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Neural networks for analyzing service quality in public transportation

Concepción Garrido, Rocío de Oña, Juan de Oña *

TRYSE Research Group, Department of Civil Engineering, University of Granada, ETSI Caminos, Canales y Puertos, c/Severo Ochoa, s/n, 18071 Granada, Spain

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ABSTRACT

It is essential to take into account the service quality assessment made by the passengers of a public transportation system, as well as the weight or relative importance assigned to each one of the attributes considered, in order to know its strengths and weaknesses. This paper proposes using Artificial Neural Networks (ANN) to analyze the service quality perceived by the passengers of a public transportation system. This technique is characterized by its high capability for prediction and for capturing highly non-lineal intrinsic relations between the study variables without requiring a pre-defined model. First, an ANN model was developed using the data gathered in a Customer Satisfaction Survey conducted on the Granada bus metropolitan transit system in 2007. Next, three different methods were used to determine the relative contribution of the attributes. Finally, a statistical analysis was applied to the outcomes of each method to identify groups of attributes with significant differences in their relative importance. The results show that statistical significant differences exist among several categories of attributes that have a greater or lesser impact on service quality and satisfaction. All the methods agree that Frequency is the most influential attribute in the service quality, and that other attributes such as Speed, Information and Proximity are also important.

1. Introduction

Currently, an extended use of public transport modes among citizens is one of the key aims of public administrations. Nowadays, the role of public transportation is viewed as an alternative to private cars instead of being just the support for the movement of passengers (Simoes, 2013). For individuals, car travel is generally perceived as more comfortable, flexible and faster for supporting busy lifestyles (Jakobsson Bergstad, Gamble, Hagman, Polk, & Garling, 2011). However, the excessive use of these private vehicles generates environmental and social problems in cities (e.g. pollution, traffic congestion, noise, etc.), greatly exacerbating of the unsustainability of citizens' mobility.

Public transport services have to prove that they can compete with other modes, by guaranteeing effective and high quality services. The authorities are attempting to impose strong incentives on operators (Mouwen & Rietveld, 2013) by using a good definition of service quality and a good measuring method. Given that public transport services are offered directly to customers, the resultant quality of a service should be seen as an outcome of user perception (Das and Pandit, 2013) because as Bordagaray, Dell'Olio, Ibeas, and Cecín (in press) stated, "Without the consumer, the market has no reason to exist". Therefore, the level of quality in a service will be high when the performance of the service fits passengers' needs and expectations.

In recent decades, practitioners, managers and researchers have focused their attention on this point of view (De Oña & De Oña, in press), striving to learn more details about how passengers evaluate a service, by considering the impact of various attributes that characterize it. Several authors have stated that service quality is a complex, fuzzy and abstract concept (Carman, 1990; Parasuraman, Zeithaml, & Berry, 1985), mainly because of the three properties of service: intangibility, heterogeneity and inseparability, but also because of the subjective nature of considering passengers' opinions for measuring this quality. In the literature, there are very different methods for determining this influence, although there is no consensus as to which is the best one. That is why measuring service quality is still a challenge for researchers and transport planners.

Various authors pointed to the existence of several categories of attributes that have a greater or lesser impact on service quality and satisfaction. Philip and Hazlett (1997) proposed a model with a hierarchical structure, based on three classes of attributes: pivotal, core and peripheral attributes. This model was subsequently contrasted for the rail transportation industry (Tripp & Drea, 2002). The pivotal attributes exert the greatest influence on the satisfaction levels. The UNE-EN 13186 (2003) standard classifies

* Corresponding author. Tel.: +34 958 24 99 79; fax: +34 958 24 61 38.
E-mail address: jdona@ugr.es (J. de Oña).

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the service's characteristics into basic, proportional and attractive, depending on how compliance and non-compliance affects customer satisfaction. The Transit Capacity and Quality of Service Manual (Transportation Research Board, 2004) groups attributes into availability factors (more important to passengers), and comfort and convenience factors (less important). Eboli and Mazzulla (2008) empirically demonstrated the existence of two categories of attributes (basic and not basic) in the preferences showed by users.

The influence of these characteristics on passengers' overall evaluation can be determined in different ways. For example, in recent years, structural equation models have gained popularity among researchers, such as De Oña, de Oña, Eboli, and Mazzulla (2013), Eboli and Mazzulla (2007, 2012), Irfan Syed Muhammad and Shahbaz Saman (2011) or Ngatia, Okamura, and Nakamura (2010). For others (e.g. Bordagaray, Dell'Olio, Ibeas, & Cecín, (in press); Eboli & Mazzulla, 2008, 2010; Hensher, 2014; Hensher & Prioni, 2002; Hensher, Stopper, & Bullock, 2003; Marcucci & Gatta, 2007) discrete choice models are a great method for deriving the importance of service quality attributes. However, most of these models have their own model assumptions and pre-defined underlying relationships between dependent and independent variables, such as normal data, linear relationships between dependent and independent variables, low multi-colinearity, and so on. According to Garver (2003), these assumptions are almost always violated in customer satisfaction research.

