

PUBLIC TRANSPORT DEMAND ELASTICITIES IN DEVELOPING AGGLOMERATIONS: THE CASE OF TUNISIAN REGIONS

Lassaad Makhoulf ¹

Received 10.04.2024.

Sent to review 18.05.2024.

Accepted 06.01.2025.

Original article



¹ Faculty of Economics and Management, Research Unit CODECI, University of Sfax, Tunisia

Corresponding Author:

Lassaad Makhoulf

Email: lassad.makhoulf@fsegs.usf.tn

JEL Classification: R41; D12; C23

Doi: 10.2478/eoik-2025-0008

UDK: 656.025.2:625.7/.8(611)

ABSTRACT

This paper examined the characteristics of public transport demand in some major Tunisian cities. It followed the research trend which calculated the public transport demand elasticities. The adopted procedure in this study consists in estimating a log linear dynamic panel model relating per capita bus patronage to bus fares, users' income, and service quality. Two variants of the basic model were estimated for the most important Tunisian agglomerations for the period 2003 - 2020. In the first variant, this paper considered the same fare elasticity value for the different regions, whereas in the second it's proceeded to the calculation of specific fare elasticity values for each region. The estimation results show interesting and different elasticities compared to those revealed by earlier studies for occidental agglomerations. This result can be explained by specifics users' characteristics and networks' configuration. Although these results may sometimes contradict the theoretical suggestions, they still highlight the specificities of the public transport demand in Tunisia and its users' characteristics. The demand for public transport in large Tunisian agglomerations is not very sensitive to fares changes. Second, income does not have the same effect as that advocated by economic theories. Indeed, we have found a positive impact of income on demand for public transport. Finally, the quality of service has the most important effect on demand. Changes in travel habits and cultures, improvements in the quality of services and their differentiation can be more effective for public transport than fares changes.

Keywords: Public Transport Demand, Fare Elasticity, Income Elasticity, Dynamic Panel Model

1. INTRODUCTION

For most of the last century, the use of the car and other private modes of transport has increased. Public transport, on the other hand, has experienced a downward spiral in terms of ridership, investment, and deteriorating service quality. In addition, land use and development plans have often been geared towards car use. Some studies have argued that outside of a few large cities, there is little reason to expand public transport service or encourage its use (Cox, 2000; Orski 2000; Balaker 2004). However, current trends increasingly emphasise the importance of public transport (Litman, 2006; Puentes 2008). The reasons for this renaissance in public transport are: an ageing population, rising fuel prices, increasing urbanisation, traffic congestion, rising

road expansion costs, changing consumer preferences and growing health and environmental concerns. So that, several cities have experienced a shifting of the demand for transport from the car to alternative modes.

Several actions can be taken to improve the efficiency of this service. Analysis of the demand for public transport and its various components is necessary in order to choose the best policy to adopt. Since the 1980s, several economists have been interested in determining the elasticities of demand for public transport in large Western cities (Webster and Bly 1980 ; Copley and Lowe 1981). In the 1990s and 2000s there was a significant increase in work aimed at determining these elasticities (Goodwin, 1992 ; Oum et al 1992 ; Fowkes et al 1992 ; Preston, 1998 ; Dargay and Hanly 2002 ; Bresson, et al. 2003 ; Dargay, et al, 2002; Holmgren 2007....) The latest work in this area has tried to introduce other factors that may have a direct or even indirect influence on the elasticities of demand for public transport. (Wardman and Shires 2011; Iseki and Ali 2014; Dunkerley, et al. 2018; Wardman et al. 2018 and 2022).

All these studies have been developed for cities in Western countries where the transport sector is generally well structured with a multiplicity of public modes (bus, tram, metro, train). Studies specific to developing cities are almost non-existent. Thus, in this paper, we will analyse the characteristics of the demand for public transport for the large Tunisian cities. The calculation of the elasticities of demand for this service for the Tunisian case will allow us to identify the specificities of these cities and to compare our results with those of previous studies. The socio-economic characteristics of customers, the unfair competition from informal modes of transport and the quality of the service offered, will certainly have a direct influence on the demand for public transport in Tunisian cities. The elasticities estimated will therefore be different - or even contradictory - from the general trends identified in the theoretical studies.

The remaining of this paper is organized as follows: Section 2 reviewed the literature on public transport demand elasticity. The econometric modeling that allowed us to calculate the elasticity of public transport demand in Tunisia as well as the retained variables were introduced in section 3. Finally, the results were revealed and the effects of the various elements influencing this demand were discussed in the 4th section. This enabled us to better specify the best practical actions that might be taken to improve the performance of this model. The conclusions were drawn in the final section.

2. LITERATURE REVIEW

Studies that aimed to determine the elasticity of urban travel demand and, more specifically, public transit are numerous and have studied the issue in the context of Western cities. There has been growing interest in the sensitivity of public transport demand to fares and other economic variables since the 1980s. One of the first studies on the public transport demand elasticities was published by Webster and Bly (1980). This study is rightly considered to be the “white book” in this area. The authors concluded that the very reasonable basic value of the price elasticity for public transport is to be set at around -0.3 causing most studies of the 1980s to adopt this figure. However, in the early 1990s, the price elasticity started to be revised upwards by admitting that it might vary between -0.3 and -0.4 or more.

Goodwin (1992) and Oum et al. (1992) summarize most studies on the elasticity of demand for public transport before 1990 and highlight the process of updating the work of Webster and Bly (1981). Goodwin (1992) reviewed 50 studies on demand elasticity for bus use, carried out in the UK and elsewhere. He calculated an unweighted average of -0.41 and concluded that it would be wise to consider the static elasticity figure -0.3 of Webster and Bly (1981) to be a reasonable figure for the first year's effects. In the “medium-term”, this elasticity would be

about -0.55 and -0.65. Overall, the long-run elasticity is from 1.5 to 3 times higher than that of the short term.

Oum (1992) considered most of the studies that have been carried out in North and South America and Asia and came out with a wide range of elasticity estimates. This study deals with peak and off-peak traffic separately taking into account all the types of users and concludes that off-peak traffic is more price-sensitive than peak traffic. This is rather expected since most of the peak traffic is for work and school trips, which are not easy to give up, while off-peak trips are for leisure or shopping. These peak trips are also difficult to replace by car trips because of the rising costs in terms of time, due to congestion, or the exorbitant parking fees.

Gilbert and Jalilian (1991) study of on-demand bus transport in London provides considerably high elasticity values, i.e. (-0.8) for the short run. The relationship between short and long-term values is consistent with those of other studies stating that the long-term elasticity is 50% more than that of the short term. "The London Transport" also estimated the public transport demand elasticities in London in 1987 and 1992. These studies rather considered the question of distinguishing the tariffs' direct price elasticity from the conditional elasticity. The direct price elasticity shows a change in demand only when there is a change in bus fares. In contrast, the conditional elasticity affects the bus transport demand if the fares of the underground and other modes change in the same proportion. The direct price elasticity was (-0.4) in 1987 and rose to (-0.62) in 1992, and the conditional price elasticity was (-0.27) in 1987 and (-0.35) in 1992.

