Energy Assessment of Buses Allocation to Specific Routes

Bernardo Leiria Ribeiro
bernardo.l.ribeiro@tecnico.ulisboa.pt

Instituto Superior Técnico, Universidade de Lisboa, Portugal
November 2018

Abstract

In Portugal, the transport sector represents more than 36.9% [1] of the final energy consumption, with public transports contributing with almost 9% [2] of the consumption used in transports.
This study aims at simulating and assessing the energy consumption of buses in several routes, in order to allocate them, obtaining a better energy efficiency. A tool was created through an experimental proceeding, where measurements were made in real driving conditions with vehicles of "Rodoviária de Lisboa". The methodology here presented was calibrated and validated, comparing the estimated energy consumption with the real energy consumption for 20 travels, showing a 4.3% average error.
A more adequate vehicles' allocation has the potential of reducing energy consumption by 3.8%, for the present reality of the company, allocating only the existing vehicles, without any extra investment. This would represent a reduction of about 805 tons of CO_2 emissions, 1946kg of CO, 8556kg of NO_X and 241 kg of particles.
On the other hand, a more adequate situation was evaluated, where replacing the Citaro vehicle with the OM 457 motorization by others with the OM 906 motorization, since this will have enough power to make the courses. The potential reduction of fuel consumption would be of 9.3%, reducing 1849 tons of CO_2 emissions, 4704 kg of CO, 20711kg of NO_X and 583kg of particles.
The introduction of this tool in the company would enabled a better allocation of the existing vehicles, and also makes the choice of new vehicles and its allocations easier.

Keywords: heavy passenger vehicles, vehicles allocation, fuels, energy efficiency, transports

1. Introduction

One of the major problems nowadays is associated with air pollution, which comes largely from the combustion of fuels, and of course, much of that energy use is associated to the transport sector, representing 36.9% of primary energy consumption in Portugal [1].
As regards heavy passenger vehicles, they account for less than10% of final energy consumption in the transport sector [2] at European level, in Portugal this percentage is below the European average, due to the high use personal and private transport.
Although the percentage of energy consumption spent on this type of vehicle may seem insignificant, it should be noted that in Europe more than 80% of the consumption of land transport is carried out by light passenger vehicles, but in Portugal this value comes close to 90% [2].
In addition to being able to make large investments in new and more efficient vehicles, buses companies also have other alternatives according to their resources. Some of these alternatives require only small investments and changes inside the companies. Eco driving programs and courses, vehicle allocation programs, traffic monitoring and management, fleet adequacy study and choice of typology, maintenance and timely verification of vehicles are some of the ways to reduce energy consumption. This type of behavior from companies is extremely important at the environmental level, in an attempt to reduce the emissions of pollutants and also reducing their operational costs.
Consequently, the main objective of this dissertation is to study energy efficiency measures with special focus on fleet management improvement through a more adequate allocation of vehicles to routes, by quantifying potential fuel consumption and pollutant emissions savings as well as operational costs.
The application and use of this tool enables estimating energy consumption of a vehicle in a given route without it necessarily passing there. In this way, whenever necessary, monitoring of a route may be used to anticipate the vehicle's expected energy consumption, taking the decision of where to allocate it.
This work was carried out at Rodoviária de Lisboa, under the Galp21 project, which results from the partnership between Instituto Superior Técnico and GALP ENERGIA. The data collected for this

dissertation are based on data and information collected at Rodoviária de Lisboa.

2. Data acquisition and analysis methodology

2.1. Case Study

For the development of this dissertation, a study was carried out at the company Rodoviária de Lisboa, which operates in the suburban region of Lisbon. The headquarters are in Campo Grande and operate in three centers: Santa Iria, Caneças and Bucelas. Rodoviária de Lisboa has 375 vehicles, carrying around 200.000 passengers daily. By 2017, fuel consumption was approximately 7.8 million liters, traveling 17 million kilometers.

One of the problems found in Rodoviária de Lisboa is the allocation of vehicles, which the company executes without great care. Only the needs related to the type of vehicle of each center are taken into account. Since the performance of the vehicles is not analyzed before allocating them, the destination of each vehicle is made without great care. Therefore, it is not known whether the allocation of each car is being carried out in the best way at the energy level and, consequently, at the economic level.

Since it is not possible to study all the models of the company's fleet and since the Mercedes-Benz Citaro vehicles represent about 50% of the fleet, it was decided to study the behavior between the two engines that equip this model, being the different characteristics of the vehicles tested in Table 1.

