Thermie Project

★THERMIE★

E.V.D. POST

Measurements performed in Belgium
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1. Introduction

In the framework of the Thermie E.V.D.Post project, CITELEC is responsible for evaluation of the electric vehicles deployed in the framework of this project, on a common basis, in order to have the opportunity to make a comparison of the different electric vehicle technologies that are used in this project.

In this framework measurements are being performed on postal vehicles used for the project on different sites. After defining the used methodology during the first measurement campaign performed in Kajaani, Finland, in February 1998 (where special attention was given to winter operations) a second Finnish measurement was held in Turku in August 1999. A third campaign took place in February 2000 in Sweden, while the underlying report gives an overview of the methodology used and of the results obtained in a fourth campaign performed at 3 different sites in Belgium.

2. Electric vehicles for the Belgian Post

For about one year and a half, 15 Peugeot Partner Electric are operating at different locations, 2 in Brugge, 2 in Gent, 2 in Oostende, 4 in Wavre , 4 in Brussels and 1 in Antwerp. The introduction of electric vehicles is expected to strengthen the image of the Belgian Post as a responsible enterprise caring for the environment. The tests were performed in Brussels, Oostende and Wavre, as to tackle different topographical characteristics on one hand and different aspects of postal operation on the other hand.

2.1. Electric vehicles in Brussels

Brussels, capital of Belgium, is situated in the heart of Belgium with a population of about one million people. As capital of the country, it functions as an important regional, even national business centre. Moreover with the presence of the European community, it plays a premier role in the international policy and business theatre.

The electric vehicles are deployed in Brussels 1, the central post office. The typical duty of the postal delivery vehicle tested goes as follows :

- 7u30 - 9u20 : First mail round, normal delivery
- 11u00 – 14u10: Second mail round, “registered delivery”, which means that the receiver has to sign to get his documents.

2.2. *Electric vehicles in Wavre*

Wavre, situated in the southeast of Brussels, is a regional and commercial centre in the middle between the Belgian capital and Namur. It is characterised by a quite hilly topography.

The electric vehicles are used for similar duties then in Brussels.

2.3. *Electric vehicles in Oostende*

The city of Oostende, located at the coast, is one of Belgians famous seaside resorts. The presence of the harbour gives rise to one of the most important industrial centre in the region.

In Oostende the vehicle tested was used in a different manner. The typical operation is as follows :

- 12u10 - 13u35 : First mail round
- 14u00 – 14u40: Second mail round
- 16u30 - 18u00 : Third mail round
- 18u30 – 18u50: Fourth mail round

In these rounds, the postman collects mail from post boxes and deliver this to the sorting centre He also provides a shuttle service between sub-post offices.

3. The CITELEC measurement system[1]

[1] Cf. W. Deloof et al., *On-Road Measuring and Testing Procedures for Electric Vehicles*, EVS-14, Orlando, 1997

The measurement system used test equipment consists of the following instruments:

Figure 1 : The measurement system installed on board the Elcat, vehicle used in Finland in the same project

The CITELEC data-acquisition measurement system is constituted as follows:
An intern serial datalogger, built in a portable 19”-rack, provides all the signal conditioning, multiplexing, discretisation and digitalisation. The rack is small and meets the needs that are demanded for such a device (electric and electromagnetic isolation, proof against external shocks, no obstacle for driver or passengers, ...).
In Figure 2 one can see the principal outline of the measurement system. Voltages, currents and digital speed measurements are converted into load-independent output signals by internal transducers with linear characteristics. Outputs from the LEMs (Hall effect shunts) are converted into input voltages for the transducers by means of precision measuring resistances. The transducers provide filtering and galvanic isolation for the signals. Other parameters pass a buffer and a low-pass filter (Butterworth 5th order). The logger accepts input voltages up to 10 V. Data-acquisition is done by a serial logger, consisting of a 16-channel data-acquisition card and a 64 Kbytes buffer microcontroller card. An external 12 V maintenance-free Pb-battery provides the supply of all the electronics and auxiliary devices, even for the speed sensor.
The logger is controlled by a Macintosh PowerBook via a serial connection, and is controlled by a specific application, EV-Powerlogger, written in LabVIEW. On the front panel, the setting parameters include: scan rate (Hz),

number of channels, path name, and so on. While measuring, the data are stored in ASCII-files for easy data processing.