Fowkes et.al (1992) reviewed the existing literature looking for possible differences in price elasticity for different reasons for travel. They suggest average price elasticity values of (-0.3) for work and business and (-0.6) for leisure. These results confirm the previous ones as the price elasticity for leisure travel (generally during off-peak hours) is twice that of work and business trips (generally peak). **Fox H (1993)** studied the transport demand elasticities from declared preferences as part of the "London Congestion Charging Project". He distinguished a direct price elasticity from a generalized cost one (including travel costs etc.). He found that the generalized cost elasticity is more significant than those related to prices alone. Indeed, the bus travel demand may vary following the variation in the costs supported by the user other than the bus fare eg. parking fees and fees of other means used to reach the bus stop. Two obvious conclusions can be drawn: First, higher income groups are more sensitive to bus fares and generalized cost. This could be explained by the fact that a more significant proportion of this group has access to cars as an alternative mode of transport and has a more significant time value. Second, traveling for other purposes than work is much more price-sensitive than travelling to work. This can be attributed to the essential nature of this type of trip.

Dargay and Hanly (2002) studied the effects of changes in bus fares in England. They found that demand was slightly more sensitive to a rise in tariffs (-0.4 over the short run and -0.7 in the long run) rather than to a decline (-0.3 over the short run and -0.6 in the long run). It tends to be more price-sensitive for higher tariff levels. The cross elasticity of the bus modal share with respect to the car use cost is negligible in the short run but increases to 0.3 to 0.4 over the long run. Finally, the cross elasticity of motorization for transport tariffs, over the long run, is 0.4, while the car use elasticity for transport tickets is 0, 3.

Balcombe et al. (2004) elaborated a guide for the Transport Research Laboratory on the factors influencing the public transport demand. The authors estimate that the average fare elasticity for buses is around (-0.4) in the short run, (-0.56) in the medium run and (-1.0) in the long run. However, for the underground, this same elasticity is (-0.3) in the short term and (-0.6) in the long term. During peak periods, bus travel demand is less price-sensitive than during off-peak hours. Indeed, the bus fare elasticity values during these two periods are (-0.24) and (-0.51), respectively.

Bresson et al. (2003) used a dynamic model to calculate public transport price elasticity for panel data from the British and French cities. They found that users are relatively sensitive to fare modifications, with a price elasticity of -0.3 and -0.5 in the short run and -0.6 and -0.7 in the long run. The study also revealed that demand is sensitive to the quality of service. Thus, an increase in tariffs can be compensated by the improvement of the service. The authors explained the significant difference between elasticities for the two countries by the nature of the two cases data and not by a divergence in users' behavior. Indeed, they used data relating to urban areas only for French cities, but data relating to urban and non-urban areas for English towns.

Nevertheless, the difference between income elasticities is so significant that it cannot be convincingly explained in terms of the data differences only. These elasticities amount to (-0.48) in the short term and (-0.66) in the long term in the case of England and (-0.013) in a short run and (-0.023) in a long run in France. One possible interpretation is that public transport is considered as an inferior good. It was less sensitive to the income in France than in England, which reflects a better quality public transport service in France.

Preston (1998) also examines the variation in elasticity over city size. His study relied on the **ISOTOPE (1997)** study results, in which data for 89 European cities were analyzed. The results of this study suggest that the bus fare elasticity is higher in small towns (those with a population of fewer than 500,000 inhabitants) than in large ones (-0.50 compared to -0.34). This contradicts the conclusion of **Webster and Bly (1980)** for the cities of North America highlighting opposite results instead. **Preston (1998)** justifies this low fare elasticity in major European cities by the fact that passengers are more attracted to public transport. Indeed, they generally travel longer distances than the inhabitants of small towns. Thus, other alternatives such as walking and cycling are less attractive. In addition, congestion and parking problems in large cities make car journeys less attractive. The same study also indicates that service elasticity is more significant in large cities than in small towns (0.49 and 0.33, respectively). This is explained by the greater modal competition in large cities. Normally, while the fares for all modes change proportionally, service changes in public transport modes are not proportional. The service higher elasticity in large cities should take into account the greater competition between public transport services.

Bresson et al. (2004) used the generalized method of moments (GMM) models to estimate public transport elasticities for a data sample from 62 French areas during 1975–1995. The estimated long-run fare elasticity was -0.65. The authors also calculated the elasticity of the kilometers covered by the buses, and found that it amounts to 0.68 in the long run. They estimated the long-run elasticities of income level to be - 0.23, confirming the microeconomics theory predictions for the state of public transport as an inferior good.

Holmgren (2007) has explained the different elasticities obtained by different studies using meta-analysis approaches. Concerning the fare elasticity, he found an average of - 0.38 for 81 studies. The average elasticity for the service level amounts to 0.72 in 58 studies. The author noted that the service level variable was not treated in the same way, which could have resulted in biased parameters. He recommended the endogenous treatment of this and other variables. Once this endogeneity is taken into account, the estimated fare elasticity rose to - 0.75 and the service level elasticity increased to 1.05. These values are higher than those calculated without considering the service level dependence on demand for transport. For the available European research, the short-run elasticities are -0.62, 0.4 and -1.48 for income, fuel prices and car ownership, respectively. **Holmegren (2007)** concluded that these figures validate the fact that public transport in Europe is considered a cheap commodity. Therefore, this service use could continue to decline if income and car ownership rates keep rising.

Holmegren (2013) studied the different factors affecting public transport in Sweden for the

1986-2001 period. He used an econometric FD-model, allowing for unobserved effects. The estimated short-run elasticities for fare, vehicle kilometers, income, and car ownership were -0.4 , 0.55 , 0.34 , and -1.37 . However, together with the clear direct effect, income has a secondary indirect effect on demand through car ownership. Combining these effects with opposite signs, the author found a total income effect close to zero. If the full effect of changes in income is taken into account, there is no evidence that public transport demand might fall with an increased income.

Recent studies reveal other factors that may affect public transport elasticities. (Dunkerley, et al. 2018; Iseki and Ali 2014; Taylor et al. 2009; TRL 2004; Wang 2011; Wardman and Shires 2011; Wardman et al. 2018 and 2022). The user type affects the transport demand elasticity. Dependent-transit users are generally less price sensitive than discretionary users. Low-income, disabled, young and elderly people tend to be more transit dependent. These transit-dependent people represent a relatively small portion of the total population, but a large one of transit users, while discretionary users are a potentially large but more price-sensitive market segment. The demand of the first group is therefore more elastic than that of the second.

The trip type is also another factor that explains elasticities diversities. Price elasticities for off-peak trips are generally 1.5 to 2 times higher than peak period elasticities. The elasticities for these public transport trips are therefore low, indicating a very low sensitivity of this demand to transport fares. The third factor is the mode and route. Price elasticities also differ according to the mode of public transport: rail and bus. In large cities, rail demand is less price sensitive than bus demand. Rail fare elasticities are typically around -0.18 . For example, the Chicago Transportation Authority found that the price elasticity for bus riders is -0.30 in peak hours and -0.46 in off-peak hours, while those for rail riders are -0.10 and -0.46 , respectively. Fare elasticities tend to increase on routes where passengers have viable alternatives, such as suburban rail systems. Price elasticities tend to be lower and lower as city size increases. The proportion of residents' dependent on public transport is reduced in small cities and suburbs. The Type and direction of price change can also explain these elasticities variations. Changes in fares are often non-symmetrical. While fare increases reduce ridership, its reduction of the same magnitude does not necessarily increase it. In effect, a price increase induces households to use individual modes, which can be somewhat irreversible as people often continue to resort to this option. This is usually omitted by standard travel demand models which often apply the same elasticity value to price increases and reductions. Finally, the transit type has a significant effect on transit elasticities. The negative impact of car ownership on rail demand is not as important as on bus demand. In addition, the overall effect of income on rail demand is often positive, despite the significant variations between market segments and distance bands.