Table 1 - Mercedes-Benz Citaro vehicles tested [3], [4]

Number of the vehicle	Center	Motor	Displacement (c.c.)	Power (kW)	Year
A	Caneças	OM457	11967	260	2003
B	Santa Iria	OM457	11967	260	2004
C	Caneças	OM906	6370	210	2004
D	Santa Iria	OM906	6370	210	2005

The tests were carried out in the centers of Santa Iria and Caneças, disregarding the center of Bucelas because it is a smaller center. In order to characterize the vehicles in the different centers, the vehicles were tested in real environment, to later create the tool that allows analyzing their behaviors. The entire testing process was planned to collect the following variables: fuel consumption, geographic travel data, instantaneous speed and acceleration and number of passengers on board. Therefore, it was decided to register data externally, using a GPS with barometric altimeter. The number of passengers was counted on board, counting the number of passengers entering and leaving each stop.

2.2. Methodology of collecting and analyzing data

The STP (Scaled Tractive Power) methodology was used to characterize the vehicles under test. This methodology was developed to analyze the distribution of power throughout each trip to estimate the consumption and pollutant emissions of heavy goods vehicles and passenger cars [5].

This method comes from the VSP (Vehicle Scaled Power) methodology used for light vehicles, which evaluates the instantaneous power through the dynamics of each trip, but given the different characteristics of heavy passengers, the VSP method is not viable using the STP. Consequently, the STP methodology was used because only the topography, the dynamics and the weight of the vehicle are needed for its characterization.

2.2.1. Experimental procedure for data collection

For the characterization of each vehicle, the variables presented in Table 2 were monitored.

Table 2 - Variables needed to characterize vehicles

Variable	Mode of acquisition	Method of calculation	Acquisition Frequency
Velocity	GPS with barometric altimeter (Garmin GPSMap 64st)	Change of position in every second	1 Hz
Acceleration		Speed variation in every second	
Slope		Quotient between position variation and altitude variation	
Vehicle weight	Coming from the characteristics of the car	-	-
Passenger weight	Counts made on board during the trip	Variation between passengers entering and leaving in each stop	Each stop
Total fuel consumption	Fuel in the vehicle	Reading liters of fuel attested at the end of the trip	Beginning and end of the trip
Consumption of *ralenti*	Fuel in the vehicle	Reading liters of fuel attested at end of test	Beginning and end of the test

Data from GPS, geographic coordinates and altitude were recorded in seconds, serving as the basis for calculating speed, acceleration and road grade. Speed was calculated by varying the latitude and longitude data. Similarly, knowing the speed every second enables calculating acceleration. The slope was calculated knowing the variation of coordinates and the variation of altitude.

In terms of experimental procedure, the GPS started recording at the moment the vehicle is powered on after fuel supply and is switched off when the vehicle is last turned off before refueling. When the bus is disconnected in the middle of the trip, this time is counted and subsequently disregarded.

The total weight is divided into a fixed part and a variable part, the fixed weight refers to the gross weight of the vehicle, derived from its characteristics, the variable weight refers to the passengers on board, using a weight per passenger of 69 kg, average weight of the Portuguese population [6].

In terms of refueling, fuel supplies were made to the mouth of the tank and not the shot of the supply gun, for this the following procedure was performed:

1. The vehicle begins to be attested until the moment the gun is fired and stopped
2. Let it pass for a few seconds until the fuel stops bubbling and descending, as this is an air signal inside the tank
3. Continue to fill the tank until it is filled to the nozzle without creating bubbles, repeating as necessary point 3.

For the idling energy consumption tests, the same applies to supplies made before and after journeys. After checking the vehicle, it is switched on and left to work for half an hour, after half an hour the vehicle is turned off and replenished, with the strictness and care of the supply procedure.

The tests performed on the different vehicles followed the same procedure, and five tests were performed on each vehicle.. In Table 3, important data regarding each trip for the different vehicles is presented.

