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ICT solutions in transportation systems: estimating the benefits and environmental impacts in the Lisbon

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Abstract

Information and communication technologies (ICT) holds the potential to dramatically change the way people drive and their mobility patterns, thus potentially reducing GHG emissions, air pollutants and fatalities. In this work, we study the potential environmental and the economic impacts of implementing ICT measures in personal transportation, for three scenarios of ICT applications. In the first application, we seek to investigate the effects of limiting driving speed. Non-compliance with speed limits accounts for a large part of fatal car accidents in Portugal, and therefore understanding the impact of such applications is crucial in the context of a national transportation safety policy. In this application, stricter speed limits can be obtained either by on-board vehicle devices influencing the driver not to exceed certain speed limits or on the road network imposing lower speed limits. In the second application, the impacts of fostering an eco-driving behavior are studied. In that case, we study the impact of a massive adhesion by the public to eco-driving using ICT to present the drivers with the results of their behavioral changes. The third case study assesses the impacts of the implementation of a taxation system based on on-board vehicle devices that indicate where and when the vehicle is being driven and rewarding or penalizing the driver for it. For this study the Lisbon region was addressed. The results show that different ICT applications can have considerable impacts in terms of energy consumption reductions: Scenario 2 (with main variable being speed limitation) reached a 12% reduction in 2020 compared to the BAU, followed by Scenario 4 (with main variable being eco-driving) with a 5.5% reduction, and the taxation Scenario 6 presented a 1.8% reduction. In terms of CO_2 emissions, the avoided CO_2 emissions from implementing these scenarios varies from 19 to 276 kton in Scenarios 3 (with main variable being eco-driving) and 2 respectively. In terms the avoided cost from the fuel not consumed and CO_2 emissions not emitted, as well as the revenue from the taxation scheme, the scenarios results range from 9 to 134 M€ for Scenarios 3 and 2 respectively.

Keywords: Information and communication technologies; road transportation sector; speed limits; eco-driving; pay as you drive taxation

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1. Introduction

In many regions of the world, the transportation sector faces increasing challenges on how to decrease energy consumption, emissions and manage congestion. Researchers and modelers have been studying this issue under the lenses of alternative vehicle technologies choices, and estimating how different energy pathways would shape emissions and energy consumption. However, very little has been done so far to understand how changes in driving behavior could be used to reduce emissions, lower energy consumption, and enhance safety. Thus, focusing directly on the user/driver, educating him/her towards a more sustainable travelling/driving behavior, might provide opportunities for energy savings and avoided emissions. Information and communication technologies (ICT) can potentially be a powerful driver to promote change, namely by ICT applied to vehicles through on board user aid devices for educating the driver, improving efficiency, reducing costs and environmental impacts of urban mobility.

ICT deployed in the road network are the more traditional way of enforcing a change in behavior, by enforcing stricter speed limits. These stricter speed limits can be applied at all times by specific signalization, or through variable speed limits (VSL) depending on traffic, infrastructure and weather information. Studies on VSL state that these systems stabilize traffic flow by reducing several traffic characteristics, such as average speed, number of lane changes, speed variance or time headways and contributed to avoid congestion (Hines 2002). An example of application of VSL was the case of Barcelona, where the Autonomous Government of Catalonia implemented a VSL system, where pollution levels are monitored and used in the speed limit specification. In general, speed limits were reduced to 80 km/h in the main roads accessing the city (Gonçalves 2008).

As for ICT applied on the vehicle, several on-board user aid technologies are under development to educate the user towards better driving habits (Toledo 2008; Larsson 2009). However, the impact of such devices is largely unknown. Currently, in Portugal several pilot projects applied both for light-duty vehicles (Rolim 2010; IMTT 2011; ITDS SA 2011) or for bus fleets have proved the potential to educate the driver, reducing fuel consumption up to 20% over several months (Duarte 2010; MNAC - Electricidade Industrial 2010). The issue of how long the reduction in fuel consumption prevails is of large interest, since in other contexts, (e.g., smart meters) it has been found that the prevalence of the energy reducing behavior decays over time (Ferraro 2011). Additionally, numerous studies have started to address these issues by monitoring drivers behavior before and after they were given eco-driving sessions and presenting the driver with driver specific information regarding the way he is using the vehicle. Beusen monitored 10 drivers over a period of 10 months and in the four months after a general eco-driving training session the average fuel consumption was reduced by 5.8%, with most of the drivers showing immediate gains that were stable over time (20% were found to go back to their original driving habits) (Beusen 2009). Other option is to provide individual information on better gear and speed management under different driving conditions, and how these impact safety and fuel efficiency based on previously measured data for each driver (Rolim 2010). In the future this individual driver information may be provided to the driver on a regular basis using ICT platforms. However, all these studies usually target very small fleets and an estimation of the gains for a wide adoption in larger fleets has not been performed. ICT applications have also been used to influence the vehicle insurance value. In the Netherlands, a collaboration with five Dutch car insurance companies tested the effects of a pay as you drive insurance fee on driving speed (Bolderdijk 2011). This project targeted young drivers in order to reduce traffic accidents in the age bracket. The users could save money on their monthly insurance fee by keeping below the speed limit (monitored by GPS technology for one year). Comparing the results before and after the enrolment of users in this policy, this “pay as you drive” system is estimated to have reduced speeding by 14% (Bolderdijk 2011).

