Public Transport Fares as an Instrument of Impact on the Travel Behaviour: An Empirical Analysis of the Price Elasticity of Demand

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Abstract The studies on the elasticity of demand for urban public transport services have a very high theoretical and application value, proven by the fact that despite the knowledge already possessed new studies in this field are permanently undertaken worldwide. The paper presents the hitherto results of studies in the field of price elasticity of demand for public transport services. Also results of studies on price elasticity of demand have been presented, based on empirical data related to the sales of tickets for public transport services in the Upper Silesian conurbation in Poland. Moreover, the paper identifies the non-price factors that determine changes in demand for urban public transport services. The obtained results became the basis to discuss estimation limitations of demand elasticity in the urban public transport and also allowed to determine directions of further studies.

Keywords Urban public transport · Public transport fares · Elasticities · Fare elasticity · Demand

1 Introduction

The world literature of the subject pretty often considers the issues related to studies on the price elasticity of demand. Results of studies from various countries and for various market conditions can be shown here, e.g. [1–5]. In Poland, the studies on elasticity of demand for public transport services, including price elasticity, are not that extensive in the transport economics theory as in the world literature. Papers of Ciesielski [6], Grzelec [7], and Hebel et al. [8] deserve special attention. Polish literature of the subject does not comprise many result of studies based on empirical data, which would be the basis to formulate conclusions on the specific nature of Polish cities in this field.

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New studies on elasticity of demand for the urban public transport are permanently undertaken worldwide. It happens like that primarily because the issue of demand elasticity is very important not only from the theoretical research point of view, but first of all from the application point of view for entities managing the mobility in cities.

The paper is aimed at the discussion of hitherto results of studies on price elasticity of demand as well as at an attempt to study the price elasticity of demand based on empirical data related to the sales of tickets for public transport services in the Upper Silesian conurbation in Poland. Moreover, the paper attempts at identifying the non-price factors determining changes in demand for urban public transport services.

2 Travel Demand and Transport Elasticities

The demand for transport services is a demand for a specific amount and type of transport services notified in a defined time. The mobility-related needs are the original source of travel demand. In accordance with the law of demand, the demand for transport is obviously affected by the price, which is one of the main factors directly influencing the demand size. However, it is not the only factor affecting the demand. In the group of factors that influence the travel demand and travel behaviour in a given area in specific transport system, it is possible to distinguish primarily the demographic factors as well as preferences and trends (including, as shown also by the studies, the awareness and ecological sensitivity), the level of household incomes, economic activity, geography and land use patterns, transport options and their quality, information about options, and also factors related to the demand management strategies in the given area [9]. Litman distinguishes five main groups of factors affecting the travel demand in a given area, which should be considered in transport planning and modelling and which can be used in the process of demand management (Table 1).

The demand elasticity is a measure of demand response to changes in factors that affect it. The demand elasticity is a unitless economic ratio, which can be defined as a ratio of a relative (percentage) change in the demand size to a relative (percentage) change in the demand-affecting factor [9, 10]. Most generally, it can be presented by means of a formula, where Q means demand and x is a demand-affecting variable [10]:

$$E = \frac{\Delta Q/Q}{\Delta x_i/x_i} \quad \text{or} \quad E = \frac{\Delta Q x_i}{\Delta x_i Q} \tag{(1)}$$

In the theory of economics, the following are the most important and most frequently used types of demand elasticity [11]:

– price elasticity of demand, which is a measure of demand change intensity under the influence of price changes,

– and income elasticity of demand, which is a measure of demand response to a specific good or service under the influence of customer income changes.

In the transport sector, also other types of elasticity are frequently studied, which are specific to studies on the economics of transport, e.g. [10, 12]:

– public transport service elasticity, which is the degree of increase in demand for public transport services due to changes in the transport offer,
– or travel speed elasticity or travel time elasticity, as measures of response intensity of the demand for transport services under the influence of changes in the travel speed or the travel time in the latter case.