Table 3 - Trips realized with each vehicle

Vehicle	Center	Trip Code	Career	Total travel time (s)	Ralenti time (%)	Consumption (l/100km)	Maximum number of passenger	Evaluation of circulation
A	Caneças	5.1	5	12893	38,1	59,0	38	Urban
		2.1	2	8916	30,5	44,6	37	Suburban
		4.1	4	16421	32,5	50,0	37	Suburban
		3.1	3	16285	42,0	43,1	47	Suburban
		1.1	1	16952	37,5	48,7	50	Urban
B	Santa Iria	8.1	8	13756	30,4	44,9	82	Suburban
		7.1	7	13995	51,8	51,8	61	Urbano
		8.2	8	14803	33,7	49,9	76	Suburban
		8.3	8	14683	34,5	51,8	73	Suburban
		7.2	7	12883	37,3	52,1	56	Urban
C	Caneças	2.2	2	9688	33,1	45,3	56	Suburban
		5.2	5	11987	37,4	49,3	44	Urban
		4.2	4	16298	31,1	46,6	42	Suburban
		3.2	3	17107	37,9	43,0	46	Suburban
		1.2	1	16948	41,2	45	51	Urban
D	Santa Iria	6.1	6	13695	32,5	37,1	44	Urban
		6.2	6	9712	41,8	48,6	58	Urban
		6.3	6	12924	31,0	38,7	47	Urban
		6.4	6	12273	34,6	43,4	44	Urban
		6.5	6	12579	30,1	33,8	50	Urban

Each of the 20 trips made has been assigned a travel code, this code refers to the career where it was performed (varying between 1 and 8) and after the career number follows a point and another number, this number characterizes the turn that this career has been used (eg "3.2" represents career 3, being the second trip of this career).

2.2.2. Metodology of analyzing data

The STP methodology used to characterize and analyze the collected data is governed by the equation 1.

$$STP_t = \frac{Av_t + B{v_t}^2 + C{v_t}^2 + m_t v_t (a_t + g \sin\theta)}{f_{sca}} \qquad \text{(eq. 1)}$$

where:

STP_t - *Scaled Tractive Power* at instant of time t, kW (scaled);
v_t – Velocity at instant of time t, m/s;
a_t – Acceleration at instant of time t, m/s^2;
m_t – mass of the bus (fixed) + mass of passengers at instant of time t, in tons;
f_{sca} – scaled factor, fixed value of 17,1;
$\sin\theta$ - slope, fraction between altitude and coordinates;
g - gravitational acceleration, fixed value of 9,81 m/s^2;
A – rolling resistance factor, kW.s/m;
B – rotating resistance factor, kW.s^2/m^2;
C – aerodynamic resistance factor, kW.s^3/m^3.

All the instantaneous power data calculated by STP was distributed in a modal distribution. For this, the various powers were grouped according to their truncated value (eg, if the value is in the range [5,6[, it becomes a group of value 5). The STP may have negative, positive, or null values. When the STP is zero, it means that the vehicle is stationary. When values are positive, they usually indicate load situations, usually accelerations and constant speed situations. When the values are negative, they usually indicate deceleration situations. The values of A, B and C were taken from the study by V. A. Petrushov, for both heavy and bus vehicles, as shown in Table 4.

Table 4 - Values of the constants for the STP calculation

	Heavy-duty vehicles, [3,855; 6,350] tons	Heavy-duty vehicles, [6,350; 14,968] tons	Heavy-duty vehicles, >14,968 tons	Buses
$\frac{A\ [kW.s/m]}{M\ [ton]}$	0,0996	0,0875	0,0661	0,0643
$\frac{B\ [kW.s^2/m^2]}{M\ [ton]}$	0	0	0	0
$\frac{C\ [kW.s^3/m^3]}{M\ [ton]}$	${}^{1,47}/_{mass\ (kg)} + 5,22 \times 10^{-5}$	${}^{1,93}/_{mass\ (kg)} + 5,90 \times 10^{-5}$	${}^{2,89}/_{mass\ (kg)} + 4,21 \times 10^{-5}$	${}^{3,22}/_{mass\ (kg)} + 5,06 \times 10^{-5}$

.

2.3. Methodology for estimating consumption curves

Through the power distribution carried out in a modal distribution, it was possible to verify that the idling time of each trip was around 30 to 50%, which later had a great influence on the consumption calculation. Figure 7 shows an example of the temporal modal distribution of STP of a trip of one of the vehicles.

