

# **DEVELOPING MONITORING AND MAINTENANCE AGREEMENT AND TOOLS FOR 5 PORTUGUESE CITIES WITH ELECTRIC MINI-BUSES**

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## **Abstract**

Why are public transport operators so reluctant in deploying electric vehicles in their fleets?

The limited market supplies (although some recent progress can be observed) and the operators' technical and operational inexperience with electric traction, sometimes cause a setback in the use and maintenance of electric vehicles. Aware of these facts, the Portuguese Directorate-General for Inland and River Transport (DGTTF), the Portuguese Electric Vehicle Association (APVE) and Coimbra's Municipal Urban Transport Company (SMTUC), have developed a monitoring and maintenance agreement and achieved the adhesion of the 5 Portuguese Cities that use electric mini-buses (Coimbra, Portalegre, Bragança, Viseu and Viana do Castelo), which aim, among others, is to diminish the disadvantages of long distance technical assistance through mutual support and trading experiences, sharing of information and of know-how and through a formalised benchmarking process.

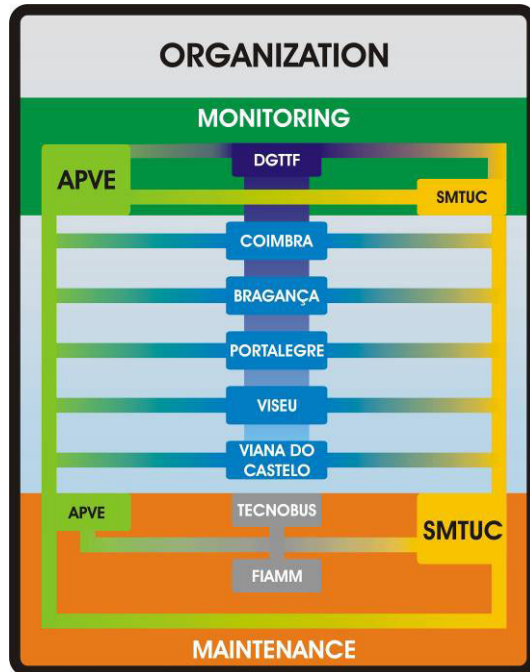
The cooperation between these five cities will allow for assessing the advantages / disadvantages of using electric vehicles in urban transport fleets, not only in technical and economical terms, but also in terms of the social and logistic levels of urban mobility. The Portuguese Electric Vehicle Association has developed tools and manuals in support to a training and full monitoring program that has now been implemented in the five cities

In parallel with the monitoring and maintenance process, great interest in mobility concepts and changing philosophies on urban transport supply, mobility and clients' / passengers' behaviour have also developed. The monitoring performed on the five lines serves not only for benchmarking, but also to draw lessons from an evolving technology and mobility mentality.

**Keywords:** A 3.1 Public Transport;  
M-1.1 Introduction, Demonstration;  
M-3.1 Training;  
K 2.1 Environmental Impact.

# 1 Monitoring and Maintenance Agreement - overview

The Portuguese Electric Vehicle Association (APVE) devised and operated a demonstration program for the "Introduction of Electric buses in Urban Public Transport Fleets in Portuguese Cities", in 25 cities over a period of two and half years [1][2][6]. During the same period, a full monitoring program was developed, in order to determine the use as well as the social, mobility, environment and energetic impacts related to these services [1][2][3]. The challenge now is to collect as many data as possible from the five permanent electric mini-buses lines (14 buses in total) running in Portugal, as well as to ensure that the service provided by these vehicles is not interrupted due to lack of maintenance or on the account of having to wait for remote maintenance services.



In this context, APVE, together with the Portuguese Directorate-General for Inland and River Transport (DGTTF) and Coimbra's Municipal Urban Transport Company (SMTUC) drafted and negotiated a monitoring and maintenance agreement [7], which concept is illustrated in figure 1. All five cities that use electric mini buses adhered, with the aim, among others, to reduce the disadvantages of remote maintenance, and to enhance their knowledge by exchanging data information.

The aim of this agreement is to attain interaction between the partners, in such a way that the experiences (good, as well as bad) can easily be transmitted and assimilated, allowing for the creation of a communication basis, and the development and sustainable application of measures, supported by a

philosophy of sharing experiences and learning.

Figure 1: Schematic view of the Monitoring and Maintenance Agreement [7].

The major objectives are to ensure vehicle maintenance, (central) spare parts stock management and monitoring of the different services performed in each city. Within this context, the following manuals were developed:



Figure 2: Agreement Framework, Monitoring and (preventive) Maintenance Proceedings Manual [7] [8] [9].



Figure 3: Blue Line Concept, Traction batteries and Driving Manual [10][11][12].



Figure 4: Spare parts Stock catalogue (central and local) and contact list [13][14].