A few methods of demand elasticity calculations can be found in the literature. In the case of scientific research on the elasticity in the transport sector, the following are used most frequently:

– point elasticity E^{Point} illustrating the elasticity in a given point of demand curve, which is used in particular in the case, when the demand changes result from a relatively small change in factor x [10]:

$$E^{\text{Point}} = \frac{\lim}{\Delta x_i \to 0}\left(\frac{\Delta Q/Q}{\Delta x_i/x_i}\right) = \frac{\partial Q x_i}{\partial x_i Q} \tag{2}$$

– or arc elasticity E^{Arc}, which illustrates demand changes in a given section of demand curve [9]:

$$E^{\text{Arc}} = \frac{\Delta \log Q}{\Delta \log X} = \frac{\log Q_2 - \log Q_1}{\log X_2 - \log X_1} \tag{3}$$

The demand elasticity can have a negative, zero or a positive value. A negative value means changes in the opposite direction, for example, an increase in specific

Table 1 Factors affecting travel demand

Demographics	Commercial activity	Transport options	Land use	Demand management	Prices
Number of people (residents, employees and visitors), Employment rate, Wealth/incomes, Age/lifecycle, Lifestyles, Preferences,	Number of jobs, Business activity, Freight transport, Tourist activity,	Walking, Cycling, Public transport, Car-sharing, Private cars, Taxi services, Telework, Delivery services,	Density, Walkability, Connectivity Public transport service proximity, Roadway design,	Road use prioritisation, Pricing reforms, Parking management, user information, Promotion campaigns	Fuel prices and taxes, Vehicle taxes and fees, Road tolls, Parking fees, Vehicle insurance, Public transport fares,

Source Litman ([9], p. 2)

factor implies a decrease in demand. Instead, a positive value means changes in the same direction. The demand elasticity can have the following values [9]:

- $|E| > 1$ demand is elastic, i.e. responding more than proportionally to changes in specific factor,
- $|E| = 1$ demand is unit elasticity, which is the factor changes resulting in a proportional demand change,
- $|E| < 1$ demand is inelastic, responding to factor changes less than proportionally.

The demand elasticity is most frequently studied and considered within a defined period of time—short- and long-run elasticities. In the long run, the demand usually responds stronger and is more elastic than in a short run, because consumers have more time to make decisions and to change their consumption patterns [13].

Because of a large scope of substitution, in particular in the urban public transport, very often also cross-elasticity is studied, which measures the response of demand for one transport type to changes in substitutive transport prices [9, 14].

3 Price Elasticity of Demand for Urban Public Transport Services

3.1 The Price Elasticity of Demand: A Literature Review

The studies carried out so far do not give unequivocal results in relation to the price elasticity value of the demand for urban transport in cities. The price elasticity of transport services, and in particular of public transport in cities, is usually specified as rather low. Meta-analysis of public transport demand shows that the coefficient of price elasticity of demand for the urban public transport can range from -0.009 to -1.32, with an average value of around -0.38 [10].

The longer is the period of time, the higher is the price elasticity of demand. In the long run, the price elasticity of demand for urban transport services can achieve a value smaller than -1, which means that these are goods and services with elastic demand and that demand is relatively strongly diminishing under the influence of price increase. Table 2 presents results of various studies on the price elasticity of the bus transport and metro in long and short run.

The price elasticity factor varies also because of geographical character of the area, in which public transport is used for travels. The study carried out in the UK shows that in urbanised (metropolitan) areas the demand for public transport responds weaker to price changes than in the case of lower urbanisation areas (Table 3).

A relatively high price elasticity of demand in highly urbanised metropolitan areas is confirmed also by studies carried out in 1981 in London, New York, and Paris (Table 4).

In the studied big cities, the demand for public transport responded to price changes not elastically, which is proven by a low value of demand price elastic-

ity coefficient, on average around −0.30. However, it is worth noting that passengers of the rapid rail service were much less sensitive to price than bus passengers, which probably resulted from a better transport offer, primarily from the travel time point of view.