It is expected that, in the near future, developments of these on-board user aid devices may generate accurate information on how, when and where the user is driving its vehicle. This type of systems can be used in a “pay as you drive” framework, allowing the vehicle user to be rewarded or penalized according to his behavior, which is in accordance with the European Union’s (EU) guidelines. The EU (European Commission 2011) argues that this might be the next logical step for the transportation sector, as stated: "Transport taxes must be restructured in the direction of the 'user-pays' principle"; and "[…] reflect the maintenance cost of infrastructure, congestion, air and noise pollution." The design of policies instruments that would implement the user-pay principle requires an understanding on how drivers would react to price changes, and to different tariff structures.

Several transportation activities are found to be sensitive to price variations. This price sensitivity is measured using price elasticity, which may approximated by "the percentage change in consumption of a good caused by a one-percent change in its price or other characteristics" (Santos 2010; Litman 2011). Short-term elasticities usually refer to less than two years and long-term elasticities to 10 years. In the short-term it is more difficult to adjust to price differences so elasticities tend to be lower, while in the long-term other factors can be used to adjust to price differences so elasticities tend to be higher. One could foresee that a "user-pay principle" would entail a system where the price of driving would be coupled with the time of use (TOU). Such strategies are already currently under way in the electricity sector. However, in the case of electricity and other utilities, the consumer pays as they spend energy. In the case of transportation, the consumer fills up the tank, and thus the TOU mechanism cannot be coupled with fuel prices. Instead, it is likely to require a taxation or pricing scheme where a TOU system using on-board vehicle devices would penalize driving in main road networks depending on the time of day.

A first order analysis on how users would react to this scheme can be done by studying the reaction to an additional cost of driving resulting on a higher fuel price. If fuel prices increase, fuel consumption tends to decline by lowering the number of kilometers traveled, by changing to more fuel-efficient vehicles and by shifting to alternative transportations modes. Several studies addressing different geographic areas and different time periods have been performed and Table 1 presents a summary of some of those studies, showing that in average on the long term a 10% increase in fuel price cause a 4.5% reduction in fuel consumption.

Table 1. Summary of fuel price elasticity studies.

References	Scope	Method	Elasticities	
			Short term	Long term
Espey (1996)	US (1936-1986)	Review of 101 gasoline price elasticity studies	-0.26	-0.58
Agras (2001)	US (1982-1995)	Gasoline price elasticity	-0.25	-0.92
Glaister (2002)	US and Europe (2nd half 20th century)	Review of various fuel price and income elasticity studies	-0.30	-0.80
Lipow (2008)	US and Europe (2nd half 20th century)	Review of selected energy price elasticity studies	-0.17	-0.40
Goodwin (2004)	US and Europe (1929-1991)	Summarized various fuel price and income elasticity studies	-0.25	-0.60
Small (2005)	1966-2001	Gasoline price elasticities, comprehensive model	-0.07	-0.34
Hughes (2006)	US (1975-2006)	Gasoline price elasticities, comprehensive model	-0.03	-0.08
Hymel (2010)	US (1966-2004)	State-level cross-sectional time series of gasoline price elasticities, comprehensive model	-0.06	-0.29
Konanoff	US (2004-2011)	Short run fuel price elasticity	-0.29	-
Boilard (2010)	Canada (1970-2009)	Fuel price elasticities, comprehensive model	-0.09	-0.26
Li (2011)	US (1968-2008)	Fuel price elasticities with separate analysis of tax increases and price fluctuations, comprehensive model	-	-0.24
		Average	**-0.18**	**-0.45**