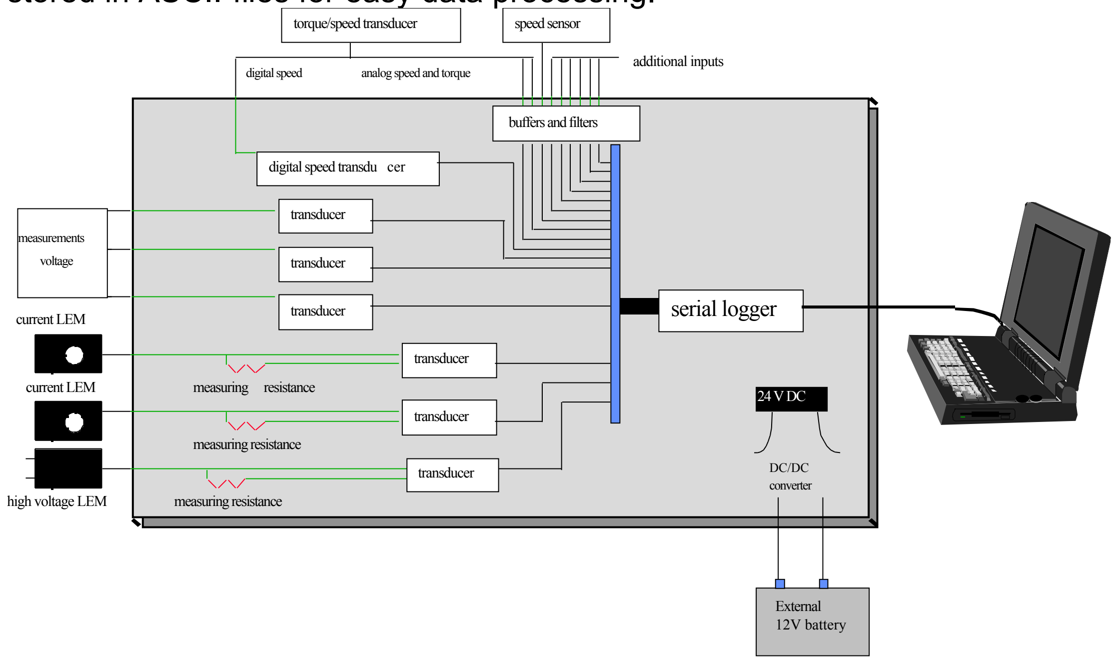

Figure 2 : Principal outline of the measurement system

3.1. Description of the external components

device	measuring range	overall accuracy
Current LEM module LT 1000 SI	0-1500 A	± 0.3 % of nominal current (1000 A)
High voltage LEM module LV 100	0-1200 V	± 0.7 % of nominal voltage (800 V)
Speed sensor DATRON LM-sensor	0.5-400 km/h	± 0.2 %

Table 1 : Sensors in use by the measurement system

Other transducers than those specified in the table can be connected to the measure rack.
The speed sensor is based on a correlation optical method with spatial-frequency filtering and produces an excellent result with very high accuracy. It is easy to mount on the vehicle as can be seen in fig. 3. The 12 V lead-acid battery provides the supply voltage.
A last external device is the Macintosh PowerBook 190cs, which controls the serial logger and stores the measured data in ASCII-files. These files are further treated in a spreadsheet application (Excel)

Figure 3 : The speed measurement system

4. Practical realisation of the tests

The measuring campaign was realised as follows :

- Friday 25/02/2000 : Installation of the equipment in the vehicle
- Monday 28/02/2000 : First day of measuring in Brussels
- Tuesday 29/02/2000 : Second day of measuring in Brussels
- Wednesday 01/03/2000 : Vehicle's transfer from Brussels to Wavre
- Thursday 02/03/2000 : First day of measuring in Wavre
- Friday 03/03/2000 : Second day of measuring in Wavre
- Monday 06/03/2000 : Vehicle's transfer from Wavre to Oostende
- Tuesday 07/03/2000 : First day of measuring in Oostende
- Thursday 09/03/2000 : Second day of measuring in Oostende
- Friday 10/03/2000 : Vehicle's transfer from Oostende to Brussels and removal of the equipment out of the vehicle

5. The postal service in Belgium

5.1. Brussels

The electric vehicles used in Brussels are charged at the post sorting office in the centre of the city. There, secure underground parking with charging facilities is available.

The delivery round, located in the northwest fringe of the city centre, considered in these measurements, starts from here, the load for distribution already inside the vehicle. In this round mainly private customers are served, although some corporate customers are situated in this district. The first time this round is covered the ordinary mail is served; the second time is dedicated to registered delivery.

