Internal and external costs of transport in Portugal

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Urban dispersion (sprawl) is a reality, however unplanned it may be. Its supporters advocate contact with nature, space and intimacy; however, alleged disadvantages include land consumption, public infrastructure and mobility costs, and housing prices.
The Research Project "Costs and Benefits of Urban Dispersion on a local scale" seeks to contribute to the debate with an objective approach based on the quantification of costs, externalities and benefits of different urban settlement patterns, thus "bringing urban form back to planning".
This paper presents one of the Project's tasks, the one concerning mobility costs, both internal and external. Quantified internal costs include investment, inspection, insurance, energy and maintenance; external ones include accident and environmental costs, calculated for road and rail transport.
Different methods are combined depending on available data sources in order to achieve figures for each of the cost components per vehicle-km, ton-km and passenger-km for 2005, at 2009 prices.
Results show that internal costs are larger than external ones for the majority of motorized transport, except two-wheelers, and for rail. External costs are larger than internal ones for soft modes, mainly due to high accident costs. Cost components, both internal and external, related to fuel consumption are the most relevant in heavy modes' cost structures. Investment costs are the most important category for the majority of the remaining modes.
Results also stress that current occupancy rates, load factors and vehicle mileages hinder the economic efficiency of collective and two-wheeled modes of transportation and may contribute to the pervasiveness of cars in Portugal.

Keywords: mobility costs, externalities, transport modes, urban dispersion

1 Introduction

The world's population is increasingly urbanized, yet today's city is quite different from the traditional, continuous and compact one. In the emergent city, social and spatial *rapports* have been transformed by mobility, while construction is intertwined with increasingly abandoned green spaces and land use patterns are fragmented and dispersed. This *city-territory* thus encompasses not only old compact and continuous cores but also fragments and dispersed development which, thanks to the spread of infrastructure and to an increasing mobility allowed by the car, have expanded to increasing vaster areas.

This phenomenon of urban dispersion[1] has not been supported by many key urban theorists - F. L. Wright's *Broadacre* is the most well-known exception (Wright, 1958) -, yet it is practised and consented, and increasingly so.

Urban dispersion has rightfully become the subject of several publications and research (e.g. Bauer and Roux, 1976; Indovina, 1990; Burchell, Lowesntein, Dolphin, Galley, Downs, Seskin. Still and Moore, 2002; Font, 2004; Portas, Domingues and Cabral, 2003) that acknowledge and describe it, but do so mainly on a regional or metropolitan scale. And there are not almost any studies on a

[1] The phenomenon is worldwide, but it carries its local idiosyncrasies, including in Portugal. We refrain from using the more pervasive term in Anglophone literature "sprawl", because it often has implicit morphologies when employed; "urban dispersion", on the contrary, gives room for Portugal's several morpho-tipologies of dispersed areas.

local scale that, regarding dispersion as an urban form, compare it with other (compact) ones or that draw recommendations on how to plan it.

Still, and even if not particularly rigorous or based on solid evidence, arguments for and against dispersion have long been put forward in a debate that Breheny (1996) has summarised as opposing centrists to decentrists (Carvalho and Gomes, 2009; Martins, Lopes, Silva and Gomes, 2008):

- Apologists of dispersion claim contact with nature, spaciousness and intimacy as quality of life improvements, and lower real estate prices and congestion in roads as more objective advantages.
- Its detractors see dispersed environments as simulacra of nature, isolation and anonymity and as implying greater land consumption, infrastructure costs and a bigger number of trips and an increase in the use of private vehicles.

If dispersion is real and needs planning and regulation, then an opinion as precise as possible should be sought. That is the purpose of the project «Costs and Benefits of Urban Dispersion on a local scale»[2]: to contribute to the debate with an objective approach based on the quantification of costs, externalities and benefits of different urban settlement patterns on a local scale. It considers mobility costs (both internal and external) as well as local infrastructure costs; on the benefits vector, it will assess people's valuation of distinct settlement patterns.

This paper will present the results of one of the Project's tasks, that of the quantification of internal and external costs of transport in Portugal. These costs will subsequently be confronted with results from a large scale survey undertaken in two mid-sized Portuguese cities on residents' mobility patterns thus achieving mobility costs associated with different settlement patterns.

Mobility planning and management has become one of the most relevant issues in efforts towards urban sustainability: notwithstanding a myriad of mitigation efforts, namely in technology efficiency, transport's environmental impacts are yet to be curtailed, as increases in transport use offset gains in vehicle efficiency (Martins *et al.*, 2008).

One of the most pressing challenges mobility planning faces thus resides in changing people's mobility patterns. Studies on the relationship between land use and mobility patterns are one of the means by which answers have been sought. Another strand of research has focused on markets' functioning instead: transport users do not pay for all the costs caused by their trips, causing suboptimal prices and traffic volumes, where too low a price generally causes too high a traffic volume (Sirikijpanichkul, Iyengar and Ferreira, 2006). This strand of research seeks quantification of external costs (those not paid for by users) so that price internalization policies and mechanisms may be accordingly devised.

