

1 **Public Transport Pricing Policy – Empirical Evidence from a** 2 **Fare-Free Scheme in Tallinn, Estonia**

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ABSTRACT

1
2 Cities worldwide are looking for new policies to attract travellers to shift from car to public
3 transport. Policies focused on reducing public transport fares are aimed to improve social
4 inclusion and lead to a modal shift. The City of Tallinn, the capital of Estonia, has recently
5 introduced a fare-free public transport (FFPT) in an effort to improve accessibility and
6 mobility for its residents. The case of Tallinn is a full-scale real-world experiment which
7 provides a unique opportunity to investigate the impacts of FFPT policy. This paper presents a
8 macro-level empirical evaluation of FFPT impacts on service performance, passenger demand
9 and accessibility for various travellers' groups. In contrast to previous studies, the influence of
10 FFPT on passenger demand was estimated while controlling for changes in supply. The
11 results indicate that the FFPT measure accounts for an increase of 1.2% in passenger demand
12 with the remaining increase attributed to extended network of public transport priority lanes
13 and increased service frequency. The relatively small effect could be attributed to the previous
14 price level and public transport share as well as the analysis of the short-term impact. The
15 evidence-based policy evaluation is instrumental in supporting policy making and facilitating
16 the design of public transport pricing strategies.

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1. INTRODUCTION

Public transport provides people with mobility and access to employment, community resources, medical care, and recreational opportunities, especially among those who have no other choice of transport (1). Ensuring an effective and efficient public transport system is a priority of planning authorities worldwide due to its fundamental role in providing better accessibility in urban areas. Accessibility in this case refers to the ease of reaching various destinations as measured by service availability, speed and affordability. Measures to improve public transport accessibility could hence consist of investments in infrastructure, increasing supply outputs or the introduction of public transport pricing schemes.

Public transport is often considered both as public good and market product. Public transport pricing schemes may reflect this spectrum by charging a market price, the full operational cost or providing it for free. Public financing is an important and sometimes the primary contributor to the cost structure of public transport systems across Europe and North America. Transport pricing policies are often discussed in the public debate with strong links to the attitudes towards freedom, fairness as well as personal norms (2,3). The term FFPT is used here rather than ‘free public transport’, since public financing would have to compensate for the income from lost fares and fully subsidize the service.

FFPT is also regarded as a potential measure to promote a modal shift towards public transport. The increase demand to public transport services may even trigger the well-known ‘Mohring effect’ (4). This effect refers to the desired vicious cycle where a service improvement that reduces the disutility associated with traveling such as shorter waiting times or travel times or indeed lower fares, would lead to a higher demand that will result in a need to increase the supply and improve the priority given to public transport which will further improve the service and lead to a further increase the demand and so forth. Since the economics of public transport are characterized by the economies of scale, the marginal benefit from increasing service supply exceeds the marginal cost and therefore increases the net social welfare.

Transport economics often argue that the fundamental problem with travel costs is that travelling by car is under-priced and this should be addressed by internalizing car externalities (5). Studies that analysed how sensitive people are to various price changes found that more people would shift from car to public transport if the price of the former is increased rather than if the latter is reduced by the same magnitude. This suggests that strategies focused on increasing the cost of travelling by car might be more effective in achieving the modal shift objective. FFPT could be therefore considered a second-best pricing scheme in this respect. Moreover, it is argued that people tend to underappreciate things that they get for free.

The absence of a direct cost attached to the consumption of a public good may even lead in some cases to its over-utilization. In the context of public transport this implies riding public transport instead of walking or cycling which is clearly not the purpose of a sustainable transport solution. Another risk is that it may lead to fewer investments in public transport in the long run due to the lack of a direct and independent income source.

The City of Tallinn, the capital of Estonia, introduced in January 2013 a FFPT scheme for all its residents on all public transport services that are operated by city-run operators. Public transport services in Tallinn are provided by a municipally-owned company. Tallinn with 425,000 inhabitants is currently the largest city in the world that provides a full-scale FFPT service for all residents. The main objectives of this policy are: promoting modal shift from private car to public transport; increasing the mobility of unemployed and low income groups and; stimulating the registration of inhabitants as a residents of Tallinn and hence increase the municipal income tax (6). The FFPT scheme is hence in effect a tax incentive

1 scheme. Note that it does not entail any other economic implications at the individual level
2 since the municipal income tax is uniform across Estonia.

3 The case of Tallinn is a full-scale real-world experiment that provides a unique
4 opportunity for investigating the impacts of FFPT policy. This study presents a macro-level
5 empirical evaluation of FFPT impacts on service performance, passenger demand and
6 accessibility for various travellers groups. The introduction of FFPT was often accompanied
7 in previous studies by an increase in service supply and hence the effects of the two measures
8 could not be easily distinguished. The influence of FFPT on passenger demand was estimated
9 in this paper by accounting explicitly for supply changes. The evidence-based policy
10 evaluation is instrumental in supporting policy makers and facilitating the design of public
11 transport pricing strategies.