The location of the five adherent cities, which are scattered all over Portugal, can be observed on the map in figure 5.

Coimbra has been running, since September 2003, three electric mini-buses on a permanent city centre “blue line” service (no fixed stops, getting on and off on demand). Being the only Portuguese city where there are still trolley buses, its operator, therefore, has a valuable experience / knowledge in electric vehicles maintenance, which enables this operator to provide assistance to other cities.

It is the APVE’s responsibility to develop and perform the monitoring/benchmarking process, together with the participating cities/operators [7].

Figure 5: Localization of the five Portuguese cities that use electric mini-buses.



Figure 6: Five Portuguese Cities with Electric Mini-Buses.

## 2 Monitoring

PLANO DE MONITORIZAÇÃO	Responsável	Registo	Diário	Semanal	Mensal	Bimestral	Quadrimestral	Semestral	Anual
Registo Diário das Deslocações e Consumo Energético	Motoristas	6							
Registo de Recarga das Baterias	Responsáveis pela Recarga	5							
Registo de Ocupação Diária	Motoristas	7							
Monitorização Grupo 3 Baterias	APVE								
Recolha de Dados em Tempo Real	APVE								
Inquéritos aos Passageiros (primeiro ano de serviço)	Operador / CM	INQ							
Registo de Intervenções de Rotina	Operador	1							
Registo de Ocorrências	Operador	2							
Registo de Ocorrências / Assistência 1	SMTUC	3							
Registo de Ocorrências / Assistência 2	APVE	4							

Figure 7: Monitoring/Benchmarking Schedule [8]

APVE has developed tools and a manual "Monitoring Guide" [8] (see figure 2) to assist a full monitoring program that includes passenger surveys (social and user profile and opinion on technology and service), passenger statistics (by line sections), and driver's and battery service logs. This document summarizes the monitoring procedures related to the registering of the various indicators, and by whom and when these have to be filled in. A total of seven registers and two inquiries were developed and later adopted by the municipalities:

- Register 1      Routine Interventions  
This register contains the scheduled interventions performed within the scope of preventive maintenance.
- Register 2      City incidents  
This register should be provided by the operator every time there is an incident that requires repair / an intervention on the vehicle that was not foreseen in the periodic maintenance plan.
- Register 3      SMTUC (Coimbra's Municipal Urban Transport Company) occurrences – being the logistics base with a mobile intervention unit  
This register should be filled by SMTUC every time a city asks for any kind of assistance (involving long distance inquiry by phone or mail or mobile unit intervention).

- Register 4 APVE incidents  
Occurrences recorded by APVE every time a city asks for any kind of assistance.
- Register 5 Battery charging  
Filled in by the person responsible for charging the batteries; this register gathers information related to the recharging process.
- Register 6 Route and energy consumption log  
Filled in by the driver; this register records information such as daily travelled distance and consumption, type of service and battery used.
- Register 7 Passenger flow chart  
This periodic register allows to calculate the number of passengers boarding and getting off the buses, by circuit sections and run.

Furthermore, two types of periodic full range passenger surveys - to be carried out by inquirers - were developed: one that applies to the blue line concept, and a second that applies to the normal service with predefined stops.

In order to reduce and summarize, in this document we will focus on the three cities that have the most up to date data (Portalegre, Viseu e Viana), and which can be consulted in the following subchapters.

## 2.1 Data on Portalegre

Portalegre has been running a "blue line" service (no predefined stops) with three electric mini-buses, since September 2004, with an approximate line length of 4 km. The average energy consumption is circa 114 kWh/100 km (average for the 3 buses) [15].

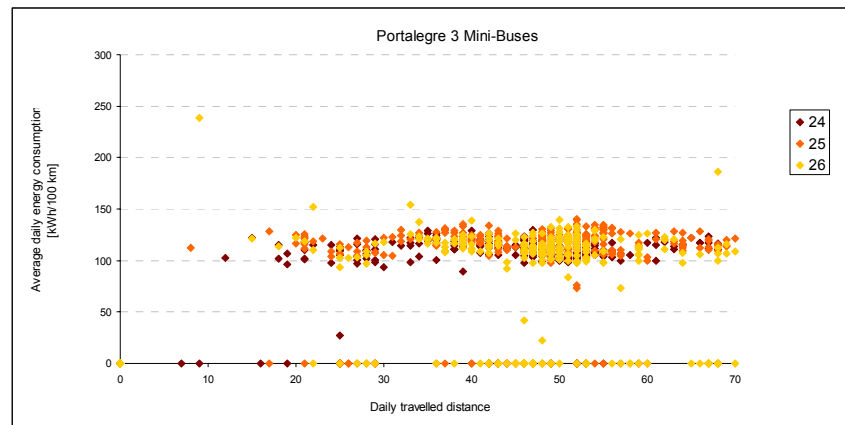


Figure 8: Portalegre, three electric mini-buses, average daily consumption against daily travelled distance [15].