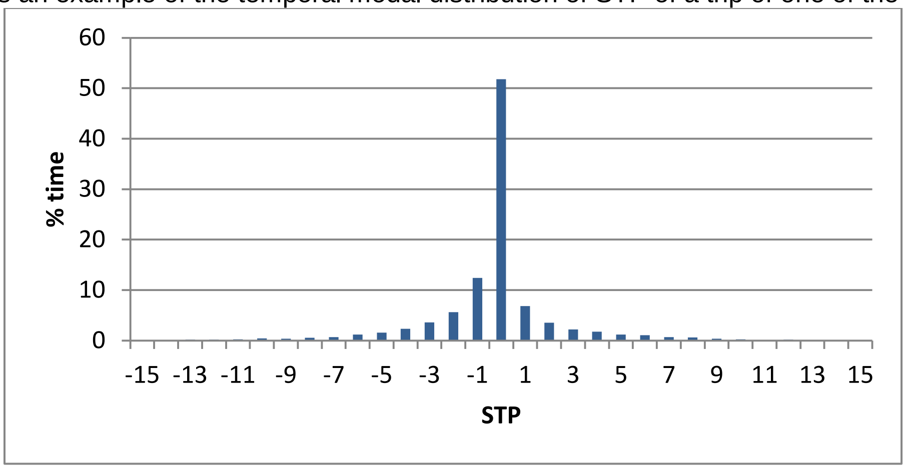

Figure 1 - Time distribution of STP (example of vehicle B)

After obtaining the STP distribution of all trips, these were used, together with the consumption of each trip, to estimate the consumption curve characteristic of each vehicle.

Taking into account the consumption curves used for light vehicles, it was assumed that for buses the consumption curve would be of the same type, presenting 3 different phases: for power with STP <-10, the consumption value is constant; for power ratings between [-10, + 10], the consumption value varies according to a second degree equation as a function of the STP value; and for powers with STP> +10, the consumption value varies linearly as a function of the STP value.

The values of the points -10 and +10, used for the boundary between the different phases, were chosen because they were the ones with the lowest error, and were found by iterative process, using several values of continuity.

In order to determine the constants a, b, c, d, e and f, a system of equations of 6 equations was used, four of these equations coming from continuity at points -10 and +10, finding continuity in the consumption curve and its derivative.

δ is the element relating to idling consumption, using the calculated value of $8,89 \times 10^{-4}\ l/s$ from the tests carried out. The idling consumption, STP=0, is not defined by the second degree equation, because when the vehicle is at idle, the consumption is low since the load to which the engine is subjected is lower than when the vehicle is moving , regardless of whether positive or negative power values are present.. Figure 2 presents an example of a consumption curve for one of the vehicles tested.

$$\begin{cases} cons._1 = \sum_{i=-\infty}^{-11} a \times t_{STP} + \sum_{i=-10}^{-1} (bSTP^2 + cSTP + d) \times t_{STP} + \delta \times t_{STP=0} + \sum_{i=+1}^{+10} (bSTP^2 + cSTP + d) \times t_{STP} + \sum_{I=+11}^{+\infty} (eSTP + f) t_{STP} \\ cons._2 = \sum_{i=-\infty}^{-11} a \times t_{STP} + \sum_{i=-10}^{-1} (bSTP^2 + cSTP + d) \times t_{STP} + \delta \times t_{STP=0} + \sum_{i=+1}^{+10} (bSTP^2 + cSTP + d) \times t_{STP} + \sum_{I=+11}^{+\infty} (eSTP + f) t_{STP} \\ a = b(-20)^2 + c(-20) + d \\ b(+20)^2 + c(+20) + d = (+20)e + f \\ 0 = 2b(-20) + b(-20) + c \\ 2b(+20) + c = e \end{cases}$$

(eq.2)

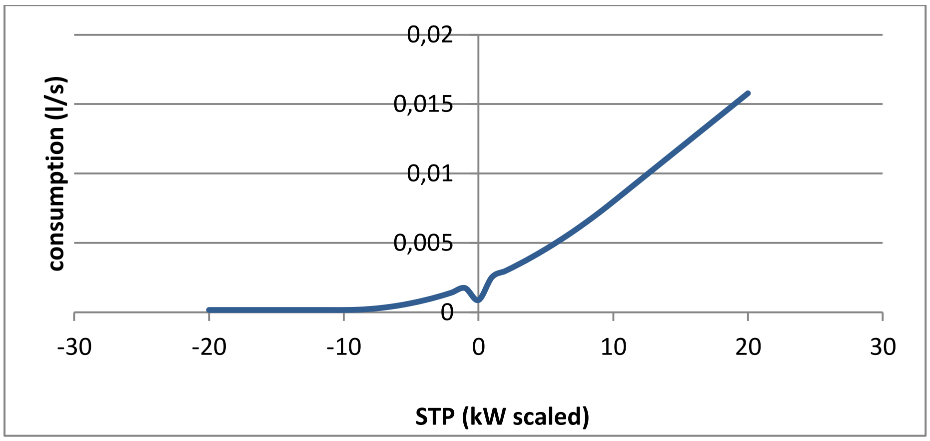

Figure 2 - consumption curve (vehicle C)

3. Allocation Tool Description

With the data collected for the calculation of the STP distribution of each trip and through the consumption curve of each vehicle, a tool was developed to simulate the consumption of each vehicle in the different trips, without such a vehicle needing to go through such route. This way, taking advantage of the STP distributions of each route, it is possible to simulate the theoretical consumption of each vehicle in the same route, based on the equations presented in previous chapter.

