Environmental Impact of Population Mobility from College of Health Technology of Coimbra

Mário Prata Pina[1], Nelson Leite Sá[2], João Paulo Figueiredo[3], Ana Ferreira[4]

Abstract – The abusive use of private transport has been a contribution to climate change and the degradation of environmental quality. This study aims to analyze how professors, students and non-teaching staff of the College of Health Technology of Coimbra make their journeys home-school-home to investigate the differences in behavior between these groups and calculate the value emissions of some pollutants (CO, CO_2, NO_x, VOC, PM).
Study was carried out between October 2009 and October 2010, and the period of data collection occurred during May and June 2010. As mentioned, the target population was composed of teachers, non-teaching staff and students of the College of Health Technology of Coimbra. The sample was 33 teachers, 27 non-teaching staff and 169 students. To gather information, a questionnaire about mobility was delivered. This study demonstrated that it is necessary more investment in informing the people about the advantages of public transport and improving the quality of alternatives to the car so that in future the population enjoy more public transport and feel the same convenience, safety and speed of individual transport.

Keywords – Sustainable Mobility, Public Transport, Single Transport.

Introduction

It is becoming increasingly universal consensus that there are causes of climate change that are of human origin and are directly related to the emission of greenhouse gases into the atmosphere due to combustion of fossil fuels. This global climate change threatens unprecedented about humanity and about nature. Inevitable in this century its consequences will have significant impacts on social, economic and environmental issues [1].
The various impacts described above led to the theme Mobility win a space for reflection and an increasing importance over time. Concepts such as "Sustainable Mobility", "hybrid cars", "hydrogen vehicles," "electric vehicle" and "bike paths", among others, have entered the everyday vocabulary in a natural and gradual form. [2]

Mobility is a way of leisure but also an imperative of the more developed societies, being natural that global policies have this issue into account during any decision making. The products and services tend to move away from the places of consumption, people have a constant need to travel greater distances and in less time. Thus, the theme mobility has a several limitations associated to the environmental, social and economical developments, which had a significant boost with the signing of the Kyoto Protocol. Quoting Sara Abade, "Mobility cannot be seen as a means or an end to any subject, but rather as a starting point." [2]
Thus, a good transport system is a determinant factor on the urban economy competitiveness and in the quality of life of citizens. The trans-European transport networks and, in general, the efficient services on transport are crucial to the urban development and policies. The concept of sustainable mobility became the main goal on the common transport policy, which intends to reconcile the mobility demand by individual and economical activities with the recognition of the

[1] Environmental Health Professional, mariopina88@hotmail.com
[2] Department of Environmental Health from College of Health Technology of Coimbra, nelsonsa@estescoimbra.pt
[3] Department of Complementary Sciences from College of Health Technology of Coimbra, jpfigueiredo@estescoimbra.pt
[4] Department of Environmental Health from College of Health Technology of Coimbra, anaferreira@estescoimbra.pt

resources limits and the impacts of these transport operations on the environment. [3]

It is also important to consider that according to MacKay, David JC about 1/3 of the existing energy is consumed by the transport sector. This raises the question whether it is possible with current technology to reduce this share of consumption?

To understand how the energy is consumed in a car, you need to understand where this is directed. Three key concepts will be explained:

1. In short distance trips with many stops and starts, the energy is mainly spent on accelerating the vehicle and its components. The main strategies for reducing energy consumption in movement with these characteristics are, for example, to use vehicles with lightweight, to seek to drive as more as possible between each immobilization of the vehicle or using a car with start-stop system, which allows the recapture of energy when the vehicle stops. [4]

2. In long-distance travel at constant speed, train or automobile, most energy is consumed due to the movement of air around the vehicle. The main strategies to reduce this energy consumption are to reduce the speed and use long and thin vehicles. [4]

3. In all forms of travel, there is a "chain of energy conversion" that transforms any type of fuel into energy and then uses a portion of this to move the vehicle. Inevitably, this "energy chain" has inefficiencies. In a standard car, powered by fossil fuels, only 25% of energy generated is used to drive the car, so it is obviously important that this energy conversion should be more efficient. [4]

For people who do not give up the car, then it is important to have the notion that their energy consumption can be reduced.

