https://doi.org/10.55343/CogSust.46

Marginal Cost in Private and Public Transport

Pedro Pablo Jiménez Gómez
Faculty of Social Sciences
UCAM-Catholic University of Murcia
Murcia, Spain
ppjimenez@alu.ucam.edu

Abstract:
For decades, different economic theories have been trying to find an answer to determining the total costs of road transport and the best way to internalise these costs, with the most widespread answer among experts being pricing concerning marginal cost. This article presents a classification of transport costs with their corresponding mathematical functions to finally obtain the marginal cost of both public and private transport to develop an optimal pricing system. Finally, a system of equations for determining the optimal price based on the short term and under the economic premise of maximising social welfare is presented.
Keywords
Marginal cost, road transport, emissions, externalities, pricing

1. Introduction

Transport is undoubtedly one of the sectors that have most contributed to the growth of modern economies. The rapid mobility of people and goods has been essential to reach the level of globalisation we find ourselves today. Like any other economic sector, the transport sector presents negative externalities which, due to the dynamism of the sector and its heterogeneous nature, have been the subject of debate among economists since the 1960s, with the main point of disagreement always being the determination of the best way to internalise costs.

However, it is not all discrepancies. There is one thing on which economists are unanimous, and that is the answer to the question of what price transport users should pay: the vast majority agree that they should pay the marginal cost, a variable that we define as the cost resulting from adding vehicle or transport unit to the infrastructure. However, the very dynamic characteristics of the transport industry, which means that these costs can vary from minute to minute, mean that we are back to the lack of consensus among economists on how to determine these marginal costs and whether to use those relating to the short or long term to develop the best possible pricing policy.

The big difference between the transport industry and other industries is that many of the sector's externalities are not only borne by the user but are also passed on to society as a whole, which is why in transport economics, the term "social marginal cost" is constantly used when discussing the pricing of transport services. In 1998, in its report "Fair pricing of infrastructure use", the European Commission established a strategy for the implementation of common pricing according to social marginal costs, which can be considered one of the most important events in transport economics, as it was a starting point for Community transport pricing policies, with the environmental objective at the centre of the problem. This environmental approach has gained weight over the years and has become the undisputed protagonist of transport pricing policies.

2. The costs of private and public transport:

In any economic activity, we speak of opportunity cost as the value of the productive resources used to carry out that activity. The value of resources must be calculated, considering what other possible alternative uses would be and selecting the best option in terms of cost-benefit for society. In the road transport sector, the cost to society is the sum of the monetary value of all the inputs needed to transport people and goods from one place to another.

One of the characteristics of the transport sector that differentiates it from others is that when we talk about the consumption of productive factors to carry out its activity, we must not only take into account the vehicles, infrastructure, technology or energy consumed by the means of transport, there is a fundamental factor that is at the heart of the demand for transport services, and that is the time invested by users in making these journeys as well as the impact that these journeys have on the rest of society.

https://doi.org/10.55343/CogSust.46

Experts agree on classifying transport costs according to who bears them (*Maibach, 2008*), distinguishing between producer and user. The sum of these three costs allows us to obtain the total social cost that society faces to achieve an acceptable level of transport services (1):

(1) $$Cs = Cp + Cu + Ce$$

The **costs of the producer** include all the expenses necessary to build, operate and maintain the infrastructure, as well as the expenses related to the acquisition, operation and maintenance of the vehicles used to transport passengers, and finally, the operating costs of producing the services (personnel costs, fuel, spare parts).

User costs should reflect all the inputs consumed in private and public transport activities. Like the producer of transport, the private consumer faces the costs of purchasing and maintaining his vehicle, fuel costs, vehicle insurance, and the corresponding taxes or charges of the region in which he drives. In public transport, the user does not face any of these costs directly but pays a ticket to the service producer that is used as compensation for those costs that he/she will incur to produce the transport activity.

However, as mentioned above, there is a characteristic that differentiates it from other sectors when determining the total cost of the activity in the transport sector. This factor included in user costs is the importance of making a monetary valuation of the time invested in the transport activity, which is the sum of travel time and waiting time or the time spent on transfers in the case of public transport. This variable is key for analysing policies to solve externalities such as road congestion; congestion occurs due to the capacity limitations of infrastructure when there are additional users. This leads to an increase in time costs and fuel that we pass on to the user's cost function since, although they cause external effects to society, which will be discussed later, the user bears these congestion costs.

The **external costs** of transport are those that have a direct impact on the rest of society, whether or not they are transport users, causing a reduction in their welfare. In recent years, the European Commission has focused its efforts on the transition towards a more sustainable transport system that drastically reduces the external cost of pollution, which directly impacts air quality and the health of citizens.

