A PROXY COST MODEL FOR TRAMWAY SERVICES

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ABSTRACT
In this paper, we build a proxy cost model for tramway services. We estimate separately: (i) transport services production costs; (ii) infrastructure costs; (iii) maintenance costs; (iv) administrative and general costs and (v) the cost of capital. We apply the proposed methodology to estimate the standard cost of Italian tramway services. Detailed data about costs, technical and environmental characteristics were collected by means of questionnaires sent to Italian companies providing 100% of tramway services in 2012. We perform a simulation study in order to highlight the marginal impact of efficiency gains obtained by manipulating cost-driving variables both under the control of the operators (trains and drivers productivity) and of the local authority who assigns the service (number of train revenue kilometers (TRK) assigned within the service contract, average fleet age). The simulations show how the local authority should allocate extra resources if it wants to increase the quality–quantity mix of tramway services. Our results might help the decision-maker to define the maximum economic compensation (auction base) in competitive tendering procedures or a benchmark for the bargaining with the local monopolist.
Keywords: standard costs, local public transport, tramway services, fiscal federalism, cost proxy models.

1 INTRODUCTION

Standard cost reflects the cost of a local public transport (LPT) service with a specified service quality and provided by an efficient operator. The 'efficiency levels' can be estimated statistically on the basis of the activities and costs of several operators (top-down approach), by building up the cost function of a specified service moving from the detailed knowledge of the industrial process (bottom-up approach) and/or by combining aforementioned approaches (hybrid approach).

Only a few papers had dealt with the specific definition and measurement of the standard cost of LPT services, mainly focusing on bus operations, e.g. [1]-[7], rail and metro operations, e.g. [8]-[9]). Conversely, a vast literature explored the cost structure of bus transit, metro and railroad systems (e.g. [10]-[11], see [12]-[13] for reviews).

To the best of our knowledge, this is the first paper providing a model for the estimation of the standard cost of tramway services. We set up a proxy cost model based on the bottom-up approach where we estimate separately: (i) transport services production costs; (ii) infrastructure costs; (iii) maintenance costs; (iv) administrative and general costs and (v) the cost of capital. Based on the proposed methodology, we define the standard cost of Italian tramway services. Disaggregated information about costs, technical and environmental characteristics was collected in 2012 through questionnaires sent to Italian companies providing 100% of the production of tramway services in 2012. We then perform a simulation study in order to highlight the marginal impact of efficiency gains obtained by manipulating cost-driving variables.

The paper is organized as follows. Section 2 describes the cost model. Section 3 presents data and results, with case studies and sensitivity analysis. Section 4 concludes.

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2 THE PROXY COST MODEL

Let us consider a tramway service i in year t. We estimate separately: (i) standard cost of transport services production, $\bar{C}_{tr}$; (ii) infrastructure standard cost, $\bar{C}_{inf}$; (iii) ordinary maintenance standard cost, $\bar{C}_{omnt}$; (iv) administrative and general standard cost, $\bar{C}_{adm}$ and (v) the standard cost of capital, $\bar{C}_{cap}$. For the sake of notation, we refer to $\bar{C}_{tr}$ to indicate $\bar{C}_{tr,i,t}$ the cost of service i in year t. We will follow the same logic with respect to the entire notation. The standard cost of tramway service i can be determined as:

$$\bar{C} = \bar{C}_{tr} + \bar{C}_{inf} + \bar{C}_{omnt} + \bar{C}_{adm} + \bar{C}_{cap} \tag{1}$$

We may derive the standard cost of tramway services per train revenue kilometre as:

$$\bar{C}_{TRK} = \frac{\bar{C}}{TRK} \tag{2}$$

where TRK is the number of train revenue kilometres.