12 The remainder of the paper is organized as follows: the following section provides a
13 literature review concerning the effects of fares on public transport demand, arguments in
14 favour and against public transport and results from previous FFPT programs. Section 3
15 describes the case of Tallinn and the data analysis related to this study. The results of the
16 supply performance and passenger demand analysis are presented in Section 4. The paper
17 concludes with remarks concerning the generality of the results and suggests directions for
18 future studies.

19 **2. LITERATURE REVIEW**

20 **2.1 The Effect of Fares on Public Transport Demand**

21 The identification and analysis of the main determinants of demand for public transport has
22 been a subject of extensive research. In particular, numerous studies have analysed the
23 elasticity and cross-elasticity of public transport fares. Several studies conducted a meta-
24 analysis of fare elasticity (7,8,9). The values reported in the literature for fare elasticity show
25 large variations ranging from -0.009 to -1.32 with a mean value of -0.38 (9). Paulley et al. (8)
26 examined how fare elasticities depend on travel mode, type of area, analysis horizon, type of
27 fare change, current fare levels as well as the specific local circumstances.

28 Elasticities were derived using various methods including stated and revealed
29 preference surveys, before and after studies and time series analysis. Individual choice models
30 resulted in higher price elasticities than those obtained from aggregate demand analysis (7).
31 Chen et al. (10) argued that because of the different underlying assumptions used in micro-
32 and macro-level studies, behavioural results of the former could not be directly applied at the
33 aggregate level. In a discussion on the limitations of public transport elasticity studies,
34 Hensher (11) highlighted that it should always be preferred to use primary data for evaluating
35 the effects of policy changes.

36 Fare elasticity depends on the magnitude, sign and time-span of a fare change. Chen et
37 al. (10) found that fare elasticity is strongly asymmetric – passenger demand decreases in
38 response to an increase in price but the estimate associated with a price reduction is
39 insignificant. Holmgren (9) concluded the long-run fare elasticity was found significantly
40 higher (in absolute terms) than the static or short-run elasticity. In addition, supply should be
41 treated endogenously when analysing public transport demand. Previous studies have also
42 found that fare elasticities vary among travellers groups. Elasticity goes down with age, goes
43 up with income and is higher for off-peak and non-commuting trips (12,13).

44 The elasticity of public transport demand with respect to level of service variables was
45 found systematically higher when compared with fare elasticity (8,9,13). The elasticity of
46 passenger waiting time – which is pre-dominantly determined by service frequency - was
47 estimated at -0.64 on average. In-vehicle travel time elasticities were estimated in the range of
48

1 -0.4 to -0.6. Elasticity with respect to service supply as measured by total vehicle-kilometres
2 has an average value of 0.72, considerably higher than the fare elasticity. Furthermore, the
3 cross-elasticity with respect to the cost of car is similar or higher than the direct fare elasticity.
4

5 **2.2 Fare-Free Public Transport Arguments**

6 Even though the results from previous studies suggest that reduced fare levels are probably a
7 second best pricing strategy compared with car disincentives, pull strategies are more popular
8 than push policies in the public debate realm (3). The key arguments in favour of FFPT
9 include improving social inclusion and attracting people to public transport and hence
10 reducing car traffic externalities and road infrastructure investments. FFPT could potentially
11 induce a fundamental demand change that could not be assessed through fare elasticities.
12 Behavioural studies indicate that when facing the alternative of free consumption, people do
13 not act according to the standard cost-benefit analysis and appear to perceive it as an
14 additional benefit beyond the actual cost reduction (14).

15 The main argument against FFPT claims that this is a second-best pricing scheme because
16 travelling by car is under-priced. Auto disincentives such as parking fees, road pricing or
17 gasoline price might be a more effective measure for triggering modal shift from car towards
18 public transport than fare incentives of the latter would (13,15). In order to bring about an
19 equivalent impact, a larger public transport fare reduction would be required depending on the
20 extent to which the cross-elasticity dominates the direct elasticity. Moreover, a differential
21 fare scheme could have attracted demand to underutilized segments of the public transport
22 service avoiding supply increase in the peak hour where the marginal operational cost is the
23 highest.

24 The introduction of FFPT is a costly measure that could have been invested instead in
25 improving the level of service. Given that other service attributes were found in the literature
26 to have higher elasticities than public transport fares, a policy targeting level-of-service
27 improvement could potentially be more cost-effective. The evaluation of FFPT has to
28 consider also the opportunity cost of an alternative investment.

29 From a macroeconomic point of view, income inequality could be better addressed
30 through adjustments to income tax schemes. FFPT introduces a non-discriminatory benefit to
31 all public transport users and therefore subsidized for all travellers regardless of their income
32 level. Alternatively, user-specific fare schemes could directly address disadvantaged travellers
33 groups and hence better address income inequality. Furthermore, it is not clear that the market
34 distortions that exist due to pricing reasons are larger than distortions caused by taxation
35 which covers public funding.