Hence, the value of demand price elasticity coefficient depends on very many factors, among which the following can be primarily mentioned [4, 9, 17]:

a. Type of passenger, in particular income, age, professional activity, ownership of a car—persons having a possibility to choose between public and individual transport are more sensitive to price than persons somehow dependent on the public transport.
b. The accessibility of alternative methods of travelling and costs of using those alternatives (fuel costs, parking costs), i.e. the degree of freedom to choose the method of travel.
c. Travel type, its obligatory or optional nature and related travel length and time, and also whether it is carried out during off-peak or peak hours—off-peak public transport price elasticity is usually higher than in peak hours.
d. Geographical features of the city, the level of urbanisation, the population density—in big cities, and metropolises travellers are less sensitive to fare changes. The percentage of persons dependant on the urban transport is higher in big, densely populated cities than in suburbs and areas of low urbanisation level. This dependence results primarily from the fact that in big cities and metropolises travels by car are much worse due to the congestion and parking problems, and vehicle parking costs.
e. Analysed time period (short run, medium run or long run).
f. Mode of transport and distance.

Table 2 Fare elasticities in UK

Time period	Bus				Metro			
	Range of value reported		Mean	Number of studies	Range of value reported		Mean	Number of studies
	From	To			From	To		
Short run	−0.07	−0.86	−0.42	33	−0.15	−0.55	−0.30	15
Long run	−0.85	−1.32	−1.01	3	−0.61	−0.69	−0.65	2

Source Paulley et al ([4], p. 297)

Table 3 Bus fare elasticities in UK by type of area and time period (UK, 1999)

Time period	Metropolitan areas	Shire counties
Short run	−0.21	−0.51
Long run	−0.43	−0.70
	London	Outside London
Short run	−0.42	−0.43

Source Dargay and Hanly ([15], p. 88)

Table 4 Public transport fare elasticities by mode in New York, London, and Paris

City	Bus service	Rapid rail service
New York	-0.32 ∓ 0.11	-0.16 ∓ 0.04
London	-0.33	-0.16
Paris	-0.20	-0.12
Mean and standard deviation	-0.30 ∓ 0.10	-0.15 ∓ 0.13

Source Lago et al. ([16], p. 44)

g. The current level of urban public transport service prices as well as the type of ticket, which price changes—users of single-travel tickets are more sensitive to price changes than season ticket users.
h. The transport offer and its quality (travel times, comfort, frequencies, coverage, etc.)
i. The method of paying for travels. Persons buying tickets/paying cash for travel are more sensitive to price changes than persons using prepaid public transport fare instruments, or electronic tickets or paying for the travel by means of payment cards [18].

Diversification of factors affecting the demand price elasticity causes difficulties in comparing the obtained indicators of demand price elasticity between cities and regions.

4 Results of Empirical Studies in the Upper Silesian Conurbation

Municipal Transport Union of the Upper Silesian Industrial Region (KZK GOP) is the urban transport organiser in the area of 29 municipalities in the central part of Silesian Voivodeship in Poland. This is the biggest, in terms of operations area, public transport organiser in Poland and one of biggest in Europe. KZK GOP performs functions typical of an urban public transport organiser, which include the competence to determine the ticket prices as well as their distribution and sales. Basic sources of urban transport services financing consist of tickets sale revenue and subsidies of municipalities, KZK GOP members. In the years 2009–2013, KZK GOP was raising the tickets prices every year. The KZK GOP policy carried out in the field of service prices to a large extent was determined by the increasing transport expenditures, which resulted to a lower extent from the operational work and to a larger extent from the need to perform indexation of transport rates based on the inflation, changes in fuel and electricity prices, and also expenses related to the carried out investment projects (Table 5).