2.1 The standard cost of transport services production

The transport services production standard cost, $\bar{C}_{tr}$, can be determined as:

$$\bar{C}_{tr} = \bar{C}_{drv} + \bar{C}_{ms\,staff} + \bar{C}_{trac\,pwr} + \bar{C}_{rs} \tag{3}$$

where

- $\bar{C}_{drv}$ is the standard cost of the driving personnel;
- $\bar{C}_{ms\,staff}$ is the standard cost of the staff dedicated to movement activities and station agents;
- $\bar{C}_{trac\,pwr}$ is the standard cost of traction power;
- $\bar{C}_{rs}$ is the standard cost of the fleet use.

2.1.1 The standard cost of the driving personnel

This cost item can be calculated as:

$$\bar{C}_{drv} = \bar{N}_{drv} \cdot \bar{C}_{drv,u} \tag{4}$$

where

- $\bar{N}_{drv}$ is the standard number of drivers;
- $\bar{C}_{drv,u}$ is the standard unit cost of the driving personnel (i.e. per driver). It includes health and social insurance and retirement funds.

The standardized number of drivers can be derived from the standardized number of gross driving hours as follows:

$$\bar{N}_{drv} = \frac{TRK + TK_{out}}{\overline{gH}_{drv,u} \cdot \left(V_{com} \cdot \overline{ADJ}_{V_{com}}\right)} \tag{5}$$

where

- TK_{out} is the number of train kilometres produced out of service;
- $\overline{gH}_{drv,u}$ is the standard number of gross driving hours per driver (i.e. standard driver's productivity). This parameter values hours spent in driving total production of train kilometres, including train kilometres produced out of service, that is, in turnarounds at the end of the line and to store vehicles in depots;
- V_{com} is the commercial speed, calculated as the ratio between total TRK and net driving hours (i.e. hours spent in driving);
- $\overline{ADJ}_{v_{com}}$, with $0 < \overline{ADJ}_{v_{com}} \leq 1$, is the conversion coefficient to switch from commercial speed to service speed (calculated as the ratio between total production of train kilometres, including train kilometres produced out of service, and gross driving hours).

Thus, the number of drivers is calculated also by taking into account for driving hours spent in turnarounds at the end of line and to store vehicles in depots.

2.1.2 The standard cost of the staff dedicated to movement activities

This cost item can be calculated as:

$$\bar{C}_{ms\,staff} = \bar{N}_{ms\,staff} \cdot \bar{C}_{ms\,staff,u} \tag{6}$$

where

- $\bar{N}_{ms\,staff}$ is the standard number of staff dedicated to movement activities;
- $\bar{C}_{ms\,staff,u}$ is the standard unit cost of the staff dedicated to movement activities and station agents (i.e. per unit of staff). It includes health and social insurance and retirement funds.

In particular, the standard number of staff dedicated to movement activities can be derived as follows:

$$\bar{N}_{ms\,staff} = \bar{N}_{ms\,staff,u} \cdot N_{drv} \tag{7}$$

where

- $\bar{N}_{ms\,staff,u}$ is the unit standard number of staff dedicated to movement activities and station agents (i.e. per driver).

2.1.3 The standard cost of traction power

This cost item can be calculated as:

$$\bar{C}_{trac\,pwr} = \left(TRK + TK_{out}\right) \cdot \bar{C}_{pwr,u} \tag{8}$$

where

- $\bar{C}_{pwr,u}$ is the unit standard cost of traction power (i.e. per kilometre), including train kilometres produced out of service.

2.1.4 The standard cost of the rolling stock

This cost item can be calculated as:

$$\bar{C}_{rs} = \bar{N}_{train} \cdot N_{seats\_train} \cdot \overline{DEPR}_{seat} \tag{9}$$

where

- $\bar{N}_{train}$ is the standard number of trains used to provide the service;
- N_{seats_train} is the unit number of seats on trains used for the provision of service;
- $\overline{DEPR}_{seat}$ is the standard train depreciation per seat.