The assumed efficiency of the battery charging process was 65%, based on the average efficiency calculated for the demonstration program [3]. Bearing in mind the above mentioned registers, it is possible to put together a utilization map as the one illustrated in figure 9, where the service periods and shifts of each bus can be consulted on a daily basis.

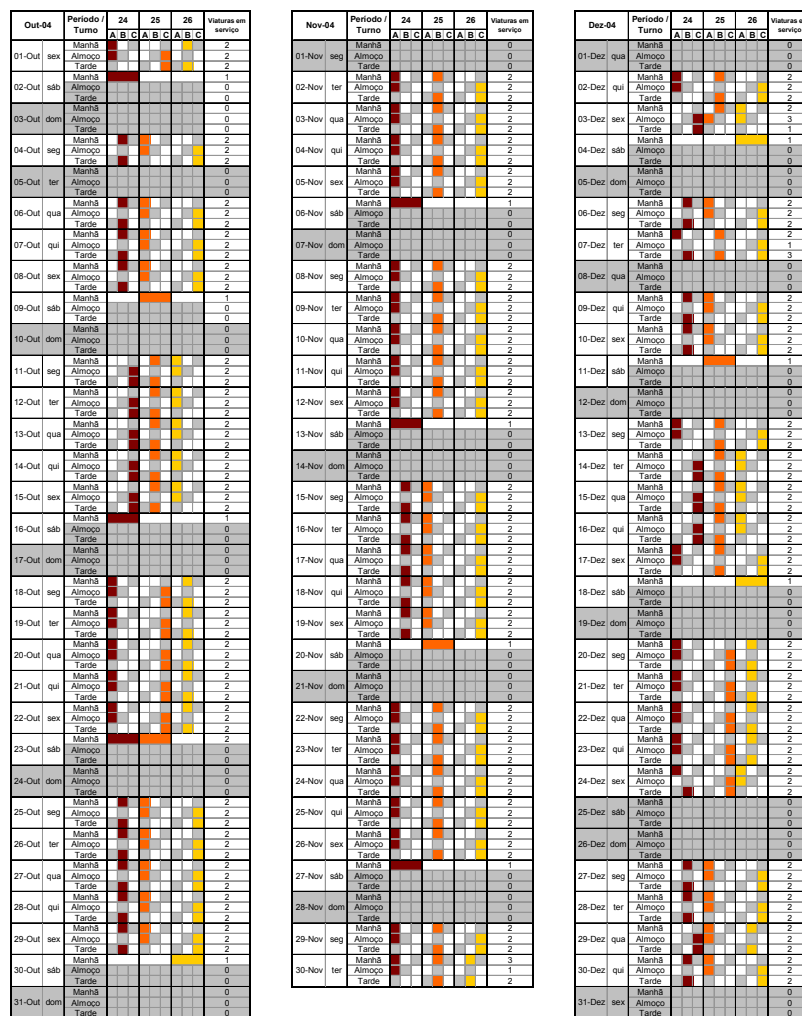


Figure 9: Utilization map for the three Portalegre mini-buses [15].

As far as passengers is concerned, Portalegre presents an average of 7.000 passengers per month, which considering the average of 20 service days per month, corresponds to 400 passengers per day (total for the three buses). Also counting the average of 36 runs per day, the number of 11 passengers per run can be obtained.

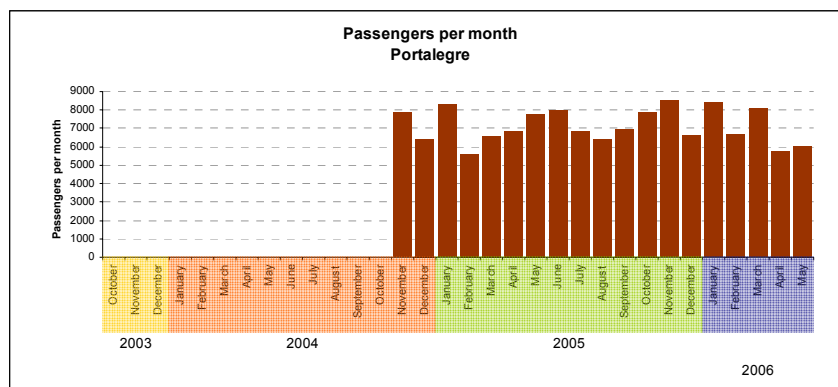


Figure 10: Portalegre Monthly ridership statistics [15].

Furthermore, since October 2004 until March 2006, the three Portalegre buses have travelled a total of 32.782 km, in a total of 219 service days, corresponding to an average of 50 km per day and per bus.