Table 5 Basic data on KZK GOP expenditures and revenue on tickets sale in the years 2009–2014

Years	Expenditure on transport services provision (PLN million)	The number of vehicles-km in the KZK GOP area (million)	Revenue on ticket sales (PLN million)	Average tickets price change	All-items HICP (%) previous year = 100	Price of 1 L of diesel oil (PLN)
2009	438.1	84.0	225.4	0.0%	103.5	3.80
2010	464.6	84.4	224.9	5.5%	102.6	4.64
2011	498.5	84.4	233.3	11.8%	104.3	5.61
2012	541.4	84.3	242.2	6.9%	103.7	5.64
2013	555.7	83.8	247.4	7.7%	100.9	5.46
2014	579.8	85.7	243.5	0.0%	100	4.81
Change (%) 2013/2009	26.84	−0.19	9.77	35.80	11.97	43.7
Average yearly rate of changes (%) in the period 2009–2013	6.12	−0.05	2.36	7.95	2.87	9.48

Source Own study based on GUS [19] and KZK GOP data [20]

The sales of monthly tickets in the years 2009–2013 were analysed to study the demand price elasticity in KZK GOP. Such an analysis period was selected because during that time regular ticket price rises were performed and at the same time no significant changes were made in the field of available ticket types, their entitlements as well as the distribution technology (paper tickets). In the studied period, the ticket prices were raised in various months of the year (March, April or August), hence the need to study elasticity in the long run; the sales figures for October every year were analysed. In the studies on the demand for urban public transport services in Poland, October is considered a representative month, i.e. due to a standard number of holidays as well as to the fact that this is a month of school and academic youth education.

Two most popular in KZK GOP types of season tickets were analysed to study the demand price elasticity: a monthly ticket for one selected city and a monthly ticket for the entire available network of KZK GOP connections. Both tickets exist in two price versions: normal tickets with a standard price and concessionary tickets. The analysis of price elasticity of demand for season tickets provides the basis to formulate conclusions on the price impact on the behaviour of permanent passengers of the urban public transport. Table 6 specifies the amounts of analysed tickets sales in October in the years 2009–2013 together with prices effective in a given year

Table 6 Number of tickets sold in October in the years 2009–2013, with nominal and real price

Ticket type	October 2009	October 2010	October 2011	October 2012	October 2013	Change 2013/2009 (%)
Monthly ticket for one city, regular SM/AT						
Price (PLN)	88	94	108	116	126	43.2
Real price (PLN)	88	90.43	102.31	111.83	121.56	38.1
Number of tickets sold	13,281	10,651	9942	9598	8500	−36.0
Monthly network ticket, regular SC/AT						
Price	104	112	128	138	150	44.2
Real price	104	107.75	121.25	133.04	144.72	39.1
Number of tickets sold	29,935	23,828	20,958	19,498	15,067	−49.7
Monthly ticket for one city, reduced SM/AT						
Price	44	47	54	58	63	43.2
Real price	44	45.22	51.15	55.91	60.78	38.1
Number of tickets sold	18,764	15,473	13,910	12,124	11,068	−41.0
Monthly network ticket, reduced SC/AT						
Price	52	56	64	69	75	44.2
Real price	52	53.87	60.63	66.52	72.36	39.1
Number of tickets sold	44,241	35,441	30,081	25,463	20,250	−54.2

Source Own study based on KZK GOP internal data

in nominal and real terms. The study on price elasticity, especially in the long run, should be based on real prices; therefore, nominal ticket prices were adjusted by the index of average monthly gross pay rise. The increase in the average monthly gross pay in Poland in the years 2009–2013 was more dynamic than inflation changes; therefore, the adjustment by the index of average monthly gross pay changes better reflects the real tickets price in that period (Tables 5 and 7). Based on the collected data, also approximate curves of demand for the analysed ticket types in the years 2009–2013 were drawn (Fig. 1).

A decline of analysed ticket types sales is visible in the years 2009–2013. The performed analysis became the basis for calculations of demand price elasticity for individual ticket types (Table 8).

The performed analysis shows that the demand for the analysed ticket types elastically responded to price changes in the studied period. In the case of an exponential demand function, the exponent determines a point elasticity of the demand function.

