strength of the relationships can be quantified and compared with one another in terms of both direct and indirect effects.

Nurul-Habib et al. (2009) developed a multinomial logit (MNL) model combined with latent variable models for capturing unobserved latent variables in defining perceptions and attitudes. The paper presents a critical investigation of reasons for using transit expressed as a function of peoples' perception and attitude towards transit service quality and attributes. Essentially, the authors focus only on transit users in order to find influential factors. The respondents are required to scale their satisfaction along a scale from 1 to 5. In addition to other questions, the respondents were asked to identify the main reason of using transit rather than any other modes of transportation. As a matter of fact the latent variable model can be used to connect the relationship between the reason for choosing transit rather than other modes of transportation and variables defining the perception or attitude towards transit service.

Other research is based on the analysis of service quality by means of the user perceptions expressed in terms of choice. Choice data were collected from experiments based on stated preferences (SP) techniques, in which the interviewed users make a choice among some alternative services characterized by some service quality attributes varying on more levels. Therefore, by logit model estimation, the importance of each service attribute on overall service quality can be evaluated. In Prioni and Hensher (2000) and in Eboli and Mazzulla (2008a, 2010) choice data were used to calibrate MNL models. SP data were used for calibrating mixed logit models proposed in Hensher (2001) and in Eboli and Mazzulla (2008b) in order to explore observed and unobserved heterogeneity among users. Furthermore, a nested logit model was proposed in Hensher et al. (2003) for comparing the service quality levels within and between some bus operators.

In addition to the methods of service quality measure based on passenger perceptions, in the literature there are also some examples of research studies about the objective performance measures.

The Transportation Research Board, through the Transit Cooperative Research Program, developed interesting researches about service quality measures, summarized in some reports in which the different transit service aspects are widely and fully described (Transportation Research Board, 1999, 2003a, 2003b). In these reports five categories of service quality measures are defined: availability in terms of passengers' ease of access and use of transit service, service monitoring, travel time, safety and security in terms of real and perceived chances of being involved in an accident or being the victim of a crime while using transit, and maintenance and construction. For each service quality aspect some examples of objective measures are suggested.

A study of Bertini and El-Geneidy (2003) describe how an archived database of Bus Dispatch System data can be used to generate performance measures that should be prepared by transit agencies in order to measure their own performance and help them to increase their service standards and effectiveness to the population. Here the authors recommend a series of measures related to transit accessibility, mobility and economic development.

Actually, few studies have analysed both traveller satisfaction and transit performance measures; examples are reported in Tyrinopoulos and Aifadopoulou (2008) and Nathanail (2008).

Tyrinopoulos and Aifadopoulou (2008) propose a methodology for the quality control of passenger services in the public transport business. Essentially the work provides an overview of the methodology developed by the Hellenic Institute of Transport to assess the levels of quality and performance of public transport services. Here 39 indicators are analysed, classified in the following seven categories: safety–comfort–cleanliness; information–communication with the passengers; accessibility; terminals and stop points performance; lines performance; general elements of the public transport system; compound indicators based on the results of the indicators of the previous categories. Among the compound indicators, a customer satisfaction measure is considered in order to take into account customer perceptions. In fact, the authors suggest using factor analysis and multinomial logistic regression for investigating the influence of the operational performance indicators of the transportation system on customer satisfaction.

Nathanail (2008) presents a framework developed for assisting railway operators into monitoring and controlling the quality of services provided to their passengers. This framework is based on the estimation of 22 indicators, grouped under six criteria (itinerary accuracy, system safety, cleanness, passenger comfort, servicing, and passenger information). The valuation of the indicators is achieved through the analysis of quantitative, as well as qualitative parameters obtained either from statistical sources maintained by the railway operator, or data gathered from a questionnaire survey addressed to passengers, in which the service quality aspects are judged according to a scale from 1 to 10. In the work both objective indicators and subjective judgments of the passengers are analysed; in order to estimate an overall performance index, the objective and subjective indicators are scaled according to the same scale and combined through a multicriteria analysis.

As far as the authors' know, there are no studies in which subjective and objective measures of transit performance are jointly analysed and combined in a single output measure. Linking transit riders' perspectives to objective disaggregate measures of transit performance is very important in order to allow the agency both to evaluate its service and to define realistic and measurable goals for service improvements (Transportation Research Board, 1999). Clearly, the consideration of passengers' perceptions alone can lead to many biases especially when users' judgements are too heterogeneous; in addition, subjective measures are based on transit users' opinions, while non-users' perceptions are not considered. On the other hand, a specific objective indicator could be not appropriate for evaluating a transit service aspect, or could describe not exhaustively a transit service aspect characterized by various factors.

3. Methodology

3.1. Logical basis

The proposed methodology is based on the calculation of an indicator for each service aspect which combines both subjective and objective indicators, by taking into account passenger perceptions and performance measures. The methodology aims to develop an indicator which assumes an intermediate value between the subjective and objective measures of service quality, calculated by considering the bias of the two different measures. The final indicator can be obtained by solving a problem of optimization which minimizes the distance of the desired indicator from the subjective and objective ones. Indeed, the proposed methodology yields a meaningful service quality measure because it is based on two basic concepts: (1) both subjective and objective measures are equally important for evaluating service quality, and (2) the most reliable measure gives the most contribution to the final indicator.