5.2. Wavre

Also in this municipality the post office is located in the centre and is equipped with parking and charging opportunities.

Also in this place the rounds starts at the post office, but the distribution mainly serves industrial estates. The main purpose is to deliver the daily mail to the industrial clients as quickly as possible, so only a few private customers are served on the first round. The second time the registered delivery in the industrial area is done and a residential street, which is the connection between the industrial zone and the post office, is covered.

5.3. Oostende

In this town the postman equipped with an electric vehicle has to collect the post-boxes, bring their content to the central post office and distribute postbags to the sub-offices.

Figure 4 : The electric vehicle charging facility in Oostende

6. Quantitative analysis

6.1. Instantaneous consumption and characteristics of the rounds

Out of the measuring of currents one can calculate the instantaneous energy consumption or energy consumption in Ampere-hour (Ah) The following tables give an overview of the delivery rounds in the different sites. Those tables represent the arithmetic means, the average of two days.

		Brussel 7:30	Brussel 11:00	Average in Brussels
TIME	total time (hh:mm:ss)	1:32:49	1:11:52	1:22:21
	stop time (hh:mm:ss)	1:02:05	0:46:27	0:54:16
	% stop	66.9%	64.6%	65.9%
	run time (hh:mm:ss)	0:30:44	0:25:25	0:28:05
	% run	33.1%	35.4%	34.1%
DISTANCE	total distance(m)	10734	9441	10088
	# stops	99	41	70
	stops per km	9.2	4.3	6.9
	average interval(m)	108	230	144
SPEED	Commercial speed	6.94	7.88	7.35
	Maximum speed	64.7	60.1	64.7
	running average	20.96	22.29	21.55
CON-SUMPTION	Ah/km out of batteries	2.22	1.96	2.10
	Ah/km regenerated	0.47	0.42	0.45
	Ah/km net	1.75	1.54	1.65
	% recuperation	21.4%	21.5%	21.4%

Table 2 : Results obtained in Brussels

The first round, starting around 7:30, has a length of approximately 10734m, covered in about one hour and a half, only driving for a third of the time. The high percentage of standstill is related to two facts. First, the postman has to distribute in a street with terraced houses where he has to go on foot. The second reason is the distribution in a large apartment block.

Although the number of stops in the second round is reduced to less than the half, the standstill percentage doesn't vary much. In fact, this is quite normal because of the nature of registered mail operation: the receivers in this round have to sign to get their documents. With the knowledge that the apartment building is served also served, it is obvious that standstill time rises enormously. The higher number of stops in the first round can also be attributed to the traffic conditions (morning peak hour).

The higher energy consumption in the first round is directly related to the number of stops, nevertheless the percentage of recuperation stays the same, due to the same nature of route and traffic.

With only 20, 25 kilometres a day and an energy consumption 1.65Ah/km on average it must be possible to run two days on one charge, knowing the content of the battery is 100Ah. This operation is recommended to reduce the memory effect of the batteries. However, personnel may be less tempted to do so, as they will have to exploit the full capacity of the battery (down to 0% state of charge), and may feel less confident to venture out with a partially charged battery.

		Wavre 7:30	Wavre 10:30	Average in Wavre
TIME	total time (hh:mm:ss)	1:37:20	1:54:14	1:45:47
	stop time (hh:mm:ss)	0:33:15	1:10:10	0:51:43
	% stop	34.2%	61.4%	48.9%
	run time (hh:mm:ss)	1:04:05	0:44:04	0:54:05
	% run	65.8%	38.6%	51.1%
DISTANCE	total distance(m)	29227	20038	24633
	# stops	105	115	110
	stops per km	3.6	5.7	4.5
	average interval(m)	278	174	224
SPEED	Commercial speed	18.02	10.52	13.97
	Maximum speed	76.6	71.1	76.6
	running average	27.36	27.28	27.33
CON-SUMPTION	Ah/km out of batteries	1.66	2.00	1.80
	Ah/km regenerated	0.31	0.38	0.34
	Ah/km netto	1.35	1.62	1.46
	% recuperation	18.6%	19.1%	18.8%

Table 3 : Results obtained in Wavre

Here, the number of stops is almost equal in both rounds, whereas the average distance in the second one is much lower, resulting in a smaller average interval between the stops. In relation to Brussels, this interval is very large. As a result of the larger interval, the energy consumption is lower and so is the regeneration, illustrated by the percentage of recuperation. Despite the hilly route in Wavre, energy consumption is lower than in Brussels, which shows that, in this case, the influence of the route characteristics are of higher weight..