Table 7 Basic data for the Silesian Voivodeship in the years 2009–2013

Years	Population of Silesian Voivodeship		Number of cars in Silesian Voivodeship per 1000 residents	Price of 1 L of unleaded petrol (PLN)	Average gross salary (PLN)	Minimum gross salary (PLN)
	Million	Share of persons up to 24 years of age				
2009	4.641	27.5%	420.2	4.29	3,101.74	1276
2010	4.635	26.9%	440.5	4.81	3,224.13	1317
2011	4.626	26.4%	463.6	5.45	3,403.51	1386
2012	4.616	25.9%	478.1	5.53	3,530.47	1500
2013	4.599	25.4%	494.4	5.38	3,659.40	1600
Change 2013/2009	−0.9%	−2.1 p.p.	17.7%	25.4%	18.0%	25.4%
Average yearly rate of changes [%] in the period 2009–2013	−0.2	–	4.2	5.8	4.2	5.8

Source Own study based on GUS [19]

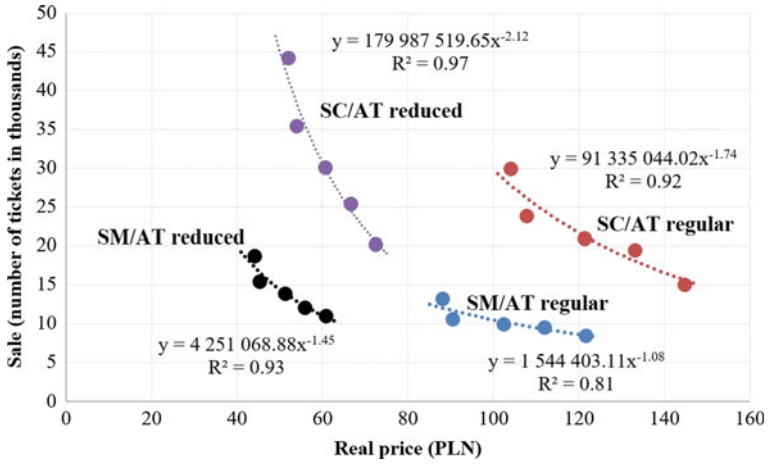

Fig. 1 Curves of demand for studied ticket types *Source* Own study based on KZK GOP internal data

Table 8 Coefficients of demand price elasticity for studied ticket types

Ticket type	Elasticity	October 2009	October 2010	October 2011	October 2012	October 2013
SM/AT monthly pass, one selected city, regular fare	Arc	–	−8.096	−0.558	−0.396	−1.456
	Point	−1.08				
SC/AT monthly pass, entire network (all cities), regular fare	Arc	–	−6.444	−1.087	−0.779	−3.064
	Point	−1.74				
SM/AT monthly pass, one selected city, reduced fare	Arc	–	−7.075	−0.863	−1.544	−1.092
	Point	−1.45				
SC/AT monthly pass, entire network (all cities), reduced fare	Arc	–	−6.264	−1.389	−1.797	−2.723
	Point	−2.12				

Source Own study

In the analysed cases, the exponential trend was the best matching function, which is proven by a high value of determination coefficient R^2. The analysis of arc elasticities shows that the demand changed most elastically in the upper part of the demand curve (the lowest price level) and in the lower part (the highest price change in the studied period).

It is also visible that the demand for tickets for the entire network (comprising all KZK GOP municipalities) featured a higher demand elasticity than the demand for tickets for one selected city. It is possible to presume that in longer-distance travels, going beyond one city, passengers more frequently decided to choose a means of transport competitive to the public transport, i.e. a car. What is interesting, in the studied tickets group the concessionary tickets featured a definitely higher elasticity, which in a definite majority of cases were bought by pupils or students. Because of obligatory nature of transport needs of this passenger group, one can presume that the reason for a decline of demand for such tickets can consist of—in the case of students—the choice of a car in daily commuting to the place of study or choosing other ticket types, e.g. single-travel of medium-term season tickets, which in many cases could be related to travelling without a valid ticket. In this case, also the issue of society ageing and a diminishing share of persons up to 24 years of age in the population structure is important (Table 7).