Subjective indicators can be calculated on the basis of transit user expectations and perceptions. Expectations are generally expressed by the customers through the indication of a level of importance; perceptions, instead, are expressed by a judgement of satisfaction. Customer satisfaction can be evaluated by collecting customer perceptions alone, or through the comparison between expectations and perceptions (Parasuraman et al., 1985). In this case, users express their judgments about the services according to a pre-defined scale of measure, which can be qualitative (e.g. Likert and verbal scale) or quantitative (e.g. numerical scale).

Objective measures can be derived from different sources of data. A number of performance measures can be calculated from information an agency would normally have on hand for other purposes (schedule data, system maps, service design standards, accident and incident records, financial data, fleet data, complaint records, and so on). Moreover, alternative data can be national transit database, information provided by other transit agencies, data collected by automated vehicle locators (AVL), manual data collection provided by operators, trained checkers or field supervisors. A particular form of manual data collection can be represented by the Passenger Environment Surveys (PES), which generally assess qualitative elements which are difficult to measure by any other way. In fact, PES use a "secret shopper" technique, according to which mystery riders travel through the transit system and rate a variety of trip attributes in order to provide a quantitative evaluation of factors that passengers would think of qualitatively (Transportation Research Board, 2003a). In this way the objective indicators are generally compared with standards, which can be represented by annual averages, baselines, trend analyses, self-identified values, and typical industry standards (Transportation Research Board, 2003a). Alternatively, the performance indicators can be expressed in a format that provides built-in interpretation. An example of such formats is represented by levels of service (LoS) developed for evaluating transit service quality analogously to those developed by the Highway Capacity Manual (Transportation Research Board, 2003b). Another format is represented by ratios, which are developed by dividing one individual measure by another; they facilitate comparisons between routes, areas, or agencies. Finally, index measures are adopted when service quality aspects involve a number of different factors; these indexes combine results from several other performance measures in an equation to produce a single output measure (Transportation Research Board, 2003a).

In the development of the proposed methodology the subjective indicators were calculated by the average of the satisfaction rates expressed by a sample of users about some transit service aspects according to a scale from 0 to 10. On the other hand, the objective indicators were calculated on the basis of pre-defined parameters (P). The majority of the indicators were calculated by comparing the value of the parameter with a standard of quality (S). In order to obtain these indicators the criterion proposed by Nathanail (2008) was adopted, according to which grade zero is given to the indicator (I) in case that the parameter is higher than or equal to the double of the standard; ten, when it is less than the standard; the intermediate grades (between 0 and 10), proportionally, for the intermediate cases. In this last case I is calculated according to the following formula:

$$I=\left[\frac{2S-P}{S}\right]\times 10 \tag{1}$$

A part of the indicators were calculated as the ratio of the value assumed by the parameter to the maximum value that the parameter can assume; this ratio, which naturally has a value between 0 and 1, is easily changed into a 0–10 score.

Finally, for the most qualitative service attributes the indicators were calculated as the average of the scores assigned by operators or mystery riders to the parameters defining the indicators, in order to provide a quantitative evaluation; specifically, they expressed the scores according to a scale from 0 to 10.

The parameters used for calculating the indicators are random variables, since their values vary over time and/or space. So, for each parameter the average value and the variance from the mean are calculated on the basis of the sample surveys. The variance of the indicator is calculated starting from the variance of the parameter, by using the well-known variance properties.

3.2. Mathematical formulation

The mathematical formulation of the proposed procedure is described in the following.

Let $\overline{S}_k$ denotes the average rate of satisfaction (user perception) about a k generic service attribute expressed by a sample of interviewed users according to the specific scale of evaluation. We consider the $\overline{S}_k$ value as the estimated value of the k subjective indicator. The distance between the estimated value for the k indicator and the actual value of the indicator (S_k) is represented by the average error about the perception of the indicator (ε_k^{PER}):

$$\overline{S}_k=S_k+\varepsilon_k^{PER} \tag{2}$$

The ε_k^{PER} error is mostly due to the heterogeneity among the judgements expressed by the users. Indeed, this heterogeneity may depend on the qualitative nature of some aspects, the different attitudes of the users towards the use of transit services and their aspects, the user social background.

Let $\overline{O}_k$ denotes the estimated value of the objective performance indicator of the k generic service attribute calculated on the basis of transit agency information and converted to the same scale of evaluation adopted for the satisfaction rates. Also in this case, the distance between the estimated value for the k indicator and the actual value of the indicator (O_k) is represented by the average error (ε_k^{OBS}) representing the error observed in the measure of the $\overline{O}_k$ indicator

$$\overline{O}_k=O_k+\varepsilon_k^{OBS} \tag{3}$$

The value of ε_k^{OBS} represents the difference between the actual value of the indicator and a value calculated from elements intrinsically containing errors of measuring because measured by instruments and equipment (e.g. the length of a line path), or calculated as mean of elements which can have different values varying with the survey period; these elements represent random variables for which an average value is considered (e.g. operating speed, number of road accidents per year).