Taylor et al (2009) analyzed public transport demand behavior in US cities. In addition to pricing and supply, they introduced various geographic and demographic factors. The results of their study indicate a value of the aggregate price elasticity (all types of public transport) of -0.51 which is higher than those of previous studies. Moreover, the hours-of-service elasticity values are in the range of 1.1 to 1.2. Dunkerley, et al. (2018) evaluated bus fare and journey time elasticities and cross elasticities based on the analysis of numerous studies for the British case. They find that the values of bus fare elasticities recommended by the official authorities and introduced by Dargay & Hanly (2002), still hold. The recommendations of Toner et al. (2010) for short-run fare elasticities (SR) for the full fare market are very close to the recommendations. Wardman (2014) also finds that bus fare elasticities are in line with these two studies and the official recommendations. However, Dunkerly et al. (2018) recommends elasticity values for segmentations that depend on area type and trip purpose. The fare elasticity thus varies according to the zone and the reason for travel. For work trips, it is equal to -0.3 in the short term and

-0.65 in the long term in urban areas, but it is around -0.4 and -0.85 for London and rural areas. For leisure trips, the tariff elasticities for the same zones are - 0.4 and -0.55 for the short term and -0.85 and -1.1 for the long term.

Watkins, et al. (2021) sought to explain the decline in public transport ridership in the US between 2012 and 2018. During this period, and in contrast to the trend in other countries, bus and train ridership fell by 15% and 3%, respectively. They show that service improvements and land use changes have increased the bus ridership by 4.7% and the rail one by 10.7%. Similarly, the restructuring of bus networks resulted in average increases of 4.7% in bus patronage above other service expansion gains. However, other factors offset these increases. Increased carpooling led to a 10% decline in bus and rail ridership in medium-sized metropolitan areas. Lower gas prices, rising fares, higher incomes, car ownership, and the increase in telecommuting have also contributed to the fall in transit ridership.

Mattson (2008) analyzed the effects of rising fuel prices on public transport use in US cities from 1999 to 2006. The analysis found that the long-run fuel price elasticities of demand for public transport were 0.12 for large cities, 0.13 for medium-large cities, 0.16 for medium-small cities and 0.08 for small cities. He concluded that people in large cities react quickly to rising fuel prices, usually within one or two months, while for medium and small cities the effects are not as quick and take five to seven months.

Wardman (2022) introduces a meta-analysis of the price elasticities of transport demand. The study was based on 2023 elasticities from 204 UK studies published between 1968 and 2020. The results highlight a large number of credible variations in elasticities, challenging some official recommendations. The significant variations in elasticities depend on the key transport planning variables of mode, trip purpose and distance. Elasticities for work trips are the lowest, followed by commuting and leisure trips. Intercity trips have a higher price sensitivity than urban trips and car trips. The estimated model reveals that the static elasticities are slightly higher than the short run ones, but the long run elasticities are slightly higher. The meta-model distinguishes between elasticities according to the purpose of the trip and the travelled mileage. It concludes that car travel and especially leisure travel are more elastic. Similarly, the rail elasticities obtained from choice models are relatively high. Elasticities for leisure trips obtained from mode choice models are likely to be lower. There are plausible variations in rail fare elasticities by ticket type, but the results of the analysis indicate that cross-elasticities between tickets are low.

Knowledge about the elasticity of diverse variables could be helpful by providing information for public transport managers and operators. The variation of the demand may impact the system sustainability through changes in income, occupancy, and other factors.

3. METHODOLOGY AND DATA

In this section the theoretical formulation of the public transport by bus demand models incorporating macroeconomic variables of income per capita was introduced. The study areas are presented along with the available data for estimating the models.

3.1. PUBLIC TRANSPORT DEMAND MODELING

Most of the previously-presented studies in the above section have provided evidence about the influence of different transit demand variables. They have focused on the effect of 3 variables: fare and service levels, and income. (Bresson et al. (2004), Holmgren (2007), Bresson et al. (2003), Balcombe et al. (2004)).

We assume that the long-term equilibrium demand for bus services, in terms of trips per capita,

$Y_{i,t}$, in zone i in year t can be expressed as a function of the bus fare, level of service and disposable income capita.

$$Y_{i,t} = f(\text{fare}, \text{Service}, \text{income}) \quad (1)$$

To accommodate delays in adjusting to changes in the explanatory variables, a partial adjustment model was used to connect the actual demand, $Y_{i,t}$, to the long-term equilibrium level. This resulted in the following model:

$$Y_{i,t} = f(\text{fare}, \text{Service}, \text{income}) + \theta_i Y_{i,t-1} \quad \text{where } 0 < \theta_i < 1 \quad (2)$$

The adjustment coefficient $(1-\theta_i)$ indicates the difference between the equilibrium level and the effective demand each year. The previous demand as an explanatory variable can be interpreted in terms of habits or inertia. Public transport users do not respond instantly to changing circumstances but rather do so with a delay.

The selected specification is a partial adjustment model, and the demand function is supposed to be logarithmic, therefore:

$$\text{Log } Y_{i,t} = \alpha_i + \beta_{pi} \text{Log}(\text{fare}_{i,t}) + \beta_{si} \text{Log}(\text{service}_{i,t}) + \beta_{ri} \text{Log}(\text{income}_{i,t}) + \theta_i \text{Log } Y_{i,t-1} \quad (3)$$

The short-run elasticities are obtained directly from the coefficients of the independent variables, while the long-run elasticities correspond to the ratio between the short-run elasticities and the adjustment coefficient $1-\theta_i$; $\left(\frac{\beta}{1-\theta_i}\right)$. When the value of θ_i increases, the adjustment speed will be slower, and the difference between short and long-run elasticities will be more significant.

By grouping the data into a panel, the differences between regions that are not captured by the included explanatory variables can be assumed to be fixed or random. In the fixed-effects model, the differences between the zones can be represented by a parameter specific to each region (α_i). As for the random-effects model, it represents the differences between regions as differences in terms of random error. There is no a priori reliable way to choose which of the two specifications is more appropriate. The choice should be based on statistical tests.

In standard panel data literature, it is usual to pool observations with or without distinct intercept terms by assuming that the slope coefficients do not differ between individuals and/or over time. The distinct intersections $\delta = \delta_0 + \mu_i$ can be supposed to be fixed or random if the specific individual effect μ_i is considered as fixed or random. In the first case, the dynamic model with fixed effects can be written as follows:

$$\text{Log } Y_{i,t} = (\delta_0 + \mu_i) + \alpha \text{Log } Y_{i,t-1} + \sum_{j=1}^{k1} \beta_j \text{Log } X_{j,i,t} + \varepsilon_{i,t}$$

In the second case, the specification of the dynamic error component can be presented as follows:

$$\text{Log } Y_{i,t} = \delta_0 + \alpha \text{Log } Y_{i,t-1} + \sum_{j=1}^{k1} \beta_j \text{Log } X_{j,i,t} + \mu_i + c$$

In this case, the unobservable individual-specific effects are represented by μ_i and c is the residual disturbance. For the fixed-effects model, the practitioner makes inferences conditional on the effects. For the random-effects model, the inferences are made unconditionally.

3. 2. DATA

Before starting the econometric analysis of the determinants of public transport demand in Tunisia, it is useful to introduce the main variables that can significantly affect this demand. Like most of the above-presented studies, we have retained the variables that measure the demand, price and quality of public transport service and per capita income for the different regions. The data used in this study cover the period 2003-2020.