On the other hand, one can address this issue by studying user behavior concerning a toll payment when using specific roads, or even as congestion charging, where the toll value is higher during peak periods and lower during off-peak periods. These forms of road user pricing may be viewed as travel demand management measures, since they include policies that are designed to affect the amount, time, or place that people travel. The following three road pricing strategies can be defined:

Link or point charging, where the users pay for access to a roadway segment such as a toll road or bridge. These are normally used to provide funding for the construction and maintenance of transportation infrastructure and can have variable rate tolls (if toll levels increase as congestion increases).

Cordon toll, where drivers are charged when crossing the boundary of a predefined tolling area. Their revenue is usually directed to facilitate modal shift to public transportation, and is suitable for travel demand management in central business districts of major cities (to promote congestion and pollution mitigation).

Distance charging, where users pay according to distance driven on a specific road network. Driving distances can be monitored by satellite and/or on-board monitoring devices. These distance charges can be applied either at a flat rate or it can be influenced by vehicle type, congestion level, and environmental conditions. There are no implemented cases of distance charging for passenger vehicles. However, the Netherlands plan to implement a national system that will use satellite-based tracking to compute charges based on vehicle type, location and time. As a result, distance charges will replace the current car sales tax, road tax, and local taxes, although fuel taxes will remain.

Table 2 presents the traffic volumes to tolls elasticities for different geographic areas in different time periods showing that on average on the long term a 10% increase in road charging causes a 4.5% reduction in traffic volumes. From these studies, the Puget Sound Traffic Choices Study (PSRC 2005) is worth being highlighted, since it assessed the response of 275 volunteer drivers to road pricing in the US. Each driver's vehicle was equipped with a device (similar to taxi meters) tracking where and when they drove and subtracting tolls from a debit account assigned to each of them. These tolls were variable according to time of day and location.

Table 2. Summary of traffic volumes to road pricing elasticities.

Type	Reference	Scope	Elasticities	
			short term	long term
Toll road studies	Weusfield and Regan (1981)	16 toll facilities in the US (1970s)	-0.03	-0.31
	Goodwin (1988)	Literature review of previous studies (1980-88)	-	-0.45
	Harvey (1994)	Golden Gate Bridge, SF Bay Bridge and Everett Turnpike, New Hampshire (1979-84)	-	-0.15
	Wilbur Smith and Associates (1995)	Numerous US facilities	-0.10	0.35
	Hirschman et al. (1995)	Six bridges and two tunnels in NY city area (1979-90)	-0.09	-0.50
	UTM (2000)	New Jersey Turnpikes (1999)	-	-0.20
	Burris et al. (2001)	Lee County Florida (1999)	-0.03	-0.36
	Matas (2002)	Panel data of 72 roads in Spain	-0.21	-0.83
	Odeck (2008)	19 Norwegian tolled roads	-0.45	-0.82
	PSRC (2005)	275 US volunteer drivers, tolls variable according to time of day and location	-0.12	-0.16
	Holguín-Veras (2005)	Six interstate bridges and tunnels to link New Jersey with New York City, with peak hour toll rates on weekdays from 6-9 AM and 4-7 PM and on weekends and holidays from 12 noon – 8 PM	-0.31	-1.97
Cordon pricing studies	Olszewski (2007)	Singapore (1975-2006), variable charge price 7:30 am to 7 pm	-0.21	-0.31
	Curacao (2009)	London (2003), fixed price, 7 am to 6:30 pm, Monday to Friday	-	-0.16
	Eliasson et al. (2009)	Stockholm (2008), variable price, 6:30 am to 6:30 pm, Monday to Friday	-	-0.22
	Curacao (2009)	Milan (2008), fixed price, 7 am to 7 pm	-	-0.12

	Curacao (2009)	Bologna (2005), fixed price, 7 am to 8 pm	-	-0.23
	Curacao (2009)	Rome (2001), fixed price, time varies by zone	-	-0.18
Distance pricing	Ubbels (2006)	Netherlands (2005), survey to 50000 respondents on their response to different road pricing measures	-0.60	-1.50
	Arentze (2004)	Internet state adaptation survey to 477 Dutch respondents	-0.35	-0.39
		Average	**-0.23**	**-0.45**

Regarding the price per kilometer imposed to users, Harvey et al (Harvey 1998) found that 19 US cents per mile driven in the South Coast Los Angeles region in congested roads leads to reductions of 3.3% in total vehicle trips and reducing traffic by 32%. Milne (May 2000) estimated that in order to achieve a 10% reduction in vehicle trips, a 20 UK pence per kilometer would be effective. Mekky (Mekky 1999) found that applying a 10 US cents per vehicle kilometer penalty would lead to considerable reductions in traffic volumes and trip lengths.