36 The introduction of FFPT could also save related costs and improve operational
37 efficiency. The public transport agency saves fare collection and control costs and can
38 capitalize on public transport economies of scale when extending system supply. In case of an
39 on-board payment validation, FFPT is expected to result with shorter dwell time at stops due
40 to smoother boarding, which may result in higher commercial speeds and even fleet
41 operations savings. The introduction of FFPT is sometimes also motivated by nontangible
42 arguments such as promoting a barrier-free and equal public space.

43 Other arguments include the potential risk that in the case of short-distance trips public
44 transport may become a substitute for walking and cycling rather than car trips which may
45 counteract the environmental and well-being benefits (16). The lack of an independent income
46 source for public transport funding may also undermine future investments in public transport
47 in the long-run. A fully subsidized public transport service could also potentially reduce the

1 operational efficiency. An under-priced service might also generate non-productive trips and
2 even vandalism (17).

4 **2.3 Previous and On-Going Fare-Free Public Transport Programs**

5 Few small European cities introduced a FFPT policy since the late 90s. FFPT schemes were
6 introduced in Hasselt (c.a. 75,000 inhabitants), Belgium; Templin (15,000), Germany and;
7 Aubagne and nearby municipalities (100,000 in total), France in 1996, 1997 and 2009,
8 respectively. All these programs were introduced together with substantial additions to the
9 network supply and were followed by a dramatic increase in ridership. However, only a
10 relatively small substitution effect (10-20%) was caused by a modal shift from car to public
11 transport (17,18). In the case of Aubagne, the introduction of FFPT was motivated by the fact
12 that user fares accounted for only 9% of the public transport system budget to start with. In
13 Templin, the vast majority of the increase was attributed to children and youth which led to an
14 increasing problem of vandalism.

15 There are few other cases of FFPT policies directed toward specific user groups such
16 as students, youth or off-peak riders. A limited-scale FFPT pilot study was carried out on the
17 Leiden-The Hague corridor, Holland during 2004 (18). It was concluded that the scale of the
18 pilot was insufficient to address its objective and allow a significant congestion reduction. A
19 FFPT policy was also introduced in 2004 for students admitted to Flemish universities in
20 Brussels, Belgium (19,20). Similarly, all students in Holland are eligible to FFPT in the entire
21 country since 1991 (18). Both programs reported the generation of new trips as well as a
22 substitution effect for active transport modes. An analysis based on interviews and focus groups
23 of the health impacts of a FFPT program for youth in London, UK, was performed by Jones et
24 al (16). They reported mixed results concerning the level of activity, likelihood of injury, and
25 cases of assaults.

26
27 While previous implementations of FFPT shed light on the anticipated impacts of such a
28 policy measure, there is lack of a systematic analysis which limits the validity and prevents
29 the quantification of FFPT impacts. The Federal Transit Administration in the US coordinated
30 several demonstration experiments across the US, most of them initiated in the mid-1980s.
31 McCollom and Pratt (12) concluded from a review of over 20 FFPT programs that most of the
32 reported results are anecdotal. A comprehensive analysis would be valuable for assessing the
33 impacts of this policy measure to assist planners and policy makers. The case of Tallinn
34 provides a valuable opportunity to evaluate empirically the impact of a full-scale pricing
35 policy implementation.

37 **3. CASE STUDY**

38 **3.1 The Case of Tallinn**

39 The public transport system in Tallinn consists of trams, trolley buses and ordinary buses. The
40 share of public transport trips decreased dramatically during the last two decades since
41 Estonia restored its independence. The current mode split is still favourable towards public
42 transport with a market share of 40% followed by walking (30%) and private car (26%).
43 During the same period, the motorization rate has more than doubled up to 425 cars per 1,000
44 residents in 2012.

45 Before FFPT was introduced in Tallinn, the farebox recovery rate – the proportion of
46 public transport operational costs that was covered through ticket sales – was 33%. The cost
47 of a single ticket and a monthly card were 1 and 20 euros, respectively. The cost of a monthly
48 card corresponds to approximately 2.5% of the average monthly disposable income after tax.

1 The additional subsidy amounts to an annual cost of 12 million euros. Note that public
2 transport fares were already reduced on 2003 by 40% for Tallinn residents. Moreover, 36% of
3 all passengers were already prior to FFPT exempted from paying public transport fare based
4 on their socio-demographic or occupational profiles. Additional 24% are entitled for special
5 discounts.

6 Public transport fares were identified as a primary mobility hinder in Tallinn. On an
7 annual municipal public transport satisfaction survey from 2010, 49% of the respondents were
8 most unsatisfied with public transport fares followed by crowding (29%) and frequency
9 (21%). This led the City of Tallinn to propose a FFPT policy on a popular referendum where
10 it was supported by 75% of the voters with a participation rate of 20%. Following the
11 referendum, the city council approved the measure (6). The FFPT measure was accompanied
12 with supply changes which aimed to increase the system capacity in order to accommodate
13 the induced demand. Tallinn residents are entitled to free rides but are required to validate a
14 smart card, while other users (e.g. tourists, residents of other municipalities) have to purchase
15 a travel ticket.