Actually, the more the judgments expressed by the users are homogenous, the more the estimated value of $\overline{S}_k$ is reliable. The $\overline{O}_k$ values are generally more reliable than the $\overline{S}_k$ values because the $\overline{O}_k$ indicators are calculated on the basis of almost accurate measurements effected in different periods but not very variable among the periods (e.g. number of cleaning services per week, service frequency). However, the objective indicators represent service quality measures which do not take into account user perceptions. Therefore, a univocal estimation of the indicator of the generic service attribute named X_k can be conveniently obtained by combining the subjective indicator with the objective one, and by assuming that the X_k indicator tends at the same time to the value of S_k and O_k. Therefore:

$$S_k=O_k=X_k \tag{4}$$

By considering m service attributes adopted for describing service quality of a transit system, we have the following expressions of the indicators in terms of vectors:

$$\overline{\mathbf{S}}=\mathbf{S}+\boldsymbol{\varepsilon}^{PER} \tag{5}$$

$$\overline{\mathbf{O}}=\mathbf{O}+\boldsymbol{\varepsilon}^{OBS} \tag{6}$$

$$\mathbf{S}=\mathbf{O}=\mathbf{X} \tag{7}$$

in which all the vectors have a $[m\times 1]$ dimension.

The $\mathbf{X}$ vector can be obtained by solving a problem of optimization with a constraint, by maximizing a $Z[\mathbf{X}]$ objective function which is sum of the $Z_1(\overline{\mathbf{S}},\mathbf{X})$ and $Z_2(\overline{\mathbf{O}},\mathbf{X})$ functions; these functions can be considered as measures of the distances between the $\mathbf{X}$ vector and the $\mathbf{S}$ and $\mathbf{O}$ vectors, respectively

$$\mathbf{X}^*=\underset{\mathbf{X}\geq 0}{\operatorname{argmin}}[Z(\mathbf{X})]=\underset{\mathbf{X}\geq 0}{\operatorname{argmin}}[Z_1(\overline{\mathbf{S}},\mathbf{X})+Z_2(\overline{\mathbf{O}},\mathbf{X})] \tag{8}$$

Through the above expression the $\mathbf{X}$ vector, which is at a minimum distance from the subjective and objective estimated indicators, can be obtained.

The functional structure of $Z_1(\bar{\mathbf{S}},\mathbf{X})$ and $Z_2(\bar{\mathbf{O}},\mathbf{X})$ varies with the nature of the information which can be experimental measures deriving from surveys or not experimental measures deriving from models, and which depend on the probability distribution associated with the information. If the information is collected from experimental surveys we can adopt the statistical theory, and specifically the generalized least square (GLS) method which provides the estimation of a parameter vector starting from a system of linear stochastic equations. This system can be obtained starting from the expressions of the indicators in terms of vectors by considering the hypothesis for which $\bar{\mathbf{S}}$ and $\bar{\mathbf{O}}$ are correct estimators of the **S** and **O** vectors; in this case ε^{PER} and ε^{OBS} are random vectors with mean equal to 0

$$E(\varepsilon^{PER}) = 0 \tag{9}$$

$$E(\varepsilon^{OBS}) = 0 \tag{10}$$

Let **P** and **M** denote the $[m \times m]$ matrices of the variances and co-variances of the above mentioned vectors; the matrix elements can be calculated by using the expressions of the variances and co-variances for the sample estimations. The GLS estimator of the **X** vector can be obtained as

$$\mathbf{X}^{GLS} = \underset{\mathbf{X} \in I}{\operatorname{argmin}}[(\bar{\mathbf{S}}-\mathbf{X})^T \mathbf{P}^{-1}(\bar{\mathbf{S}}-\mathbf{X}) + (\bar{\mathbf{O}}-\mathbf{X})^T \mathbf{M}^{-1}(\bar{\mathbf{O}}-\mathbf{X})] \tag{11}$$

By assuming that **P** and **M** are diagonal (co-variances among the errors equal to 0) the optimization problem has the simplified expression

$$\mathbf{X}^{GLS} = \underset{\mathbf{X} \geq 0}{\operatorname{argmin}}[Z(\mathbf{X})] = \underset{\mathbf{X} \geq 0}{\operatorname{argmin}} \left[\sum_{k=1}^{m} \frac{(\bar{S}_k - X_k)^2}{\operatorname{var}(\varepsilon_k^{PER})} + \sum_{k=1}^{m} \frac{(\bar{O}_k - X_k)^2}{\operatorname{var}(\varepsilon_k^{OBS})} \right] \tag{12}$$

This expression means that the estimation of the **X** vector is the $\mathbf{X}^{GLS}$ vector, which minimizes the sum of the standard deviations of **S** and **O** vectors from $\bar{\mathbf{S}}$ and $\bar{\mathbf{O}}$ sample estimation. The standard deviations are weighted in inverse proportion to the variances of the errors; this fact entails that the deviation of the sample estimation from a component of the **X** vector will weigh the more the variability of the sample values from the mean values is. If the variance of an indicator is very low (close to 0) the X value coincides with the O indicator, by ignoring S indicator, and vice versa. The simplified optimization problem can be solved by calculating the partial derivatives of the $Z(\mathbf{X})$ objective function.