The huge range of choice that consumers have available, shows that it takes extra incentives and legislation that will lead consumers to opt for cars more energy efficient. There are several ways to help a consumer to opt for efficient cars: increase the price of fossil fuels, taxing the tax on new vehicles in accordance with the level of vehicle efficiency (rate existing in Portugal), assign parking privileges for efficient vehicles, among other measures. However, all these measures would be unpopular and would lead to loss votes by those who implement. So perhaps the best legislative technique was to apply energy efficiency limits of rather than allowing consumer choice. Or simply to prohibit from a certain date, the sale of any vehicle whose energy consumption was above 80 kWh per 100 km, and then, after some time, reducing it to 60 kWh per 100 km, and later, 40 kWh per 100 km, until reaching the limits of environmentally friendly. [4]

With practice, drivers can also modify their behaviour so that it becomes more economical. They can be more efficient using the accelerator without abrupt changes, use less brake and move always in the greatest change possible for the transit vehicle at high speeds, can contribute for a 20% reduction in fuel consumption. Another way to reduce fuel consumption is to reduce road congestion. Stops and starts, accelerations and constants decelerations make driving inefficient. If there are traffic jams, it is because there are more vehicles than it should be on the roads. Thus, a simple way to reduce congestion is to bring together people who have the same destiny in the same vehicle (carpooling). Other alternatives to consider are the creation of other valid options of transport, as bike lanes and public transportation, or collecting tolls in areas with easy congestion [4].

For all that has been said before, it is easy to see that mobility is assumed as a sine qua non of personal relationships, economic or leisure in societies. In this sense, there is a strong need to reflect on the whole paradigm of mobility and make it more efficient and sustainable [5].

Materials and Methods

This study was conducted between October 2009 and October 2010, and the period of data collection occurred during May and June 2010. It is characterized by a level I study, type descriptive and exploratory and Transversal in nature.

The target population consisted in professors, non-professors staff and students of College of Health Technology of Coimbra (ESTeSC). The sample was 33 professors, 27 non-professors staff and 169 students. The sample size calculation was used for finite populations (<100,000 cases) using the formula n = σ2. (Pq) .N/e2. (N-1) + σ2. (Pq), and was considered a confidence level of 95% and an error (α) of 10%. The design of the sampling design was established for the type of Non Probabilistic sample and as technique used it was accidental/convenience.

To gather information on the subject under study, a survey which is divided into 3 main parts: Part 1 was the characterization socio-biographic of individuals, part 2 consists in the characterization of daily life of the individuals regarding the mobility and part 3 concerned on individual's characterization of the car, if this was their means of transport used for journeys from home – college - home.

After having examined all surveys, responses were divided according to their engine size and category.[6] All of these vehicles were considered to have an occupancy rate of one person per vehicle.

Table 1 – Number of cars, distributed by fuel, engine size and category - type.

Fuel	Displacement	Type of Category	Nr. of Vehicles
Gasoline	<1,4	ECE 15/03	1
		EURO I	3
		EURO II	9
		EURO III	12
		EURO IV	2
	1,4-2,0	EURO I	3
		EURO II	3
		EURO III	3
		EURO IV	2
	>2,0	ECE 15/04	1
		EURO II	1
Diesel	<2,0	CONVENTIONAL	1
		EURO I	2
		EURO II	8
		EURO III	16
		EURO IV	11
		EURO V	1
	>2,0	EURO I	1
		EURO II	3
		EURO III	2

After collecting the information through the survey, data processing, as regards the emission of pollutants (CO, CO_2, NO_x, VOCs, PM) and fuel consumption of cars and buses, fulfilled them up using the software COPERT IV v6 .1 [7] and Excel (Microsoft).

Using COPERT IV, it was introduced some data which are detailed in the following assumptions:

1) Temperature: The average monthly temperatures were determined as the arithmetic mean of the average temperatures of each month in the city of Coimbra. [8]
2) RVP (Reid Vapor Pressure): The vapour pressure of gasoline each month is the arithmetic mean of maximum and minimum values listed in Annex III of Decreto-Lei (Act) 89/2008 [9].