16 17 **3.2 Data**

18 The evaluation of FFPT in Tallinn consisted of the analysis of extensive automatic vehicle
19 location (AVL) and automatic passenger counts (APC) data. The Transport Department of the
20 City of Tallinn circulates vehicle positioning and passenger counting equipment over the
21 service lines throughout the year in order to cover the entire network and allow year-over-year
22 comparisons. Data is therefore available for a subset of the trips for all lines. The disaggregate
23 data contains the arrival and departure times as well as the number of boarding, alighting and
24 on-board passengers for each stop-visit.

25 The evaluation of the FFPT policy consisted of a before-after analysis of AVL and APC
26 data. The 'before' period corresponds to fall 2011-spring 2012, while the 'after' period refers
27 to the period directly after the introduction of FFPT, January-April 2013. The intermediate
28 period of fall 2012 constitutes a distinguished analysis period due to the implementation of
29 several service improvement measures. The network of dedicated public transport lanes was
30 extended from 17.4 km to 28 km prior to the introduction of FFPT. In addition, frequency
31 changes took place throughout the analysis period.

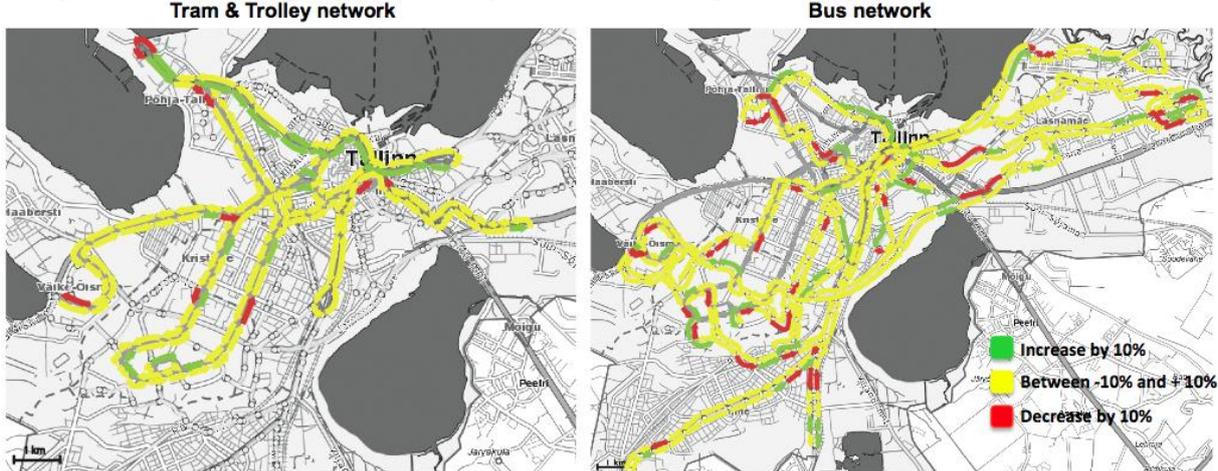
32 The AVL and APC equipment circulation implied that only about half of the lines were
33 sampled during the first quartile of 2013, following the introduction of FFPT. A subset of the
34 public transport lines was selected for evaluation based on data availability constraints,
35 demand levels and spatial and modal coverage concerns. In order to ensure the overall
36 representativeness of the analysed routes, the selected sub-network includes all public
37 transport modes (bus, tram and trolley buses). Moreover, the selection ensured that all
38 neighbourhoods and key activity centres in the study areas are covered by the selected routes.
39 The sub-network for analysis consists of 22 lines – 3 tramlines, 12 bus lines and 7 trolley lines
40 - which carry 64% of the total ridership. Low-demand lines are underrepresented in the
41 selected sub-network. However, their exclusion does not have a significant impact on the
42 overall demand analysis as their ridership levels remained low throughout the analysis period.
43 On average, data from 300 weekday trips was available for each line which facilitated the
44 analysis of performance and ridership measures. The number of APC and AVL data records
45 that was used in this analysis amounts to almost 150,000 stop visits.

1 **4. RESULTS**

2
3 **4.1 Descriptive Analysis**

4 The introduction of FFPT in Tallinn had implications on three key service quality aspects –
5 waiting time, in-vehicle time and crowding. These changes are the result of the accompanying
6 supply changes – frequency and priority lanes - rather than the FFPT policy per-se and would
7 hence be explicitly distinguished in the demand analysis in Section 4.2.