Public transport in Tunisia is provided in almost all Tunisian cities by public monopolies oper-

ating at the regional level. However, there is a substantial disparity between the different Tunisian regions regarding public transport demand characteristics and nature. Therefore, cities and networks choice were made relying primarily on the criterion of population number and density and data availability. Thus, we have chosen five regions: Sfax, the Sahel (Sousse, Monastir and Mahdia), the Cap Bon (Nabeul and Zaghouan), and Kairouan and Gabes and Kebili.

The used transport data were collected from the activity reports of the regional transport companies for the different zones, and which are: The Regional Transport Company of the Governorate of Sfax: SORETRAS, the Nabeul Regional Transport Company: SRTGN, the Sahel Transport Company STS, the Kairouan Regional Transport Company SORETRAK and the Regional Transport Company of Gabes: SOTREGAMES.

Demand Measurement

To evaluate the demand for public transport by bus, the aggregate commonly chosen by studies carried out in this context is the number of passengers transported per capita. The table below shows the evolution of this aggregate for the different zones during the study period.

Table 1. Public transport uses per capita

	Sfax	Gabes	Sahel	Nabeul	Kairouan
Average	79.56	67.56	57.36	49.31	26.85
Std dev	3.87	15.46	5.81	2.79	6.42
Min	74.53	40.68	48.12	42.92	17.87
Max	86.69	82.98	63.87	52.97	34.97

Source: Author Calculation

The average number of people transported per capita varies considerably from one region to another. Sfax has the highest number of trips per inhabitant with an average of 79.56, followed by Gabes with an average of 67.56 while the lowest average corresponds to Kairouan (26.85). The trend in the number of travelers per capita also varies from region to region. Rates of change are inversely proportional to the extent of demand in each region. The average annual growth rate shows the same trends as the aggregate demand evolution. Sfax has the lowest rate, 0.38%; this rate reaches 6.11% in Kairouan. This is explained in particular by the nature of the public transport network in each region and the urban nature of the studied areas.

In Sfax, SORETRAS mainly serves the urban area where demand is relatively high. In addition to the large number of Sfax inhabitants, the large number of pupils and students in this agglomeration explains the increased use of collective mode for daily journeys. The Sahel region is characterized by several cities of various sizes (often small towns), relatively close to each other. Thus, a large part of the STS's public transport service is devoted to suburban transport across these towns and villages. Regarding Gabes and the Cap Bon areas, public transport networks are split between urban and interurban. This explains the relative weakness of the bus clientele. Indeed, most cities in these regions are relatively small, which results in fairly low demand on the urban network. Finally, the Kairouan area is rural, and consists of small localities where the population density is relatively low.

Fare Measurement

The Tunisian public authorities consider the collective transport service as a social service provided for non-profit purposes. Fares charged by public transport companies are administered prices fixed by the Ministry of Transport. These prices are lower than the costs paid by the transport companies. School season ticket fees and reduced fares for specific social categories

do not cover 1/10th of their travel costs. To deal with the pricing problem and the existence of various types of fares and services, an average public transport price is usually calculated. This average fare is obtained by dividing the company's annual revenue by the number of carried passengers.

The following table summarizes the fares evolution for the chosen public transport companies for the period of study.

Table 2. Fares evolution

	Sfax	Gabes	Sahel	Nabeul	Kairouan
Average	0.195	0.308	0.157	0.455	0.153
Std dev	0.014	0.036	0.009	0.048	0.021
Min	0.179	0.259	0.139	0.407	0.095
Max	0.225	0.366	0.168	0.564	0.167

Source: Author Calculation

The low fares for all the examined companies is explained by the relatively low revenue and bus users. The majority of public transport customers in these regions are pupils and students who travel almost free. This will have an immediate consequence on revenues and therefore on the average price. The fares variation is negative for all the regions except for the Cap Bon area. The most substantial decline is recorded in Kairouan area with a rate of 43.3% over 15 years or an average annual rate of change of -3.68%.

Finally, we conclude that changes in this average price are inversely proportional to the change in transport demand as already presented and discussed.

Service Quality

The most appropriate measure that evaluates the public transport offer is the mileage traveled by the various vehicles, i.e., the "vehicle kilometers". Moreover, most of the studies presented above have used this variable to reflect the offered service quality. However, to eliminate the effect of regional size, the number of kilometers traveled per capita was calculated. These «vehicle kilometers per capita» statistics show the distance in kilometers the public transport company provides to each person per year.

The variations in the number of traveled kilometers per capita for the five transport companies under study are shown in the following table.

Table 3. Number of kilometers traveled per capita

	Sfax	Gabes	Sahel	Nabeul	Kairouan
Average	16.98	23.33	13.14	23.26	3.215
Std dev	0.649	1.21	0.362	0.87	0.497
Min	15.99	21.59	12.35	21.52	2.52
Max	17.92	25.32	13.76	24.65	4.12

Source: Author Calculation

The average values of each company mileage are similar for the different regions, i.e., values between 13.4 (km) for the Sahel and 18.9 (km) for the Cap Bon. The is the Kairouan area is rather an exception since its average is only 3.4 vehicle kilometers per capita. This proximity of the different average values justifies the fact that public transport is considered as a social service. The supply of this public transport service is not correlated with demand. Several trips are made with a minimal number of users. These companies' buses often provide either almost

empty outings or returns, especially when it comes to school transport. We also observe a relative stagnation of this transport offer over the entire period.

Income

Income is always a fundamental element explaining the variations in demand. All the previous research works consider that transit demand is explained by gross disposable income per capita. The problem that arises in our case is related to this variable's unavailability for the various Tunisian regions. To face this issue, we calculated the regional average per capita expenditure ratio to the national average. We obtained a coefficient reflecting each region's relative importance compared to the national level in terms of expenditure. Knowing that the expenditure is mainly explained by income, we can assume that the ratio of regional income to national income is the same as that of expenditure. Thus, by multiplying the national income per capita by this expenditure weighting coefficient, we obtained a statistic that primarily reflects the disparities between regions in terms of income. Table 4 shows the income evolution for the different regions over the entire study period.

Table 4. Regional income simulator

	Sfax	Gabes	Sahel	Nabeul	Kairouan
Average	5910.14	5289.18	5740.32	4575.84	3281.68
Std dev	1708.53	1529.23	1659.41	1322.86	948.23
Min	3501.32	3133.43	3402.73	2710.82	1942.68
Max	8859.17	7928.31	8604.54	6859.64	4915.41

Source: Author Calculation

The areas of Sfax and the Sahel have almost the same income values. Regional revenues for these areas are significantly higher than the national ones. This results from the importance of their contribution to the Tunisian GDP. Likewise, the income values of Gabes and Cap Bon are quite close to the first two zones. This highlights the widely held idea of the concentration of economic activities and investments in the country's coastal areas. The low-income values for the case of Kairouan Governorate reflect regional disparities between coastal and inland areas. The unit root test for model variables follows. In this stage, we interpret unit root tests that assume inter-individual independence. We can simply establish the statistical distributions of the tests and obtain asymptotic or semi-asymptotic normal distributions with this assumption. Correlations between people are nuisance parameters, hence these tests do not account for them.

Thus, we use [Levin et al. \(2002\)](#), [Im et al. \(2003\)](#), and [Hadri \(2000\)](#) first-generation tests. Our panel data unit root tests employing LLC, IPS, and LM techniques for the four variables are shown in Table 5. These results show that panel data three-unit root tests fail to reject the null hypothesis of non-stationarity at the level. Level-wise, the variables are non-stationary. We find stationarity in the first difference series testing. According to the first-generation tests, all variables are integrated of order 1 $[I(1)]$.