This Research Project will therefore contribute to both the aforementioned debates. On the one hand, presenting internal and external costs (per vehicle-, passenger- and ton-km) will allow comparisons among themselves that will shed light on the current transport system's alleged inefficiency. This data allows comparisons between the transport modes under scrutiny, which may prove useful for urban mobility scenario building and policy making. On the other hand, subsequent

[2] «Costs and Benefits of urban dispersion on a local scale» is a Research Project funded by the Portuguese Science and Technology Foundation (FCT), coordinated by Jorge Carvalho. Project Reference: PTDC/AUR/64086/2006.

confrontation with data from the survey will address the debate on the relationship between settlement patterns and mobility.

This paper is structured as follows: after the definition of concepts and research scope, a few remarks on data and methods employed will follow. Results for internal, external and integrated costs will then be presented. Concluding remarks will shed light on further developments and policy implications of the achieved results.

2 Definitions and methodology

2.1 Definitions and scope

Despite the consensus on definitions of internal and external costs – internal are those directly borne by transport users, whilst external are so by others than the users causing them – there are disagreements on the classification of certain components. Controversy, usually over accident and delay costs due to congestion, derives mostly from differing interpretations on the extent of cost internalization mechanisms' coverage of externalities (Baum, Geiβler, Schneider and Bühne, 2008) as well as distinct conceptual and methodological assumptions.

Internal costs may be divided into investment and operation costs. Investment ones are related to vehicle purchase, including its price, taxes and interest. Operation costs, in their turn, derive from vehicle operation and are dividable in fixed and variable ones; fixed costs are independent of intensity of use, such as legally imposed (in Portugal) circulation taxes and vehicle inspections while variable ones depend on the intensity of vehicle usage, including maintenance, tolls, parking and energy consumption, among others. There are other direct costs of transport such as those deriving from infrastructure development and maintenance, freight handling, labour, management, administration and organisation (e.g. Ricci and Black, 2005).

Among external costs, the most relevant ones are environmental (pollution, climate change, noise, nature and landscape depredation, and other impacts up- and downstream the transport), additional costs in urban areas (barrier effects and space shortage), accidents (medical care, production losses, pain and sorrow) and congestion (time wastes and increasing operation costs). (EEA, 2001)

Not all of the cost components listed for both internal and external costs will, however, be taken into account in this piece of work, as the Project's goals, structure and methodology enforce certain decisions, even if they may go against mainstream research on mobility costs.

As the Project's purpose is not to establish users' expenses with transport (at market prices), rather mobility costs associable to different settlement patterns, per transport mode, (i.e. from a systemic/territorial standpoint), all cost components which are a consequence of internalization mechanisms were excluded from calculation as well as those aiming at financing the system's operation. Consequently, all taxes, tariffs and capital costs were subtracted from said market prices.

Moreover, all costs concerning infrastructural development and maintenance have also been discarded, as these are the subject of another of the Project's tasks (see above). This exclusion also applies to external costs deriving from infrastructure, for the same set of reasons.

Another issue influencing choice of cost components is the type of cost studied, usually average and/or marginal costs. In this study, as its purpose is to compare costs between different urban settlement forms, average costs were chosen. The objective is not to calculate costs of additional vehicles in the system, but that that of the average mobility pattern associable to a given land use pattern (Carvalho and Gomes, 2009).

Therefore, external costs will not take into account congestion costs either, as «parts of the congestion costs are 'paid' by waiting and delay costs of the users, others, namely those imposed on other users, are not. The measurement of the external part has to consider congestion dynamics. Since marginal costs are above average costs with increasing congestion, the difference between these two levels are considered as [the] external part, since average costs are paid by the user» (Maibach, Schreyer, Sutter, van Essen, Boon, Smokers, Schroten, Doll, Pawlowska and Bak, 2008: 14). As this Project deals exclusively with average costs and these are internalised within transport users, then they should not be taken into account in this context.

Consequently, the following cost components were analysed: in internal costs, investment, insurance, inspection, energy and maintenance costs; in external costs, accident, air pollution, climate change and noise costs.

Choice of transport modes was influenced by the case studies' characteristics (namely by dictating that some, such as metro, trams and fluvial transport, needed not be included). Road, including non-motorized modes, and rail transport were analysed. Some modes, like heavy goods vehicles and freight rail, despite not being relevant for the survey, were still included, in order to give a fuller picture of the Portuguese transport system. In the end, the following transport modes were considered: passenger cars, light goods vehicles, buses and coaches, heavy goods vehicles, mopeds, motorcycles, bicycles, pedestrians and passenger and freight rail transport[3].

2.2 Methodology

The purpose of this study is, then, to achieve average integrated (or social) costs per transport mode, encompassing both internal and external ones, so that costs of mobility patterns associable to different settlement patterns may be calculated and compared with other costs and benefits.

Average costs (€/vehicle-km, €/passenger-km, €/ton-km) were sought for each transport mode, taking into account each one's different average lifetimes, mileages and occupancy rates or load factors.

The costs' reference year is 2005, except when stated otherwise. However, monetary values were inflated to 2009 prices via Eurostat's Consumer Price Index, so that comparability with data on benefits derived from the survey is possible.