8 Changes in public transport speed could arise from the direct impact of the extension of
9 priority lanes or due to a secondary impact caused by a shift away from cars which will result
10 in less traffic congestion. The overall average speed remained at the same level of 19.14
11 km/hour throughout the analysis period. As expected, speeds are lower in the centre of the
12 city and higher in the periphery and along major arterials. However, an analysis at the link
13 level reveals significant spatial variations. Figure 1 presents the change in the average speed
14 of each network link for buses and trams when comparing the before and after periods. There
15 is a noticeable increase in average link speed in the city centre, particularly where priority
16 lanes were introduced and along the northern east-west tram line. In contrast, speeds decrease
17 along arterial links in proximity to major intersections, particularly for buses.



18
19 **Figure 1 Change in average travel speeds for buses (left) and trams and trolley buses**
20 **(right) following the introduction of priority lanes and FFPT**

21
22 A before-after comparison of the total number of boarding passengers reveals an
23 increase of 3% in passenger demand. The corresponding increase in total passenger-
24 kilometres was 2.6%. Figure 2 presents the geographical distribution of changes in passengers
25 demand at the district level. The central district of Kesklinn which accounts for the lion share
26 of the demand (40%) throughout the analysis periods experienced an increase of 3.5%. The
27 highest increase of more than 10% occurred in the north-eastern district of Lasnamäe which is
28 the most populous and dense district and characterized by higher unemployment rates and a
29 predominantly Russian speaking population.

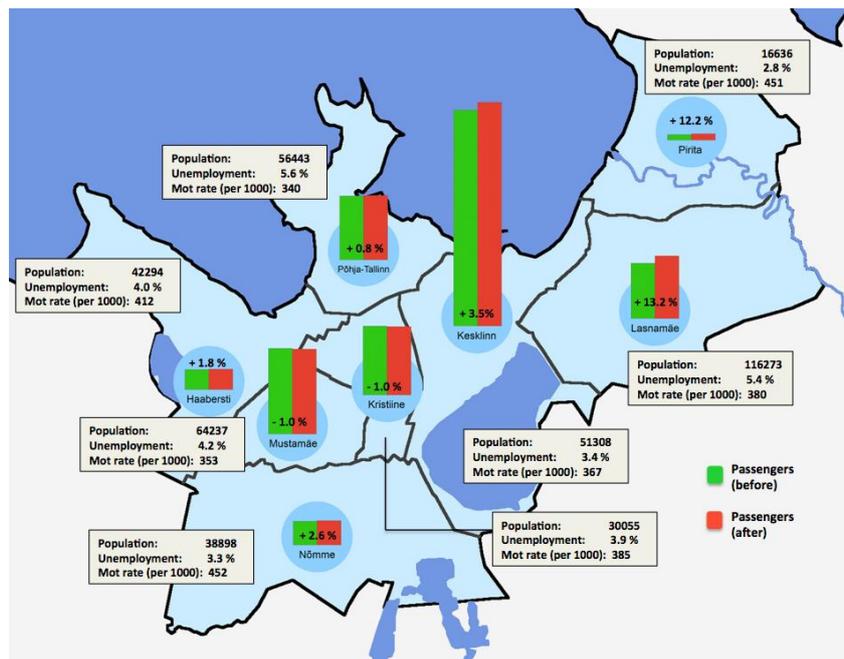


Figure 2 Background information and ridership changes in Tallinn's districts

The overall increase in the number of vehicle runs for the sub-network is 9.0% when comparing before and after periods. The total capacity increased by 9.6% which exceeded the increase in passenger demand. The FFPT scheme therefore does not induce any further capacity needs. Passengers are hence expected to experience less crowding compared with the before period. This figure has also been confirmed by calculating the vehicle load utilization which is twice as high for buses and trollies as for trams.

The average trip length could be derived from the total number of boarding and passenger-kilometres metrics. The average trip length decreased from 2.72 km in the before period to 2.43 km during the after period, a reduction of 10.6%. This result suggests a modal shift from soft modes and in particular walking to public transport, following the introduction of FFPT. Part of this shift is presumably attributed to non-regular passengers that previously used single tickets and may be more inclined to transfer after the introduction of FFPT.

4.2 Multivariate Analysis

As shown in Section 4.1, the FFPT policy was followed by changes in ridership and the overall public transport performance. However, it is very difficult to infer the impacts of the policy, given all other external and internal variability that may influence the system. Therefore, a multivariate analysis is employed in order to measure the impacts of the policies after all other socio-demographic, land use, infrastructure conditions and temporal characteristics have been controlled for. A series of multiple linear regression models for public transport demand model were estimated in order to quantify the impact of FFPT and supply changes. Various multiple linear regression models were specified and estimated at the individual stop-level. Each single APC record was supplemented with three sets of independent variables that were compiled to facilitate model development:

- *Temporal indicators* – dummy variables for time-of-day periods, day of the week, month-specific and FFPT (year 2013).
- *Supply variables* – mode-specific dummies, the availability of a priority lane, a dummy variable for stops that are also served by parallel express line, service frequency and the number of stops available in the respective district.

