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Research on the Impact of Quality on Demand for Bus Transport

Vladimír Konečný[1,*], *Róbert* Berežný[1] , and *Miroslava* Bartoníková[1]

[1]University of Žilina, Faculty of Operation and Economics of Transport and Communications, Department of Road and Urban Transport, Univerzitná 1, 010 26 Žilina, Slovak Republic

Abstract. The demand for transport services is determined by several factors at the same time. The impact of these factors is varied. One of the most important factors is the quality of transport services. The aim of the paper is to identify and characterize potential methods for measuring and evaluating the impact of quality of service on passenger demand for suburban bus transport. These methods are applied to a specific transport system for assessing the impact of quality on demand. The results may contribute to the stabilization of the demand for bus services or they can serve as a basis for the improvement of transport services in the bus transport sector.

1 Introduction

In recent years the number of passengers transported by public passenger transport (PPT) has decreased not only in the Slovak Republic but also abroad. The aim is to slow down or to stop this negative development. In order to do this it is necessary to know the impact of the individual demand factors. One of the most important factors is the quality of transport services. They prove it current studies and projects in this area. E.g. Anderson et al. (2013) when assessing the sensitivity (elasticity) of passenger demand to change a particular factor found that the quality of the transport service is a significantly more influential factor than the cost of travel and also a more influential factor than the income of the population. Knowing the impact of the quality of transport services on demand can be valuable information for stakeholders (carriers, transporter, etc.) to improve the quality of transport services [1].

Before assessing the impact of the quality of services on demand in bus transport it is first necessary to quantify the quality level in an objective manner. This can be achieved by measuring and evaluating quality using quantitative methods. Measurement, evaluation and numerical expression of criteria that characterize the quality of public passenger transport. Also a numerical expression of the demand is needed. Consequently, it is possible to examine the impact of quality on demand through selected methods.

The aim of the paper is to identify and characterize potential methods by which it is possible to examine and assess the impact of quality on demand in bus transport.

* Corresponding author: vladimir.konecny@fpedas.uniza.sk

Subsequently, these methods are applied to a specific transport system for assessing the impact of quality on demand.

In Fig. 1 shows the stages of the methodology examining of the relationship between the quality of the transport services and the demand for them [2, 3]

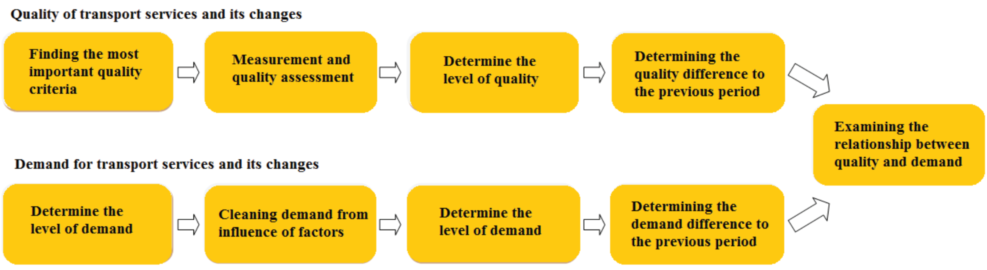

Fig. 1. Stages of the methodology for the examination of the relationship between the quality of transport services and demand. Source: authors

2 Analysis of possible procedures and methods of examining the impact of quality on demand

2.1 Methods of relationship analysis

2.1.1 Correlation analysis

The correlation analysis examines the tightness of statistical dependence between quantitative variables. Correlation analysis unlike regression does not indicate a causal-consequence relationship. The variable Y does not depend on the variable X but the two random variables X and Y change together. The regression analysis assumes that the variable Y is random and the variable X is fixed.

The correlation analysis tool is so-called coefficient of correlation (r_{xy}). Provides a measure of the tightness (degrees) dependent. Its definition is based on the consideration of the sum of the deviations of the individual values of the two correlated characters and their diameters. The relationship for calculating the correlation coefficient can be found in the literature (HINDLS 2013) [4].

The correlation coefficient reaches values from the interval <-1, +1>. In the case of independence between X and Y the correlation coefficient is 0. The positive values of the correlation coefficient refer to direct dependence and negative value for indirect dependence.

At the correlation coefficient r_{xy}, it is possible approximate schematic diagram of the statistical dependence intensity can be used. Values ranging from -0.1 to +0.1 say about linear independence values from - 0.4 to -0.1 or from +0.1 to +0.4 by weaker dependence values from -0.7 to -0.4 or from +0.4 to +0.7 with the mean dependence and values from -1 to -0.7 or from +0.7 to +1 by strong (or tight) dependency [4, 5].