Table 5. Unit root tests

Variables	In level				In first difference			
	LLC	IPS	LM	Decision	LLC	IPS	LM	Decision
PTuse	-1.119 (0.132)	0.239 (0.594)	50.558 (0.000)	NS	-3.163 (0.000)	-6.345 (0.000)	-1.293 (0.902)	S
service	-0.915 (0.180)	-0.682 (0.548)	37.684 (0.000)	NS	-6.933 (0.000)	-8.356 (0.000)	-1.743 (0.960)	S
Income	-0.271 (0.126)	-0.726 (0.689)	49.816 (0.000)	NS	-5.260 (0.000)	-5.186 (0.000)	6.445 (0.996)	S
Fare	-1.277 (0.101)	-0.401 (0.382)	37.883 (0.000)	NS	-6.366 (0.000)	-8.006 (0.000)	-1.335 (0.909)	S

Note: Values in brackets represent probability. S and NS represent significance and non-significance respectively.

Source: Author Calculation

Since most variables are stationary in first difference, cointegration must be investigated. Cointegrated series are those that are integrated of order one (i.e., become stationary after the first difference) and have a stationary linear combination without differencing. This shows a long-term series link [Azmi et al., \(2023\)](#). We will use [Kao \(1999\)](#), [Pedroni \(2004\)](#), and [Westerlund \(2007\)](#) first-generation tests, to investigate.

Table 6. Cointegration tests

Tests	Value	p-value	Decision
Kao (1999)	3.591	0.009	Cointegration
Pedroni (2004)	5.301	0.000	Cointegration
Westerlund (2007)	4.077	0.000	Cointegration

Source: Author Calculation

Panel cointegration tests in Table 6 show at least one cointegration relationship. The odds of these three statistics are all below 5%. Therefore, we may certainly reject the null hypothesis of no cointegration. This indicates that the variables analyzed are co-movements with a stable equilibrium due to long-term relationships.

Models Presentation

In order to determine the elasticity of public transport demand, we estimated the functional modal presented in section 2. Two variants of the model were estimated; one considers that the fare elasticity is the same for all the studied areas. The second determines each region a specific value of the fare elasticity.

In this context, the functional form retained to estimate a homogenous fare elasticity for all regions studied is as follows:

$$\text{Log } Y_{i,t} = \alpha_i + \beta_{ft} \text{Log}(\text{fare}_{i,t}) + \beta_{st} \text{Log}(\text{service}_{i,t}) + \beta_{it} \text{Log}(\text{income}_{i,t}) + \theta_t \text{Log} Y_{i,t-1} + \varepsilon_{it} \quad (1)$$

We used the GMM method to estimate this dynamic model (1) on the panel data. The table 5 below shows the estimation results.

To determine the specific fare effect on public transport demand for each region we develop another variant of model in which the price elasticity was calculated for each of the studied areas. To this end, we introduced some dummy variables into the previously estimated equation, which would allow us to detect this effect in each zone. This approach was already used by several previous studies, particularly those of [Dargay J.M and Hanlay M \(2002\)](#). The applied functional form is as follows:

$$\begin{aligned} \text{Log } Y_{i,t} = & \alpha_i + \beta_{st} \text{Log}(\text{service}_{i,t}) + \beta_{it} \text{Log}(\text{income}_{i,t}) + \beta_{p1} d_1 \text{Log}(\text{fare}_{i,t}) + \\ & + \beta_{p2} d_2 \text{Log}(\text{fare}_{i,t}) + \beta_{p3} d_3 \text{Log}(\text{fare}_{i,t}) + \beta_{p4} d_4 \text{Log}(\text{fare}_{i,t}) + \\ & + \beta_{p5} d_5 \text{Log}(\text{fare}_{i,t}) + \theta_t \text{Log} Y_{i,t-1} + \varepsilon_{it} \end{aligned} \quad (2)$$

With $d_1 = 1$ if it is the Sfax area and zero if not, $d_2 = 1$ if it is the Gabes area and zero if not, $d_3 = 1$ if it is the Sahel area and zero if not, $d_4 = 1$ if it is the Kairouan area, and zero if not, $d_5 = 1$ if it is the Nabeul area and zero if not.

The GMM method was adopted as above for the estimation of this dynamic Panel model. The estimation results are shown in table 7.

4. RESULTS AND DISCUSSION

4. 1. ESTIMATION OF HOMOGENOUS FARE ELASTICITY

Table 5 summarizes the results of the estimation of the first variant of the model which deter-

mines the same values of fare elasticity for all regions

Table 7. Estimation results of homogenous fare elasticity model.

Dependent Variable: PT use			85 observations
Variable	Coefficient	T statistic	Significatively level
PTuse (-1)	0,6935	14,67	1%
service	0,1815	4,15	1%
Income	0,1	3,06	1%
Fare	-0,1477	-3,21	1%
Constante	-0,296	-1,17	N.S
Arrelano Bond test		Z=-1,49	pr > Z = 0,135
Sargan Test			
F(4,80) = 2019,05			

Source: Author Calculation

First, it is worth noting that all the coefficients are highly significant. This proves that our choice of the explanatory variables was good as they are important in determining public transport demand for large Tunisian cities. The Fisher statistic is quite high $F(4, 80) = 2019.5$, which indicates a high significance of the model. Arellano Bond's test presents a statistic $Z = -1.49$ with a probability $pr > Z = 0.135$. This is synonymous with the rejection of the null hypothesis concerning the autocorrelation between variables. Finally, the robustness of the choice of the instrumental variables is justified by Sargan's test, for which the statistic is.

In addition, the coefficients signs are broadly in line with the microeconomic theory suggestions and almost all the studies presented in section 2. Only the income displays a particular sign. This positive sign for the income elasticity represents a peculiarity compared to the previous works and the microeconomic theory suggestions. This result shows that public transport is not an inferior good in the chosen Tunisian regions, but rather a normal good. The two following facts can justify this particularity: first the adopted income measure: lacking an exact measure of the per capita income values for each Tunisian region, we opted for an approximate calculation of this aggregate. And secondly the socioeconomic specificities of the public transport users in Tunisia: more than 80% of travelers are pupils and students who pay only 10% of their transport costs.

Students use public transport not only for their trips to study but also for their leisure trips. These two reasons for travel have become more and more critical. The increase in this category of transport users generated an increase in the demand for leisure travel.

For the demand elasticity, since we have estimated a log-linear model, the explanatory variables coefficients represent the short-run elasticities' values. To calculate the long-run elasticities, it would be enough to divide the short-run values by the adjustment coefficient 1-. The following table determines these values of the short and long-run elasticities.

Table 8. Short and long-run elasticities

Variable	Short-run elasticities	Long-term elasticities
Fare	-0,1477	-0,4819
Income	0.1	0,326
Service	0,1815	0,5291

Source: Author Calculation

The low positive values of the income elasticities (0.1 in the short run and 0.326 in the long run) indicate that the collective transport service in large Tunisian agglomerations is a normal commodity of primary necessity. This is in total contradiction with all previous studies on transport demand elasticity (Goodwin, 1992; Oum et al., 1992; Fowkes et al., 1992; Preston, 1998; Dargay and Hanly, 2002; Bresson et al., 2003; Dargay et al., 2002; Holmgren, 2007; Wardman et al., 2018 and 2022). Indeed, as we have already indicated, public transport is considered as an inferior good due to the fact that the income elasticity of demand is negative. This particularity of this service for Tunisian cities can be explained by several aspects and characteristics of the users of this mode. It is the most deficient social categories benefiting from free transport who use this service for their daily trips, especially in the large cities. The increases in the income for these categories will be used for buying other goods or services. To this end, the demand for transport will naturally increase owing to the rise in income.