- 1 • *Residents' socio-demographic attributes, at district level* – population size and
2 density, shares of age groups, unemployment rate, shares of education levels, real-
3 estate prices, motorization rate, distance from the city centre, density of various land-
4 uses – all of them at the respective district level, which were extracted from the
5 central and municipal bureaus of statistics.

6 Model selection was based on a backward estimation approach by iteratively reducing
7 the number of variables and removing statistically insignificant variables. The estimated
8 model is not developed for forecasting purposes and is therefore not evaluated based on the R-
9 square values. Instead, alternative models are evaluated by the inclusion of variables that are
10 significant explanatory factors of the number of boarding passengers. This process obtained
11 the following model:

$$12 \quad D_{s,k} = \beta_0 + \beta_1 \cdot FFPT_k + \beta_2 \cdot PMpeak_k + \beta_3 \cdot PLane_{s,k} + \beta_4 \cdot FFPT_k \cdot PLane_{s,k} + \beta_5 \cdot F_k +$$
$$13 \quad \beta_6 \cdot B_k + \beta_7 \cdot T_k + \beta_8 \cdot PEL_s + \beta_9 \cdot FFPT_k \cdot PEL_s + \beta_{10} \cdot NrStops_s + \beta_{11} \cdot E65_s + \beta_{12} \cdot$$
$$14 \quad FFPT_k \cdot E65_s + \beta_{13} \cdot UE_s + \beta_{14} \cdot FFPT_k \cdot UE_s + \beta_{15} \cdot RE_s + \beta_{16} \cdot FFPT_k \cdot RE_s + \beta_{17} \cdot M_s +$$
$$15 \quad \beta_{18} \cdot FFPT_k \cdot M_s + \varepsilon_{s,k} \quad (1)$$

16
17 Where the dependent variable, $D_{s,k}$, is passenger demand at stop s for vehicle trip k as
18 measured in terms of boarding passengers. β s are the estimated coefficients and $\varepsilon_{k,s}$ is the
19 error term. Table 1 provides a list of all the independent variables that are included in this
20 model in the same order as they appear in Eq. 1. Note that all the socio-demographic variables
21 as well as the presence of priority lanes and the parallel express lines were also specified as
22 interaction variables with $FFPT_k$ in order to capture how the impact of FFPT varies with
23 socio-demographic variables in addition to their general influence to passenger demand. Other
24 variables were excluded from the model, either due to high multi-correlation between the
25 variables or statistically insignificant impact.

26

1

TABLE 1 Description of Independent Variables

	Variable symbol	Variable name	Description
Temporal	$FFPT_k$	Free-fare public transport (2013)	Dummy variable for FFPT (2013)
	$PMpeak_k$	PM peak period	Dummy variable for trips on PM peak period (16:30-18:30)
Supply	$PLane_{s,k}$	Priority	Dummy variable for the presence of a priority lane adjacent to the stop
	F_k	Frequency	The number of vehicle departures per hour
	B_k	Bus mode	Dummy variable for bus
	T_k	Trolley mode	Dummy variable for trolley bus
	PEL_s	Parallel express lines	Dummy variable for stops served by parallel express lines
	$NrStops_s$	Number of stop	The number of public transport stops in the respective district (2012)
Socio-demographic	$E65_s$	Share of elderly	Share of people who are 65 years or older in the respective district (2012)
	UE_s	Unemployment	Registered unemployment rate in the respective district (2011)
	RE_s	Real estate price	Price of residential m2 in hundred euros in the respective district (2012)
	M_s	Motorisation rate	Number of cars per 1000 residents in the respective district (2012)

2

3

1 The a-priori hypothesis is that FFPT and the afternoon peak period would be positively
2 associated with passenger demand. Supply variables such as frequency and availability of
3 priority lanes are indicators of public transport level-of-service and are hence expected to
4 contribute to higher demand levels. The bus network in Tallinn includes express lines which
5 operate only during peak periods and provide a radial connection along the main commuting
6 corridors. The express lines serve key stops along these corridors and had a higher fare level
7 before the introduction of FFPT. Hence, these lines are expected to attract a higher share of
8 passengers following the FFPT policy as it provides a faster connection without inducing a
9 price difference. The express lines are not included in the sub-network but their presence is
10 therefore expected to reduce demand levels for other lines serving the same stops. The
11 number of stops located within a district was included as a proxy for accessibility to stops at
12 the district level.

13 The socio-demographic variables were specified at the district level due to data
14 availability limitations. The a-priori hypothesis is that demand for public transport at districts
15 with higher shares of elderly, unemployed and a low car ownership will be higher than
16 elsewhere. In the case of elderly, the FFPT policy does not influence their travel cost. In the
17 absence of data concerning income at the district level, real-estate prices were used as a
18 potential explanatory variable in the model. Furthermore, residents' movement in the city
19 does not allow a perfect linkage between the traveler's district of residence and their boarding
20 stop. Nevertheless, travelers are more likely to use stops in proximity to their residency and
21 hence yield district-related passengers' profile.