Passenger surveys were also performed in Portalegre, with a very high level of satisfaction as far as buses, service and concept are concerned, figure 11 summarises the global satisfaction of the

passengers regarding the global action (electric mini-buses applied to a micro-urban service with a "blue line" concept), with 46% of the responses in the "very good" category and 50 % in the "good" category. Many other variables were monitored; however their inclusion in this graph would make it too extensive.

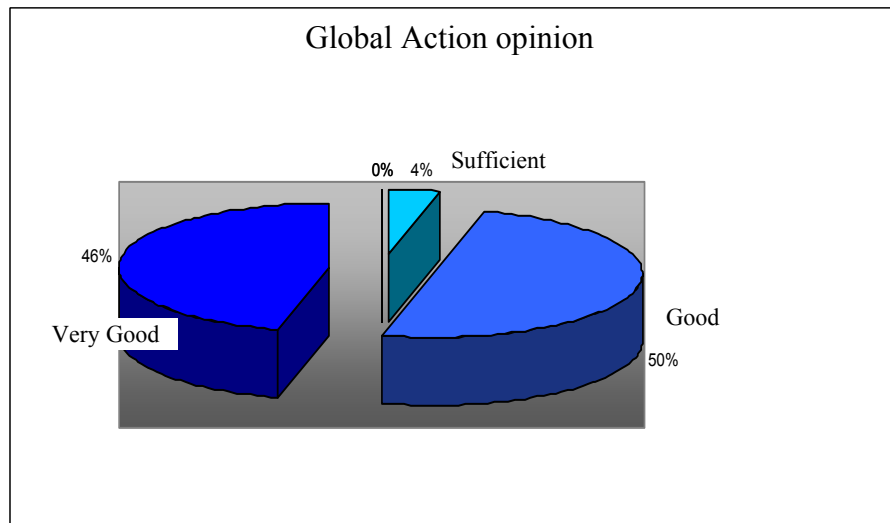
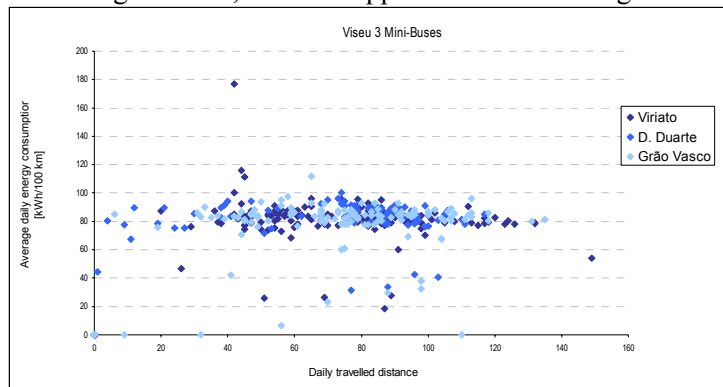


Figure 11: Portalegre passengers' global satisfaction, regarding the global action [15].

## 2.2 Data on Viseu

Viseu has been running a "blue line" service (no pre-defined stops) with three electric mini-buses, since August 2005, with an approximated line length of 6 km. The average energy consumption is circa 84 kWh/100 km (average for the 3 buses).



The assumed efficiency for the battery charging process was 65%, against the average efficiency calculated for the demonstration program [3]. A utilization map was also performed for the Viseu buses (see figure 13).

Figure 12: Viseu - three electric mini-buses' average daily consumption versus daily travelled distance [15].

Out-05	Viriato	D. Duarte	Grão Vasco	Viaturas em serviço
01-Out sáb				2
02-Out dom				0
03-Out seg				2
04-Out ter				2
05-Out qua				0
06-Out qui				2
07-Out sex				2
08-Out sáb				2
09-Out dom				0
10-Out seg				2
11-Out ter				2
12-Out qua				2
13-Out qui				2
14-Out sex				2
15-Out sáb				3
16-Out dom				0
17-Out seg				2
18-Out ter				2
19-Out qua				2
20-Out qui				3
21-Out sex				2
22-Out sáb				2
23-Out dom				0
24-Out seg				2
25-Out ter				2
26-Out qua				2
27-Out qui				2
28-Out sex				2
29-Out sáb				2
30-Out dom				0
31-Out seg				2

Nov-05	Viriato	D. Duarte	Grão Vasco	Viaturas em serviço
01-Nov ter				0
02-Nov qua				2
03-Nov qui				3
04-Nov sex				3
05-Nov sáb				2
06-Nov dom				0
07-Nov seg				3
08-Nov ter				3
09-Nov qua				3
10-Nov qui				2
11-Nov sex				3
12-Nov sáb				2
13-Nov dom				0
14-Nov seg				2
15-Nov ter				3
16-Nov qua				3
17-Nov qui				3
18-Nov sex				3
19-Nov sáb				3
20-Nov dom				0
21-Nov seg				3
22-Nov ter				3
23-Nov qua				3
24-Nov qui				3
25-Nov sex				3
26-Nov sáb				2
27-Nov dom				0
28-Nov seg				3
29-Nov ter				3
30-Nov qua				3