Another remarkable aspect is the time distribution. In the first round of the day the vehicle is standing still for only one third, where in the second round stop time and the time when the vehicle is running are reversed. This is due to the larger distances covered in the first round (industrial estate delivery) and the longer stop times connected with the delivery of registered mail.

With an average daily distance of 50 kilometres in postal services, characterised by a higher energy consumption (here : 1.46Ah/km net) in relation to normal traffic (1.28Ah/km in town ; 1.12Ah/km[1] in suburbs), the batteries of this vehicle can be charged every day without any possibility of making them bad conditioned, since the daily discharge is deep enough.

		Oostende 12:10	Oostende 14:00	Oostende 16:30	Oostende 18:30	Average in Oostende
TIME	total time (hh:mm:ss)	1:20:01	0:51:32	1:36:15	0:29:36	1:04:21
	stop time (hh:mm:ss)	0:35:32	0:23:35	0:50:23	0:13:03	0:30:38
	% stop	44.4%	45.8%	52.3%	44.1%	47.6%
	run time (hh:mm:ss)	0:44:29	0:27:57	0:45:52	0:16:33	0:33:43
	% run	55.6%	54.2%	47.7%	55.9%	52.4%
DISTANCE	total distance(m)	18997	13932	18602	6400	14483
	# stops	57	29	59	19	41
	stops per km	3.0	2.0	3.1	3.0	2.8
	average interval(m)	336	489	318	337	356
SPEED	Commercial speed	14.24	16.22	11.60	12.97	13.50
	Maximum speed	72.72	72.44	62.4	65.88	72.72
	running average	25.62	29.91	24.33	23.20	25.77
CON-SUMPTION	Ah/km out of batteries	1.76	1.29	1.83	1.73	1.67
	Ah/km regenerated	0.45	0.40	0.43	0.34	0.42
	Ah/km netto	1.32	0.89	1.40	1.39	1.25
	% recuperation	25.2%	31.2%	23.6%	19.6%	25.1%

Table 4 : Results obtained in Oostende

The different rounds mentioned in the table above vary a lot in distance but the average interval remains almost unchanged. Only the second round has a larger interval. In this round there is a very small energy consumption, which might be related with a driver well acquainted with electric vehicles.

The average stop time is almost 50%, although the number of stops is quite low. This can be easily explained when we consider the operations: collecting mail from postboxes on one hand, and delivery and collection from sub-officeson the other hand. Both operations involve a long stop. The electric vehicle operations in Oostende are completely different from what is done in the other sites (although another electric vehicle in Oostende is used for delivery duties). This results also in the lowest energy consumption, close to what was measured by CITELEC in normal traffic. Also, the flat topography

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[1] In annex one can find the results obtained in a complete test of the Peugeot Partner Electric done by Citelec as well.

and the relatively fluent urban traffic in Oostende contribute to lower consumption values.

The average daily covered distance at this location is around 60 km. With an average consumption of 1.25Ah/km, one can conclude that the batteries are used in a good way.

Figure 5 : Emptying post boxes in Oostende

6.2. Postal delivery

The tables above determine some typical characteristics of postal delivery traffic as measured in Belgium:

- The actual stop time is about 50% of the total mission time.
- The average distances between two stops in these cases (between 150 and 350m) are quite large for postal delivery, due to the specific operation mode, large in relation to the measurements done in Finland for the same project where the average distance was 75 and 141m respectively for Kajaani and Turku. (contrary to operations in Finland, kerbside delivery from the vehicle straight to the mailbox is not performed in Belgium). In addition the average speed when running is around 25 km/h, which is very high, knowing the average urban speed

in Brussels is only 18km/h[1]. The average speed in Wavre is the highest value obtained because it's a poor traffic area.

- Also the commercial (end-to-end) speed is higher (14km/h) than normal in postal use (almost walking speed).
- Energy consumption is considerably more than the value of ordinary traffic.

These are some basic characteristics of postal traffic in the Belgian operation mode. These results will be compared with results from the other cities involved in the E.V.D. Post project, in order to allow characterisation of post delivery cycles in different cities.