Whenever available, secondary data was used, sometimes combining distinct sources; otherwise, primary data was gathered via several enquiries to local stakeholders and agents. Depending on available sources, approaches for cost calculation were either top-down (departing from aggregate values for the whole of the vehicle fleet) or bottom-up (identifying costs for one single average vehicle). Table 1 summarizes the diversity of data sources and methods used in calculating internal costs. "N/A" stands for "Not Applicable", meaning the cost component in question was not

[3] Results for rail are still provisional.

calculated for that transport mode. A note should be made on pedestrians, for whom no internal costs were calculated. As all costs are referenced to a vehicle, the pedestrian, as a “vehicle”, is assumed in all transport modes. Accordingly, arguments, such as Litman’s (2009), on the higher caloric needs of pedestrians and cyclists and estimates on shoes’ cost and average lifetime were not taken into account either.

Studies on external costs are more abundant, yet results reached are varied, depending both on differing conceptual and methodological options (including type of cost) and on the «specifics of the situations» (Quinet, 2004), namely countries’ distinct settlement patterns and vehicle fleets. Therefore, only sources dealing with average costs were considered and, within these, those relating specifically to Portugal were privileged. Three sources fulfilling these prerequisites were found: INFRAS/IWW (2000; 2004) and Macário, Carmona, Caiado, Rodrigues, Martins, Link, Stewart, Bickel and Doll (2003).

Having compared these three sources, data from INFRAS/IWW (2004) were chosen. However, some adjustments had to be made so that these data would answer research goals laid out, because, unlike the 2000 version of the study (INFRAS/IWW, 2000), this report does not present national data disaggregated per cost component. Such disaggregation was needed, as some of the cost components stem from infrastructure (nature and landscape, additional costs in urban areas and upstream and downstream effects) and had, therefore, to be excluded. To do so, the Portuguese cost structure from the 2000 study, referring back to 1995, was used, for there are substantial differences between the Portuguese and European situations, as their cost structures portray.

Moreover, the report does not contemplate soft transport modes (bicycles and pedestrians). It was assumed that these modes do not have any environmental costs, but accident costs still had to be determined. This was done by crossing data on accident victims per transport mode and type of casualty in 2005 in Portugal (INE, 2006) with external accident costs per victim and casualty type according to INFRAS/IWW (2000; 2004). This method was then applied to the remaining transport modes, because they not only relate directly to the Portuguese reality, but also refer back to data from the original source of the remaining cost components. Accidents costs calculated with this method are generally higher than those achieved by simply applying the national cost structure from 1995 to average total external costs in 2000.

3 Results

3.1 Internal costs

Table 2 presents vehicle fleet characteristics in Portugal in 2005. Tables 3, 4 and 5 display results for internal costs in Portugal in 2005, in €/vehicle-km, €/passenger-km and €/ton-km, respectively, and Figure 1 shows each transport mode’s cost structure. When interpreting the results, it is important to bear in mind that the figures do not include capital costs nor taxes, which may mean, in some of the cost components, costs much lower than market prices. One should also keep in mind that, generally, figures describe the Portuguese situation and fleet use, which is determining when explaining some of the results.

Table 1. Data sources and methods for vehicle fleet characteristics and internal costs calculation

	Transport Mode								
Variable	Passenger Cars	Light Duty Vehicles.	Buses and Coaches	Heavy Duty Vehicles	Mopeds	Motorcycles	Bicycles	Pedestrians	Rail
Nb, of Vehicles	Pereira *et al.* (2009)[4]	Pereira *et al.* (2009)	Pereira *et al.* (2009)	Pereira *et al.* (2009)	Pereira *et al.* (2009)	Pereira *et al.* (2009)	From The Gallup Organization (2007) e INE (2009)	From INE (2002; 2009)	Enquiry to CP (National Railway Service)
Vehicle fleet: age structure	ACAP (2006)	ACAP (2006)	ACAP (2006)	ACAP (2006)	Due to absence of specific data, assumed to be equal to motorcycles	ACAP (2006)	N/A	INE (2009)	N/A
Average lifetime	Enquiry to VALORCAR	From VALORCAR e ACAP (2006), analogy with passenger cars.	Enquiry to 6 service providers.	From ACAP (2006), analogy with buses and coaches	Due to absence of specific data, assumed to be equal to motorcycles.	From ACAP (2006), analogy with passenger cars.	From literature and enquiry to 2 repair shops.	INE (2007)	Enquiry to CP
Vehicle mileage	Parlamento Europeu (2008)	Parlamento Europeu (2008)	Enquiry to 6 service providers.	From Parlamento Europeu (2008), analogy with buses and coaches	Pereira *et al.* (2009)	Pereira *et al.* (2009)	From Alonso (2009)	Transportation Research Board (2000)	Enquiry to CP
Load factor / Occupancy rate	From INFRAS/IWW (2004)	From INFRAS/IWW (2004)	From INFRAS/IWW (2004)	From INFRAS/IWW (2004)	Due to absence of specific data, assumed to be equal to motorcycles	From INFRAS/IWW (2004)	Litman (2009)	N/A	From enquiry to CP and CP (2006)
Investment costs	Bottom-up; from AutoFoco n.º 292	Bottom-up; from AutoFoco n.º 292	Bottom-up; enquiry to 8 service providers and manufacturers	Bottom-up; enquiry to 7 service providers and manufacturers	Bottom-up; from Motociclismo n.º 174	Bottom-up; from Motociclismo n.º 174	Bottom-up; from literature and enquiry to 4 establishments.	N/A	Top-Down; from enquiry to CP and CP (2007)
Inspection costs	Bottom-up; from applicable legislation: DL 55/99, Portaria 1468/2004	Bottom-up; from applicable legislation: DL 55/99, Portaria 1468/2004	Bottom-up; from applicable legislation: DL 55/99, Portaria 1468/2004	Bottom-up; from applicable legislation: DL 55/99, Portaria 1468/2004	N/A	N/A	N/A	N/A	N/A
Insurance costs	Bottom-up; from enquiry to 2 insurance companies.	Bottom-up; from enquiry to 2 insurance companies.	Bottom-up; from enquiry to 2 insurance companies.	Bottom-up; from enquiry to 2 insurance companies.	Bottom-up; from enquiry to 2 insurance companies.	Bottom-up; from enquiry to 2 insurance companies.	Bottom-up; FPCUB (2010)	N/A	N/A

