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Integrated Evaluation of and Vision on Truck Parking in Flanders, Belgium

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Abstract

The Flemish government launched two related projects in Belgium between 2020 and 2023. First, they rolled out an Intelligent Truck Parking Service (ITPS) along a part of the E17 motorway. Then we supported them to develop a vision on truck parking. The ITPS consisted of an app for the truck drivers, combined with information on variable message signs. We evaluated the ITPS so as to provide answers to the following research questions: (i) which technology best measures parking occupancy? (ii) what is the impact of providing parking occupancy information to the truck driver? (iii) how do users deal with the information (user experience)? In order to evaluate the ITPS, we performed a technical analysis, an impact analysis, a user acceptance analysis, and performed interviews with stakeholders regarding the ecosystem. In addition, the analysis of GPS measurements provided insights into used parking locations and occupancies for developing the vision.

Keywords

Intelligent traffic and mobility management, User behaviour and acceptance

Background and research questions

The Flemish government launched two related projects in Belgium between 2020 and 2023. First, they rolled out an Intelligent Truck Parking Service (ITPS) testing ground along the E17 motorway corridor between the community of Kalken and the French border (see also Figure 1). Then we supported them to develop a vision on truck parking. After some quality improvements, the ITPS was commissioned with the launch of an app, a dynamic DATEX II flow, a web interface, and the visualisation on VMS boards. The goal of the evaluation of the ITPS was to provide answers to the following three research questions:

- **RQ1**: What is the best technology to measure parking occupancy?
- **RQ2**: What is the impact of providing information to the truck driver on the occupancy of the parking?
- **RQ3**: How do users deal with the information (user experience)?

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During our evaluation, we performed a technical analysis, an impact analysis, a user acceptance analysis, and performed interviews with stakeholders regarding the ecosystem. Finally, we analysed GPS measurements to obtain insights into used parking locations and occupancies for developing a vision on truck parking. We will provide details on each of these aspects in the following sections.

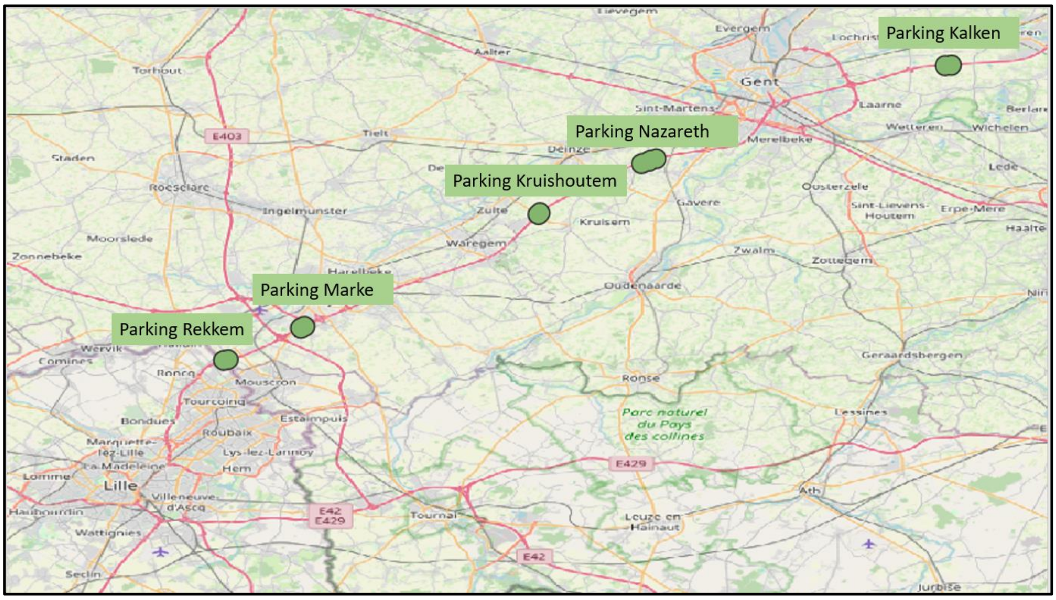

Figure 1 – Geographical overview of the truck parkings along the E17 motorway within the pilot project.