6.3. Graphical representation of postal delivery cycle

The following graphs give some examples of postal traffic curves :

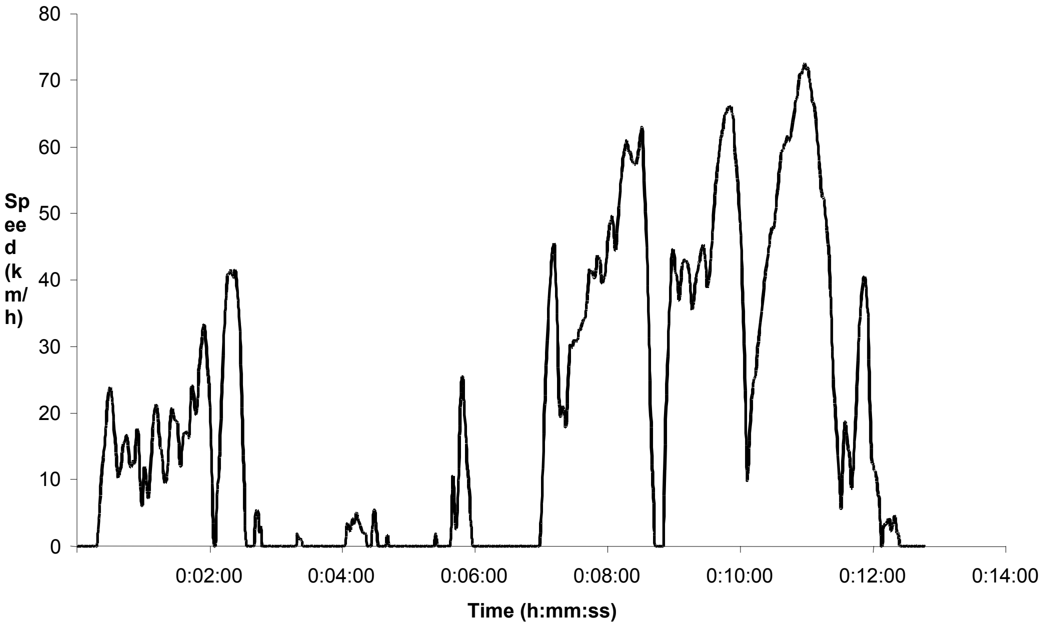

Figure 6 : Typical speed versus time delivery profile in Oostende

The figure above shows an extract of a typical delivery run in Oostende. Within this figure one can see a 2-minute running part, a second part with large stop times, included a stop at one of the post offices and traffic conditions that required standstill of the vehicle (i.e. crossing the street, traffic lights) and a run to the next offices.

The figure below shows a 10-minute extract, recorded in Wavre, in which one can discover the progress between the stops deserved, as well as the

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[1] Test data of the Peugeot Partner Electric in "normal" use.

stoptime between them. It is quite obvious to see the difference between the two situations. Brussels contains both; parts with large runs and large stoptimes alter with parts with short distances and smaller stoptimes.