However, as Kikuchi (2012) says "the traditional paradigms of prediction, diagnosis, and regulation or optimization are not sufficient to deal with the extremely complex social and human systems, of which transportation engineering and planning are part". Following this idea, a novel insight has been proposed by De Oña, de Oña, and Calvo (2012); De Oña, de Oña, Eboli, and Mazzulla (in press) applying a data mining technique for overcoming the aforementioned weaknesses and analyzing quality of service for transit operation. The methodology used was a decision tree model, which needs neither model assumptions nor predefined underlying relationships between the independent and the dependent variables. Following this direction, and because of the powerful results obtained with the decision tree model, the authors' interest for other data mining techniques increased.

To the authors' knowledge, the neural network approach, which is also a non-parametric model with similar advantages to the tree models has not been used before for analyzing service quality in public transportation, although it has been successfully used in other transportation engineering fields such as choice behavior (Lee , Ran, Yang, & loh, 2010; Xie, Lu, & Parkany, 2003). As an example, Lee et al. (2010) applied the ANN and decision trees methodology to analyze the factors affecting car drivers' alternative route choice; while Xie et al. (2003) modeled work travel mode based on three different methodologies: decision trees, ANN and multinomial logit models. Both studies concluded that ANN achieved the best fitting of the problem, with higher accuracies than the decision tree models. Thus, the aim of the present study is to use an ANN approach to investigate the influence of service characteristics on passengers' overall evaluation of a service to know the relative importance assigned to the service quality attributes. Three different methods of relative contribution (Connection Weights, Perturb and Profile) will be used. Another objective of this paper is to verify the hypotheses of Eboli and Mazzulla (2008) on the existence of different categories of attributes, and to determine if significant differences exist among groups of attributes that have higher and lower importance in overall service quality.

This paper is structured in five sections. First, the experimental context is described, specifying the survey conducted for collecting the data, and the main characteristics of the sample and perceptions rates. The following section is about the methodology and framework adopted in this context. In the fourth section the results of the analysis are shown and discussed. Finally, a brief concluding section is reported.

2. Experimental context

The survey supporting the research targeted sample of users of the metropolitan public transport service operating in Granada (Spain). The service was provided by a bus system in which 15 bus companies operated, connecting different urban agglomerations of the metropolitan area of Granada. The Transport Consortium of Granada carried face-to-face interviews on March 2007, during 5 days of a week. Passengers were interviewed at the main bus stops of the service, collecting a final random sample of 858 people.

The questionnaire was structured into two main sections. The aim of the first section was to collect data concerning: general information on the trip (e.g. time of the interview, bus stop, line, operator, origin, destination), socioeconomic characteristics of passengers (e.g. gender, age, private vehicle availability) and travel habits (travel reason, frequency, ticket, complementary modes from origin to bus stop and from bus stop to destination).

The majority of the respondents were female (Table 1). More than a half of the respondents were 18–30 years old, and only 9.5% were older than 60. Most of the people sampled (61.1%) had a private vehicle available for doing the trip. About a 29.4% of people traveled for business reasons and a similar percentage for studies purposes. The rest of the respondents traveled for other reasons, such as doctor, shopping, holidays and so on. Most of the passengers traveled with an almost daily or frequently frequency, while occasionally and sporadic passengers represented only about 10% of the sample. The most usual complementary mode used for reaching the bus stop or for reaching the destination from the bus stop was on foot. Other complementary modes had also been used, such as car, urban bus, motorbike, etc., although its representativeness was low. Finally, the consortium card and the standard ticket were the most widespread types of tickets among passengers, representing more than an 80% when combined.

The second section was more oriented to collect passenger opinions about the service. Specifically, users rated importance and perception on 12 service quality attributes that characterize the service, and also rated the overall quality of the service. A cardinal scale from 0 to 10 was used for state the ratings. The attributes used to characterize the service included information, punctuality, safety on board, driver courtesy, bus interior cleanliness, bus space, bus temperature, accessibility to/from the bus, fare, speed, frequency of service and stops proximity to/from origin/destination.

Table 2 shows the average rates calculated from the collected data. It can be seen that there is very little variation in the importance rates stated by the passengers in the survey, considering that all the attributes are highly important. The average value of importance is concentrated in the 8.5–9.5 range. Therefore, this importance is uniform and practically equal in all the attributes. This is one of the serious drawbacks encountered when studying the importance of variables based on the stated opinions of passengers (De Oña et al., 2012; Weinstein, 2000).

On the contrary, the average perception rates show higher differences among attributes. In all the cases they are lower than the mean values of the importance rates. They are concentrated in a range from 6 to 8. Nonetheless, these values are quite good because all the attributes are perceived with at least adequate quality (>6), and some of them with quite good quality (>7). The attributes characterized by the highest levels of quality were