In particular, the standard number of trains used to provide the service can be calculated as follows:

$$\bar{N}_{train} = \frac{TRK + TK_{out}}{\overline{Prod}_{train}} \tag{10}$$

where

- $\overline{Prod}_{train}$ is the standard number of train kilometres produced per vehicle, including train kilometres produced out of service (i.e. standard vehicle's productivity).

The parameter $\overline{DEPR}_{seat}$ takes into account standard depreciation of the rolling stock (including rents and leasing) as well as planned cyclical maintenance, which increases the book value of the asset, i.e. which raises depreciation expenses in future periods. For this reason, such maintenance is capitalized.

2.2 The standard cost of the infrastructure

Infrastructure includes tracks, overhead wire and electric substations, as well as depots, shed and workshops. The standard cost of the infrastructure use can be determined as:

$$\bar{C}_{inf} = D_{emnt} \cdot L_{track} \cdot \bar{C}_{inf\_emnt,u} + (1 - D_{emnt}) \cdot L_{track} \cdot \bar{C}_{inf\_no\,emnt,u} \tag{11}$$

where

- D_{emnt} is a dummy variable that is equals to 1 if the cost of extraordinary maintenance is included in the service contract, otherwise equals to 0;
- L_{track} is the length of track (in kilometres);
- $\bar{C}_{inf\_emnt,u}$ is the unit standard cost of infrastructure (i.e. per kilometre), including depreciation and extraordinary maintenance of facilities, depreciation of capitalized maintenance of non-owned facilities and rental fee for infrastructure;
- $\bar{C}_{inf\_noemnt,u}$ is the unit standard cost of infrastructure (i.e. per kilometre), when extraordinary maintenance is not included in the service contract.

2.3 The standard cost of ordinary maintenance

A significant cost item is related to maintenance of infrastructure and rolling stock. It can be calculated as:

$$\bar{C}_{omnt} = \bar{C}_{omnt\_inf} + \bar{C}_{omnt\_rs} \tag{12}$$

where

- $\bar{C}_{omnt\_inf}$ is the standard cost of infrastructure maintenance;
- $\bar{C}_{omnt\_rs}$ is the standard cost of vehicle maintenance.

2.3.1 The standard cost of infrastructure maintenance
This cost item can be calculated as:

$$\bar{C}_{omnt\_inf} = \left(TRK + TK_{out}\right) \cdot \bar{C}_{omnt\_inf,u} \tag{13}$$

where

- $\bar{C}_{omnt\_inf,u}$ is the unit standard cost of ordinary infrastructure maintenance (i.e. per train kilometre produced, including train kilometres produced out of service).

Ordinary infrastructure maintenance (and related cost) also comprises cleaning, surveillance and safety and takes into account ordinary repairs necessary to keep infrastructures functioning. Ordinary maintenance is simply recorded as expenses in the current period, and the book value of the asset remains unchanged.

2.3.2 The standard cost of vehicle maintenance
This cost item can be calculated as:

$$\bar{C}_{omnt\_rs} = \bar{N}_{train} \cdot \bar{C}_{omnt\_rs,u} \tag{14}$$

where

- $\bar{C}_{omnt\_rs,u}$ is the standard unit cost of ordinary vehicle maintenance (i.e. per train).

Vehicle maintenance (and related cost) includes maintenance outsourced to third parties, the cost of spare parts, labour costs for in-house maintenance, the cost of equipment, machinery and other fixed assets used for in-house maintenance. It also comprises cleaning, surveillance and safety. Ordinary repairs are simply recorded as expenses in the current period, and the book value of the asset remains unchanged.

2.4 The standard cost of administrative and general activities

The standard cost of administrative and general activities, $\bar{C}_{adm}$, can be determined as:

$$\bar{C}_{adm} = \left(\bar{C}_{tr} + \bar{C}_{omnt}\right) \cdot \bar{C}_{adm,u} \tag{15}$$

where

- $\bar{C}_{adm,u}$ is a measure of the incidence of general and administrative activities costs on total costs calculated as a percentage on the transport services production cost.