4. Application

4.1. Study case

The study area is the single built-up area made up of the towns of Cosenza and Rende, sited in the South of Italy. This urban area has grown over the years also thanks to the presence of the University of Calabria, which expanded in the North of Rende at the beginning of the seventies. Cosenza and Rende is a centre of attraction for all the towns of the whole province, because of the administrative functions, job opportunities and supply of services. The urban area has about 110,000 inhabitants. In addition, a fair proportion of university students from other places of Calabria lives in Rende or Cosenza; the students attending the University of Calabria are approximately 35,000. The total number of people employed in the urban area is about 46,000. About 41% of the employed works in the public sector, about 41% in the business or the other private services, only 10% in the industry sector and 9% in the agriculture one.

The analysed transit service is a suburban bus service offering the connection between the urban area and some small villages sited in the North of Cosenza. The bus service is the sole public transport service available in this very low density suburban area.

A sample survey was addressed to the habitual passengers of a bus line in order to have a service quality measure based on the user perceptions. In addition, some information given by the transit agency offering the analysed bus services or derived from data gathering were collected. The bus line covers a distance of about 19 km, and the route has 23 bus stops. Daily service time is about 14 hours, from 6.00 a.m. till 8.00 p.m.; service frequency is about 1 run/h in the period from 6.00 a.m. till 2.00 p.m., and in the afternoon only two runs are delivered. Also, the ticket cost varies with the distance, from a minimum fare of 50 Euro cents to a maximum of 1.50 Euros. There are about 800 passengers travelling daily on the bus line in a catchment area of about 8500 inhabitants. Therefore, these numbers imply that the modal split is inclined towards the private car.

The survey was realized in the spring of 2008, when an operator effected face-to-face interviews on board, during the service time. As a result 123 passengers were interviewed and their characteristics are reported in Table 1. Out of 123 respondents, there are 75 females. Most of the sample is younger than 20 years old and 28% of the respondents are employed and 54% are students. About 68% of the sample belongs to a middle class of family income and about 24% to a lower class; the remaining 8% of the sample belongs to an upper class of family income. The classes of income refer to the net monthly income of the family unit, expressed in Euros. The number of members in a family unit is 3.8 on average. Each family has 1.8 cars on average.

Basically users evaluated 26 service attributes regarding the following service aspects: route and service characteristics, reliability, comfort and cleanliness, fare, information, safety and security, personnel and customer services, and environmental protection. Users expressed a rate of satisfaction on each attribute, according to a scale of evaluation from 0 to 10; in addition, a rate of satisfaction on overall service was requested. Moreover, the analysis of the user satisfaction was made on the basis of the perceptions of the 123 interviewed passengers; the data collected in terms of rates of satisfaction were used for calculating a subjective indicator for each service quality attribute.

Objective indicators were calculated for 22 service attributes, because for four attributes there were not elements for the calculation of an objective indicator. A detailed description of the service attributes and the calculation of the objective indicators is reported in the following.

Table 1
General characteristics of the respondents (n=123).

Characteristics	Statistics
1. Gender	Male (39%), female (61%)
2. Age	$<=$20 (49%), 21–40 (31%), 41–65 (16%), $>$65 year-olds (4%)
3. Place of living	Urban area (5%), small villages (95%)
4. Family members	1 (2%), 2 (11%), 3 or more members (87%)
5. Employment	Employed (28%), unemployed (7%), housewife (4%), student (54%), pensioner (7%)
6. Family income level	$<=$1000 (24%), 1000–2000 (46%), 2000–3000 (17%), 3000–4000 (5%), 4000–5000 (2%), $>$5000 Euros (6%)
7. Car driving licence ownership	Did not own car driving license (53%), own car driving license (47%)
8. Family members with car driving licence	0 (1%), 1 (13%), 2 (36%), 3 or more members (50%)
9. Family car ownership	0 (4%), 1 (27%), 2 (44%), 3 or more members (25%)
10. The way to reach stop	Walking (84%), others (16%)
11. Ticket kind	One-way ticket (33%), one-day travel card (29%), monthly travel card (37%), other (1%)

4.2. Service quality attributes

4.2.1. Route and service characteristics

The attributes belonging to this category are represented by characteristics of the route in terms of path, number of bus stops and distance between bus stops, location of the bus stops, and characteristics of the service, like service frequency and daily service time. Anyway, all the indicators regarding these service attributes were calculated by adopting the criterion of Nathanail (2008).

The indicator regarding line path was evaluated on the basis of the travel speed of the runs observed during the survey period. The values of travel speed were provided by the agency: an operator registered the travel times of a sample of runs. For calculating the indicator a standard equal to 20.45 km/h was assumed, which corresponds to a LoS "B" as reported in the TCRP Report 26 (Transportation Research Board, 1997).

The indicator of the attribute "number of bus stops and distance between bus stops" was calculated on the basis of the stop spacing, which is the average distance between transit stops. The value of the indicator was calculated by considering a standard of stop spacing of 1400 m, as suggested in the TCRP Report 100 (Transportation Research Board, 2003b).