Both fuel price and road pricing elasticities are in fact good proxies for possible changes in behavior. However, there are limitations and differences between these two methods, namely different frequency of use (if the user drives every day, road pricing will be more frequent and incremental than refueling his fuel tank) and magnitude of the payments (since the payment for fuel is usually more significant than the road pricing).

In this study, we expand on previous research to understand how on board ICT with different types of designs will impact energy consumption, CO_2 emissions and cost benefits. We use three case-studies with different ICT solutions. These applications were considered in the Lisbon region and include:

(i) Stricter speed limits, obtained either by on-board vehicle devices influencing the driver not to exceed certain speed limits or even on the road network imposing lower speed limits, trying to replicate the Barcelona case study;

(ii) Fostering an eco-driving behavior by a massive adhesion by the public to eco-driving using ICT trying to understand the potential impacts of the small scale tests previously presented ; and

(iii) The implementation of a taxation system based on on-board vehicle devices that indicate where and when the vehicle is being driven and penalizing the driver for it, based on the several case studies presented earlier, of which the Dutch case-study may be the most innovative solution.

2. Methodology

In this study three areas of ICT deployment were assessed: one dealing with imposing stricter speed limits; another concerning a widespread adoption of eco-driving; and another considering that a taxation system would be imposed penalizing driver that drove on main traffic road at rush hours.

In the first two scenarios (Scenarios 1 and 2), imposing stricter speed limits can be achieved either by on-board vehicle devices influencing the driver not to exceed certain speed limits or even on the road network imposing lower speed limits, possibly reaching approximately 1.4 million vehicles in the Lisbon region, which corresponds to approximately 25% of the vehicles in Portugal (Baptista 2010). Real data specific to address this issue was not available for Lisbon, so data from real world driving was collected in order to simulate the possible effect of this speed restriction. In a study by Pereira (Pereira 2011) 49 drivers (69% male, 31% female drivers with an average age of 39 years old) were monitored using on-board data logger during a Monday to Monday cycle in 2010 in the Lisbon metropolitan area in order to capture the typical work and personal driving routines. Information on the vehicle dynamics and engine management were collected. Eighty percent of the drivers had diesel vehicles and the remaining ones gasoline vehicles, which is in accordance with the increasing dieselization of the Portuguese fleet achieving up to 73% of new vehicle sales in 2009 (ACAP 2010). This monitoring period corresponds to over 26000 km in the Lisbon metropolitan area, which allowed collecting their speed profiles characterization, considered representative of the Lisbon's typical driving patterns. The average speed observed was of 49.6 km/h and the distribution between urban and extra-urban driving corresponded to 36% urban and 64% extra-urban driving. These results agree with the official data for Lisbon (CML 2005) stating that 72% of the traffic occurs in the principal network roads and 28% in secondary and local network roads.

As previously mentioned, the sample's driving cycles were collected. Using this data, for all the driving cycles collected for the 49 drivers a speed limitation was imposed, considering that the vehicles would not be allowed to reach more than 80 km/h and, consequently, the author of the study (Pereira 2011) limited the driving cycles to that maximum value of 80 km/h. The effect on the vehicle usage (tank-to-wheel, TTW) energy consumption of this restriction was computed and is presented in Table 3.

Table 3. Impact on TTW energy consumption of imposing an 80 km/h speed limit.

	TTW Energy consumption (MJ/km)		
	Average of 49 drivers sample	Minimum value from the 49 drivers sample	Maximum from the 49 drivers sample
Monitored value	**2.82**	2.12	4.37
Estimate after 80 km/h limit	**2.31**	1.49	3.70

Based on these results two scenarios were defined for the 2011-2020 period: one considering a maximum introduction of 15% in 2020 (**Scenario 1**) resulting of a mild introduction of on-board vehicle devices influencing the driver not to reach more than 80 km/h; and another considering a maximum introduction potential of ≈70% in 2020 (**Scenario 2**), as a result of combining the on-board aid devices and full coverage of the Lisbon's principal network roads with this speed limit. These scenarios consider a linear growth rate from 2011 to 2020 associated to these options.