This cost item refers to expenses related to economic planning and control costs, membership fees, tolls and insurances, business consulting and information systems costs, labour costs of personnel employed in general activities. So overall, costs other than those specified explicitly in the model are included in this cost item.

2.5 The standard cost of capital

These cost items relate to the standard cost of capital, $\bar{C}_{cap}$, corrected for tax effects. We note that firms must generate a return on the net invested capital to fully reward all providers of financial sources, that is, debt and equity. Thus, the cost of capital calculation needs taking into account the minimum return a company must generate on net invested capital.

It results:

$$\bar{C}_{cap} = \bar{C}_{cap\_rs} + \bar{C}_{cap\_inf} \tag{16}$$

where

- $\bar{C}_{cap\_rs}$ is the cost of capital invested in the rolling stock;
- $\bar{C}_{cap\_inf}$ is the cost of capital invested in the infrastructure

We consider:

$$\bar{C}_{cap\_rs} = WACC_{rs} \cdot \left(\bar{C}_{rs} \cdot l_{rs}\right) \tag{17}$$

$$\bar{C}_{cap\_inf} = WACC_{inf} \cdot \left(\bar{C}_{inf} \cdot l_{inf}\right) \tag{18}$$

where

- $WACC_{rs}$ is the Weighted Average Cost of Capital invested in rolling stock;
- $WACC_{inf}$ is the Weighted Average Cost of Capital invested in infrastructure;
- l_{rs} is the average age of vehicles;
- l_{inf} is the average age of infrastructure.

3 DATA AND RESULTS

Disaggregated information about costs, technical and environmental characteristics was collected in 2012 by means of questionnaires sent to Italian companies providing tramway services in 7 Italian Regions and producing more than 26 million of TRK, i.e. 100% of the production of tramway services in 2012 (see Table 1). The questionnaire has been later adopted by the national observatory on LPT policies, which is in charge of collecting economic and transport information from LPT firms and creating a complete, certified and constantly updated database for the monitoring of this industry. Tramways services are mostly offered in the urban segment, while we observe the case of suburban tramways in Milan (Lombardia). A suburban service is a commuter passenger transport service that primarily operates between a city centre and its belt suburbs, which normally draw large numbers of commuters. Compared with an intercity service, suburban services normally exhibit lower commercial speed, close to that of urban services

Table 1: Technological characteristics of tramway services included in the database.

Region		Lazio	Lombardia		Friuli Venezia Giulia	Toscana	Piemonte	Campania	Veneto
			Suburban	Urban					
Line length	[km]	70	11.60	254.67	5.18	15.00	144.00	17.70	19.60

Interviews and indications provided by the Working Group set by the Unified Conference contribute to define the standards values for each cost driver by identifying two levels of analysis: the first one represents the average level of efficiency observed among tramway services included in our dataset and the second one refers to the best performing operator for each cost driver. The standards for the cost of the driving personnel are presented in Table 2, consistently with observations conveyed in Section 2 on the role of turnarounds at the end of the line, the standard number of gross driving hours per driver and the standard commercial speed adjusted to take into account the total production depending on operator performances.

When we take into account the incidence of TRK over total production through the coefficient $\overline{ADJ}_{v_{com}}$, we note that net driving hours – net of driving hours spent in turnarounds at the end of line – are slightly different between an averagely well-run operator and the benchmark. Standards variables are also provided in relation to the economic cost of the rolling stock for specific technological characteristics. In fact, the firm may have an incentive to invest in the quality of the rolling stock. However, the implementation of standard costs may spur distortions such as 'gold plating' of the fleet that the policy-maker may wish to correct. In order to prevent such distortions in the procurement of new trains, $\overline{DEPR}_{seat}$, represents an upper bound to the depreciation per seat. The Working Group set by the Unified Conference has provided precise indications to compute $\overline{DEPR}_{seat}$ (see Table 3): (i) a standard and fairly representative composition of the fleet tramway services; (ii) the average market values (at 2012) for specific vehicles including the present value of their (capitalized) planned cyclical maintenance through their life cycle; (iii) an average number of seats on trains used for the provision of tramway services in Italy and (iv) the standard vehicle's productivity.