This conclusion can be confirmed by the relatively low service elasticities (0.1815 at the short run and 0.529 at the long run). Indeed, these low values indicate that the demand for public transport very slightly depends on the provided service quality. The socioeconomic characteristics of the public transport customers as well as the public monopolies offering this service are also important elements in explaining the rigidity of demand about fares and the low elasticities compared to previous studies. Indeed, as indicated above, almost all the studies on transit demand (Goodwin, 1992; Dargay and Hanly, 2002; Balcombe et al., 2004; Bresson et al., 2003; Bresson et al., 2004; Holmegren, 2007) among others) suggest that the short-run price elasticity is of the order of -0.3 and that of the long run ranges between -0.5 and -1. However, the values of short and long-run fares elasticities we have just calculated for the case of Tunisian cities are respectively -0.14 and -0.48.

The public transport pricing system is an essential element in explaining this rigid demand. The responsible ministry fixes public transport tariffs in Tunisia without considering the relationship between supply and demand or the evolution of other competing transport modes costs and prices. Changes in the prices of student subscriptions are rarely made, even though it represents only 10% of its real trip's costs. Thus, it is clearly observable that the social and political choices are the main factors explaining the reason the central authorities keep transport tariffs unchanged for rather long periods.

4. 2. ESTIMATION OF SPECIFIC FARE ELASTICITY FOR EACH REGION

Looking at the evolution of the different variables income, quality of service and fares, we can see that the variation in these variables is relatively small over the study period for each region. However, for bus fares, we note a significant variation between regions. As a result, it is to be expected that bus fares do not have the same effect on public transport demand for the various regions. In order to detect the specific effects of fares on demand for each region, it makes more sense to introduce dummy variables that will enable us to calculate specific fare elasticities for each region.

Table 7 summarizes the estimation results of the variant 2 of the model in which specific fare elasticities of public transport demand for each region were calculated.

Table 9. The estimation results of specific fare elasticity for each area

Dependent Variable: PT use			85 observations
Instruments Numbre: 17			Groups Numbre: 5
Variable	Coefficient	T statistics	Significativity
PT use (-1)	0,9573	19,6	1%
service	0,1549	2,26	5%
Income	-0,151	-1,43	N.S
Fare			
Sfax	-0,125	-2,23	5%
Gabes	-0,245	-3,87	1%
Sahel	-0,127	-2,67	1%
Kairouan	-0,178	-2,9	1%
Nabeul	-0,164	-1,73	N.S
Constant	-0,72	-0,24	N.S
Arrelano Bond test $Z=-1,77$			$pr > Z = 0,076$
Sargan Test			
$F(8,76) = 882.68$			$pr > F=0,000$

Source: Author Calculation

Statistically, the robustness of this model is justified by: a high value of the Fisher statistic $F(8.76) = 882.68$; the significance of the variable's coefficients at 5%; only the income and price coefficients of Nabeul β_{p5} are not significant; Sargan's test indicates a , which proves the robustness of the choice of our instrumental variables; and Arellano bond's test indicates the lack of autocorrelation between variables.

All the signs of the estimated coefficients seem to be fully in line with the suggestions of the microeconomic theory of demand. For all the studied cities, demand is on the increase compared to previous period and to the quality of service. However, this demand decreases when it comes to price and income. The negative sign for the income coefficient may, at first glance, appear to contradict the results of the previously-estimated model. The short-run income elasticity is of the order of (-0.151). This coefficient is not significant even at the 10% level which proves that the income variable has only a very marginal effect. Thus, the previous conclusions related to the particularities of the relationship between income and demand for public transport remain well-founded.

The low value of the quality-of-service elasticity, i.e. (0.154), is explained, as previously indicated, by the nature and socioeconomic characteristics of the public transport users. The lagged endogenous variable ($PTuse_{-1}; Y_{i,t-1}$) has a high and significant coefficient (0.95). This value reflects a certain stability in demand. In fact, bus customers always belong to the same social categories and, therefore, have the same attitudes throughout the study period. Travel habits explain, better than any other variable, the behavior of the bus users. The changes in prices and characteristics of the other competing transport modes do not significantly affect public transport demand in Tunisia. However, both quantitatively and qualitatively, the stability of this service supply is a fundamental element in explaining this continued demand.

The following table provides short and long-run fares elasticities for each area:

Table 10. Short and long-run fares elasticities for each area.

Variable	Short run elasticity	long run elasticity
Fare of Sfax	-0,1254	-2,508
Fare of Gabes	-0,2456	-4,912
Fare of Sahel	-0,1278	-2,556
Fare of Kairouan	-0,1781	-3,562
Fare of Nabeul	-0,1641	-3,282

Source: Author Calculation

According to these price elasticity values, we can divide the studied areas into three groups:

A first group that consists of the regions of Sfax and Sahel where the fare elasticities are very low over both the short (-0.12) and long runs (-2.5); a second group includes the areas of Kairouan and Nabeul where the elasticity values are relatively moderate ranging between (-0.16) and (-0.18) in the short term and (-3.2) and (-3.8) in the long run; and finally, the elasticity remains relatively high in the region of Gabes where it is about (-0.245) in the short run and (-4.9) in the long run.

The socioeconomic characteristics of the different areas prove this difference. The low values of fare elasticities for the Sfax and Sahel regions are justified by a significantly higher level of economic and social development than that of the other areas, and consequently significantly better income, purchasing power and high motorization rate; the availability of other collective transport modes competing with buses at very competitive prices (mainly the common taxi). Others factors can explain this difference such as the high concentration of the population and a very high urbanization rate; the existence of large universities, vocational training centers and a large number of high schools and colleges, resulting in a very high number of pupils and students; the most of the trips are for work places and the fact that public transport networks are essentially made up of urban and suburban lines, which are relatively short.

All these elements mean that 85% of the bus customers in Sfax and Sahel are pupils, students, and most deprived people. In other words, public transport users in these areas benefit from almost free journeys or have very low income that does not allow them to use other modes of transport. Thus, the effect of the fare on-demand for public bus transport is only marginal, and the fare elasticity is therefore very low.

For the zones of the second group, namely Kairouan and Nabeul, the price elasticity values are explained by the public transport networks specificity serving rural areas and small towns that are quite distant; the number of pupils and students is not that high and their mobility is low; the population low motorization and the composition of the public transport users involving a large number of full-price users.

Thus, the demand for public transport in the regions of Nabeul and Kairouan are more price sensitive than the areas of Sfax and the Sahel. This is mainly due to the fact that full-fare riders are likely to change their travel mode when buses' relative fares increase.

The Gabes region has the highest fare elasticity compared to the other areas (-0.245). The geographical and urban characteristics of this region is an essential element explaining this peculiarity. Indeed, this zone includes cities of relatively large size and which are quite far away from each other. Thus, the public transport network essentially consists of interurban lines serving areas that are quite distant from each other. With the exception of Gabes, which has a real urban transport network, other towns such as Mareth, El Hamma, Matmata, Kebili, and Douz do not have urban lines. The public transport network for these towns includes lines connecting them to nearby villages or other larger towns in the region. The large number of full-fare

users between these different cities and the low mobility of pupils and students contribute to a fairly significant price effect on demand, and therefore a higher fare elasticity than in the other regions.