2.1.2 Theory of demand elasticity

The notion of elasticity of demand is mainly used in the area of the economy but we can also meet this concept in the transport sector. Elasticity of demand is considered to be a simple and comprehensible quantitative measure of dependencies (responses) of one variable to the other.

a) Point elasticity

The point elasticity concept is used when we want to know the relative price elasticity of demand at a given point on the demand curve for decision-making and price changes. Through point elasticity it is possible to know the impact on revenue which is the total multiplication of the price with the quantity of demand (PxQ). Dominick Salvatore defines point elasticity of demand as: "Price elasticity of demand at a particular point on the demand curve." The elasticity point is determined as the distance from the Q axis to the point distance from the P axis. [4]

$$e_{x_i}^{point} = \frac{lim}{\Delta x_i \to 0} = \left(\frac{\frac{\Delta y}{y}}{\frac{\Delta x_i}{x_i}} \right) = \left(\frac{\frac{\partial y}{y}}{\frac{\partial x}{x}} \right) = \frac{\partial y}{\partial x}\frac{x}{y} = \frac{d\,(\ln y)}{d\,(\ln x)} \tag{1}$$

b) Curve (arc) elasticity

We find the elasticity between the two points of the curve taking into account the average between the starting and final quantities and the average between the starting and the final price. It is calculated using the following relationship:

$$e_{x_i}^{arc} = \left(\frac{\ln y_2 - \ln y_1}{\ln x_2 - \ln x_1} \right) = \frac{\Delta\,(\ln y)}{\Delta\,(\ln x)} \tag{2}$$

Where y_1 and y_2 represent a change in demand before and after each change in the demand factor x_1 and x_2 (eg, travel prices, quality level, etc.). This estimate provides average elasticity at intervals <X_1, X_2>. Estimation requires two observations. One before and one after the change that occurs. An important function of such estimation is the convex relationship with the convex functional shape [4].

c) Linear elasticity

Linear elasticity is a very often used method for calculating elasticity. It is appropriate to use it if the monitored pointers are not expressed by function but by arranged pairs of points. It can be calculated based on the following relationship:

$$e_{x_i}^{line} = \left(\frac{\frac{y_2 - y_1}{1/2\,(y_2 + y_1)}}{\frac{x_{i2} - x_{i1}}{1/2\,(x_{i2} + x_{i2})}} \right) = \frac{(y_2 - y_i)(x_{i2} + x_{i1})}{(y_2 + y_1)(x_{i2} - x_{i1})} \tag{3}$$

2.2 Methods of causal analysis

2.2.1 Regression analysis

The meaning of regression analysis is to examine the two X and Y sign. The task is to model the dependence of the values of the Y variable on the values of the X variable. This is a pair regression task.

In regression modelling the task is to formulate which variable is to be considered independent (X) and which is the dependent variable (Y). The variable X should be the cause and the variable Y as a consequence of the phenomenon. In some cases it may be problematic to specify the cause and the consequence at the discretion of the investigator which of the variables will be the cause of cause X and consequence [4, 5].

a) Regression line

In the case of a line, the general model changes to the form: $y_i = b_0 + b_1 x_i + e_i$ and the particular regression line model has the form $y_i = b_0 + b_1 x_i$ where the estimate of y_i (i = 1, 2,…n).

Another task is to estimate values of parameters b_0 and b_1 based on the obtained values [xi, yi], i = 1, 2, ..., n (by measurement, observation, etc.). There are several parameter estimation methods. The most common method is the least squares method. Parameters b_0 and b1 are estimated so that the sum of the deviation squares is minimal (as small as possible) with respect to the parameters [4, 5].

b) Multicriterial regression analysis

Multicriterial regression analysis allows to express the influence of multiple independent variables (X, P, Q, R ...) on the observed indicator (Y) simultaneously. Multicriterial regression function should take into account all the important variables that result from the dependent variable Y. Each of the independent variables considered must be in a causal relation to the dependent variable. This dependence can be confirmed for example by calculating the correlation coefficients. The influence of independent variables on the dependent variables is determined by the parameter values of the universal multicriterial regression model.

The individual regression coefficients (b_1, b_2, ...,b_n) represent the average change of the dependent variable Y which is caused by the change of the respective independent variable. It is also important to reevaluate the inclusion of the b_0 coefficient in the proposed multi-criteria function i.e. from a logical point of view the model gives meaning if the independent variables X_1 to X_n reach 0 if the variable Y has a zero value or its value is nonzero a non-zero coefficient b_0.

3 Case study - the impact of quality of transport services on demand for suburban bus transport in the Žilina node

In this part of the article is processed a case study focuses on the application of selected methods, for assessing the impact of quality on demand in the suburban bus transport (SBT) in the Žilina node. The case study respects the phases of the methodology shown in Fig. 1 [3, 6].