Dez-05	Viriato	D. Duarte	Grão Vasco	Viaturas em serviço
01-Dez qui				0
02-Dez sex				3
03-Dez sáb				2
04-Dez dom				0
05-Dez seg				2
06-Dez ter				3
07-Dez qua				2
08-Dez qui				0
09-Dez sex				3
10-Dez sáb				2
11-Dez dom				0
12-Dez seg				3
13-Dez ter				3
14-Dez qua				3
15-Dez qui				3
16-Dez sex				3
17-Dez sáb				3
18-Dez dom				0
19-Dez seg				3
20-Dez ter				3
21-Dez qua				3
22-Dez qui				3
23-Dez sex				3
24-Dez sáb				2
25-Dez dom				0
26-Dez seg				3
27-Dez ter				3
28-Dez qua				3
29-Dez qui				3
30-Dez sex				3
31-Dez sáb				2

Figure 13: Utilization map for the three Viseu mini-buses [15].

As far as passengers is concerned, Viseu presents an average of 1.500 passengers per month, which considering the average of 18 service days per month, corresponds to 75 passengers per day (total for the three buses). Also counting with the average of 40 runs per day, the number of 2 passengers per run can be obtained. This average has showed to be to low, and circuit modifications are under consideration.

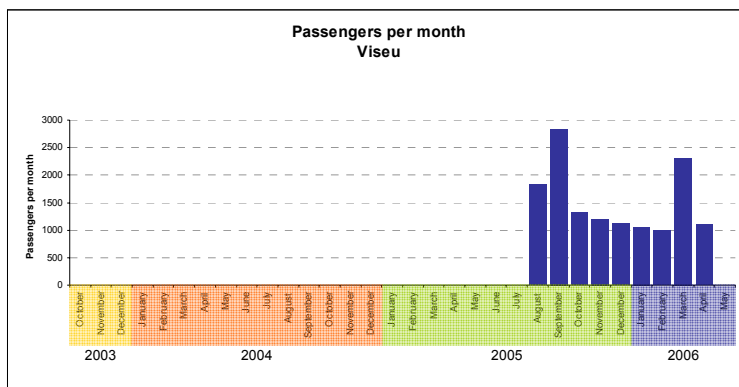


Figure 14: Viseu monthly ridership statistics [15].

Since August 2005 until January 2006, the three Viseu buses travelled a total of 25.670 km, in a total of 110 service days, corresponding to an average of 80 km per day and per bus. Once again, other values are being monitored, but their introduction in this document would only cause it to be too extensive.

## 2.3 Data on Viana do Castelo

Fev-06				12	13	Viaturas em serviço
01-Fev	qua	Manhã	Tarde			0
02-Fev	qui	Manhã	Tarde			0
03-Fev	sex	Manhã	Tarde			0
04-Fev	sáb	Manhã	Tarde			0
05-Fev	dom	Manhã	Tarde			0
06-Fev	seg	Manhã	Tarde			0
07-Fev	ter	Manhã	Tarde			0
08-Fev	qua	Manhã	Tarde			0
09-Fev	qui	Manhã	Tarde			0
10-Fev	sex	Manhã	Tarde			0
11-Fev	sáb	Manhã	Tarde			0
12-Fev	dom	Manhã	Tarde			0
13-Fev	seg	Manhã	Tarde			1
14-Fev	ter	Manhã	Tarde			1
15-Fev	qua	Manhã	Tarde			1
16-Fev	qui	Manhã	Tarde			1
17-Fev	sex	Manhã	Tarde			1
18-Fev	sáb	Manhã	Tarde			0
19-Fev	dom	Manhã	Tarde			0
20-Fev	seg	Manhã	Tarde			1
21-Fev	ter	Manhã	Tarde			1
22-Fev	qua	Manhã	Tarde			1
23-Fev	qui	Manhã	Tarde			1
24-Fev	sex	Manhã	Tarde			1
25-Fev	sáb	Manhã	Tarde			0
26-Fev	dom	Manhã	Tarde			0
27-Fev	seg	Manhã	Tarde			1
28-Fev	ter	Manhã	Tarde			0