3) Sulphur: It was considered a fuel sulphur content of 0.005%, both for gasoline vehicles, and both for diesel vehicles, according to the informative report of Portugal 1990-2007 of Portuguese Environmental Agency. [10]
4) Lead content: It was considered a lead content in fuel of 4.93 g/ton for petrol cars and 20.00 g/ton for diesel vehicles, according to the informative report of Portugal 1990-2007 of Portuguese Environment Agency [10].
5) Driving Share: We calculated the percentages of the route under the Urban and Rural Highway for each shift, using the ViaMichelin maps. The calculation was made from the street as that person's home to the street where is located the ESTeSC. In the case of the calculation was the same bus, but it was considered a road from the nearest starting point, instead of street person's home. Because they are urban bus circuit, considered the scheme and Rural Highway for this mode of transport 0% [11].
6) Speed: The average speeds for cars were considered 124 km/h in the regime Motorway, 61 km/h in rural scheme, 24.9 km/h in urban regime. For buses, the average speed considered for the Urban regime was 14.8 km/h. [10]
7) PM: PM values presented are the sum of $PM_{2,5}$, PM_{10} and PM exhaustion.

With COPERT IV we studied cold and hot emissions.

The densities considered petrol and diesel were, respectively, from 0.73 kg/l, [12] and 0.84 kg/l [13]

The prices of these fuels were, respectively, 1.358€ and 1.158€ [14].

The calculation of CO_2 emissions for a train course of those reporting the route between Lousã-Coimbra, it was considered that this connection has the distance of 28 km [15] and that the route is made by train engine type UTE 2240, existing model in greater quantity in the fleet of CP to conduct regional routes. This engine type stock has a consumption of 1.6 kWh/km [16] and according to data of REN, the average load factor of CO_2 emissions in electricity production in Portugal is about 0.300 kg/kWh. [13] Considering also that the maximum capacity of UTE 2240 is 257 seats[17] and that the average occupancy rate of this route is 19.8% [18].

The statistical data was performed using the SPSS software version 17.0, for Windows version. Through this software analyzed the sample using simple descriptive statistics (frequencies and percentages), measures of location (mean and median) and dispersion (standard deviation).

Regarding the distribution, the significance (p) must exceed 0.05 for it to be considered normal. In the verification of the research hypotheses were used ANOVA to a fixed factor, t-test for Independent Samples; Chi-Square of Independence.

The interpretation of statistical tests were based on the level of significance $\alpha = 0.05$ with a confidence interval of 95%.

Results

As for the characterization of the sample, it is noted most of the 229 respondents were female (160) and the mean age was 26.39 ± 10.00. The males had an average age lower than females (25.61 ± 8.75). Regarding the activity of respondents, 73.8% were students, 14.4% and 11.8% were professors and non-professors staff. On how the movement is done from home to College, it was concluded that 88 individuals use cars, 87 make this journey by foot, 43 by bus, 7 by ride and 4 in a Combined System (bus + train).When individuals who use the automobile as a means of transport were asked whether they practice carpooling (sharing the car with people who have the same fate), 75% said no and only share their vehicle, 85.1% were willing to share if the opportunity arose, and only 14.9% said they did not want to share their vehicle, and the reasons outlined more fear and lack of convenience. It was further observed that the question of car users was 0 (not available) to 5 (very affordable) would be available to change their mode of transport for a "friendly" environment use, the results were:

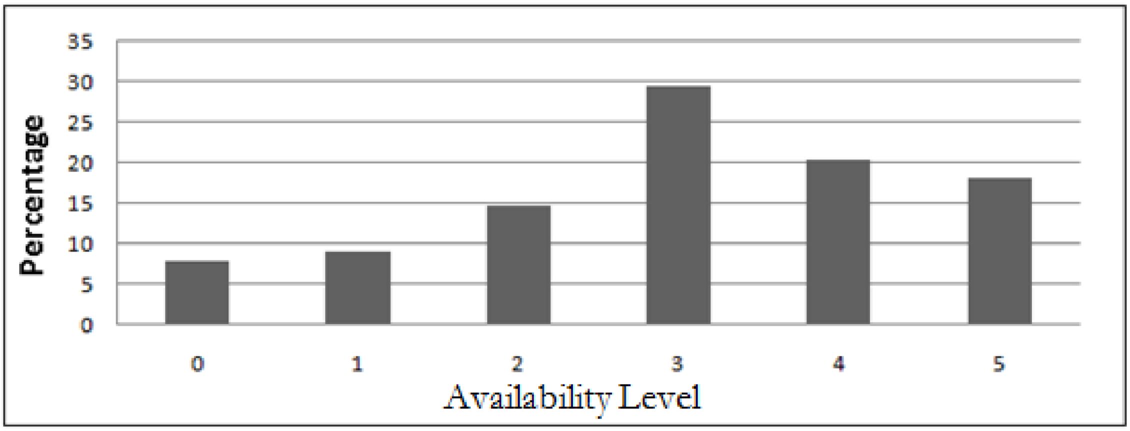

Figure 1 – Willingness to exchange the car for a more environment-friendly

Most subjects answered three (29.5%) and the value that fewer responses had been 0, with only 8% of individuals to choose this alternative, which suggests the existence of relative willingness to change the way people they use to transport and the environment.

For emissions of pollutants from cars, buses and trains, after using the methodology previously mentioned, came to the following values:

Table 2 – Emissions of pollutants from vehicles in g.pass / km and annual fuel cost of the total number of vehicles indicated

Fuel	Displacement	Category	Nr. of Vehicles	CO g.pass/km	CO_2 g.pass/km	PM_{total} g.pass/km	COV g.pass/km	NO_x g.pass/km	Cost € (annual)
Gasoline	<1,4	ECE 15/03	1	23,01	229,05	0,023	9,78	3,78	7291,16
		EURO I	3	5,56	187,40	0,028	0,56	0,60	3031,02
		EURO II	9	3,35	190,79	0,023	0,28	0,26	2394,41
		EURO III	12	3,23	180,32	0,023	0,15	0,11	1782,33
		EURO IV	2	0,97	189,69	0,028	0,09	0,065	681,77
	1,4-2,0	EURO I	3	5,41	250,26	0,04	0,83	0,45	239,86
		EURO II	3	2,865	233,57	0,037	0,38	0,27	643,60
		EURO III	3	2,49	243,14	0,033	0,19	0,11	669,98
		EURO IV	2	1,17	235,54	0,03	0,11	0,06	776,05
	>2,0	ECE 15/04	1	13,59	263,41	0,03	22,61	3,08	4503,09
		EURO II	1	2,27	310,85	0,035	0,285	0,247	1862,08
Diesel	<2,0	CONVEN.	1	0,73	181,36	0,73	0,19	0,52	1333,63
		EURO I	2	0,43	172,98	0,33	0,06	0,69	598,59
		EURO II	8	0,35	183,95	0,22	0,04	0,77	721,69
		EURO III	16	0,11	180,39	0,17	0,02	0,86	1256,28
		EURO IV	11	0,12	187,27	0,14	0,02	0,76	1855,03
		EURO V	1	0,16	192,60	0,036	0,02	0,51	208,28
	>2,0	EURO I	1	0,66	263,50	0,276	0,12	0,78	284,95
		EURO II	3	0,44	263,97	0,25	0,14	0,89	1045,92
		EURO III	2	0,10	229,01	0,15	0,05	0,78	2228,87

Table 3 – Pollutant emissions values from public transport in g.pass/km

Transport	CO g.pass/km	CO_2 g.pass/km	PM_{total} g.pass/km	COV g.pass/km	NO_x g.pass/km
Bus	0,23	76,41	0,12	0,40	0,80
Train	[redacted]	9,41	[redacted]		

After analyzing the values obtained, it is possible to conclude that CO_2 emissions, a gas that contributes most to climate change, have their lowest value in the train (9.41 g.pass/km), followed by bus (76.41 g.pass/km) and only finally comes the car, in which the best example has a value of 172.98 g.pass/km.

We also verify that the emission of various pollutants examined in cars, with some exceptions, fall is issued when a new EU directive, i.e., considering petrol vehicles with less than 1.4 cc per cylinder, we see that in cars entered in the Euro II emission of CO_2 are 190.79 g.pass/km and vehicles entered into the following EC directive (EURO III) this value is already 180.32 g.pass/km.

As for fuel costs in gasoline vehicles, the automotive category ECE 15/03 has an annual consumption of 7291.16€ while the 3 cars of the category EURO I with capacity from 1.4 cc and 2.0 cc, revealed It were cheapest with a cost of 239.86€. Already in diesel vehicles, the less economic cars were the third category of EURO III at a cost of 2,228.87€ per year, and was the most economical vehicle in the category EURO V with an expenditure of 208.28€ per year.