In Scenarios 3 and 4, the potential impacts of a massive adhesion by the public to eco-driving through information provided by ICT devices (by presenting the drivers with advisory measures obtained from monitoring them). In a study by Rolim (C. Rolim 2012) 9 drivers (all diesel vehicles) in the Lisbon metropolitan area were monitored for ≈52000 km before and ≈40000 km after an eco-driving training session. From the first monitoring stage, individual information was obtained and that data as well as advisory measures regarding a more efficient vehicle use provided to each driver on the training session. The impacts were then monitored on the second monitoring stage. Several indicators were assessed, namely average speed reduction from 53 to 50 km/h and percentage of time driven over 120 km/h reducing from 16 to 10% before and after the training respectively. In terms of energy consumption of the vehicle, the average results before and after the training are presented in Table 4.

Table 4. Impact on TTW energy consumption of an eco-driving training session.

	TTW Energy consumption (MJ/km)		
	Average	Min	Max
Before eco-driving training	**2.32**	2.12	2.79
After eco-driving training	**2.19**	2.05	2.44

According to these results, two scenarios were defined for the 2011-2020 period considering a linear adhesion to eco-driving. **Scenario 3** considers a maximum potential of 15% in 2020, while **Scenario 4** considers a massive adhesion to eco-driving reaching a 100% potential in 2020.

Scenarios 5 and 6 present the possibility of penalizing drivers that use principal road networks in rush hours similarly to the PSRC study (PSRC 2005), by imposing a taxation system based on the pay as you drive concept taking advantage of ICT solutions already developed. As previously stated, in the Lisbon metropolitan area 72% of the traffic occurs in the principal network roads and approximately 20% of traffic occurs in the rush hours period (8 to 9 a.m. and 6 to 7 p.m.) (CML 2005). Two scenarios are assessed: one considering a penalty of 0.01 €/km (**Scenario 5**) and another considering a penalty 0.05 €/km (**Scenario 6**) both applied to vehicles in the principal network roads from 8 to 9 a.m. and 6 to 7 p.m.. For assessing the impacts of these scenarios, since the methodology applied combines the two elasticities theories presented earlier, the average long term elasticity between the fuel price and road pricing elasticities will be used. Both these scenarios would have a maximum application of 15% in 2020, corresponding to the traffic in the Lisbon metropolitan area occurring in main roads at rush hours.

To sum up, Table 5 presents a summary of the scenarios defined earlier.

Table 5. Summary of the studied scenarios.

Scenario	Main Driver	Description
1	Speed limitation	15% potential of maximum 80 km/h speed
2	Speed limitation	70% potential of maximum 80 km/h speed
3	Eco-driving	15% adhesion to eco-driving
4	Eco-driving	100% adhesion to eco-driving
5	Pay as you drive	0.01 €/km taxation system applied to ≈15% of traffic
6	Pay as you drive	0.05 €/km taxation system applied to ≈15% of traffic

To quantify the expected impact in the Lisbon metropolitan area, the above mentioned reductions for each scenario were applied linearly over time to the expected energy consumption from 2011 to 2020, which was based on data by Baptista et al. (Baptista 2011), where a methodology to model the fleet evolution over time, the vehicle stock and the fleet kilometers travelled was developed. Combining them with the vehicles' fuel consumptions (according to the technology/fuel configuration) and emissions, the total fleet energy consumption and emissions are estimated for the in-use fleet over time.

3. Results

The six scenarios were assessed in order to estimate their potential to reduce energy consumption and CO_2 emissions accountable to the light-duty fleet (LDV) in the Lisbon metropolitan area. The expected energy consumption from 2011 to 2020 was based on Baptista et al. (Baptista 2011), corresponding to the Policy scenario that incorporates the current policies for Portugal regarding vehicle technology and introduction of alternative energy pathways (here named BAU). The expected evolution in terms of energy consumption in the 2011-2020 period for the six tested scenarios is presented in Figure 1.