Mar-06				12	13	Viaturas em serviço
01-Mar	qua	Manhã	Tarde			1
02-Mar	qui	Manhã	Tarde			1
03-Mar	sex	Manhã	Tarde			1
04-Mar	sáb	Manhã	Tarde			0
05-Mar	dom	Manhã	Tarde			0
06-Mar	seg	Manhã	Tarde			1
07-Mar	ter	Manhã	Tarde			1
08-Mar	qua	Manhã	Tarde			1
09-Mar	qui	Manhã	Tarde			1
10-Mar	sex	Manhã	Tarde			1
11-Mar	sáb	Manhã	Tarde			0
12-Mar	dom	Manhã	Tarde			0
13-Mar	seg	Manhã	Tarde			1
14-Mar	ter	Manhã	Tarde			1
15-Mar	qua	Manhã	Tarde			1
16-Mar	qui	Manhã	Tarde			1
17-Mar	sex	Manhã	Tarde			1
18-Mar	sáb	Manhã	Tarde			0
19-Mar	dom	Manhã	Tarde			0
20-Mar	seg	Manhã	Tarde			1
21-Mar	ter	Manhã	Tarde			1
22-Mar	qua	Manhã	Tarde			1
23-Mar	qui	Manhã	Tarde			1
24-Mar	sex	Manhã	Tarde			1
25-Mar	sáb	Manhã	Tarde			0
26-Mar	dom	Manhã	Tarde			0
27-Mar	seg	Manhã	Tarde			1
28-Mar	ter	Manhã	Tarde			1
29-Mar	qua	Manhã	Tarde			1
30-Mar	qui	Manhã	Tarde			1
31-Mar	sex	Manhã	Tarde			1

Figure 16: Utilization map for the two Viana do Castelo mini-buses [15].

Viana do Castelo is still considering and testing the service concept to be applied, since it started with very premature service conditions in September 2005 and is still being a case study for the final service configuration. The circuit (operated with two electric mini-buses) is approximately 3,5 km long. The average energy consumption is circa 58 kWh/100 km (average for the 2 buses).

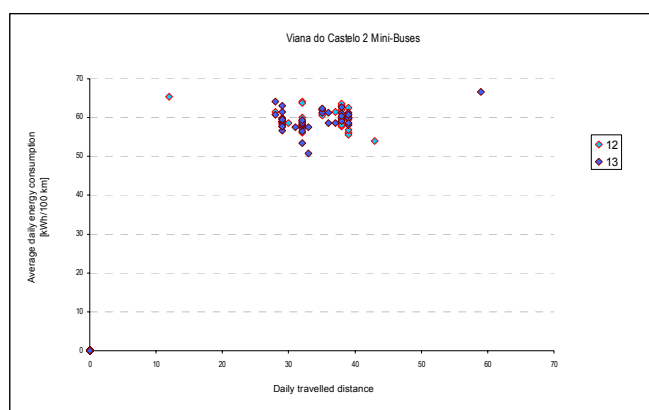
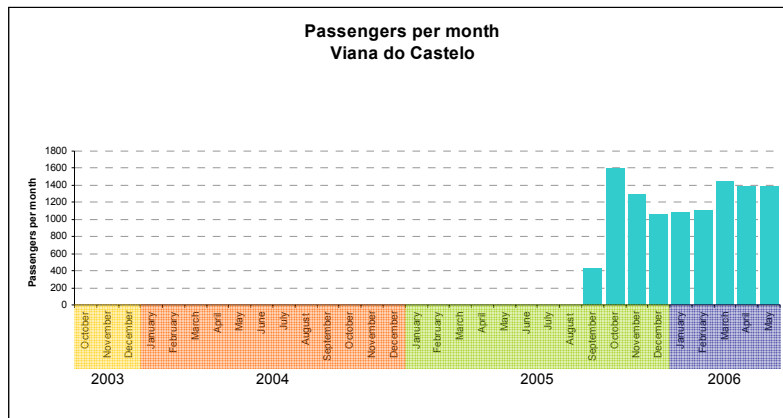


Figure 15: Viana do Castelo two electric mini-buses average daily consumption versus daily travelled distance [15].

The assumed efficiency for the battery charging process was 65%, against the average efficiency calculated for the demonstration program [3]. Again, a utilization map was performed for the Viana do Castelo buses (see figure 16).



As far as passengers is concerned, Viana do Castelo presents an average of 1.200 passengers per month, which considering the average of 15 service days per month corresponds to 110 passengers per day (total for the two buses). Also counting with the average of 20 runs per day, the number of 6 passengers per run can be obtained. The Viana do Castelo circuit has been altered and these numbers are expected to increase.

Figure 17: Viana do Castelo monthly ridership statistics [15].

Since January and until April 2006, the two Viana do Castelo buses travelled a total of 3.011 km, in a total of 44 service days, corresponding to an average of 70 km per day and per bus. Once again, other values are being monitored, but their inclusion in this document would cause it to be too extensive.