The year 2009 had 12 official holidays, 52 Saturdays, 52 Sundays and considering each individual is entitled to have 22 days in holiday, we concluded that on average each vehicle had a cost of 1.83€ per day on fuel for its user to make the journey home-ESTeSC-home. As for the bus, it is known that a ticket of the Urban Transport of Municipal Services from Coimbra allowing 11 trips, has a cost of 6.10€, equivalent to 0.55€ per journey, i.e. the bus may also prove to be a less expensive option, since the subjects claimed to use only one bus to make the route in question.

It is important to verify if diesel cars emit more CO_2 than gasoline cars. Thus, it follows the table with the results:

Table 4 – Differences in CO_2 emissions between diesel and gasoline cars. ANOVA to a fixed factor (pvalue ≤ 0.05)

	CO_2 Emissions (g.pass/km) $\bar{x} \pm s$
• Gasoline 95	207,26±32,61
• Gasoline 98	205,19±32,45
• Diesel	196,16±28,50

The analysis of results shoes that there is a difference in emissions between diesel and gasoline cars. Diesel cars are less polluting, but this difference was not statistically significant ($p > 0.05$).

It is also important to examine whether over time there has been a reduction in CO_2 emissions to the atmosphere and it made a comparison between the values of CO_2 before 2000 inclusive, and after 2000. The results are presented in the following table:

Table 5 – CO_2 emissions before and after 2000. Student t test for Independent Samples

	CO_2 Emissions (g.pass/km) $\bar{x} \pm s$
• Before 2000	210,79±35,99
•After 2000 (exclusive)	194,33±24,25

When analyzing the results, it was found that there is a statistically significant difference ($p < 0.05$) between CO_2 emissions before 2000 and CO_2 emissions after 2000, i.e. if we have 2000 as the point reference, note that the legislation has had the intended

effect, by reducing the emission of pollutants.
We sought to examine who they are after then the largest owners of more polluting vehicles (prior to 2000), if students or professors and there was still part of the professors increased car use compared with students were not yet fulfilled all the conditions required to have a statistically reliable result for any of the hypotheses. However it is possible to compare some data as shown in the tables:

Table 6 – Amount of vehicle owners before 2000 and after 2000

	Activitie			Total
	Student	Professor	Non Professor	
Before 2000	15 41,7%	9 25%	12 33,3%	36 100%
After 2000 (exclusive)	19 36,54%	24 46,15%	9 17,31%	52 100%

Table 7 – Relationship between the activity performed and car use

	Activitie			Total
	Professor	Student	Non Professor	
Vehicle	33 37,5%	34 38,6%	21 23,9%	88 100%

Although not statistically proven, it seems that, as expected the modern cars (after 2000) are used more by professors (46.15%) than for students (36.54%) and old cars (before 2000) are mostly used by students. This suggests that the more polluting cars from ESTeSC belong in larger amounts to students and not professors, and less polluting belong essentially to the professors.
Finally, examining Table 7, it seems to not prove that professors use more cars than students, as the difference between these two groups is only one individual. Again it is important to note that not analyze statistically significant values proving the situations mentioned.

Discussion

This study finds that there is not the desired sensitivity for people to exchange the car for other modes of transport more environmentally sustainable, since the car is still the most widely used means of transport for individuals who perform the journey "home -ESTeSC-home." This situation entails not only the obvious problem of air pollution, but also other negative situations such as congestion of visible parking areas within and nearby the ESTeSC, which consequently can cause mobility impairments who moves on foot or by cycling at these sites due to lack of parking penalty irregular.
Although this study show that cars tend to be less polluting over time, the best option remains the public transport instead of private transport. The capacity of existing buses allows the transport of about 75 people, what the environmental and urban space is much better that these people use the 75 cars.
During the study it was found that most people are willing to change their means of transport by a more friendly environment (Figure 1) mean, so it is necessary to use that opening mind to promote alternatives such as using public transport, encouraging walking or cycling, carpooling, etc.
It was also demonstrated with this study that individual transport is more expensive than public transport, so until the economic benefits of public transport are obvious. It is important

that people do not consider the vehicle as a status symbol and also enjoy the economic benefits of the use of public transport.