Since the two engines used for testing as having different power ratings, it was first necessary to check whether the least powerful engine (motorization OM 906, with 210kW) would be sufficient to meet the requirements of the more powerful engine (motorization OM 457, with 260kW).

In order to analyze if the required power would be enough to follow the original dynamics, equation 3 was used, which results from the balance of forces acting on the vehicle.

$$P = \left(mg\lambda v + C_D \frac{1}{2} \rho v^2 A_f + m(a + g \sin\theta) \right) v \qquad \text{(eq. 3)}$$

where:

P – Power used by the vehicle in the instant (W);

m – Mass of the vehicle, plus the mass of the passengers (kg);

g - Gravitational acceleration, fixed value of 9.81 m/s^2;

λ - Rolling resistance, fixed value of 0.01 [7];

v – Velocity in the instant (m/s);

C_D – Drag coefficient, fixed value of 0.6 [8];

ρ – Air density, fixed value of 1.25 kg/m^3;

A_f – Frontal area, fixed value of 8 m^2;

a – Acceleration in the instant (m/s^2);

$sin\ \theta$ – Slope in the instant.

This way, it was possible to verify if the vehicles with the engine OM 906 would have capacity for the originally carried out by the vehicles with the engine OM 457, evaluating the percentage of time in which it would have to be running above its power capacities.

In order to better allocate the families of tested vehicles, the different routes were analyzed, in order to understand their characteristics. Therefore, data collected by GPS was used to verify which routes would have the most similar behaviors in order to group them by groups. To distinguish the different routes, defining a context of use, we chose to analyze them according to the topography and context. In this way the separation between what would be urban and suburban was done, as well as if the vehicle was facing a flat zone, or with positive or negative slopes (see Figure 3).

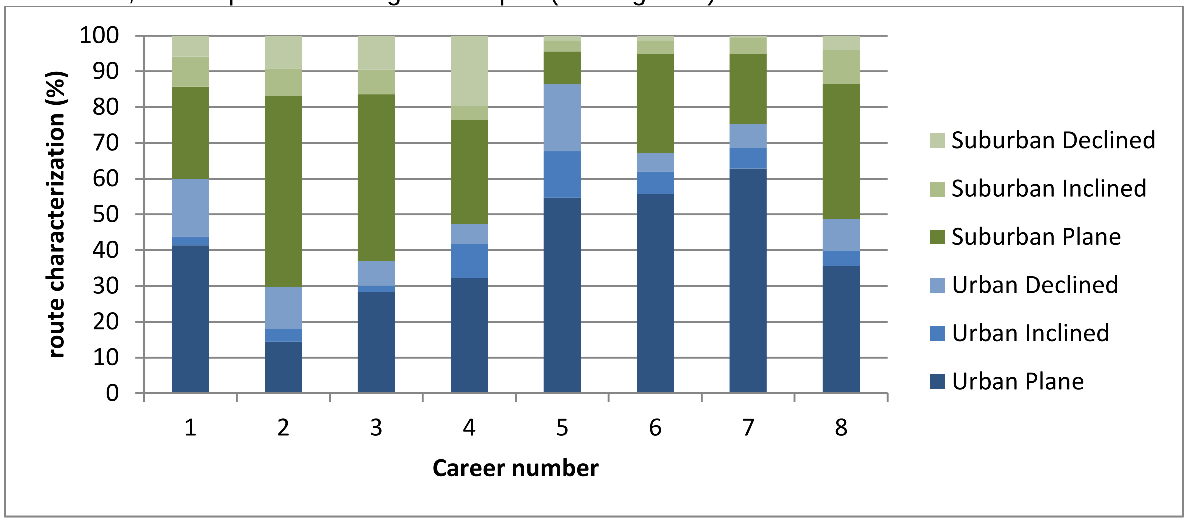

Figure 3 - Characterization of the context of each career

Although some routes that appear to have similar characterizations, this does not indicate that the vehicles behave in similar ways in these routes.