Finally, it is noteworthy that despite these divergences between the short-run fare elasticity of demand for the different zones, all these values remain quite far from the theoretical values suggested by previous studies presented in section 2, (from -0.3 to -0.5) (Webster and Bly, 1980; Copley and Lowe, 1981; Goodwin, 1992; Oum et al., 1992; Fowkes et al., 1992; Preston, 1998; Dargay and Hanly, 2002; Bresson et al., 2003; Dargay et al., 2002; Holmgren, 2007; Wardman et al., 2018 and 2022). The above-mentioned reasons on the composition of the customers base, the nature of the networks and the organization of transport and journeys explain this low fare elasticity in the short run. However, the values of the long-run elasticities are too high. This is due to the past demand importance in explaining the current demand for public transit. This similarity in the nature of demand generates a negligible effect on prices in the short run and a large effect over the long run.

Thus, improving public transport profitability, boosting this mode, and increasing its modal share compared to other modes require actions other than travel prices. Changes in travel habits and culture, an improved service quality and a differentiation of the supply can be more effective for public transport than changing fares in Tunisia. Public monopolies providing collective transport in each region have to change their attitude. A better governance of these companies will enable them to preserve the character of equity assigned to public transport in Tunisia.

5. CONCLUSION AND POLICY IMPLICATIONS

The calculation of elasticity is a fundamental element in the analysis of the determinants of public transport demand. The large number of studies dealing with this issue in various western cities indicates the importance of this approach to forecast traffic trends and recommend appropriate measures for promoting the transport service. In this context, we have chosen to estimate the elasticities of public transit demand for five Tunisian regions. According to most of the studies carried out in this field, we estimated the log-linear dynamic panel models.

The estimation of the different variants of the selected model allowed us to reach very interesting results. Although these results may sometimes contradict the theoretical suggestions, they still highlight the specificities of the public transport demand in Tunisia and its users' characteristics. First, the demand for public transport in large Tunisian agglomerations is not very sensitive to fares changes. Small differences were found between fare elasticities for the five studied regions, but all of these elasticities are lower than the theoretical values of -0, 3 and -0.5 in the short run. The advantage of free (or almost free) travel, a large part of this service users takes advantage and the relative stability of prices and subscription fees, may explain the rigidity of demand about short-run fares. Over the long run, this elasticity tends to be quite large. Changes in public transport riders' behavior and configuration can have an important impact on the price effect. Second, income does not have the same effect as that advocated by economic theories. Indeed, we have found a positive impact of income on demand for public transport. This calls on the assumption often adopted by microeconomic studies stating that public transport service is an inferior good. Once again, the users composition of this service is the main explanatory factor. More than 75% of those riding public transport in Tunisia are pupils and students or other categories benefiting from an almost free service. The increases in income generate increased

demand for goods and leisure services and therefore more trips. Finally, the quality of service has the most important effect on demand. This relatively high sensitivity is the consequence of the current service supply, the expectation from customers of better travel conditions and often unfair competition from other modes such as collective taxis.

Thus, service quality improvements can be highly effective for public transport in Tunisia. Such actions may also ensure some direct short-term effects. However, the long-term indirect effects are much more important. By acting on the demand nature for public transport and the clientele configuration and composition, possible improvements in the service quality can lead to radical changes in the current users' behavior and the potential demanders of this service.

Changes in travel habits and cultures, improvements in the quality of services and their differentiation can be more effective for public transport than changes in fares. Among the possible measures in Tunisian cities, we recommend an increasing service provision in terms of network coverage, frequency of service and operating time; a rise of the commercial speed of the service by giving priority to public transport vehicles for passage and parking; an improving vehicle comfort (cleanliness and comfort of seats), station and stop conditions, waiting seats, user information; marketing, awareness and information campaigns on the benefits and advantages of public transport; promote public transport-oriented development, which results in more appropriate and suitable land use for this mode of transport.

These improvements in the quality of the public transport service need to be complemented by other incentives to use public transport. Financial incentives can concern both consumers and companies and other economic agents within the city. Indeed, in addition to a possible reduction in transport fares, the tax and other benefits that may accrue to the citizen as a result of reduced car travel are a relatively important incentive to use the collective mode. Tax benefits can also be granted to companies that encourage their staff to use public transport.

Indeed, several economic and social variables contribute to the explanation of the variation of the transport demand. Among these variables we can quote the energy prices, the unemployment rate, the schooling rate, the price of the land and the motorization rate..... The consideration of these variables, or at least of some of them, will allow to improve the quality of the future works on the public transport demand in Tunisia.

REFERENCES

- Azmi, S.N., Khan, T., Azmi, W. and Azhar, N.(2023). A panel cointegration analysis of linkages between international trade and tourism: case of India and South Asian Association for Regional Co-operation (SAARC) countries.” *Quality and Quantity*, 57, 5157–5176. <https://doi.org/10.1007/s11135-022-01602-7>
- Balaker, T. (2004) Past Performance Vs. Future Hopes: Will Urban Rail Improve Mobility In North Carolina? *Policy Study 321*, Reason Public Policy Foundation. <https://a8d50b36.rocketcdn.me/wp-content/uploads/files/dfa9a817fac9a96f66f17ab40904e7a5.pdf>
- Bresson G., Dargay J., Madre J.L. and Pirotte. A (2003), The Main Determinants Of The Demand for Public Transport: A Comparative Analysis Of England And France Using Shrinkage Estimators, *Transportation Research A*, Vol. 37, N°.7, August 2003, 605-627. [https://doi.org/10.1016/S0965-8564\(03\)00009-0](https://doi.org/10.1016/S0965-8564(03)00009-0)
- Bresson G., Dargay J., Madre, J.L. and Pirotte. A, (2003), Economic And Structural Determinants Of The Demand For Public Transport: An Analysis On A Panel Of French Urban Areas Using Shrinkage Estimators, *Transportation Research A*, 38(4), May 2004, 269-285. <https://doi.org/10.1016/j.tra.2003.11.002>
- Cordera, R. Canales, C. Dell’olio, L. and Ibeas, A. (2015). Public transport demand elasticities during the recessionary phases of economic cycles. *Transport Policy*, 42, 173-179. <https://doi.org/10.1016/j.tranpol.2015.05.022>
- Cox, W. (2000) A Common Sense Approach to Transportation In the Atlanta Region, *Georgia Public Policy Foundation*. <http://www.publicpurpose.com/ut-atl2000.pdf>
- Dargay J. and Hanly M. (2002) The Demand for Local Bus Services in England. *Journal of Transport Economics and Policy*, 36(1), 73-91. <https://www.jstor.org/stable/i20053888>
- Dargay J. and Hanly M. (2003) Bus patronage in Great Britain: an econometric analysis. *Transportation Research Record* 1799, 97–106. <https://doi.org/10.3141/1799-13>
- Dargay J., Hanly M., Bresson G., Boulahbal M., Madre J.L., and Pirotte, A (2002), The Main Determinants of the Demand for Public Transit: A Comparative Analysis of Great Britain and France *ESRC Transport Studies Unit, University College London*. <https://trid.trb.org/View/788700>
- De Rus G. (1990) Public Transport Demand Elasticities in Spain. *Journal of Transport Economics and Policy*, May, 189 – 201. <https://www.jstor.org/stable/20052917>
- Dunkerley F., Wardman M., Rohr Ch. And Fearnley N. (2018) Bus Fare and Journey Time Elasticities and Diversion Factors for all Modes: A Rapid Evidence Assessment, *RAND Europe and SYSTRA for the UK Department of Transport* (www.gov.uk/government/organisations/department-for-transport); <https://bit.ly/2Hz8InN>
- Fosu, P. . (2021). Does Railway Lines Investments Matter For Economic Growth? *Economics - Innovative And Economics Research Journal*, 9(1), 11–24. <https://doi.org/10.2478/eoik-2021-0004>
- Goodwin P.B. (1992) A review of new demand elasticities with special reference to short and long run effects of price charges. *Journal of Transport Economics and Policy* 26, 155–170. <https://www.jstor.org/stable/20052977>
- Hadri, K. (2000) Testing for Stationarity in Heterogeneous Panel Data. *The Econometrics Journal*, 3, 148-161. <https://doi.org/10.1111/1368-423X.00043>
- Hensher D.A. (1998) Establishing a fare elasticity regime for urban passenger transport. *Journal of Transport Economics and Policy*, 32, 221–246. <https://www.jstor.org/stable/20053767>
- Holmgren, J.,(2007). Meta-analysis of public transport demand. *Transportation Research A, Policy Practice*, 41, 1021–1035. <https://doi.org/10.1016/j.tra.2007.06.003>
- Holmgren, J.,(2013) An analysis of the determinants of local public transport demand focusing the effects of income changes. *European Transport Research Review*, 5, 101–107. <https://doi.org/10.1007/s12544-013-0094-0>