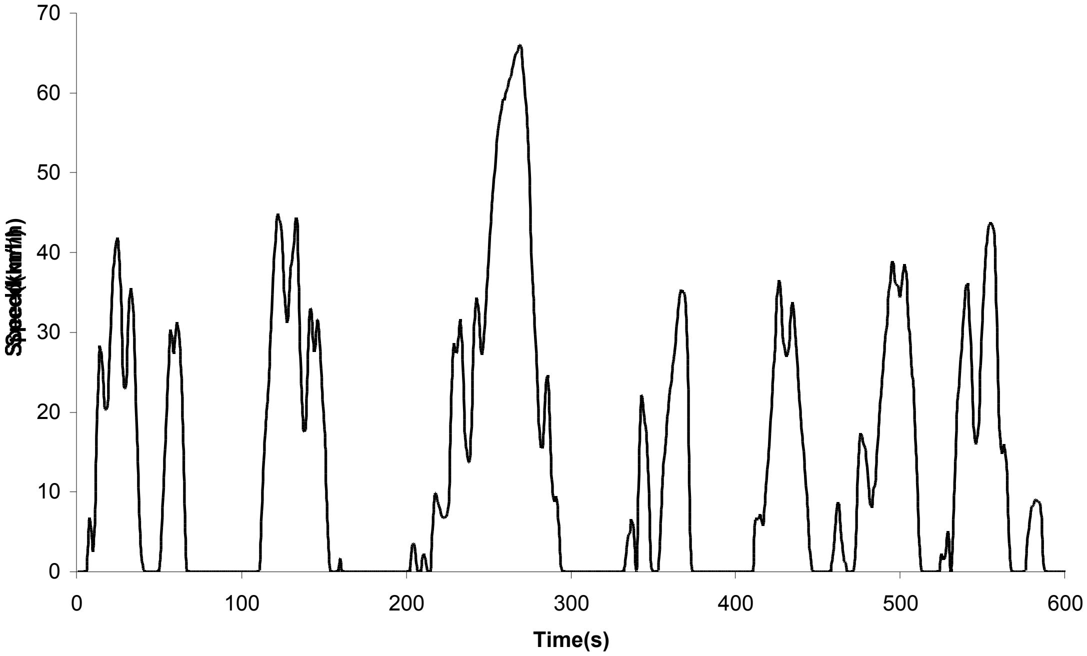

Figure 7 : Typical speed versus time delivery profile in Wavre

The speed can also be plotted against the distance covered; this gives the results of the figure below. This figure gives a better image of the geographical distribution of the stop points (i.e. mailboxes).

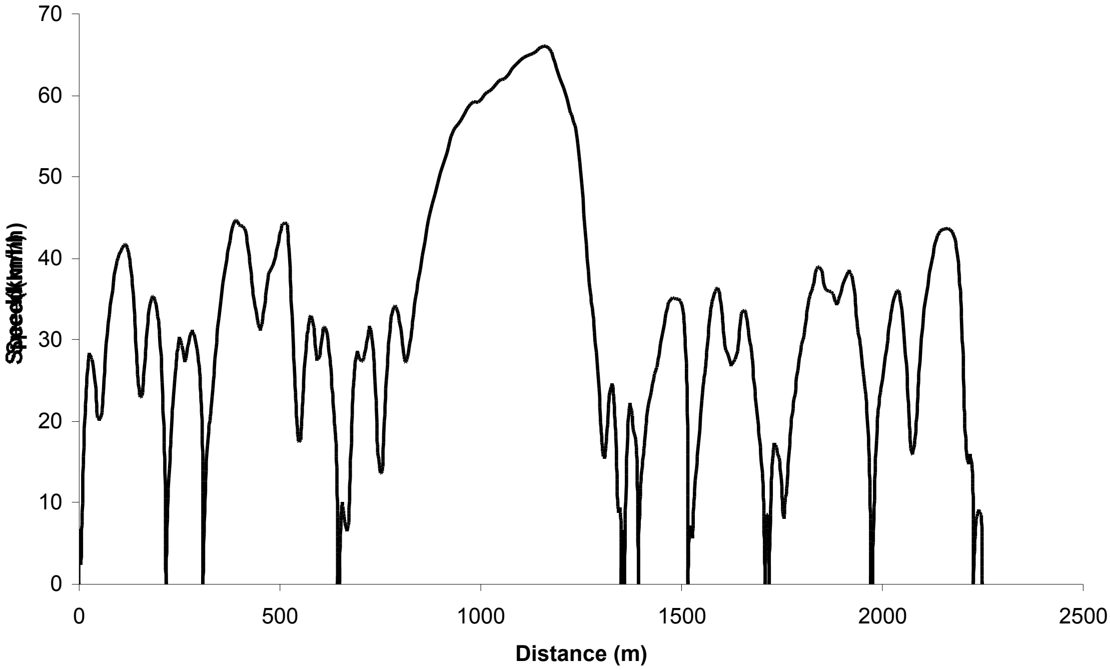

Figure 8 : Typical speed/distance profile in Wavre

6.4. Energy consumption at mains level

The operation costs of the vehicle are function of the energy consumption at the mains when charging the vehicle's batteries.
The average consumption for postal delivery duty during the test was 414 Watt-hours per kilometre. The average weight of the vehicle during the tests can be estimated at 1700 kg, the average specific consumption was 243 Wh/Tkm. These values however were varying according to the covered distances per day:

	km	kwh	Wh/km	Wh/Tkm
Brussels	20.176	9.57	474	279
Wavre	49.266	22.45	456	268
Oostende	57.932	20.7	357	210

Table 5 : Energy consumption

It is clear that the lowest values are obtained with longer trajects. The longer distances being more energy efficient because within deeper depletion of the batteries the gassing phase has a smaller impact on the global result.

How to evaluate this result?

One may recall the tests done by CITELEC on the Peugeot Partner Electric vehicle, which gave a result of 191 Wh/Tkm on average. In this case however, normal road traffic had been considered, and not the postal delivery work, the energy consumption of which is considerably higher in the Brussels and Wavre cases, while the measurements in Oostende gave a result, which is only a little bit higher.