[4] Full reference: Pereira, T. C., Seabra, T., Maciel, H., Torres, P. (2009), Portuguese National Inventory Report on Greenhouse Gases, 1990-2007. Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol, Agência Portuguesa do Ambiente. Amadora.

	Transport Mode								
Variable	Passenger Cars	Light Duty Vehicles.	Buses and Coaches	Heavy Duty Vehicles	Mopeds	Motorcycles	Bicycles	Pedestrians	Rail
Energy costs	Bottom-up; combining several sources from fuel consumption	Bottom-up; combining several sources from fuel consumption	Bottom-up; combining several sources from fuel consumption	Bottom-up; combining several sources from fuel consumption	Bottom-up; combining several sources from fuel consumption, inc. enquiry to 4 repair shops.	Bottom-up; combining several sources from fuel consumption, inc. enquiry to 5 repair shops.	N/A	N/A	Top-Down; from enquiry to CP
Maintenance costs	Santos, Santos and Cavaleiro (2008)	Due to absence of specific data, same figures as passenger cars' were used.	Bottom-up; Enquiry to 6 service providers and manufacturers.	Bottom-up; Enquiry to 6 service providers and manufacturers.	Bottom-up; survey to 4 authorized repair shops.	Bottom-up; enquiry to 5 authorized repair shops.	Bottom-up; from literature and enquiry to 2 establishments	N/A	Top-Down; from enquiry CP

Table 2. Vehicle fleet characteristics per transport mode in Portugal, 2005[5]

Transport mode	Number of vehicles	Average lifetime (years)	Average mileage throughout lifetime (km)	Average annual mileage (km)	Occupancy rate (passenger/vehicle) or Load factor (tons/vehicle)
Passenger cars	4.795.147	17,9	200.000	11.187	2,28
Light goods vehicles	788.018	15,1	250.000	16.544	0,75
Buses and coaches	12.558	16,8	1.102.778	65.642	17,1
Heavy goods vehicles	157.586	16,1	1.378.472	85.651	5,1
Mopeds	330.538	12,3	57.033	4.620	1,12
Motorcycles	157.040	12,3	46.145	3.738	1,12
Bicycles	105.696	7	11.038	1.577	1
Pedestrians	10.018.980	78,2	34.408	440	N/A
Passenger rail[6]	350	32,5	2.789.151	85.820	114
Freight rail	89	32,5	2.789.151	85.820	316

Table 3. Internal costs per transport mode in Portugal, 2005 (€/vehicle-km)

Transport mode	Investment costs	Inspection costs	Insurance costs	Energy costs	Maintenance costs	Total (internal costs)
Passenger cars	0,088	0,002	0,023	0,045	0,016	0,175
Light goods vehicles	0,061	0,002	0,016	0,039	0,016	0,133
Buses and coaches	0,164	0,001	0,018	0,227	0,145	0,566
Heavy goods vehicles	0,069	0,001	0,009	0,197	0,050	0,327
Mopeds	0,033	0,000	0,032	0,014	0,015	0,094
Motorcycles	0,149	0,000	0,066	0,024	0,037	0,276
Bicycles	0,019	0,000	(0,027)	0,000	0,013	0,032[7]
Pedestrians	0,000	0,000	0,000	0,000	0,000	0,000
Rail	1,775	0,000	0,000	0,871	1,365	4,011

In €/vehicle-km (Table 3), rail transport is undoubtedly the most costly of all, but this should be relativized given trains' carrying capacity, In motorized road transport, buses and coaches and heavy duty vehicles have the highest costs, namely the former, due to high fuel consumption and maintenance costs. Maintenance is significantly more expensive for buses and coaches, probably due to intense use and tighter safety and maintenance requirements given the type of service provided. Motorcycles are quite costly, more so than passenger cars; this occurs because the proportion of big-engined and more expensive motorcycles is quite high and vehicle mileage is quite low. Enquiries to repair shops have suggested that for many users, use is quite seasonal or restricted leisurely use on week-ends and holidays. Mopeds are, by far, the least costly of all

[5] Figures in this and following tables have been rounded a posteriori, hence the apparent mismatches that may appear on occasion.
[6] Calculation of number of vehicles (motor units) for rail transport were only possible by assuming equal mileages for every train, as data on number of vehicles was aggregate, not distinguishing between vehicles providing passenger and freight transport.
[7] As insurance is not compulsory for cyclists, this cost component was not included in the totals for this transport mode: insured cyclists were assumed to be marginal in the overall population.

motorized modes. Bicycles are the cheapest of all modes, besides pedestrians for whom no internal costs were calculated, as previously stated.