Conclusion

This study showed that we still need to rely more on information to people about the benefits of public transport and improving the quality of alternatives to the car so that in future they enjoy more public transport and feel the same convenience, safety and speed of individual transport.

It was also concluded that private transport is more efficient due to existing legislation and technological advancement, so it is important to encourage car users to the exchange from old vehicles to modern cars and therefore more environmentally friendly. During this study there were some limitations like the fact that sample must be composed of 97 students, 27 non-professor staff and 53 professors, and if the number of professors has been attained only 33 due to difficulties in gathering data. Another limitation relates to the fact that there is not always a value reduction of pollutant emission when going from an older class of vehicle for a longer current. This fact is due to the percentage of travel arrangements in urban, rural or motorway be different for each case, and pollutant emissions in each regime type are clearly different. Also other factors can influence these values, which is that the slope of land is not being considered and the Coimbra region has considerable variations in altitude.

In the future it would be interesting to invest in information and modernization of public transport and repeat again the study to see if the results hold.

References

[1] Braga, A.; Ordenamento e Mobilidade Sustentável: Contributos para a Adaptação às Alterações Climáticas. Universidade dos Açores, Mestrado em Ordenamento do Território e Planeamento Ambiental. January 2010

[2] Abade, S.; acedido em 19/10/2009 in: http://www.quercus.pt/scid/webquercus/defaultArticleViewOne.asp?categoryID=683&articleID=1910

[3] N. L. Sá & J. B. Gouveia; "Sustainable Mobility – Analysis of Sustainable mobility measures in cities" (pages 157-168) no "The Sustainable World" do WIT Press 2011, ISBN: 978-1-84564-504-5.

[4] MacKay, D.J.C.; Sustainable Energy – Without the Hot Air; version 3.5.2, November 2008

[5] Sá, N.; Loureiro, A.; Lourenço, D.; Dias, D.; Impacte Energético e Ambiental do Parque Automóvel da Escola Superior de Tecnologia da Saúde de Coimbra. Departamento de Saúde Ambiental da Escola Superior de Tecnologia da Saúde de Coimbra, July 2010

[6] European emission standards in Wikipedia search, [Online] July 2010 in: http://en.wikipedia.org/wiki/European_emission_standards

[7] Copert IV, Software MS Windows para cálculo de emissões de poluentes gasosos provenientes dos transportes

rodoviários. [Online] http://lat.eng.auth.gr/copert/.

[8] Weatherbase. [Online] 24/05/2010 in: http://www.weatherbase.com/weather/weather.php3?s=94580&refer=&units=metric.

[9] Portugal. Ministério de Economia e Inovação. Decreto-Lei n.º 89/2008 de 30 de Maio. Diário da República, I Série, n.º 104, s.l.

[10] Agência Portuguesa do Ambiente – Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento regional; Portuguese Informative Inventory Report 1990-2007 - Submitted Under The Unece Convention On Long-range Transboundary Air Pollution; Amadora, March 2009

[11] ViaMichelin. [Online] July 2010 in: http://www.viamichelin.pt/

[12] Gasoline in Wikipedia search, [Online] 9/09/2010 in: http://en.wikipedia.org/wiki/Gasoline

[13] Brandão, A.; Coelho, M.C.; Leite, N.; Sá, N.L.; Impacte Energético e Ambiental do Percurso Porto-Madrid. Livro de Poster's do Congresso Nacional sobre Alterações Climáticas, Clima 2010, Porto, 2010

[14] Preço de Combustíveis Online – Direcção Geral de Energia e Geologia [Online] 29/08/2010 in: http://www.precoscombustiveis.dgge.pt/

[15] Metro Mondego, S.A.

[16] Relatório de Sustentabilidade 2008 – Dados Adicionais Sobre o Nosso Desempenho. [Online] 15/09/2010 in: http://www.cp.pt/StaticFiles/Imagens/Fotografias/Institucional/Responsabilidade%20Social/relatorios_sustentabilidade/08_dados_adicionais_sobre_o_nosso_desempenho.pdf

[17] CP – Comboios de Portugal E.P.E.

[18] Relatório de Gestão 2009 – Actividade Operacional. [Online] 15/09/2010 in: http://www.cp.pt/StaticFiles/CP/Imagens/PDF/Institucional/Relatorios%20Financeiros/2009/04_actividade_operacional_2009.pdf