3. The costs of the producer of transport services

For this section, we consider a transport company that produces a single output, measured, for example, in passenger kilometres. Depending on this output, the company will assume two different types of costs, fixed costs that remain constant whether or not there are variations in the output and variable costs that will differ according to the production volume. Fixed costs include, for example, the salary of a bus driver, which will not vary according to the number of passengers he transports. In contrast, variable costs include, for example, the costs of increasing the capacity of a transport element due to a variation in output, in this case, an increase in passengers that requires expenditure to increase supply.

Another classification of the producer's costs would be according to the input used. In this case, there are two types: infrastructure-related and operating costs. Infrastructure costs would include, among others, road maintenance costs, while operating costs would include those related to vehicles, including, among others, personnel costs. This classification of costs would be directly related to the function (2):

(2) $$q = f(K, E, L, F, N; t)$$

Where

q is the level of production in a given unit of time,
K units of infrastructure,
E mobile equipment,
L *labour*,
F energy and spare parts,
N natural resources,
t users' time.

https://doi.org/10.55343/CogSust.46

Taking this function as a starting point and ignoring the elements *t* and *N* that are not part of the producer costs since *t* is in user costs and *N* in external costs, the producer cost function associated with the remaining factors can be defined by the equation (3) by *Campos (2003)*:

(3) $$Cp(q,K) = r(K)\,K + c(q)\,q$$

Where

r(K) is the annual cost of each unit of infrastructure,
c(q) is the cost per output unit associated with the other factors (*E, L and F*).

4. The costs of public and private transport users:

In private transport, the user acts as a producer and therefore shares most of the cost items detailed in the previous section; one of the most relevant costs of the private transport user is operating costs, which include fuel, maintenance, repairs, car insurance costs, and of course taxes related to the vehicle and its circulation.

As for public transport, the price paid by the user in the form of a ticket is not included in the user costs since it is not an input that the user contributes to the transport activity but rather a transfer that the producer receives and which forms part of the general price paid by the user to consume transport services.

The common characteristic in the user costs of public and private transport is that the main cost faced by users in both types of transport is the same: the opportunity cost of the time users spend making a journey. Within this time, we can distinguish two categories: time with congestion, which depends on the number of vehicles on the road, and time without congestion, which depends on the relationship between distance and average vehicle speed.

The opportunity cost of the time spent by users on a journey can be calculated by valuing the time spent on the journey in monetary terms, which in the case of private transport would also include the necessary rest or refuelling breaks, and in the case of public transport would include the transfers and waiting times incurred during the journey. With these assumptions, the opportunity cost of public transport users can be represented by the cost function equation (4) by *Campos (2003)*:

(4) $$Cu(q,t) = vtq$$

Where

t is the time consumed in the journey (with the assumptions defined above),
v is the value assigned to this time, which in this example is constant,
q is the number of passengers or journeys made.

In the case of the private transport user, as described at the beginning of the chapter, if he owns the car, he acts as an operator-product, and therefore, user costs and related producer costs, namely operating costs, are combined in his total cost equation (5) by *Campos (2003)*:

(5) $$Cu(q,t) + Cp(q) = (c + vt)q$$

Where c is the **marginal cost** of the user when acting as a producer, as in the case of the private car, this cost includes fuel and wear and tear on the vehicle, among others.

https://doi.org/10.55343/CogSust.46

5. The external costs of public and private transport:

Within the external costs defined in the introduction, the most relevant are environmental, noise, and accident costs.

In terms of environmental costs, a function can be defined to determine the costs of climate change caused in a 1 km interval, valued in *€/hour*, which will be determined by the value assigned to the tonne of CO_2, the intensity of traffic and fuel consumption equation (6) by *Ciommo et al., (2008)*:

(6) $$C_{CO_2} = CO_2 * \mathrm{K} * \sum I * C(v)$$

where

In the hourly vehicle intensity (veh/h),
C(v) fuel consumption as a function of speed,
CO_2 the cost of CO_2 (average value in 2022 of 83.02 €/tonne)
K the ratio between emission and consumption (*Friedrich and Bickel, 2001*).

For accidents, the cost (veh-km) will depend on the hourly intensity and will be calculated based on the ratio of injuries according to severity or fatalities, in addition to the medical cost incurred (7) by *Ciommo et al., (2008):*

(7) $$Cacc = \frac{l}{h} * (Rhl * VRhl + Rhg * VRhg + Rm * VRm + \emptyset)$$

where

l/h is the hourly intensity in veh/hour,
Rhl is the ratio of light casualties per veh-km,
VRhl is the value of the risk of light casualties (calculated as a function of GDP for all classes of casualties and fatalities),
Rhg is the ratio of severe casualties per veh-km,
VRhg value of the risk of serious injuries,
Rm ratio of fatalities per vehicle-km,
VRm value of the risk of fatalities, also calculated as a function of GDP
Ø losses of human capital, medical, administrative or infrastructure/property damage costs.