Nevertheless, it is necessary to consider that the presented analysis is only a kind of model approach. The analysis of price elasticity factors, neglecting the qualitative and quantitative changes in the transport offer, changes in the demand structure, and also the influence of other factors on the demand, can result in erroneous conclusions. After all, the demand for urban public transport is shaped by other, non-price factors, which will shift the demand curve. In 2014, KZK GOP did not decide to raise the prices, but the tickets sale, including the analysed monthly tickets, went down (Table 4). In the urban public transport, not only within the KZK GOP area, but also on the scale of entire Poland, we have been observing a systematic decrease in the passengers number for many years. In the KZK GOP area and in the entire Silesian

Voivodeship, this is approximately 20% a year. This is affected by such factors, such as the process of the society ageing, diminishing population of Silesian Voivodeship, the process of suburbanisation related to the depopulation of city centres, as well as a very strong competition of individual motorisation, which to a large extent is conditioned by very good conditions to move through Silesian cities by car [21]. Moreover, it is necessary to consider that a car is a normal good, for which the demand grows with the increasing income of buyers (a positive income flexibility of the demand). The urban public transport is a good of lower usability, for which the demand decreases together with the increasing income (negative income flexibility of the demand) [11].

The determination, what had a bigger impact on the demand change—ticket prices or another non-price factor, is undoubtedly a very important and necessary direction for further studies and analyses.

5 Discussion and Conclusions

Studies on the demand elasticity in the public transport feature various limitations and are burdened with an error resulting primarily from demand studying methods. For the needs of this analysis, the demand size was determined based on the number of sold paper tickets. However, it is necessary to consider that in paper ticket systems the sales do not represent a fully real demand for such tickets. In paper ticket-based systems, the organisers of public transport know only the number of tickets sold from their own warehouses to individual distributors, and not the actual sales. Only an analysis in a longer period, e.g. a year and from historical sales perspective, allows to take into account some correction related to the ticket distributors adjustment to the real demand on the market.

In studies on the elasticity of demand for public transport services, also the data on travels are frequently used to estimate the demand. So far, especially in Poland, the source of such information consisted in studies on vehicles occupancy carried out by means of manual counting during a selected period of time, considered a representative period. For example, KZK GOP carried out such measurements every year only on approximately a half of lines and they were performed on one selected working day and on one Saturday and on one Sunday. Results obtained on those individual days were then averaged onto the whole year, which was burdened with a big error, for obvious reasons. It is also worth adding that the cost of such studies in KZK GOP ranged between PLN 400,000 and 450,000 a year. Moreover, from the studies on the demand price elasticity point of view the data about demand obtained in this way have additional drawbacks in the form of missing information on the demand structure, i.e. about individual customer segments, but also of not considering in the analysis the passengers who do not pay for tickets (e.g. due to possessed entitlements), who are not sensitive to price changes.

Electronic fare collection systems, which are more and more widespread in the public transport in cities worldwide, including Poland, provide an opportunity for

a new quality of demand elasticity studies. The information provided by such systems creates a possibility to carry out studies on the hitherto unavailable scale of observations number, time, and precision.

The knowledge of demand price elasticity is very important in the context of pricing policy carried out by the public transport organisers. Price elasticity indicators in individual ticket segments should be considered during the process of tariff development and potential price changes. Moreover, the value of demand price elasticity decides about the importance of price management when creating the demand for public transport.

The value of demand price elasticity coefficient depends on very many factors. Also the factors affecting the urban public transport are very diversified and complex. The multitude and diversity of factors affecting the demand price elasticity cause that the elasticity should be studied always in the context of other non-price factors, which frequently result from historical and geographical conditions of city development. The carried out analysis is a starting point for further detailed studies, primarily on the force of individual factors influence on the demand, and also on their hierarchisation, i.e. identification of factors with the greatest impact and those of secondary importance. Such studies are very significant not only from the transport economics, but also from the application point of view. Results of such studies are important not only for transport policy entities of various tiers, but also for those entities, which in their financial model incur the risk of obtaining revenue on tickets sale on an appropriate level.

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