Table 2: Standards for the cost of the driving personnel.

Cost driver		Averagely efficient	Best performer
$\overline{ADJ}_{v_{com}}$		0.9305	0.9865
$\overline{gH}_{drv,u}$	[(h/driver) * year]	1,195.70	1,651.57
$\overline{gH}_{drv,u} \cdot \overline{ADJ}_{v_{com}}$	[(h/driver) * year]	1,112.64	1,629.27
$\bar{C}_{drv,u}$	[€/driver]	44,017.35	30,685.13

Table 3: Standards for the cost of the rolling stock.

Typology of vehicles	Seats	Price per vehicle (€)	$\overline{DEPR}_{seat}$
32-m electric motor vehicles	272	2,500,000	306.37
Vehicle productivity		Averagely efficient	Best performer
$\overline{Prod}_{train}$	[km/train]	37,662.02	76,593.56

We remark that since operators may use different depreciation periods for fixed assets, the depreciation rate associated with the observed services has been readjusted by considering a uniform depreciation period equal to 30 years. So that is the tramway service, it is possible to determine the standard train depreciation per seat as follows: $\overline{DEPR}_{seat} = 2{,}500{,}000 / (30 \times 272) = 306.37$ € / seat, where € 2,500,000 is the average price of train and 272 is the average number of seats on such vehicle. Cost items other than the cost of the driving personnel and of the rolling stock are calculated by comparing the average-efficiency standards with corresponding benchmarks. In fact, such cost items substantially differ across the average level of efficiency and the best practices (see Table 4). Finally, in Table 5, we show data used to compute the standard cost of capital.

In order to illustrate how our results might be used at a micro-level to define a maximum economic compensation, we build some case studies. We focus on three specific cases according to the different characteristics of the service and the efficiency level of operator.

Characteristics of services are based on reasonable assumptions for Italian urban areas. However, they can be considered representative of any specific operating context.

Table 4: Standards for the cost of the rolling stock.

Cost driver		Averagely efficient	Best performer
$\bar{N}_{ms\ staff,u}$		0.0881	0.0351
$\bar{C}_{ms\ staff,u}$	[€/work units]	44,985.38	43,751.47
$\bar{C}_{pwr,u}$	[€/km]	0.6398	0.5132
$\bar{C}_{inf\_emnt,u}$	[€/km]	84,576.00	79,563.04
$\bar{C}_{inf\_no\ emnt}$	[€/km]	4,439.50	3,344.97
$\bar{C}_{omnt\_inf,u}$	[€/km]	1.186	1.141
$\bar{C}_{omnt\_rs,u}$	[€/km]	54,482	50,127
$\bar{C}_{adm,u}$		0.1292	0.0812

Table 5: Tax effects and the cost of capital.

Cost driver	Averagely efficient	Best performer
$WACC_{rs}$	10.25%	
$WACC_{inf}$	5.5%	

3.1 Case studies

Let us assume that the following tramway services are auctioned off by means of a tendering procedure. The first one relates to the urban services in a big city (i.e. urban city); the second one concerning urban services in a town smaller than previous one (i.e. urban town) and the last one relates to the connection between the city centre and the suburbs (i.e. suburban). Table 6 collects the hypothetical characteristics of the tramway services auctioned off., it should be noted that in all cases it has been assumed an average fleet age of 15 years.