Figure 1 shows that investment costs are the most important component for all modes, besides heavy duty vehicles and buses and coaches, where energy costs prevail. Insurance costs are the second most expensive component for motorcycles and mopeds, and almost as relevant as investment ones. Energy costs rank second for passenger cars and light duty vehicles. Inspection costs, when applicable, are negligible.

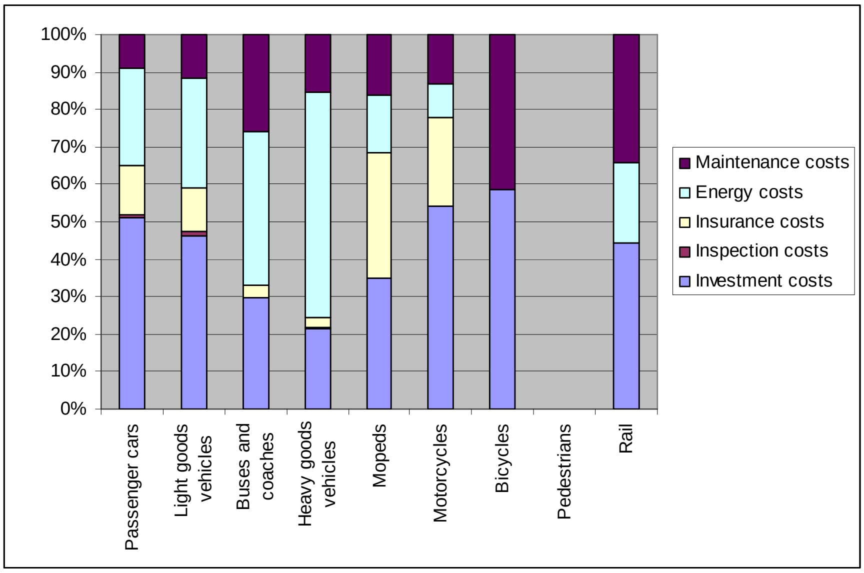

Figure 1. Internal cost structure per transport mode

Costs per passenger-km (Table 4) and ton-km (Table 5) show how important intensity of use (mileages and occupancy rates/load factors) is for the transport system's rationality. Accordingly, motorcycles and mopeds are the most expensive transport modes and passenger cars are only about 2,5 times more expensive than buses and bicycles, contradicting much of the common sense and widespread opinions. From a strictly financial standpoint, it does seem that the passenger car is not an overly irrational choice; even more so if one bears in mind that transit systems have high management and organization costs which have not been accounted for in this piece of research. For example, Carris' fleet's operation costs (excluding fuel and vehicle components' substitution) mounted to 1,272 €/vehicle-km and 0,069 €/passenger-km in 2008.

Table 4. Internal costs per transport mode in Portugal, 2005 (€/passenger-km)

Transport mode	Investment costs	Inspection costs	Insurance costs	Energy costs	Maintenance costs	Total (internal costs)
Passenger cars	0,039	0,001	0,010	0,020	0,007	0,076
Buses and coaches	0,010	0,00006	0,001	0,013	0,008	0,032
Mopeds	0,029	0,000	0,028	0,013	0,014	0,083
Motorcycles	0,132	0,000	0,059	0,021	0,033	0,244
Bicycles	0,019	0,000	(0,027)	0,000	0,013	0,032
Pedestrians	0,000	0,000	0,000	0,000	0,000	0,000
Passenger rail	0,016	0,000	0,000	0,008	0,012	0,035

Table 5. Internal costs per transport mode in Portugal, 2005 (€/ton-km)

Transport mode	Investment costs	Inspection costs	Insurance costs	Energy costs	Maintenance costs	Total (internal costs)
Light duty vehicles	0,081	0,002	0,021	0,052	0,021	0,176
Heavy duty vehicles	0,014	0,0002	0,002	0,038	0,009	0,063
Freight rail	0,006	0,000	0,000	0,003	0,004	0,013

3.2 External costs

Tables 6 to 8 present external costs of transport in Portugal, at 2009 prices, in €/vehicle-km, €/passenger-km and €/ton-km, respectively. Figure 2 portrays external cost structure per transport mode.

Table 6. Average external costs per transport mode in Portugal, 2000 (€/vehicle-km)

Transport mode	Accidents[8]	Noise	Air pollution	Climate change	Total (external costs)
Passenger cars	0,017	0,005	0,017	0,021	0,061
Light goods vehicles	0,017	0,010	0,041	0,061	0,129
Buses and coaches	0,012	0,017	0,199	0,147	0,374
Heavy goods vehicles	0,002	0,026	0,137	0,093	0,258
Mopeds	0,157	0,009	0,004	0,012	0,182
Motorcycles	0,524	0,009	0,004	0,012	0,549
Bicycles	0,558	0,000	0,000	0,000	0,558
Pedestrians	0,094	0,000	0,000	0,000	0,094
Passenger rail[9]	0,442	0,644	0,732	0,925	2,743
Freight rail	0,000	1,970	2,332	2,890	7,192

[8] Referring to 2005, except for rail transport, for whom casualties refer to the average between 2001 to 2008.