The indicator of the bus stop location was calculated on the basis of the walking distance to transit. Walking times from home to the access bus stop of a sample of users were registered. A standard equal to 5 min was assumed; the standard corresponds to a distance of 400 m walked at an average speed of 5 km/h, as reported in TCRP Report 100 (Transportation Research Board, 2003b).

Another aspect is service frequency, which measures how often transit service is provided; the indicator regarding service frequency was calculated as average value of the number of runs scheduled for each hour of the day. A standard of 2 runs/h was adopted, which is suggested as the standard for small cities (Transportation Research Board, 2003b).

Finally, the daily service time indicates how long service is provided during a day. The indicator was calculated as average value of the number of service hours per day in the different periods of the year (winter, summer, etc.). A standard of 17 service hours per day was adopted, which corresponds to a LoS "B" as reported in the TCRP Report 100 (Transportation Research Board, 2003b).

4.2.2. Service reliability

Service reliability is a very important aspect for the transit users. We considered reliability as the ability of the transit system to adhere schedule, as well as the ability of the transit vehicles to depart or arrive on time.

Essentially, the "reliability of runs that come on schedule" was evaluated on the basis of the runs removed from the daily schedule. The indicator was calculated as the ratio of the number of runs executed in a period of data gathering to the number of runs scheduled for the same period. The number of runs was registered in different days of the same time period by a transit operator.

The "punctuality of runs that come on time" was evaluated by considering the percentage of transit vehicles departing or arriving at a location on time. The indicator was calculated as the ratio of the number of runs that come on time to the number of total runs. The number of runs on time was surveyed by a transit operator in different days of the same time period. We considered on-time the runs up to 1 min early and up to 5 min late, as suggested by the TCRP Report 100 (Transportation Research Board, 2003a).

4.2.3. Comfort and cleanliness

Comfort and cleanliness are purely qualitative service aspects, which can be related to the vehicles or to the stops. Comfort on board can be a function of many aspects; in this study it was described by bus crowding, air conditioning, and cleanliness of bus interior and exterior. In addition, comfort at bus stops was considered as a function of the amenities provided at the stops.

The indicator regarding bus crowding was calculated on the basis of the number of passengers per run (pax) and the number of offered seats per run (s). Differently from the other adopted criteria, for calculating this indicator the following formula has been introduced:

$$\begin{cases} [1-(pax/s)^2]\times 10 & \text{for } pax \le s \\ 0 & \text{otherwise} \end{cases} \tag{13}$$

The indicator has values close to 10 when the number of passengers is small, and to 0 when the number of passengers is equal to or higher than the number of available seats. A manual operator collected the data regarding passenger loading on a sample of runs.

The indicator linked to air conditioning on bus was calculated on the basis of the percentage of vehicles with functioning climate control systems. The indicator was calculated as the ratio of the number of buses with the functioning air conditioning system to the total number of buses used for the line. A trained checker verified the functioning of the air conditioning in different days of the same time period.

The indicator of the attribute "availability of shelter and benches at bus stop" was evaluated on the basis of a score assigned to each stop of the line, from a minimum value of 0 to a maximum value of 10. The minimum value was assigned to the stops without any kind of furniture; the maximum value to the stops with shelter and benches. Finally, the indicator was calculated as the average value of the scores assigned to all the line stops.

The indicators regarding cleanliness were calculated by adopting the criterion of Nathanail (2008). The indicator regarding the attribute "cleanliness of bus interior, seats and windows" and "cleanliness of bus exterior" were calculated on the basis of the frequency of interior cleaning and exterior washing, respectively. Standards of 7 interior cleaning services and 3 exterior washing services per week were assumed (Transportation Research Board, 1995). The number of cleaning services was calculated as average value for the same line in the period of data gathering.

4.2.4. Fare

The indicator regarding ticket cost was calculated by adopting the criterion of Nathanail (2008) on the basis of the average one-way ticket cost. We considered a standard of 1.67 Euro, which corresponds to the average cost of the tickets for similar services adopted by the transit agencies operating in a region of Italy characterized by high standards of transit service quality.

4.2.5. Information

The service aspect regarding the level of information provided to the users was evaluated by considering the availability of information on board and at bus stops.

The indicator of the attribute "availability of schedule/maps on bus, and announcements" was calculated as the ratio of the number of vehicles with functioning information device on board to the total number of vehicles sampled in a certain time period. A trained checker verified the functioning of the information devices on different days during the same time period.

In addition, the indicator of the attribute "availability of schedule/maps at bus stops" was evaluated on the basis of a score assigned to each stop of the line, from a minimum value of 0 to a maximum value of 10. The minimum value was assigned to the stops without any kind of information device at the stop; the maximum value to the stops with schedule and maps. The indicator was calculated as average value of the scores assigned to all the line stops.

4.2.6. Safety and security

Safety refers to the possibility of being involved in a road accident, while security to the possibility of becoming the victim of a crime. The service aspects linked to safety and security were evaluated by considering safety on board, and security on board and at bus stops. The indicators of these service attributes were calculated by adopting the criterion of Nathanail (2008).

The indicator of the attribute "vehicle reliability, safety and competence of drivers" was calculated on the basis of the number of road accidents verified during the last year. We considered as a standard the average number of road accidents verified during the last three years.