The data of Table 6 allow us to calculate the service frequency, assuming 18 hours of service per day for 365 days per year, a tram running every 7.9 min, 4.93 min and 15.8 min in the case of urban city routes, urban town routes and suburban lines, respectively. Table 7 shows the result of our model. Based on the results, the maximum economic compensation that can be required by any firm for the provision of tramway services related to urban services of a big city is 15.16 €/km for average-efficient operators and 8.63 €/km in the case of highest efficiency. The unit costs decrease in the case of urban services in a medium town until 13.67 €/km for averagely well-run operator, with the option to improve performances up to 7.70 €/km. Instead, for suburban tramway services, there is a slight increase in unit cost up to 15.32 and 9.58 €/km for average-efficient operator and the best performer, respectively. We also derive the standard cost of tramway services per seat kilometre: we obtain 0.069 €/seat·km for urban city routes, 0.050 €/seat·km for urban town routes and 0.056 €/seat·km for suburban lines, with regard to the first and third cases, the result is reversed because of the higher seats capacity of suburban vehicles. This comparison shows that for tramway services, the cost reduction of suburban travel – related to higher commercial speed – is offset by an increase in train and infrastructure depreciation.

3.2 Numerical results

In this section, we perform a simulation study in order to highlight how the standard cost of the service modifies when the required level of efficiency is tuned according to regional desiderata. In particular, we show the marginal impact of efficiency gains obtained with respect to

Table 6: Case studies: hypothetical characteristics of the tramway services.

Capacity		Urban city	Urban town	Suburban
Transport characteristics				
TRK	[km]	5,000,000	1,200,000	500,000
TK_{out}	[km]	150,000	22,353	7,000
V_{com}	[km/h]	11	19	25
$N_{seats,train}$	[km/h]	220	272	272
Average fleet age (l_{rs})	[year]	15	15	15
Infrastructure characteristics				
L_{track}	[km]	100	15	20

Table 7: Case studies: standard unit cost of tramway services.

Cost item/TRK		Urban (city)				Urban (town)				Suburban			
		Averagely efficient	% on $\overline{C}_{TRK}$	Best performer	% on $\overline{C}_{TRK}$	Averagely efficient	% on $\overline{C}_{TRK}$	Best performer	% on $\overline{C}_{TRK}$	Averagely efficient	% on $\overline{C}_{TRK}$	Best performer	% on $\overline{C}_{TRK}$
$\overline{V}_{com\_adj}$	[km/h]	10.24		10.85		17.68		18.74		23.26		24.66	
Total seats Km	[seat·km]	1,100,000,000		1,100,000,000		326,400,000		326,400,000		136,000,000		136,000,000	
$\overline{N}_{drv}$		420.78		287.36		57.82		39.49		18.23		12.45	
$\overline{C}_{drv}$	[€/km]	3.70	24.43	1.76	20.43	2.12	15.51	1.01	13.12	1.60	10.48	0.76	7.97
$\overline{N}_{ms\ staff}$		37.07		10.08		5.09		1.39		1.61		0.44	
$\overline{C}_{ms\ staff}$	[€/km]	0.33	2.20	0.09	1.02	0.19	1.40	0.05	0.66	0.14	0.94	0.04	0.40
$\overline{N}_{train}$		136.74		67.24		32.46		15,96		13.46		6.62	
$\overline{C}_{trac\ pwr}$	[€/km]	0.66	4.35	0.53	6.12	0.65	4.77	0.52	6.79	0.65	4.24	0.52	5.43
$\overline{C}_{rs}$	[€/km]	1.84	12.16	0.91	10.50	2.25	16.49	1.11	14.40	2.24	14.65	1.10	11.51
$\overline{C}_{inf}$	[€/km]	1.69	11.16	1.59	18.44	1.06	7.73	0.99	12.92	3.38	22.09	3.18	33.21
$\overline{C}_{omnt\_inf}$	[€/km]	1.22	8.06	1.17	13.61	1.21	8.84	1.16	15.09	1.20	7.85	1.16	12.07
$\overline{C}_{omnt\_rs}$	[€/km]	1.49	9.83	0.67	7.81	1.47	10.78	0.67	8.66	1.47	9.58	0.66	6.93
$\overline{C}_{adm}$	[€/km]	1.20	7.88	0.42	4.83	1.02	7.47	0.37	4.77	0.94	6.17	0.34	3.60