- Im, K.S., Pesaran, M.H. and Shin, Y. (2003) Testing for Unit Roots in Heterogeneous Panels. *Journal of Econometrics*, 115, 53-74. [https://doi.org/10.1016/S0304-4076\(03\)00092-7](https://doi.org/10.1016/S0304-4076(03)00092-7)
- Iseki H. and Ali R. (2014) Net Effects of Gasoline Price Changes on Transit Ridership in U.S. Urban Areas Report 12-19, *Mineta Transportation Institute* (<http://transweb.sjsu.edu>). <http://transweb.sjsu.edu/PDFs/research/1106-gas-price-changes-and-transit-ridership.pdf>
- Kao, C. (1999) Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics*, 90, 1—44. [https://doi.org/10.1016/S0304-4076\(98\)00023-2](https://doi.org/10.1016/S0304-4076(98)00023-2)
- Levin, A., Lin, C.F. and Chu, C.S.J. (2002) Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties. *Journal of econometrics*, 108, 1-24. [https://doi.org/10.1016/S0304-4076\(01\)00098-7](https://doi.org/10.1016/S0304-4076(01)00098-7)
- Litman T. (2004) Transit Price Elasticities and Cross-Elasticities. *Journal of Public Transportation*, 7, (2), 37-58. www.vtpi.org/tranelas.pdf
- Litman, T. (2006) Changing Travel Demand: Implications for Transport Planning. *ITE Journal*, 76, 9, September, 27-33. www.ite.org or <https://www.proquest.com/docview/224877350?pq-orig-site=gscholar&fromopenview=true&sourcetype=Scholarly%20Journals>
- Makhlouf, L., & Helali, K. . (2024). Analysis Of The Public Transport Efficiency, *Productivity And Economies Of Scale: The Case Of Sfax – Tunisia. Economics - Innovative And Economics Research Journal*, 12(1). <https://doi.org/10.2478/eoik-2024-0004>
- Mattson J. (2008). Effects of Rising Gas Prices on Bus Ridership for Small Urban and Rural Transit Systems Upper Great Plains Transportation Institute. *North Dakota State University, summarized in Community Transportation*, Spring, 38-41. <https://www.ugpti.org/resources/reports/downloads/dp-201.pdf>
- Orski K. (2000) Can Alternatives to Driving Reduce Auto Use? *Innovation Briefs*, 11(1), Jan/Feb. <https://www.innobriefs.com/abstracts/2000/jan00/>
- Oum T. H. Waters II W.G. and Yong J. S. (1992), Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates. *Journal of Transport Economics*, May 1992, 139-154. <https://www.jstor.org/stable/20052976>
- Oum T.H., Van Ooststroom, H.P.C. and Yoon J.H. (1996), The Structure of Travel Demands in the Netherlands. *International Journal of Transport Economics*, 23(1), Feb., 31-62. <https://www.jstor.org/stable/42747392>
- Pedroni, P. (2004) Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the Ppp Hypothesis. *Econometric Theory*, 20, 597-625. <https://doi.org/10.1017/S0266466604203073>
- Preston J. (1998) Public Transport Elasticities: time for a re-think? UTSG 30th Annual Conference. TSU865. *Transport Studies Unit. University of Oxford*.
- Puentes, R. (2008) The Road...Less Traveled: An Analysis of Vehicle Miles Traveled Trends in the U.S., *Brooking Institution*, <https://api.semanticscholar.org/CorpusID:127283916>
- Sénquiz-Díaz, C. (2021). Transport Infrastructure Quality And Logistics Performance In Exports. *Economics - Innovative And Economics Research Journal*, 9(1), 107–124. <https://doi.org/10.2478/eoik-2021-0008>
- Small K. and Winston C. (1999). The Demand for Transportation: Models and Application,” in “*Essays in Transportation Economics and Policy* Brookings Institute. <https://trid.trb.org/View/500076>
- Taylor B. D., Miller D., Iseki H. and Fink C. (2009) Nature and/or Nurture? Analyzing the Determinants of Transit Ridership Across US Urbanized Areas. *Transportation Research Part A*, 43, 60–77. <https://doi.org/10.1016/j.tra.2008.06.007>
- TRL (2004) The Demand for Public Transit: A Practical Guide Transportation Research Laboratory, Report TRL 593. <https://www.trl.co.uk/uploads/trl/documents/TRL593%20-%20The%20Demand%20for%20Public%20Transport.pdf>
- Wardman M. (2022) Meta-analysis of Price Elasticities of Travel Demand in Great Britain: Update and Extension, *Transportation Research Part A*, 158, 1-18. <https://doi.org/10.1016/j.tra.2022.01.020>

- Wardman M. and Shires J. (2003). Review Of Fares Elasticities In Great Britain. *ITS Working Paper 573, ITS, University of Leeds*. https://eprints.whiterose.ac.uk/2059/1/ITS34_WP573_uploadable.pdf
- Wardman M. and Shires J. (2011). Price Elasticities of Travel Demand in Great Britain: A Meta-analysis *Paper 11-3544*, <http://trid.trb.org/view.aspx?id=1093095>
- Wardman M., Toner J., Fearnley N., Flugel S. and Killi M. (2018). Review and Meta-Analysis of Inter-Modal Cross-Elasticity Evidence. *Transportation Research Part A*, 118, 662-681. <https://doi.org/10.1016/j.tra.2018.10.002>
- Watkins K. E., Brakewood C., Erhardt G., Berrebi S. and Hemily B. (2021) Declines in Transit Ridership: Analysis of Recent Trends. *TR News Number 332, Marsh – April*. www.trb.org/Publications/Blurbs/182193.aspx
- Webster F.V. and Bly P.H. (1980). The demand for public transport. Report of an international collaborative study, Transport and Road Research Laboratory. *Crowthorne, Berks. Whitehall Press Limited*. ISSN: 0306-6452
- Webster, F. V., & Bly, P. H. (1981). The demand for public transport: Part I. the changing environment in which public transport operates. *Transport Reviews*, 1(4), 323–351. <https://doi.org/10.1080/01441648108716470>
- Westerlund, J. (2007). Testing for Error Correction in Panel Data. *Oxford Bulletin of Economics and Statistics*, 69, 709-748. <https://doi.org/10.1111/j.1468-0084.2007.00477.x>