22 Table 2 presents the estimated values of the coefficient and the corresponding t-statistic
23 in parentheses for three models: accounting only for the introduction of FFPT (Model 1);
24 accounting for service variables and supply changes (Model 2) and; incorporating socio-
25 demographic and service coverage variables at the district level (Model 3). All of the
26 estimated coefficients of the explanatory variables are significant at the 99% level as well as
27 the overall model goodness-of-fit. The coefficients are interpreted as the change in the
28 average number of boarding passengers at a single stop for a single vehicle trip associated
29 with a unit change in the explanatory variable.

30

1

TABLE 2 Number of Boarding Passengers per Stop Model

Variables	Model 1	Model 2	Model 3
Constant	4.880 (207.094)	2.555 (15.466)	-16.293 (-6.597)
FFPT	1.207 (30.638)	1.085 (20.117)	14.833 (2.575)
PM peak period	---	0.965 (17.515)	0.963 (17.550)
Priority lane	---	2.582 (17.821)	2.169 (14.845)
Priority lane X 2013	---	1.945 (10.313)	0.695 (9.950)
Frequency	---	0.184 (17.115)	0.224 (19.463)
Bus	---	-1.553 (-18.890)	-1.002 (-11.761)
Trolley	---	-1.044 (-13.653)	-1.057 (-13.686)
Parallel express lines	---	0.719 (14.668)	0.695 (13.979)
Parallel express lines X 2013	---	-0.597 (-7.585)	-0.429 (-5.306)
Number of stops	---	0.008 (19.339)	0.005 (9.327)
Share of elderly	---	---	0.229 (10.216)
Elderly X 2013	---	---	-0.071 (-2.872)
Unemployment	---	---	1.316 (9.453)
Unemployment X 2013	---	---	-1.159 (-8.099)
Real-estate price	---	---	0.006 (12.718)
Real-estate prices X 2013	---	---	-0.003 (-6.423)
Motorization rate	---	---	-0.007 (-2.456)
Motorization rate X 2013	---	---	-0.011 (-3.760)
Observations (N)	149,514	149,514	149,514
R-squared	0.006	0.044	0.052
Adjusted R-squared	0.006	0.044	0.052

1 Model 1 is a naïve model which reflects the overall demand change following the
2 introduction of FFPT. The model indicates an increase of 1.2 passengers per stop and trip
3 which is an average increase of 7,128 passenger trips or 2.8% at the network level when
4 comparing before and after periods. Attributing all changes in demand to FFPT results with an
5 overestimation of the FFPT effect compared with more elaborated models that account for
6 supply variables.

7 Models 2 and 3 include temporal and supply variables. In particular, they account for
8 supply changes which took place throughout the analysis period. Stops located along priority
9 lanes are associated with higher demand levels throughout the analysis period. Moreover,
10 demand increase following FFPT was substantially higher at stops long priority lanes. The
11 higher demand level is presumably due to the strategic location of these lanes and may also be
12 related to downstream in-vehicle time savings and public space design changes.
13 Unsurprisingly, service frequency is an important determinant of passenger demand. Higher
14 frequency is associated not only with overall higher demand but also with increased demand
15 per vehicle. An increase of 1% in service frequency would yield a 0.44-0.47% increase in
16 passenger demand. A lower elasticity (0.39) with respect to frequency was obtained for the
17 demand in the afternoon peak period which is associated with commuting trips. This range of
18 elasticity is in agreement with the values reported in the literature (8,9).

19 Bus and trolley coefficients are significantly negative suggesting that given everything
20 else being the same, tram lines attract more passengers. However, this result depends on the
21 current network design of the various transport modes. As could be expected, stops that are
22 served by parallel express are characterized by higher demand levels compared with other
23 stops. However, this difference decreased with FFPT as the express lines became more
24 attractive with the removal of price differentiation. Stops located in districts with a larger
25 number of stops had higher demand levels per stop throughout the analysis period.

26 The specification of models 2 and 3 allow decomposing the demand change following
27 the FFPT introduction into the direct FFPT effect and the impact of supply changes. FFPT
28 per-se led to an increase of 1.2% in passenger demand, which is approximately 42% of the
29 impact estimated by the naïve model. The rest of the increase is attributed to greater priority
30 lanes network and increased service frequency. While similar signs and magnitudes are
31 obtained for temporal and supply variables, the inclusion of socio-demographic attributes in
32 Model 3 allows investigating the impact of these variables and how the impact of FFPT varied
33 spatially as a function of these variables. The results indicate that areas that are characterized
34 by higher shares of elderly or unemployed, higher real-estate prices and lower share of car
35 ownership are associated with higher demand levels, everything else being equal. This is in
36 line with the a-priori expectations. The relationship with real-estate prices is presumably
37 mediated by the distance from the city center. Real-estate prices should not be regarded as a
38 proxy of income. In the case of Tallinn for example, properties in the city center are the most
39 expensive but city center dwellers are not the most affluent residents.