The indicators of the attributes "security against crimes on bus" and "security against crimes at bus stops" were calculated on the basis of the number of complaints registered during the last year. The assumption of the standard was made according to the same criteria adopted for safety.

4.2.7. Personnel and customer services

Personnel behaviour was described by personnel appearance and helpfulness. Personnel appearance was evaluated by means of trained checkers who verified if personnel use the uniform. The indicator was calculated as the ratio of the number of uniformed staff to the total staff number. The check on personnel was executed in different days of the same time period.

Personnel helpfulness was evaluated by means of a mystery rider who verified the behaviour of the personnel and assigned a score to each personnel unit, according to a scale from 0 to 10.

Among customer services we consider ease of purchasing the ticket. The indicator of this attribute was defined by taking into account the only opportunity of purchasing the tickets on bus by a manual operator or automatic ticket machines. The indicator was calculated as the ratio of the number of vehicles with functioning automatic ticket machines to the total number of vehicles sampled in the period of data gathering. A trained checker verified the functioning of the automatic ticket machines in different days of the same time period.

4.2.8. Environmental protection

The service aspect regarding environmental protection was evaluated by considering the use of ecological vehicles. The indicator was calculated as the ratio of the number of vehicles in keeping with the CE 2001/27/CEE regulation to the total number of vehicles of the line. The indicator is invariant in the period of data gathering.

4.3. Comparison between indicators

The values of all the indicators calculated are shown in Table 2. Specifically, the table reports, for each k service attribute, the mean and standard deviation of the subjective indicator (S_k), the mean and standard deviation of the parameter (P_k) used for calculating the objective indicator, the values of the objective indicator (O_k), and the indicator calculated through the proposed methodology (X_k).

By observing the average values of the subjective indicators, almost all the attributes are satisfactory showing a satisfaction score higher than 6.Specifically, there are three very satisfactory

Table 2
Calculation of the indicators.

Service aspect	Attribute	**S** (mean)	**S** (st. dev.)	**P** (mean)	**P** (st. dev.)	**O** (mean)	**X**
Route characteristics	1. Path	8.06	1.83	23.73	1.31	10.00	9.69
	2. Number of stops and distance between stops	8.19	1.71	1.57	0.08	8.79	8.35
	3. Bus stop location	8.48	1.90	5.32	9.97	9.37	8.52
Service characteristics	4. Service frequency	7.06	2.00	0.63	0.26	0.00	5.41
	5. Daily service time	7.08	2.02	14.25	0.06	6.76	6.77
Service reliability	6. Reliability of runs that come on schedule	8.77	1.58	0.97	0.00	9.71	9.70
	7. Punctuality (runs that come on time)	8.48	1.83	0.61	0.00	6.06	6.25
Comfort	8. Bus crowding	8.93	1.51	0.74	0.00	7.35	7.49
	9. Comfort of seats on bus	7.97	2.16	–	–	–	–
	10. Air conditioning on bus	7.36	2.95	0.90	0.33	9.00	8.88
	11. Levels of noise and vibrations on bus	7.15	2.86	–	–	–	–
	12. Availability of shelter and benches at stop	5.41	2.90	3.69	9.62	3.69	4.89
Cleanliness	13. Cleanliness of bus interior, seats and windows	7.98	1.95	6.67	0.17	9.06	8.89
	14. Cleanliness of bus exterior	7.53	2.02	2.67	0.17	7.80	7.67
Fare	15. Ticket cost	8.44	2.04	0.93	0.01	10.00	9.75
Information	16. Availability of schedule/maps on bus, and ann.	7.50	2.86	0.80	0.33	8.00	7.96
	17. Availability of schedule/maps at stops	3.63	2.35	1.15	2.40	1.15	2.30
	18. Availability of information by phone, mail.	7.79	2.20	–	–	–	–
Safety and security	19. Safety and competence of drivers	8.66	1.92	5.00	0.13	10.00	9.84
	20. Security against crimes on bus	9.28	1.24	2.00	0.17	10.00	9.66
	21. Security against crimes at bus stops	7.41	2.27	1.00	0.13	10.00	9.40
Personnel	22. Personnel appearance	9.29	1.14	0.95	0.17	9.50	9.46
	23. Personnel helpfulness	8.46	2.01	9.60	0.15	9.60	9.52
Customer services	24. Ease of purchasing the ticket	9.39	1.16	0.98	0.13	9.75	9.69
	25. Administration of complaints	7.98	2.29	–	–	–	–
Environmental protection	26. Use of ecological vehicles	6.85	2.73	0.80	0.00	8.00	8.00