One could take into account the well-known empirical formulas to assess electric vehicle energy consumption (C is the consumption in Wh/Tkm; W the weight in tons):

"Average" value corresponding to today's usual technology:

$$C = 150 + 100/W$$

"Minimal" value, corresponding to state-of-the art technology and an economic driving style:

$$C = 80 + 80/W$$

"Maximal" value, corresponding with a less efficient technology:

$$C = 220 + 120/W$$

For a 1700 kg vehicle, this gives respectively 209, 127 and 291 Wh/Tkm. In fact, these formulas refer to ordinary road use. In this case however, the fact the values are between the value for today's technology and the maximum has nothing to do with efficiency of the technology, but with the operation mode of the vehicle.

Also, it has to be considered that for internal-combustion engined vehicles, the energy consumption during postal distribution service is significantly higher than the standard consumption values, even in city traffic, for that vehicle.

6.5. Range

Even if a full range test has not been performed, forecasts about the range of the vehicle can be taken from the instantaneous energy consumption. Given the average consumption, and given the available capacity of the battery, one can forecast the available range of the vehicle.
The battery has a nominal capacity of 100Ah; when considering, a depth of discharge of 80% (80 Ah), which is the normal recommended practice, one becomes a theoretical range of 49km with the 1,65Ah/km consumption in Brussels postal duty ; 55km with the 1,46Ah/km for the Wavre case ; 64km for the measurements in Oostende. As one can see the range limit is almost reached in Oostende and Wavre and like mentioned above in Brussels two days will be possible.

7. Energy flows in the vehicle

Figure 9 the energy flows in the vehicle during a start-stop cycle.

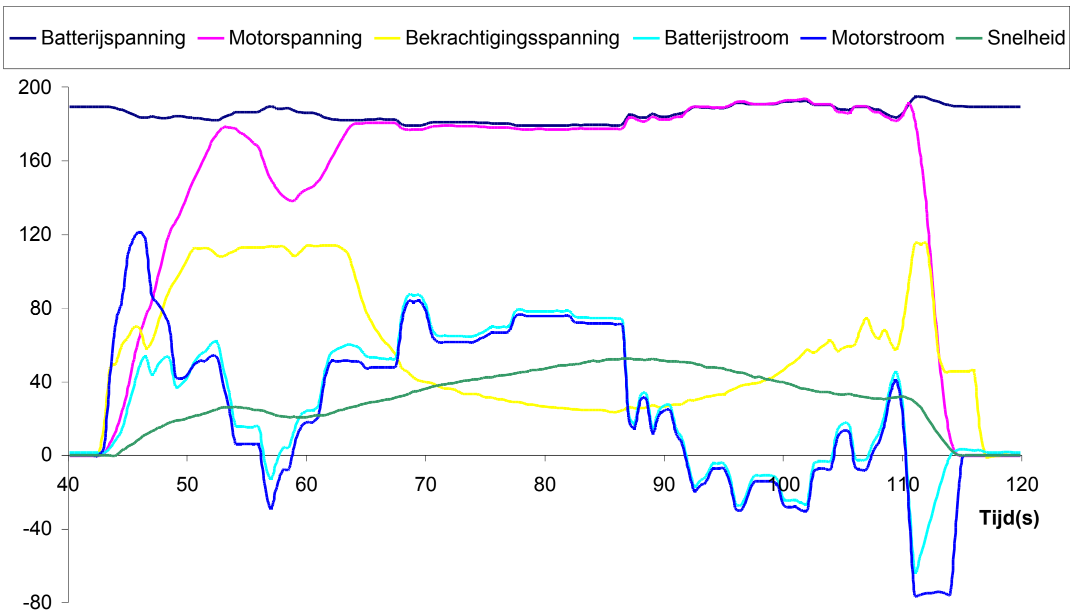

Figure 9 : Current and tension evolution related to speed

- During a first phase of acceleration the speed increases by regulating the motor tension. The motor currents up to 205A (not visible on this graph) resulting in a lower battery tension.
- When the motor tension reaches the level of the battery (a little bit lower because of resistance losses in the battery and in the cables), the motor current touches the battery tension. The difference between the latter ones is the charge current for the auxiliary battery. Acceleration of the vehicle is realised decreasing the exciting tension resulting in a lower motor flux.
- During the first phase of deceleration, motor and battery tension are still equal, the exciting tension increases. The motor tension get higher then the battery tension (cable losses) and the motor current is more negative then the battery current. The difference in power between the recuperated energy at motor level and energy recuperated in the batteries depends on the efficiencies of the chopper and the charger. In fact there is a small current to the auxiliary battery.