40 The inclusion of separate interaction variables enable to identify how demand levels
41 changed in districts, characterized by different socio-demographic profiles. Districts with a
42 higher share of elderly exercised a lower increase in demand levels. This is expected as
43 elderly passengers were exempted from public transport fare throughout the analysis period.
44 Nevertheless, their demand levels remained higher compared with other groups. Furthermore,
45 demand at districts with higher unemployment levels, real-estate prices or motorization rates
46 increased less than the overall increase in ridership. However, the aggregate level of analysis
47 does not allow drawing conclusions at the individual traveler level.

1 **5. CONCLUSION**

2 The impacts of a free-fare public transport policy in Tallinn, Estonia were evaluated
3 empirically based on a before-after comparison and a public transport demand model analysis.
4 Passenger demand increased by 3% following the introduction of FFPT. An analysis of
5 supply variables reveals that the FFPT measure accounts for an increase of 1.2% in passenger
6 demand with the remaining increase attributed to extensions made in the network of public
7 transport priority lanes and increased service frequency. Districts with high shares of elderly
8 and unemployed and low motorization rates were associated with higher demand levels but
9 less substantial increase in passenger demand when public transport became fare-free.

10 The analysis of modal shift impacts of FFPT requires distinguishing between generation
11 effects and substitution effects. The former refers to trips that are now carried out by public
12 transport that otherwise would not occur, while the latter refers to trips that without FFPT
13 were done by some other mode and switched to public transport modes. Generation effects
14 can thus indicate greater mobility and access to opportunities but could also be the result of
15 unnecessary trips. Substitution effects represent mode choice changes with the most desired
16 effect being that public transport substitutes car trips. In the case of Tallinn, the average trip
17 length decreased by 10% which indicates that FFPT has resulted with a substitution effect
18 from soft mode. There are no indications from speed changes of a modal shift from car.
19 Further analysis requires the analysis of traffic counts.

20 The impact of FFPT on passenger demand in the case of Tallinn is considerably lower
21 than the corresponding figures reported by previous FFPT programs. The relatively small
22 increase in passenger demand following the introduction of FFPT in Tallinn could be
23 attributed to one or more of the following factors:

- 24 • Public transport fare was relatively low to start with and many user groups had an
25 exemption before the introduction of full-scale FFPT
- 26 • Public transport share was relatively high (40%) to start with compared with previous
27 cities that have implemented a FFPT policy
- 28 • The introduction of FFPT had to rebound a two decades long negative trend in the share of
29 public transport

30 The prospects of FFPT would most likely depend on the existing share of tickets revenues
31 in financing system operations costs and the cost of alternative travel modes - in particular,
32 the private car – compared with the current fare level. In addition to the above caveats
33 concerning the generality of results, the results reported in this study reflect the immediate
34 impact of FFPT while previous studies have considered the mid to long term impacts of such
35 programs. Paulley et al. (8) found in their meta-analysis that fare elasticities increase over
36 time since the change of fare take place and Holmgren (9) concluded that long-run fare
37 elasticity is significantly higher than the short-run elasticity.

38 The overall evaluation of the FFPT scheme requires the assessment of all the related
39 costs and benefits. The main cost is the lost tickets revenue which corresponds to an annual
40 cost of 12 million euros. The anticipated benefits of the scheme include greater accessibility
41 and equity, reduced congestion and emissions, reduced costs for fare collection and wider
42 economic benefits. However, from the municipality perspective the scheme also serves as a
43 tax incentive program. The City of Tallinn reported that 10,000 new residents have registered
44 between January and November 2013 (21). This reflects a significantly higher pace than
45 previously reported, presumably due to the incentive to be entitled to FFPT. Each 1,000
46 residents are expected to contribute 1 million euros in tax revenue. Hence, the additional tax
47 revenue covers the lion share of the scheme costs from the City of Tallinn financial
48 perspective.

1 Previous studies did not account for supply changes and hence do not distinguish the
2 supply effect from the FFPT effect. Even though the analysis presented in this study accounts
3 for supply changes, it might be argued that there is a lag relationship between supply change
4 and travel demand which is gradually manifested at a later period. Chen et al. (10) found that
5 changes in service levels influence on ridership are best captured in the same month and four
6 months later. The same study found that the influence of public transport fare on demand is
7 best modelled with zero and ten months lag. A future study on how ridership trends evolve in
8 Tallinn will allow accounting for potentially lagged effects and establishing the long-term
9 impacts of FFPT. Furthermore, the analysis of FFPT impacts for various socio-demographic
10 groups was limited to the district level. One of the main policy objectives is to improve
11 accessibility for low-mobility and disadvantaged groups which require a more detailed
12 analysis of changes in travel patterns for different user groups. A series of before-after
13 questionnaires and travel diaries will facilitate the estimation of generation and substitution
14 effects of the FFPT policy as well as changes in mobility patterns by socio-demographic
15 groups.

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