3.1 Measuring the level of service quality

To assess the impact of quality on demand it is necessary to know the measured level of quality of services provided by the carrier in the surveyed period, the importance of the individual criteria of quality and passenger satisfaction with these quality criteria.

To identify the importance of individual quality criteria for passengers is appropriate to use a questionnaire survey. This method reflects the subjective perception of quality by the passenger. It is about finding passenger's opinions using questions asked by respondents. Table 1 shows the results of the survey of the importance of individual quality criteria for passengers carried out in 2013, 2014 and 2016 in the SBT in the Žilina node. As we can see over time there was a change in the importance of the requirements of passengers.

Measuring the quality of the services provided means the way of obtaining information about the performance or non-fulfilment of the quality criteria included in the set of measured criteria. Measurement provided services in the field can be performed by inspectors or by technical means. Table 1 shows the results of the quality measurement in 2013, 2014 and 2016 expressed as a percentage.

A questionnaire survey conducted in the Žilina node in 2013, 2014 and 2016 was also used to identify the satisfaction of passengers with the quality criteria. The statistical unit consisted of suburban bus passengers in the Žilina node who have real experience with services. The results are shown in Table 1.

Table 1. Standardized parameters of the most important quality criteria in the SBT in the Žilina node. Source: authors

Quality criteria	Importance of quality requirements (%)			Measured quality (%)			Passenger satisfaction (%)		
	2013	2014	2016	2013	2014	2016	2013	2014	2016
Punctuality	72	84	90	72	65	73	64	73	79
Information	69	79	84	80	77	99	56	73	93
Cleanliness	74	76	79	67	82	82	60	76	85
Driver behavior	65	77	84	64	88	94	67	68	85
∑	**70**	**79**	**84**	**71**	**78**	**87**	**62**	**73**	**86**

3.2 Determining the level of demand for transport services

Determining the level of demand for transport services means to quantify the level of demand. The most common way of expressing the level of demand for public passenger transport is through the number of passengers transported or through the number of tickets sold. The number of passengers transported by type of fare and total is shown in Table 2.

Table 2. The number of passengers transported in SBT in Žilina node according to the type of fare in the years 2010-2016. Source: authors, based on [7]

Relativized number of transported passengers (demand in 2010 = 1.00)				
Year	**Full fare**	**Children/student fare**	**Other fare**	**Total**
2010	0.528	0.370	0.102	1.00
2011	0.490	0.343	0.105	0.938
2012	0.466	0.317	0.111	0.894
2013	0.433	0.299	0.104	0.836
2014	0.406	0.271	0.115	0.792
2015	0.397	0.264	0.105	0.766
2016	0.381	0.247	0.106	0.734

Note: Real demand is relativized. Demand in 2010 is 1.00, or 100%.

In order to assess the impact of the quality level on demand it is possible to use data on the evolution of real demand. However. past demand is affected not only by the level of quality but also by other factors of demand such as: fares, population incomes, employment rates, etc. Therefore, it is necessary to eliminate the impact of other factors on demand by cleaning demand values.

In Table 3 is real total relativized demand for the period 2013 to 2016 which is cleaned from the impact of income, the population and the impact of the introduction of free rail transport. The average monthly nominal wage in the Žilina node in individual years was used for cleaning the demand from the impact of income. The number of inhabitants in the districts served by carrier in the Žilina node was used for cleaning the demand from the impact of population. Estimation of the impact of free rail transport on the demand for bus transport was based on the information provided by the Bus Transport Association of Slovakia, the available statistical data on the demand for free transport and the research carried out in the Žilina node. In the first year of the introduction of free rail transport

(2014) there was a reduction in the number of passengers transported in SBT on average of 2.4%. In the following year, it was 4.8% and in 2016 a decrease of 7.5% [8].

Table 3. Cleaned relativized demand for SBT from the impact of selected demand factors. Source: authors, based on [7]

Year	Relativized real demand total	Cleaned demand from the impact of income	Cleaned demand from the impact of population	Cleaned demand from the impact of free rail transport	**Final cleaned demand**
2013	0.836	0.836	0.836	0.836	**0.836**
2014	0.792	0.810	0.811	0.830	**0.830**
2015	0.766	0.798	0.799	0.837	**0.837**
2016	0.734	0.780	0.781	0.839	**0.839**

3.3 Application of correlation coefficient to assess the impact of quality on demand

To calculate the coefficient of correlation between the level of quality and levels of demand in 2013, 2014 and 2016 was used relationship referred to in the literature (HINDLS 2013).