In order to better understand the consumption of each bus in each route, the respective journeys carried out by their respective routes were grouped, in order to obtain an average consumption per career, and respective deviation. In order to quantify the environmental impact, CO_2, CO, NO_X and PM emission factors were used because they are the main pollutants resulting from the burning of fuels, in this case diesel fuel (see Table 5).

Table 5 - Average emission values for pollutants [9]

Polluting	g/kg $_{\text{diesel minimum}}$	g/kg $_{\text{diesel average}}$	g/kg $_{\text{diesel maximum}}$
CO_2	-	$3{,}14\times10^3$	-
CO	5.73	7,58	10.57
NO_X	28.34	33,37	38.29
PM	0.61	0,94	0.04

4. Results

4.1. Tool validation and characterization

The five trips made with each vehicle were grouped in all combinations of possible travel pairs in order to estimate all the hypotheses of consumption curves for vehicle characterization. The calculated consumption curves were used to estimate the consumption of the other three trips made with the vehicle, but were not used to obtain the curve. These three trips served not only to calculate the expected consumption but also to validate the tool in order to use the consumption curve that best comes close to reality, that is, to verify which one would have the smallest error.

For vehicle A the consumption curve resulting from a pair of trips with an associated error of 1.9±7.5% was chosen. For vehicle B the curve results from a pair of trips with an error of -3.8±11.8%. For vehicle C the curve results from a pair of trips with an error of -1.6±3.8%. And lastly, vehicle D results from a couple of trips with an error of -3.9±8.8%.

After validating the tool, the best curve of each vehicle was selected. The coefficients of the consumption curve that characterizes each vehicle are shown in Table 6.

Table 6 - Result of the coefficients of each vehicle

Vehicle	Coefficients					
	a (g/s)	b $\frac{(g/s)}{(skW)^2}$	c $\frac{(g/s)}{skW}$	d (g/s)	e $\frac{(g/s)}{skW}$	d (g/s)
A	9.35×10^{-4}	1.69×10^{-5}	3.38×10^{-4}	2.63×10^{-3}	6.77×10^{-4}	9.35×10^{-4}
B	2.27×10^{-3}	9.99×10^{-6}	2×10^{-4}	3.27×10^{-3}	4×10^{-4}	2.27×10^{-3}
C	1.77×10^{-4}	1.95×10^{-5}	3.9×10^{-4}	2.13×10^{-3}	7.8×10^{-4}	1.77×10^{-4}
D	1.75×10^{-3}	8.16×10^{-6}	1.63×10^{-4}	2.57×10^{-3}	3.26×10^{-4}	1.75×10^{-3}

The factors mentioned in Table 6 result in the consumption curves shown in Figure 4.

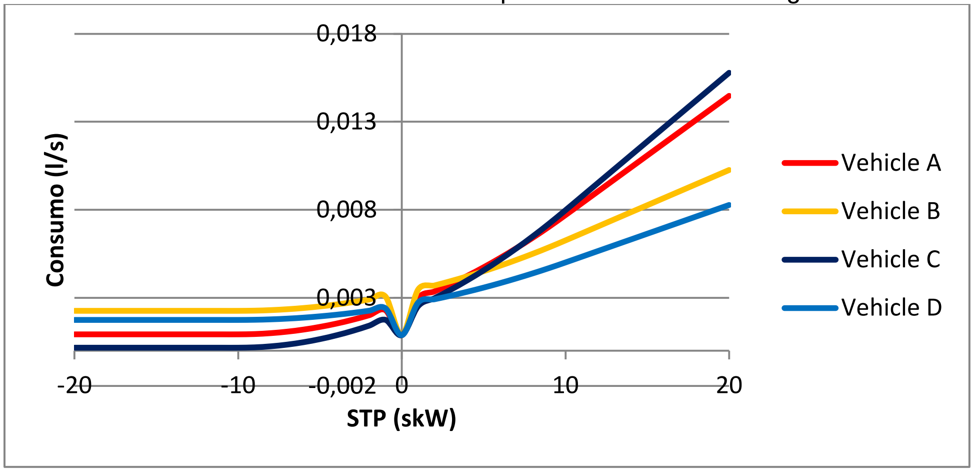

Figure 4 - Consumption curves of the various characterized vehicles

In assessing the difference in fuel consumption between the two engines tested, vehicles equipped with the engine OM 906 consume less 7.1±0.6 l / 100km compared to those equipped with the engine OM 457.