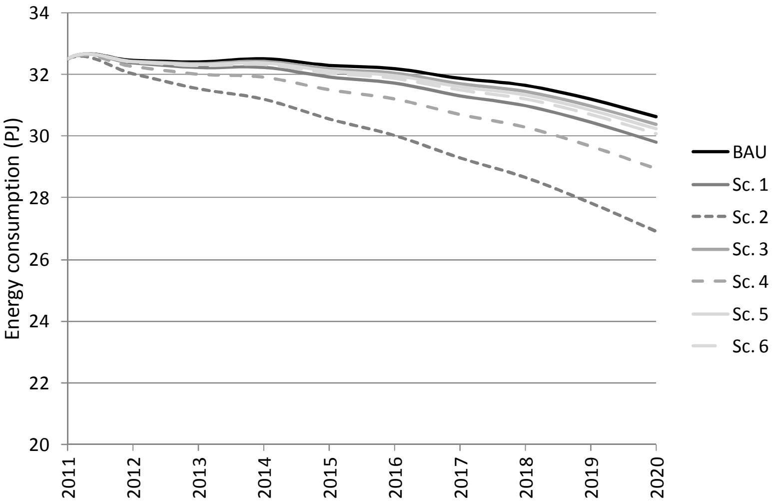

Figure 1. Energy consumption profile (in PJ) for the LDV fleet of Lisbon for the six studied scenarios.

In this period, the Scenarios leading to higher reduction correspond to Scenario 2 (with main variable being speed limitation) reaching a 12% reduction in 2020 compared to the BAU, followed by Scenario 4 (with main variable being eco-driving) achieving a 5.5% reduction, while the taxation Scenario 6 presents a 1.8% reduction.

If compared to the total Portuguese energy consumption these maximum reduction in Lisbon would correspond to a 1.4% reduction at a country scale. The results both for energy consumption and for CO_2 emissions in 2011, 2015 and 2020 are presented in Table 6.

Table 6. Summary of the energy consumption and CO_2 emissions results for the studied scenarios.

Scenarios	LDV fleet					
	Energy Consumption (PJ)			CO_2 emissions (kton)		
	2011	2015	2020	2011	2015	2020
BAU (Baptista 2011)	32.51	32.30	30.63	2403	2391	2270
Sc. 1		31.92	29.81		2363	2209
Sc. 2		30.56	26.91		2262	1994
Sc. 3		32.19	30.38		2382	2251
Sc. 4		31.52	28.96		2333	2145
Sc. 5		32.12	30.24		2377	2240
Sc. 6		32.04	30.08		2372	2229

However, the best way of comparing the influence of the different ICT applications is by comparing Scenarios 1, 3 and 5 or 6, since they present the same potential introduction/applicability in the LDV fleet (of approximately 15%). Scenario 1 reveals a ≈3% reduction in 2020 compared to the BAU, Scenarios 5/6 present a ≈2% reduction, while Scenario 3 presents only a ≈1% reduction. Another way of analyzing these results is by quantifying the avoided gasoline and diesel energy consumption in each year as is presented in Figure 2, reaching 6 to 87 kton of gasoline and diesel in 2020.

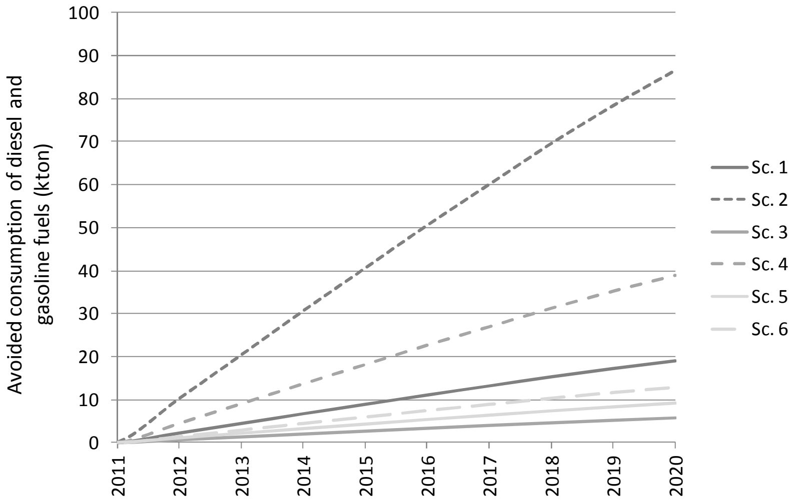

Figure 2. Avoided gasoline and diesel energy consumption in each year in the 2011-2020 period in the Lisbon metropolitan area.

Besides this avoided energy consumption, CO_2 emissions avoided from implementing these scenarios can also be quantified, varying from 19 to 276 kton in Scenarios 3 and 2 respectively.