Table 7. Average external costs per transport mode in Portugal, 2000 (€/passenger-km)

Transport mode	Accidents	Noise	Air pollution	Climate change	Total (external costs)
Passenger cars	0,008	0,002	0,008	0,009	0,027
Buses and coaches	0,001	0,001	0,012	0,009	0,022
Mopeds	0,140	0,008	0,004	0,011	0,162
Motorcycles	0,468	0,008	0,004	0,011	0,491
Bicycles	0,558	0,000	0,000	0,000	0,558
Pedestrians	0,094	0,000	0,000	0,000	0,094
Passenger rail	0,004	0,007	0,008	0,010	0,028

Table 8. Average external costs per transport mode in Portugal, 2000 (€/ton-km)

Transport mode	Accidents	Noise	Air pollution	Climate change	Total (external costs)
Light goods vehicles	0,023	0,014	0,055	0,081	0,173
Heavy goods vehicles	0,000	0,005	0,027	0,018	0,051
Freight rail	0,000	0,008	0,010	0,012	0,030

In €/vehicle-km (Table 6), rail transport has the highest external costs, especially freight transport, due to its greater environmental impact. In road transport, bicycles and motorcycles come first, mostly because of accident costs. Heavy duty modes (goods vehicles and buses) come next, mopeds, light goods vehicles, pedestrians and, finally, passenger cars. Soft modes and two-wheelers are often thought to have lower external costs, but low vehicle mileage and high accident rates lead to results that suggest otherwise.

Analysing environmental costs (i.e. excluding accident costs) of road transport, heavy vehicles cause the highest costs, followed by light ones; motorized two-wheelers' are considerably lower. As previously stated, soft modes were assumed not to have any environmental costs.

In €/passenger-km (Table 7), the situation is different. Two-wheelers bear the highest external costs, bicycles coming first. Two-wheelers are followed by pedestrians, rail transport and passenger cars. Buses and coaches have the lowest costs. Environmental costs are somewhat similar for all motorized transport modes.

In freight transport (€/ton-km, see Table 8), external costs are lowest for rail and light goods vehicles are the most costly. The same applies to environmental costs.

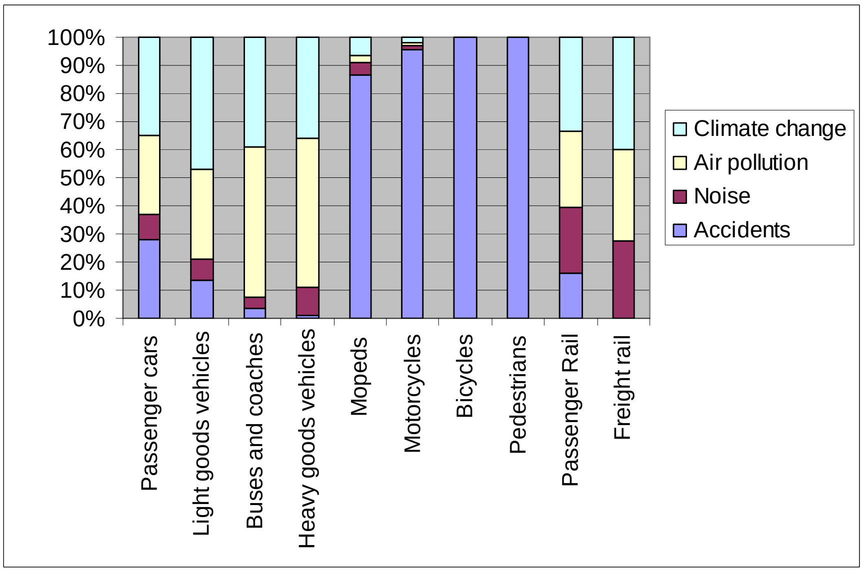

Figure 2. External cost structure per transport mode

The analysis of each transport mode's cost structure (Figure 2) highlights the prevalence of accident costs in soft modes and in motorized two-wheelers. Even in absolute terms, cost figures for this component are quite high, stressing the necessity of measures aiming at the reduction of accident rates and that take into account these transport modes' specificities, more liable to severe injury and fatality.

Conversely, environmental costs are more relevant in the remaining transport modes, particularly in heavy modes. Among these, costs stemming from fuel consumption (air pollution and climate change, consequent of polluting gases and particles emissions, including GHG) are most important. Considering vehicle fleets' characteristics, stimulating their renewal, adopting more efficient technology and less polluting fuel, may be one way to reduce their environmental impact.

Occupancy rates and load factors arise, once again, as a very relevant factor for introducing rationality and efficiency into the system, as results challenge many established ideas. Road accidents are most definitely a pressing issue to be dealt with when acting upon the transport system.

3.3 Integrated costs

Integrated costs are the sum of internal and external ones. Figures 3 to 5 present them in €/vehicle-km, €/passenger-km and €/ton-km, respectively.