6. The problems in pricing concerning marginal cost:

As described earlier in the article, the dynamic characteristics of the transport sector make the determination of its exact costs particularly complex, high fixed costs, for example, in the case of public transport, make it difficult to calculate the exact marginal cost of carrying one more passenger. In addition, the wide variety of services depending on route, speed, and other variables that make transport activities multi-product adds to the complication of pricing the exact cost and the optimal price for each trip.

Another reason for public transport is the market power that an operator may have to set prices above the cost of production in the absence of competition. Finally, and most importantly, the prices of transport services are mainly unrelated to the marginal costs of production because political acceptability criteria come into play when making decisions. In many cases, the transport service operator is forced to charge below marginal cost to make a route more attractive or encourage public transport use by administrations. This is achieved through subsidies.

The price faced by transport users is determined by the equation (8) by *Campos (2003)*:

(8) $$g = p + tv + \emptyset$$

This equation contains the elements described in the chapter on costs, where *p* is the monetary cost of the ticket or the variable cost of a vehicle in the case of private transport, *tv* is the monetary valuation of the time invested, and *Ø* is the

https://doi.org/10.55343/CogSust.46

monetary valuation of other external elements associated with the journey. This element *p* is the one that should reflect the marginal cost of the production of the service. However, this is not usually what happens in practice because the price rarely includes all the costs of the producer and the external costs generated by the transport activity that society bears.

7. The optimal price system: short term

Following the concept of economic efficiency and maximisation of social welfare, as discussed at the beginning of the article, the price to be paid by transport users must be equal to the marginal cost they incur. In this case, we detail how the marginal costs can be obtained in the short term. To this end, the possibility of increasing the capacity of the infrastructure is ruled out, and the hypothesis is focused on achieving the maximum possible efficiency with a fixed capacity component.

To obtain the costs, we return to the formula detailed in the first section of the article for total costs, but this time as a function of the output *Q*, which represents the flow of vehicle-km per unit of time in equation (9) by *Matas (2004)*:

(9) $$CT = Cp\ (Q) + Cu\ (Q) + Ce(Q)$$

The total user cost is the product of the output *Q* by the average cost of each infrastructure user (ACu). This average user cost is the equivalent of the private marginal cost in equation (10) by *Matas (2004)*:

(10) $$CTu = Q * ACu\ (Q)$$

Following this scheme, the short-run marginal cost is determined by the following equation (11) by *Matas (2004)*:

(11) $$CM = CMp + Q * \frac{\partial ACu}{\partial Q} + ACu + CMe$$

Representing *ACu* as the monetary costs of circulation and the time-related costs that the user already internalises, the optimal price can be determined according to the short-run marginal cost through the equation (12) by *Matas (2004)*:

(12) $$P = CMp + Q * \frac{\partial ACu}{\partial Q} + CM$$

The three components of the equation are the producer's marginal costs, that have been summarised in the first point of the article, and the second component, the marginal cost of congestion. Moreover, the third component relates to the external marginal costs imposed on society not internalised by the sector.

8. Conclusion:

Determining the marginal cost of road transport continues to be a challenge for economists due to the multi-product characteristics of the sector and the variety of different types of vehicles that coexist on the road. Thanks to new technological tools that facilitate traffic control, we are getting closer to developing a reliable marginal cost pricing model. As described in this article, mathematical methods exist for obtaining short-run marginal costs assuming a fixed infrastructure level. However, the challenge is to develop a model for obtaining the dynamic long-run marginal cost that allows obtaining the most efficient pricing system according to the constant changes in traffic volume and infrastructure variations.

Acknowledgement

The author is incredibly thankful for the support of Ms Eva KOZAK.

https://doi.org/10.55343/CogSust.46

References

Ciommo D. Di., Vassallo J-M. Pérez P., Monzón A. (2008). “Spanish road pricing system based on a social cost model” [in Spanish: Sistema Tarifario de las carreteras españolas en base a un modelo de costes sociales]. Retrieved from URL: https://oa.upm.es/3195/1/INVE_MEM_2008_53499.pdf

Friedrich R, And Bickel P. (2001). “Global Warming, Environmental Cost Of Transport” DOI: https://doi.org/j4n6

Maibach M., Schreyer C., Sutter D., Essen H.P. van, Boon B.H., Smokers R., Schroten A., Doll C., Pawlowska B., Bak M., (2008). “Handbook on estimation of external costs in the transport sector.” Retrieved from URL: https://transport.ec.europa.eu/system/files/2016-09/2008_costs_handbook.pdf

Matas P. A. (2004). "Transport policies and congestion" [in Spanish: Políticas de transporte y congestión en áreas urbanas: un panorama]. *Urban Public Economics Review*, 63-91. Retrieved from https://www.redalyc.org/pdf/504/50400103.pdf/

Nombela, G., Campos, J., & Ginés, D. R. (2003). “Transport Economics” [in Spanish: Economía del Transporte]. *Antoni Bosch*.