## 2.3 Comparison between data from the 5 cities

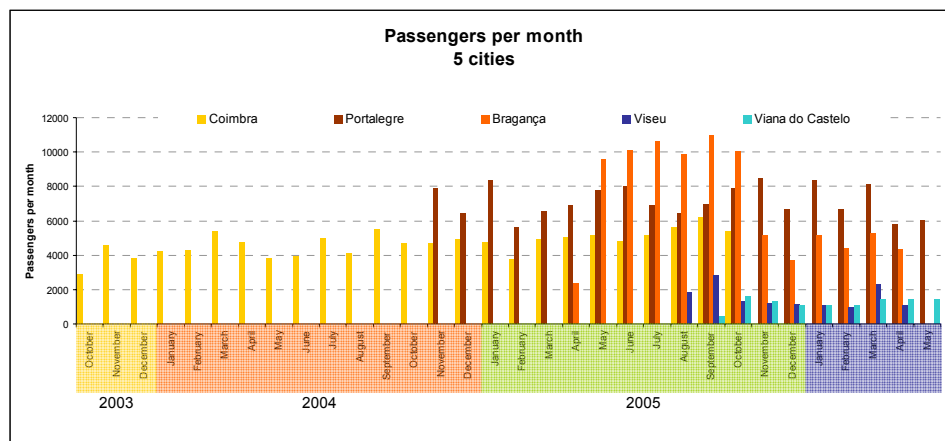


Figure 18: Viana do Castelo monthly ridership statistics - comparison between the 5 cities [15].

This data collection allows a comparison between the five cities, which can be observed in the following figures. The Coimbra data was collected in the period from October 2003 to October 2005, Portalegre from October 2004 to May 2006, Bragança from April 2005 to April 2006 (only passenger data), Viseu from August 2005 to April 2006 and Viana do Castelo from September 2005 to May 2006.

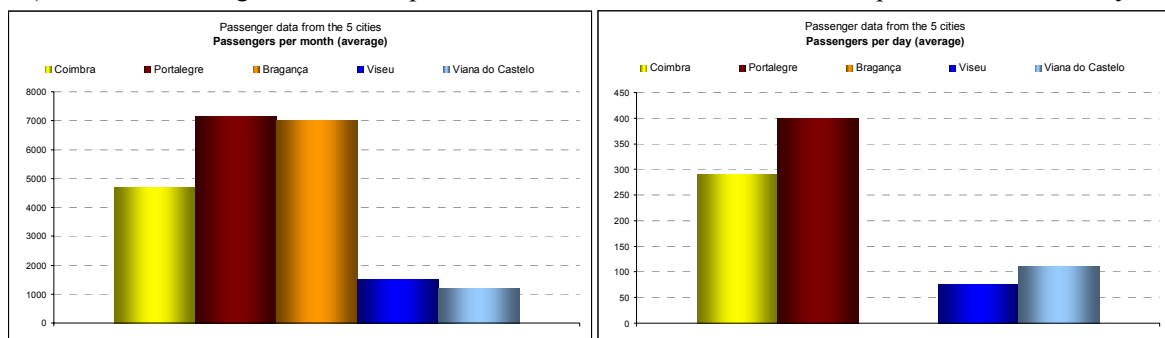


Figure 19: Passengers data from the 5 cities: average passengers per moth and per day [15].

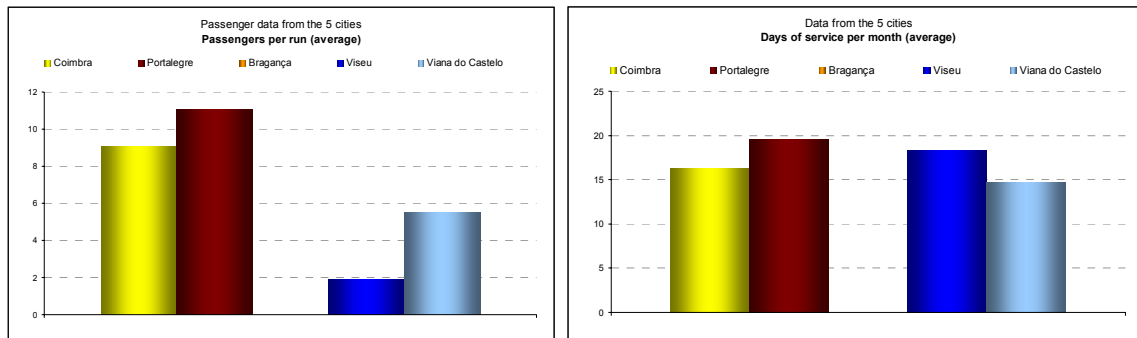


Figure 20: Data from the 5 cities: average passengers per run and average days of service per month [15].