In order to better interpret the values of the consumptions estimated in each one of the trips, the trips were organized by the respective routes. Since all routes were carried out at least twice, the average consumption of each race was calculated for each pair of vehicles with identical motorizations and also for each individual vehicle. Therefore it was possible to have a perception if the vehicles within the same range of motorizations would have very different consumptions and also what the difference between the average of fuel consumption made by each type of motorization. In Figure 5 we can see the fuel consumption and respective standard deviation of each engine family.

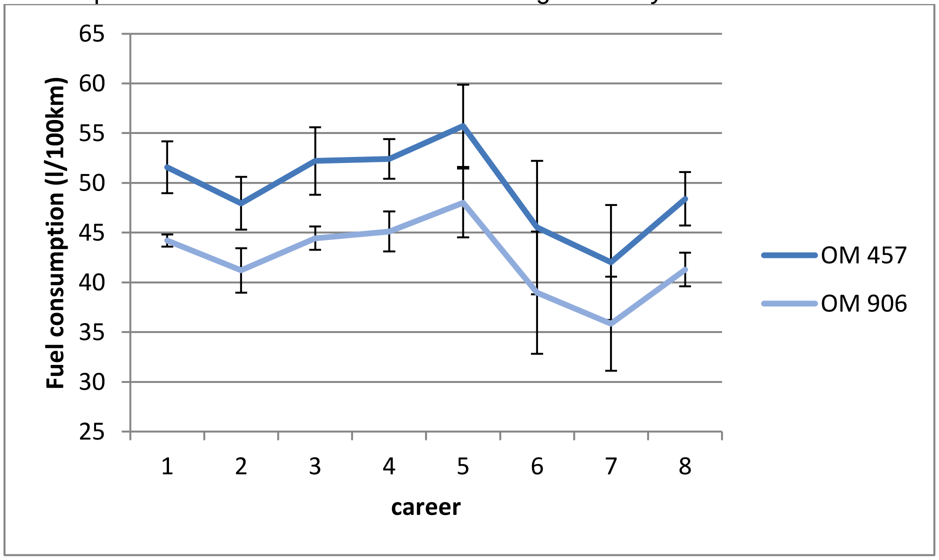

Figure 5 - Average fuel consumption predicted by motorization

The circumstances where the less powerful cars (210kW) could not perform the routes carried out by the most powerful vehicles (260kW) were also assessed, proving to be a requirement of the route. In this way, it was possible to verify if the vehicles with the engine OM 906 would have capacity for the originally carried out by the vehicles with the engine OM 457, evaluating the percentage of time in which it would have to be running above its power capacities. Since the Rodoviária de Lisboa has available both powertrains, the routes were analyzed where the motor vehicles OM 457 would have a greater differential in the environmental impact compared to the motorization OM 906, verifying which factors can most influence the difference in consumption between engines.

4.2. Allocation measures

In order to better understand the behavior of the vehicles in the different routes, several can be associated to the different estimated fuel consumption. As such, the criteria evaluated were: average and operational speed, idling time, urban or suburban context, slope of the route and number of passengers. In order to better understand the influence of each criterion on fuel consumption, a trend line was created based on the average consumption data of each motorization in the various routes.
From the evaluated criteria, average speed and slope were those that presented more interesting trend lines for analysis. The data related to the idling time, the urban/suburban context and the number of passengers were evaluated as inconclusive or not influential in the evaluation of the criteria according to their trend lines.

4.3. Application of vehicle allocation

In the 20 test trips, 675l of fuel were spent, in 1464km, with an average consumption of 46.1l/100km, which corresponds to a good approximation of the present reality of the Rodoviária de Lisboa, which in 2017 had average fuel consumption equal to 46.1l/100km

4.3.1. Allocation hypothesis adapted to the reality of the Lisbon Bus Station

The most powerful vehicles could be allocated on routes that have a shorter distance to travel, in order to obtain the lowest possible consumption. In this way, the vehicles with OM 457 engines could be allocated on routes 2, 3, 5 and 7, while vehicles with OM 906 engines were allocated to routes 1, 4, 5 and 8. In this case, knowing that they were made 1464km, presenting an average value of 641.2l of fuel. Compared to the estimated fuel consumption, with the actual fuel consumption in the tests, compared to the proposed allocation, fuel savings of 3.8±3.9% could be expected, averaging 44.3l/100km.