attributes: "ease of purchasing the ticket", "personnel appearance", and "security against crimes on bus". If we consider only the subjective indicators as measures of service quality, only two attribute can be considered as critical service aspects, because the users assign them an average rate lower than the sufficiency. Specifically, the attribute "availability of shelter and benches at bus stop" is unsatisfactory, and the attribute "availability of schedule/maps at bus stops, and announcements" is very unsatisfactory. Regarding the variability of user satisfaction, we can observe that the judgements on perceived quality are not very homogeneous; in fact, the standard deviations of the satisfaction rates of the service attributes vary from 1.14 to 2.95 (average value of 2.05) from an average satisfaction rate of 7.81. The attributes with the most homogeneous judgements are also the most satisfactory ones; on the contrary, the only two unsatisfactory attributes have very heterogeneous judgements. In fact, the attributes with the most heterogeneous judgements are the service characteristics regarding comfort and information. Comfort aspects are heavily influenced by user tastes. As an example, the high variability of the judgments about the attribute "air conditioning on bus" can be due to the strong subjectivity of this service aspect; user opinions, in fact, are motivated from their personal tastes about the temperature on board, rather than the functioning of the air-conditioning system. Actually, the heterogeneity of user judgments about information aspects can be influenced by user attitudes and experience of consulting and acquiring information, and by the attendance in using the transit services; in fact, as an example, an habitual user could consider a service providing low levels of information as a good service because he knows the service and does not need information about it.

By analysing the average values of the objective indicators, we can observe very high values for the most satisfactory attributes; in the same way, we can observe very low values for the most unsatisfactory attributes. Therefore these results prove that user judgements are unbiased enough. On the other hand, the objective measures of service quality are less variable than the subjective ones, as we can observe from the values of the standard deviations of the parameters adopted for calculating the indicators. The most variable parameters are linked to the attributes for which the value varies over space, and particularly for the attributes regarding amenities and information at bus stops, and stop location; these attributes are also the most unsatisfactory and with the lowest values of the objective indicators. On the contrary, the attributes varying over time are less variable.

An immediate reading of the results of the procedure can be made by graphically comparing the values of the objective and subjective indicators with the values of the indicator calculated by considering jointly objective and subjective measures (Fig. 1). By analysing the difference between the value of the objective and subjective indicators of each service aspect, we can observe that for many service attributes (9 out of 22) the difference between the values of the two types of indicators is not considerable (lower than 1); only service frequency presents a very high difference (about 7 points). For almost all the service attributes the value of the objective measure is higher than the value of the average satisfaction rate expressed by the users. Moreover, among them the attribute with the highest difference is "security against

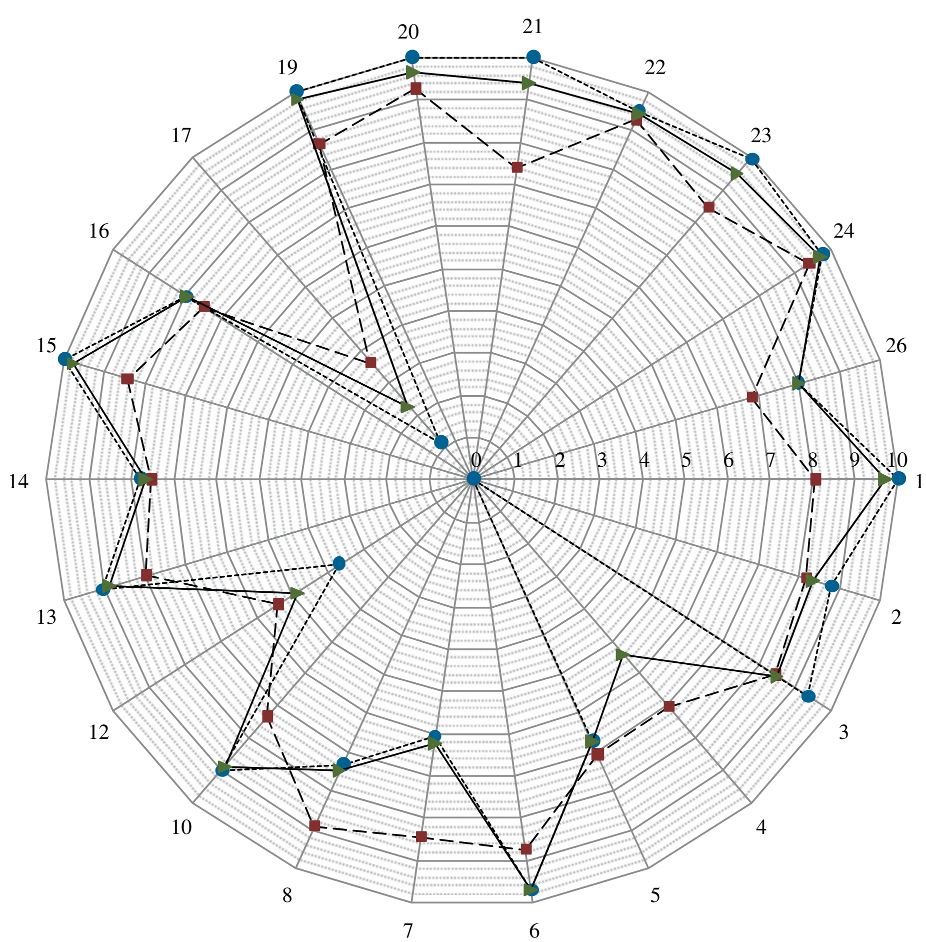

Fig. 1. The values of S (broken line and squares), O (dotted line and dots), and X (continuous line and triangles) indicators for 22 service quality attributes (the attributes are numbered as in Table 2).