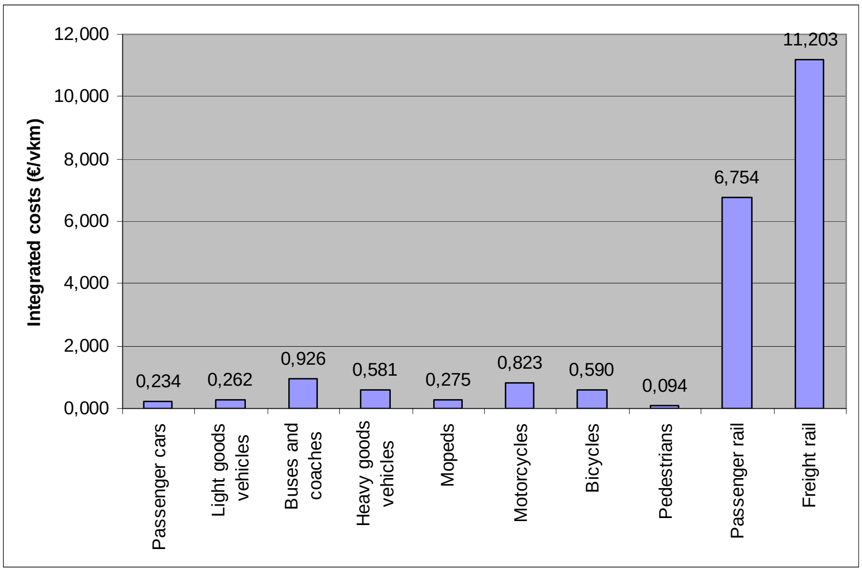

Figure 3. Integrated costs per transport mode (€/vehicle-km)

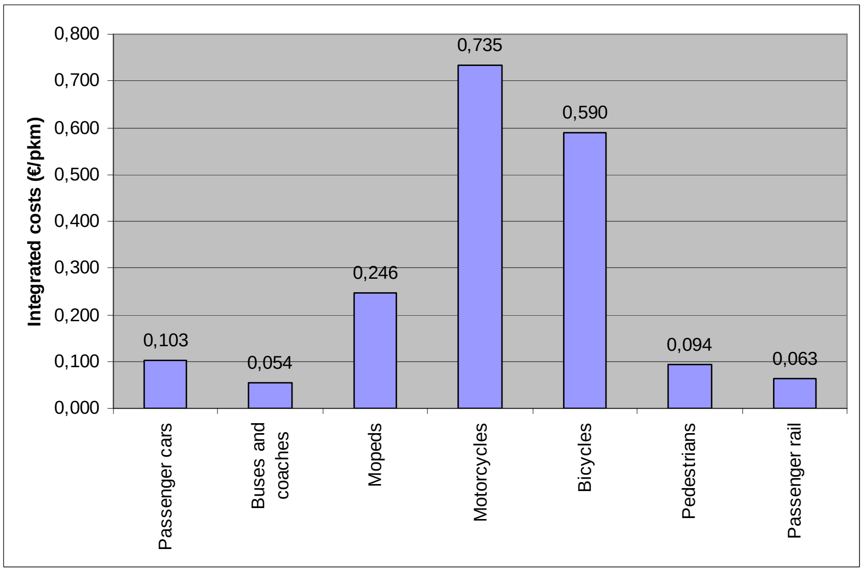

Figure 4. Integrated costs per transport mode (€/passenger-km)

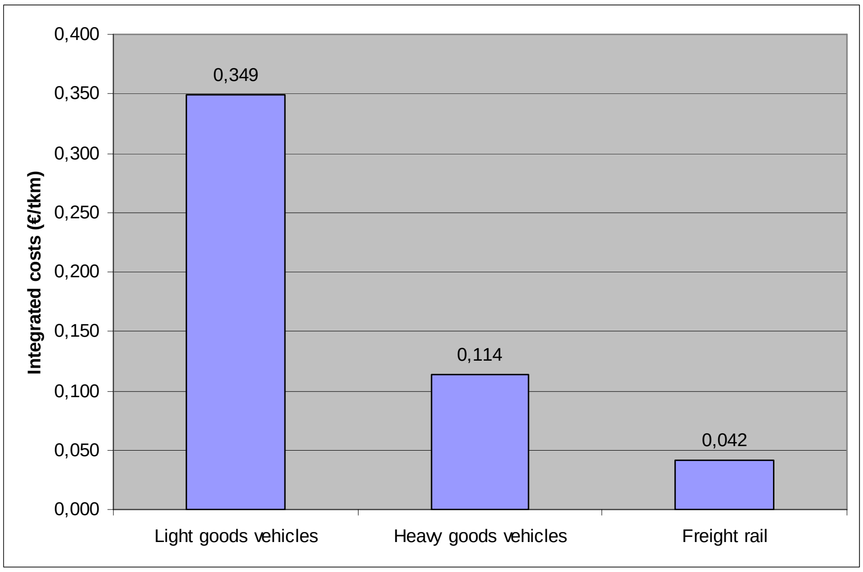

Figure 5. Integrated costs per transport mode (€/ton-km)

Final results challenge, once again, some of the preconceptions on the transport system. Mostly due to their low mileages and high accident costs (and, naturally, due to necessarily low occupancy rates), motorcycles and bicycles undoubtedly have the highest costs per passenger-km. Mopeds' integrated costs come third, but are quite lower than the previous two's. Yet, they almost double the following mode's costs, passenger cars, which, in turn, are only slightly higher than pedestrians', who only present accident costs. Collective transport modes have the least costs, but these are "only" half of passenger cars', which may lead to questioning, once again, whether massive use of private cars is as irrational as some claim.