Table 7: *Continuted*

Cost item/TRK		Urban (city)				Urban (town)				Suburban			
		Averagely efficient	% on $\bar{C}_{TRK}$	Best performer	% on $\bar{C}_{TRK}$	Averagely efficient	% on $\bar{C}_{TRK}$	Best performer	% on $\bar{C}_{TRK}$	Averagely efficient	% on $\bar{C}_{TRK}$	Best performer	% on $\bar{C}_{TRK}$
$\bar{C}_{cap\_rs}$	[€/km]	3.02	19.93	1.49	17.22	3.69	27.02	1.82	23.60	3.68	24.01	1.81	18.87
$\bar{C}_{TRK}$	[€/km]	15.16	100	8.63	100	13.67	100	7.70	100	15.31	100	9.58	100
$\bar{C}_{SK}$	[€/ seat·km]	0.069		0,039		0.050		0,028		0.056		0,035	

cost-driving variables both under the control of the operators and of the local authority who assigns the service. For the sake of space and readability, we perform our simulations on the basis of a single case study, specifically urban service in a big city (see Table 7). We first focus on cost-driving variables under the control of the operators. In particular, we analyse the marginal impact of drivers and vehicles productivity on the standard cost, i.e. $\overline{gH}_{drv,u}$ and $\overline{Prod}_{train}$, respectively. The grey shape in Figure 1 shows how the standard cost and related savings vary when there is a percentage increase of gross driving hours, other characteristics being fixed. For instance, a 5%, 10%, 20% and 30% increase of gross driving hours, respectively, leads to a reduction of unit standard costs that is almost equal to 0.22, 0.41, 0.76 and 1.05 €/km. Based on results of previous analysis the maximum efficiency gain can be reached by increasing gross driving hours about 38% that, all else being equal, reduces standard costs by 1.26 €/km. Similarly, the black shape (Figure 1) shows how the standard cost and related savings vary when there is a percentage increase of train kilometres produced per vehicle, other characteristics being fixed. For instance, a 5%, 10%, 20%, 40% and 70% increase of train kilometres produced per vehicle, respectively, leads to a reduction of unit standard costs, which is almost equal to 0.32, 0.62, 1.13, 1.94 and 2.79 €/km. Based on results of previous analysis, the maximum efficiency gain can be reached by increasing train kilometres about 103% that, all else being equal, reduces standard costs by 3.45 €/km. We note that savings in the unit standard cost are higher when efficiency is pursued with respect to vehicle productivity, rather than driver productivity (see Figure 1). In fact, tramway services are asset intensive rather labour intensive: the economic cost of the rolling stock (including the cost of fleet use, traction power, train maintenance and the cost of capital) covers more than 40% of the total economic cost (Table 7). We now focus on cost variables under the control of the local authority. In particular, we analyse the marginal impact of the number of train revenue kilometres assigned within the service contract (i.e. TRK) and the average fleet age (i.e. l_{rs}). In fact, the average age of rolling stock affects the net invested capital and hence cost of capital. The grey straight line in Figure 2 shows how the standard cost and related savings vary when there is a percentage increase of TRK, other characteristics being fixed. For instance, a 5%,