crimes at bus stops"; although no incidents at bus stops were registered, people do not feel sufficiently secure. In reality, only six attributes have a subjective indicator value higher than the objective one. Specifically, service frequency is the attribute showing the highest difference between the subjective and objective indicator; this result can be considered rather unusual. In fact, service frequency is satisfactory for the passengers, although the service offers only 1 run/h in the morning and two runs in the afternoon. Different reasons could help to explain why customers are satisfied with the service although it operates very infrequently. As an example, passengers could have low standards of quality for this service aspect due to the their social, cultural, and economic conditions. But, it should be considered also that a route serving a low density suburban area is characterized by a low service frequency, differently from a route in a dense centre city; therefore, passengers get over the fact that service is infrequent.

The attribute regarding punctuality has also an objective value lower than the subjective one, which is one of the highest; this fact could be explained by considering that users easily accept more than 5 min behind schedule. Finally, for the attributes regarding the information on bus and at bus stops the average traveller satisfaction rate is higher than the objective indicator perhaps because the service is a suburban service characterized by a low frequency, and then the passengers know the services and do not need any information.

By analysing the values obtained for the new indicator of service quality, which takes into account both subjective and objective measures, we can observe that the attributes resulting the most critical are "availability of schedule/maps at stop", "availability of shelter and benches at stop", and "service frequency"; "punctuality" is a borderline pass. While the attributes concerning amenities and information at bus stops were judged unsatisfactory by passengers, the attributes regarding service frequency and reliability were considered satisfactory according to the users' opinions. Hence, by considering also the objective measure the results of service quality obtained for these attributes overturn, given that the performance of these service aspects are not objectively admissible. Although user judgments are fundamental for evaluating transit service quality, sometimes they do not fully express the levels of quality of the service. Lastly, we can observe that for the attribute "use of ecological vehicles" the value of the final indicator coincides with the value of the objective indicator, because of the invariance of the attribute in the period of data gathering.

5. Conclusions

Passengers' point of view is fundamental for evaluating transit service quality because they are the real consumers of the services and for this reason they can be considered the most suitable judges of the services. Transit services are characterized by various aspects, since users have different perceptions of the service aspects and factors affecting each aspect. The heterogeneity of these perceptions is due to the qualitative nature of some aspects characterizing the services, different attitudes of the users towards the use of transit services, different ways in which the users understand the service aspects, user socioeconomic characteristics and tastes.

Because of the heterogeneity of users' judgments and also the risk that users could have distorted opinions, subjective measures could describe not fully the levels of quality of a transit service. For these reasons, to consider also objective measures of service quality can be useful for correcting the evaluations provided by the passengers. For this reason, the aim of this research has consisted just in proposing a methodology to account for both perceived and measured service quality, expressed by subjective and objective service performance indicators.

The formulation at the basis of the procedure entails that when the variance of the objective/subjective indicator is close or equal to 0 the new indicator tends to or coincides just with the objective/subjective indicator. Variance of the objective indicators is usually lower than the variance of the subjective ones, as we have also observed from the experimental results; this fact leads to move the value of the new indicator towards the value of the objective one. For this reason some carefulness should be taken in selecting the most appropriate objective indicators for measuring the quality of the service attributes. Furthermore, some service attributes could depend on several factors; in these cases, it would be convenient to have recourse to more sophisticated indicators which can include as many factors describing the service attributes as possible.

Last of all, transit agencies should create an adequate system for measuring their performance; this system should match the information derived from the CSS with objective parameters of service delivery. As mentioned above, in the performance evaluation there are some problems linked to the customer satisfaction measure involving methodological difficulties linked to the multidimensional nature of satisfaction, and to the selection of the most appropriate objective measures. Even more difficult is the search for the link between perceived and measured service quality.

The development of more sophisticated tools for measuring service quality produces some advantages for transit agencies, which can more easily deliver services characterized by higher levels of quality. The proposed indicator represents a useful example of a tool for evaluating the performance of a transit system, and specifically each aspect characterizing the service. Like many indicators and statistical methods based on passenger perceptions traditionally used by transit agencies for analysing and monitoring the service, the proposed methodology allows the critical service aspects to be identified with the aim to better allocate the resources. Furthermore, the proposed indicator has the advantage of providing a more comprehensive service quality measure because it considers both the passengers' perceptions of the used service and the performance of the actual service offered by the transit agency. As an example, if the users perceive a service aspect as satisfactory but the service does not objectively reach appropriate standards of quality, transit agency may not invest further resources for improving that service aspect, and not have the opportunity to attract new users thanks to the improvement of the service quality. On the other hand, if the users perceive a service aspect as unsatisfactory but the service already offers good standards of quality, the additional resources allocated for meeting customer requirements would be wasted.

Ultimately, adopting subjective indicators for measuring service quality allows considering only the customer requirements; on the contrary, considering also objective measures may be helpful in a way to meet not habitual users' needs or attract new users. Nevertheless, the suggested methodology could not be the most suitable solution for providing a real understanding of the phenomena analysed. In addition, further developments are surely necessary for better defining objective indicators and having more appropriate measures of service quality.

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