8. Charger characteristics

The charge requires the connection of the vehicle to a standard wall socket-outlet delivering 16A at 230V. The charge itself is regulated in an electronic way by the battery charger integrated in the motor control box. The following figure is an example of the charge characteristic :

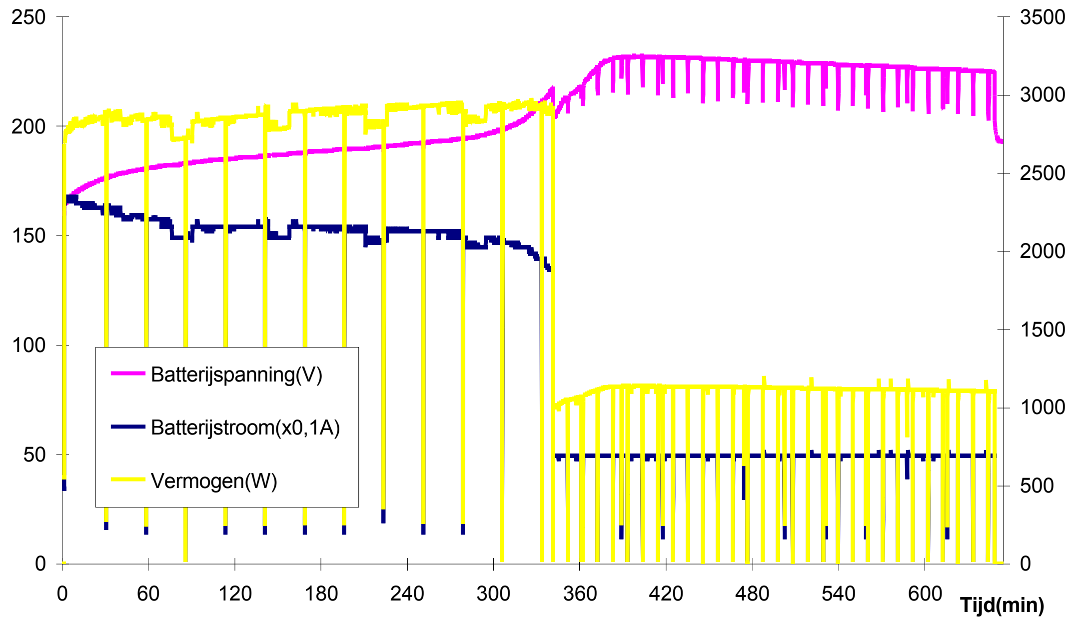

Figure 10 : Charger characteristic

Evaluating this graphic one needs to know the power can be read on the right axis, while the tension and the current are plotted on the left one.

On this graphic two parts can easily be distinguished. During the first phase the load has a constant power base. A second phase uses constant current as base. The changes between both is made by the electronic control box on the moment the tension reaches a pre-set level. It is also clear that during the charge, the charging current is briefly reset to zero at regular intervals. The interval is about 25 minutes within the main charge and only 10 minutes in the final charge.

The charge efficiencies can be obtained by comparing the the kWh, withdrawn from the mains with the energy delivered to the battery. The efficiency of the charger, the ratio between the energy absorbed in the batteries and the energy delivered by the mains, amounts in the case visualised above only 77%. Interrupting the charge after a shorter period of final charge will increase this percentage spectacularly. Within a final charge of 3h20 (above the final charge takes 5h20) the efficiency increased till 86%. This is due to the lower efficiency of the final charge phase; however, this final charge needs to be performed regularly in order to equalise the batteries and to obtain a 100% charge.

The characteristic in figure 10 is recorded when the batteries were completely depleted. It shows that a full main charge and final charge will take 11h. However in postal operation this can never be a problem, as sufficient time for charging is available overnight.

9. Conclusions

The measurements campaign performed in the E.V.D. Post project in Belgium has used the methodology developed during the first campaign in Kajaani (Finland). The comparison for the different sites has highlighted the operational and geographical differences between them. Notwithstanding these differences, there is always a possibility using electric vehicles for postal purposes.
In fact the use of electric vehicles for postal distribution continues to show itself as an ideal opportunity to improve the energetical and environmental characteristics of postal services. The commitment of the Belgian Post towards the electric vehicle is providing a major showcase for other operators. This report brings forward the information about the postal experiences, in the framework of E.V.D. Post project.

10. Acknowledgements

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