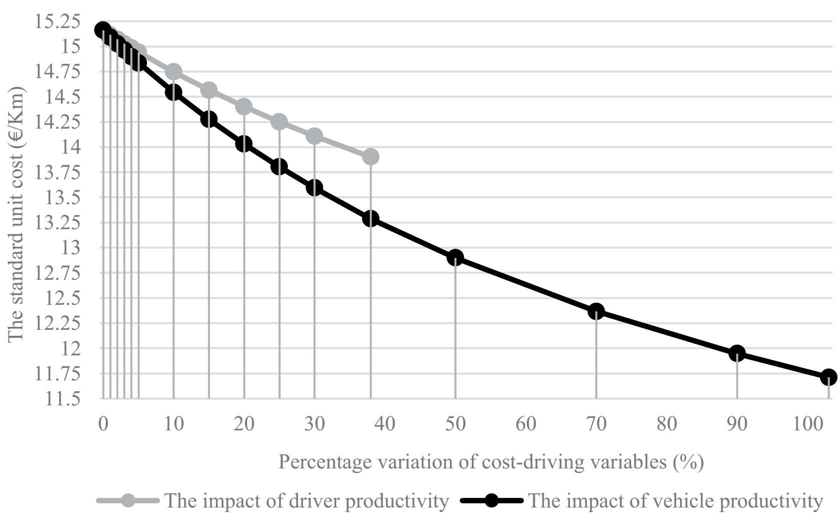

Figure 1: Variations in the standard unit cost due to efficiency gains in driver and vehicle productivity.

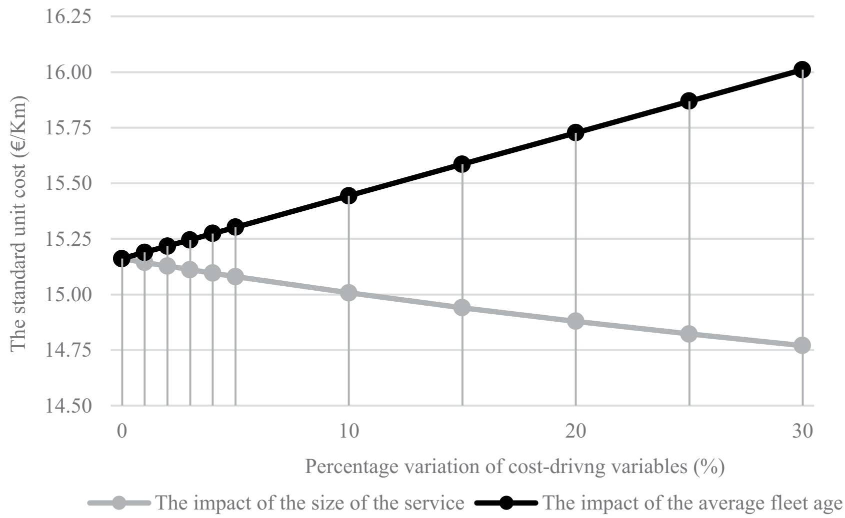

Figure 2: Variations in the standard unit cost due to changes in the service size and the average fleet age.

10%, 20% and 30% increase of TRK, respectively, leads to a reduction of unit standard costs, which is almost equal to 0.08, 0.15, 0.28 and 0.39 €/km. The unit standard cost reduces as the size of the service increases as scale economies play a role: the firm obtains cost advantages as infrastructure costs (including the cost of infrastructure use and maintenance, station power and the cost of capital) are spread out over a higher scale of operation. Similarly, the black straight line (Figure 2) shows how the standard cost and related savings vary when there is a percentage increase of degree of rolling stock renewal, other characteristics being fixed. For instance, a 5%, 10%, 20% and 30% decrease of the average fleet age, respectively, leads to an increase of unit standard costs which is almost equal to 0.14, 0.28, 0.57 and 0.85 €/m. These examples clarify how the local authority should allocate extra resources if it wants to increase the quality of the service in terms, for instance, of info mobility, quietness and comfort of the vehicles.

4 CONCLUSIONS

In this paper, we build a proxy cost model for tramway services. Based on the proposed methodology, we have estimated the standard cost of Italian tramway services. We have also performed a simulation study in order to highlight the marginal impact of efficiency gains obtained by manipulating trains and drivers productivity, as well as number of TRK assigned within the service contract and average fleet age. We find that savings in the unit standard cost are higher when efficiency is pursued with respect to train productivity, rather than driver productivity. Moreover, we find that the unit standard cost decreases as the size of the service increases, since scale economies play a role, while it increases with the average age of vehicles.

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