4.3.2. Ideal allocation hypothesis

The hypothesis presented corresponds to all vehicles being equipped with the OM 906 engine. This option is due to the fact that no plausible reason was found for the use of the OM 457 engine, which would invalidate the use of the less powerful vehicles (OM 906) in the tested routes. The reduction in fuel consumption in this case is 9.3±6.8%. and the average consumption of 612.3 liters of fuel is estimated for the accomplishment of the 20 trips of tests, counting this way with an average consumption of 41.8l/100km. This hypothesis, although it is the most environmentally and energy efficient, requires the replacement of vehicles in the fleet, OM 457 engine vehicles replaced by vehicles with OM 906 engine.

5. Conclusions

This dissertation aimed to analyze the environmental and energy impacts through the application of measures for the allocation of heavy passenger vehicles. A vehicle allocation tool was created in order to better understand the behavior of the vehicles in the different routes. This tool allows the company not only to evaluate how it should allocate the existing vehicles, but also to help in the process of selecting new vehicles.
From the tested vehicles, the less powerful ones would have sufficient power to ensure the proposed service and presenting lower consumption than the more powerful vehicles. For the ideal case, it was concluded that the Mercedes-Benz Citaro vehicles equipped with OM 906 engines would be enough to fulfill the requirements of this type of vehicle. In this case, a reduction in consumption would be expected at 9.3±6.8%, which represents an average of saving around 727600l, which would result in a reduction of 1849 tons of CO_2 emissions, 4704kg of CO, 20711kg of NO_X and 583 kg of particles.
Knowing that in the fleet of Rodoviária de Lisboa there are also vehicles equipped with the motorization OM 457, the challenge was to know where to allocate them in order to achieve the best possible savings.

Therefore, these vehicles were eventually allocated to shorter routes. In this way fuel savings of around 3.8±3.9% are achieved, representing an average of annual decrease of 300900 liters, with a reduction of around 805 tons of CO_2 emissions, 1946 kg of CO, 8565 kg of NO_X and 241 kg of particles.
This way, it can be verified that the allocation of vehicles made at this level, although it is something that is not yet recurring at the Rodoviária de Lisboa, has the potential to be applied in order to improve energy efficiency and the company's environmental footprint.

References

[1] Relatório do Estado do Ambiente, "PEGADA ENERGÉTICA E CARBÓNICA DOS TRANSPORTES." [Online]. Available: https://rea.apambiente.pt/content/pegada-energética-e-carbónica-dos-transportes. [Accessed: 08-Oct-2018].

[2] Eurostat, "Modal split of inland passenger transport, 2015." [Online]. Available: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Modal_split_of_inland_passenger_transport,_2015_(%25_of_total_inland_passenger-kilometres).png. [Accessed: 06-Oct-2018].

[3] Mercedes-Benz, "The Citaro." [Online]. Available: https://www.mercedes-benz.sk/content/media_library/hq/hq_mpc_reference_site/bus_ng/services_accessories/brochures/CITARO/citaro_technical_data_2009_ge_pdf.object-Single-MEDIA.tmp/16016_Techn_Info_Citaro_EN_low.pdf. [Accessed: 09-Oct-2018].

[4] Mercedes-Benz, "The Citaro G." [Online]. Available: https://www.mercedes-benz.sk/content/media_library/hq/hq_mpc_reference_site/bus_ng/services_accessories/brochures/CITARO_G/citaro_g_technical_data_2009_en_pdf.object-Single-MEDIA.tmp/16016_Techn_Info_Citaro_G_EN_low.pdf. [Accessed: 09-Oct-2018].

[5] J. Yun, "Study of the Driving Cycle for Heavy Duty Trucks in Hilly Terrain and Its Effect on Calculated Emissions , and Comparison of Two Mobile Emission Models," 2012.

[6] RTP, "Portugueses são dos cidadãos com menor envergadura física da União Europeia." [Online]. Available: https://www.rtp.pt/noticias/pais/portugueses-sao-dos-cidadaos-com-menor-envergadura-fisica-da-uniao-europeia_n36638. [Accessed: 08-Oct-2018].

[7] HPWizard.com, "Tire friction and rolling resistance coefficients." [Online]. Available: http://hpwizard.com/tire-friction-coefficient.html. [Accessed: 09-Oct-2018].

[8] The Engineering ToolBox, "Drag Coefficient." [Online]. Available: https://www.engineeringtoolbox.com/drag-coefficient-d_627.html. [Accessed: 09-Oct-2018].

[9] C. Kouridis *et al.*, "EMEP/EEA emission inventory guidebook 2013 update Sept 2014 1," 2014.