For measured quality (see Table 1), the correlation coefficient was 0.0209 and in the case of passenger satisfaction the correlation coefficient was 0.0409. In both cases the positive correlation coefficient was reached and therefore the relationship between demand and quality is direct, namely, the very low power of the relationship.

This method is appropriate to use if there is a sufficiently large set of ordered pairs of demand and quality values a minimum of 30 is recommended. In view of the limited availability of quality data for past years this method is only marginally applicable in this case.

3.4 Application of the method of linear elasticity to assess the impact of quality on demand

Elasticity of demand and quality can be examined in year-on-year changes and also in two and more yearly changes. To calculate the linear elasticity of demand is used relationship (3). The variable y represents the number of passengers carried in any given year and the variable x is the measured level of quality or passenger satisfaction with the quality of transport services in given year.

Table 4. Linear elasticity values for quality impact on demand. Source: authors, based on [7]

	Year-on-year changes		Two and more yearly changes			
	Real demand	Cleaned demand	Real demand		Cleaned demand	
	2014/2013	2014/2013	2016/2014	2016/2013	2016/2014	2016/2013
Measured quality	-0.5773	-0.0797	-0.6949	-0.6415	0.0795	0.0143
Passenger satisfaction	-0.3328	-0.0459	-0.4991	-0.4152	0.0683	0.0161

In examining the year-on-year changes and two and more yearly changes in real demand were calculated illogical negative values of elasticity. This would mean that with increasing quality would occur to a slight decrease in demand. While quality is considered to a factor increasing demand. The reason for this illogicality may be the fact that the year-on-year increase in the level of quality of the transport service may be due to a delayed increase in demand (with a delay of more than 1 year). It can also be caused by the existence of other factors of demand which impact on demand could not be cleaned.

By examining two or more yearly changes in cleaned demand were calculated logical positive elasticity. This means that the increase in the quality of bus transport services leads to an increase in the number of passengers. The elasticity of demand for measured quality is +0.0795 and +0.0143. The average value is approximately +0.047. This means that if the quality of the transport service improves by 1% in the short term there will also be an increase in the number of passengers by 0.047%. In the same way we could interpret the elasticity of demand in measuring passenger's satisfaction.

In both cases elasticity of demand values is less than 1. This is an inelastic demand.

3.5 Application of the method of regression analysis to assess the impact of quality on demand

With this method it is first necessary to estimate the parameters of the regression line y depending on x using the least squares method. Using relations for the regression line we then calculate coefficients b_0 and b_1. The independent variable *x* is the resulting cleaned demand (see Table 3) and the dependent variable *y* is the measured quality in the years 2013, 2014 and 2016 (see Table 1). Table 5 shows the auxiliary calculations necessary to determine the coefficients b_0 and b_1.

Table 5. Auxiliary calculations necessary to determine the coefficients b_0 and b_1. Source: authors

Year	Purified demand (x_i)	Measuring quality (y_i)	$x_i \cdot y_i$	x_i^2	y_i^2	$(x_i-\bar{x})^2$	$(y_i-\bar{y})^2$
2013	0.836	71	59.356	0.699	5 041	0.000001	58.783
2014	0.830	78	64.740	0.689	6 084	0.000025	0.445
2016	0.839	87	72.993	0.704	7 569	0.000016	69.439
In total	**2.505**	**236**	**197.089**	**2.092**	**18 694**	**0.000042**	**128.667**

Based on the above calculations, it is possible to calculate the coefficients b_0 and b_1. The coefficient b_1 is -0.463 and the coefficient b_0 is 79.053. On the basis of calculated coefficients, it is also possible to define the regression line equation, which has the form:

$$y = b_0 + b_1.x_1 = 79.053 + (-0.463)\ x$$

Using the regression line equation it is possible to estimate the future development of the demand when changing the value by measuring the level of quality of the transport services in the SBT.

4 Conclusion

This paper deals with the analysis of the various methods by which it is possible to assess the impact of quality on demand for bus transport. Consequently, these methods were applied to a specific case. In view of the limited scope of data on the level of quality of bus services in the past some methods for assessing the quality impact on demand could not be applied. The method of correlation coefficient, linear elasticity and regression analysis was used.

The linear elasticity method after cleaning the demand for suburban bus transport from the impact of other the most important factors (besides quality) confirmed the positive impact of the quality of transport services on passenger demand.

This positive effect may be the reason for further increasing the quality and stabilizing the constantly declining demand for bus transport. It can also serve to estimate the future demand due to a change in quality level planning.

It is necessary to continue the application of the methodology for measuring and evaluating quality in order to obtain objective data for longer time series.

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