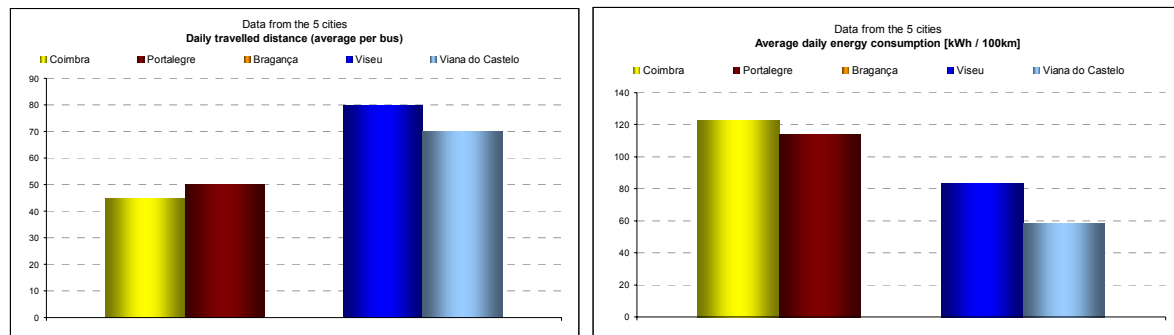


Figure 21: Data from the 5 cities: average daily travelled distance (per bus) and average daily energy consumption [kWh / 100 km] [15].

Bearing in mind this comparison between the 5 cities data:

Portalegre has the highest number of passengers per month (an average of 7.000), and per day (an average of 400) as well as per run (average of 11). Viana do Castelo is characterized by the lowest number of passengers per moth (average of 1.200), while Viseu is the city with the lowest number of passengers per day (average of 75) and per run (average of 2).

The highest number of average daily energy consumption corresponds to Coimbra and Portalegre, where the circuit topology is very hard, while Viana do Castelo, with a mainly flat circuit has the lowest consumption value (58 kWh / 100km).

Regarding the average daily travelled distance (per bus) Viseu has the highest value, with 80 km/day.

### 3 Maintenance

Considering the importance of preventive maintenance (a good preventive maintenance can avoid most of the common bus failures), APVE has developed a preventive maintenance guide [9] (based on the bus manufacturer's guide) with a maintenance plan and the respective registers to be filled in whenever these procedures are taken. The following figures show some of the contents of the guide.



Figure 22: Maintenance plan and illustrative figures of maintenance procedures [9].

## 5 Conclusions

Código	Descrição	Quantidade	Preço	Semtotal	
R000E040P	ESCOVA COM SINAL (MOTOR DE DIREÇÃO ASSISTIDA)			0.00	
	SPAZZOLA CON ALLARME	1	42.73	42.73	
RM585	ESCOVAS COMPRESSOR			0.00	
	SPAZZOLA 7.5X22.2X25	6	24.978	149.87	
R51020303				0.00	
	VENTOLA TANGENZIALE 24V SPAL	3	85.014	254.04	
R000E1122				0.00	
	VENTILATORE 12V C1	3	161.678	485.01	
R000S4301				0.00	
	CONNETTORE VERDE SBE 320A	3	42.738	128.21	
R10010331				0.00	
	CONNETTORE 175 AMP	3	26.737	80.21	
R00008101				0.00	
	RELAIS TEMP. 1 CONTATTO 16A 420/75	6	85.150	485.75	
R20002030				0.00	
	CENTRALINA MC10072V	2	2084.697	4169.38	
R0000PR1B				0.00	
	PEDALIERA AD 1 PEDALE	3	178.192	534.58	
R30001075				0.00	
	IOS TERMINALE DI PROGRAMMAZ	1	623.622	623.62	
R30001099				0.00	
	KEYB TASTIERA IOS	1	267.271	267.27	

Figure 23: Glance of spare part stock manual [14].

Partly resulting from the monitoring and maintenance process, interest in changing mobility concepts and philosophies on urban transport supply is increasing, and clients' / passengers' behaviour and mobility patterns are also evolving. This shows that the monitoring performed allows for benchmarking, provides feedback from an evolving technology concept and enables to advance proposals for conceptual modifications, in order to develop better and more attractive and sustainable urban transports.

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The implemented maintenance and monitoring has allowed to create a database which enables to redraw conclusions and redirect decisions, but has also brought new awareness to fleet operators, municipalities and to the technical staff about the monitoring procedures. When adequately applied, these simple logs can allow a technician to carry out the operator control of these indicators and predict equipment malfunction. One of the major barriers found was the data collection (as the schedules were not always complied with); however, the actors of this maintenance and monitoring agreement are now very much aware of its benefits and cooperate voluntarily and willingly.

The cooperation agreement also foresees setting up a central stock, with high cost and low frequency of substitution spare parts, and local stocks in each city, with low cost and high frequency of consumption spare parts, in order to reduce the costs and waiting times for remote shipments. The creation of a central spare parts stock is still being assessed, however, the list of spare parts having been agreed by all partners. Meanwhile, some cities have already set up their own local stock, as agreed.

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