If the cost associated both for fuels and for CO_2 emissions is considered, including their expected market value evolution of gasoline and diesel (IEA 2010) and the emissions trading value for CO_2 (based on an average in 2011 value of 10€/ton (CO2 Prices.eu 2012)), then an associated avoided cost can be estimated to these scenarios, as is presented in Table 7. When analyzing Scenarios 5 and 6, an additional value can be accounted, the taxation revenue from the application of the pay as you drive system. The aggregate results from combining these 3 components are presented in Table 7 and Figure 3. The investments cost (for instance, in infrastructure, equipment, legal deployment, etc.) must also be accounted and will be addressed in further studies. As expected, scenarios 1 to 4 present proportional cost results as their energy consumption and CO_2 reductions (reaching a

124 M€ value in 2020 for Scenario 2), but Scenarios 5 and 6 increase the energy consumption values by 2 and 5 times respectively, due to additional revenue from the road pricing scheme.

Table 7. Avoided cost from the avoided fuel consumption and CO_2 emissions, as well as the pay as you drive revenue for the studied scenarios.

Scenario	Avoided cost and revenue (M €) from:					
	Fuel and CO_2		Taxation		Total	
	2015	2020	2015	2020	2015	2020
Sc. 1	14.1	29.6	-	-	14.1	**29.6**
Sc. 2	63.9	134.0	-	-	63.9	**134.0**
Sc. 3	4.3	9.1	-	-	4.3	**9.1**
Sc. 4	28.8	60.4	-	-	28.8	**60.4**
Sc. 5	6.8	14.3	6.1	13.1	12.9	**27.3**
Sc. 6	9.5	20.0	33.7	71.9	43.2	**91.9**

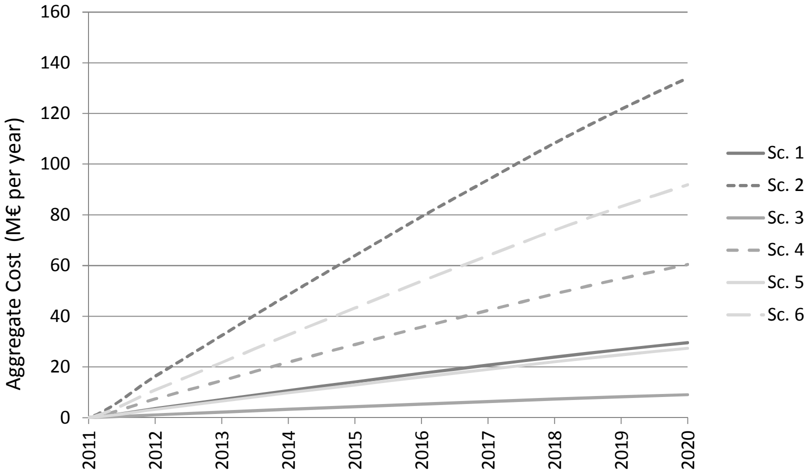

Figure 3. Aggregate avoided cost from the avoided fuel consumption and CO_2 emissions and revenue from the pay as you drive scheme for the studied scenarios.

4. Conclusions

This paper addressed the energy consumption, CO_2 emissions impacts and possible revenue of three possible applications of ICT solutions, considered for the LDV fleet in the Lisbon metropolitan area. These applications included stricter speed limits, fostering an eco-driving behavior, and penalizing the driver according to when and where he drives his vehicle. The results show that, for a similar introduction potential of these three measures (≈15% of the fleet), the influence on TTW energy consumption of the different ICT applications is: Scenario 1 a ≈3% reduction in 2020 compared to the BAU; Scenarios 5/6 present a ≈2% reduction; and Scenario 3 presents a ≈1% reduction. In terms of CO_2 emissions, the avoided CO_2 emissions from implementing these scenarios varies from 19 to 276 kton in Scenarios 3 and 2 respectively. In terms the avoided cost from the fuel not consumed and CO_2 emissions not emitted, as well as the revenue from the taxation scheme, the scenarios results range from 9 to 134 M€, for scenarios 3 and 2. These results corroborate the idea that ICT solutions in its different application possibilities can play a decisive role in reducing energy consumption and emissions on the road transportation sector. However, some of the behavioral issues associated with ICT solutions remain open (namely the users' real world response to the deployment of these solutions at larger scales and willingness to pay for them), so further complementary studies will be performed in the near future.

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