In freight transport, heavy duty vehicles and freight rail are clearly less costly than light duty transport. Cost differentials between the three modes stress the need to plan and implement freight transport by articulating them.

Internal and external costs' relative weights (see Figure 6) vary between transport modes, between 74%/26% for passenger cars and 0%/100% for pedestrians. External costs are particularly relevant in soft modes and motorized two-wheelers, mostly due to high accident costs. Freight rail also presents external costs higher than internal ones, but due to its environmental impact.

As accident costs are often determinant in final results and given that a lot of the research on the external costs of transport derives from environmental concerns, we present the relative weights of internal and external costs without accident costs (Figure 6).

By excluding accident costs from calculations, external costs' relevance in integrated ones changes; internal costs become more relevant in practically every transport mode, ranging from about 60% (passenger rail and light duty vehicles) and 100% (bicycles). Freight rail remains the exception, as it has no external accident costs. External costs' absence of soft modes thus underlines their proclaimed environmental sanity.

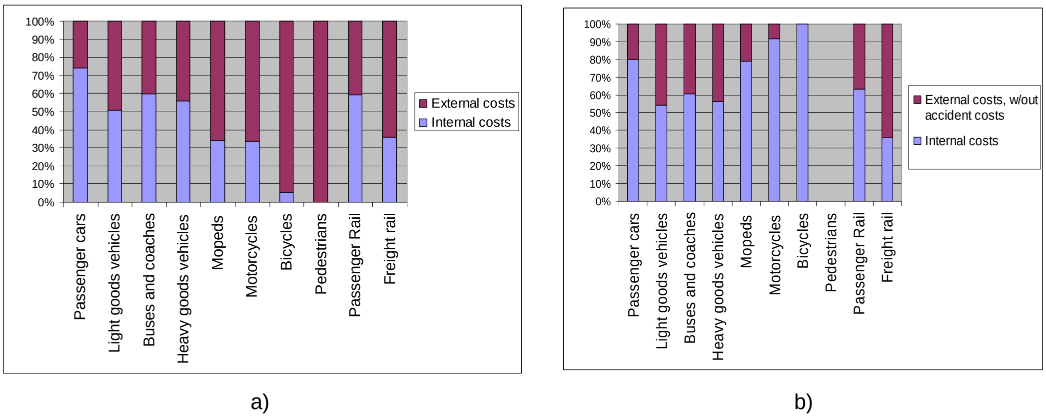

Figure 6. Share of internal and external costs of transport in Portugal (%): a) in average integrated costs b) excluding accident costs

4 Conclusions

Results put under discussion two widespread ideas about the transport system that apparently deserve more cautious treatment and further study: public transport's efficiency vis-à-vis the passenger car and bicycles' statute of a quasi-panacea for urban mobility.

Results showed that the cost differentials between buses and coaches and passenger cars are not as common sense has it. This is naturally contingent of the Portuguese reality that the data describe; for public transport's efficiency, increasing occupancy rates is fundamental, so that high costs per vehicle-km are offset. Yet, it remains unclear whether the increased costs that efforts to improve service levels that compete with the private car and therefore boost occupancy rates entail would imply would actually lead to a decrease in costs per passenger-km. Transport modelling along with cost-benefit analysis could shed some light on these matters.

However, public transport's efficiency may also be increased by decreasing its costs per vehicle-km. Results confirmed energy/fuel as one of the major issues in urban transport, including buses and coaches: not only do energy costs play a relevant role in direct costs, but external costs caused by emissions are still relevant. Considering buses and coaches' vehicle fleets' characteristics, their renewal for more recent, energy efficient vehicles and adoption of cleaner fuels could contribute to decreasing their costs per vehicle.

These results do not include organization, operation and administrative costs for public transport systems; these have to be taken into account when planning for mobility.

Perhaps more unexpected is bicycles ranking first in integrated costs per passenger-km. This is mostly due to extremely high accident costs which clearly indicate that road safety for cyclists has to be a priority if cycling is to be encouraged by policy makers. Yet, and perhaps more importantly, these results have to be questioned: it is possible that cycling is particularly unsafe in Portugal and, consequently, there is a greater incidence of accidents and casualties. It is, then, important to undertake a comparative analysis with countries, such as the Netherlands, where bicycle use is much more prevalent than in Portugal and where there are better conditions for doing so. Such

analysis will shed light on whether so high an accident cost is something contingent of the Portuguese situation or if it is somewhat intrinsic to bicycle use.

What these results show clearly is that different transport modes have different vocations and mobility planning should take advantage of said vocations in order to ensure the highest cost-effectiveness possible. But any strategy aiming at sustainable mobility must clearly understand and address people's behaviour and mobility patterns. Results from the survey to the case studies' residents will give greater insight into the specifics of their behaviour, allowing greater rigour and detail in analysis, scenario building and policy making.

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