Technical evaluation

For the technical evaluation we first elaborate on the different detections methods, then explain our statistical analysis, followed by the conclusions.

Detection methods

A number of detection methods (not the same everywhere) have been made available at the various rest areas and service zones, including:

- **Loop detectors**: these are inductive counter loops at the motorway entrances and exits. The data from these inductive counter loops was integrated in the test set-up of a parking management system. The data generated by the counter loops was also made available via an open data feed.
- **Barriers and ticket system**: with this system, all traffic can be counted at the entrance and exit of the car park.
- **Parking sensors**: this is an in-situ measurement. Each sensor will be responsible for detecting vehicles in a specific parking space. In this way, these sensors ensure that the occupancy and parking duration of each parking space can be detected.
- **DSRC readers**: via the dedicated short-range communication (DSRC) readers in the truck parkings, all OBUs of (lorries) vehicles that have an (active) DSRC device (e.g. the mandatory OBU of the kilometre charge for trucks) can be detected.
- **Traffic sensors**: vehicle detection sensors were installed at the entrances and exits of a truck parking. From there, they wirelessly forward the data to a collector that forwards the database.

- **OBU data**: all trucks (with a maximum permitted mass of more than 3.5 tons) driving on the Belgian public road must always have an On-Board Unit (OBU) switched on. These OBUs record the distance travelled and, depending on the operator’s chosen technology, the toll is calculated directly in the unit itself (thick OBU) or afterwards in the back office (thin OBU). Traffic information is also collected via a separate channel, which is pseudonymised for privacy reasons. Using this anonymous location data, the number of trucks in each parking lot can be detected. The occupancy data is made available via a web service.

Statistical analysis of the systems’ accuracies

In order to assess the accuracy of the measurement systems, manual counts were performed (which were also initially used to (re)calibrate the systems). During the baseline measurement, one measurement was performed per car park every day, at a specific time, for two weeks between September 15, 2020 and September 28, 2020. This means that a total of 14 measurements were performed per car park over the measurement period. Four measurement moments are possible per day: morning (between 6 am and 12 pm), afternoon (between 12 pm and 6 pm), evening (between 6 pm and midnight) and night (between midnight and 6 am).

For each manual count, we determined the absolute and the percentage error, and the mean absolute percent error (MAPE) in relation to the different measurement methods (in the morning when there are fewer trucks, the absolute error is decisive, at night the percentage error is decisive, and in the afternoon both are important). For each type of count, we also looked at the statistical distribution of the errors, and whether outliers occur.

By visualising the progress of the measurements per method, per parking, we were possible to carry out an initial analysis of the measurement methods. During the morning, a low number of trucks should be in the parking lot, rising during the afternoon and highest during the evening. Note that this applies to working days; this is not known for the weekends, unless an extensive manual counting campaign is carried out. It was also useful to consider the operational capacity, i.e. the number of parking spaces that can be used by trucks at that moment, against the measurements, in order to determine outliers of the data. In this way, some problems with different measurement methods came to light. In our study, we provided a detailed discussion of the measurements that went very well or very badly for each parking lot.

In Table 1 we give an overview of the average absolute error (MAPE) per truck parking determined for each measurement method (note that the OBU system was not able to relay parking occupancy information during the trials).

Table 1 – Average absolute error (MAPE) per truck parking.

MAPE	Loop detectors	Traffic sensors	Parking sensors	DSRC	Barriers and ticket system	OBU
Kalken	668 %			99 %	22 %	N/A
Kruishoutem			103 %		99 %	N/A
Marke	390 %	364 %	17 %	98 %		N/A
Nazareth	70 %	526 %	7 %			N/A
Rekkem	684 %	989 %				N/A

(note that not all detection technologies were available at all parkings)

Since parking sensors and barriers cannot detect incorrectly parked trucks, the maximum occupancy was limited to 100 % with these methods. The incorrectly parked trucks that were counted in the manual counts were therefore not included in this method for the parking lots at Kruishoutem, Marke, and Nazareth for parking sensors, and at Kalken and Kruishoutem for barriers.

Conclusions

The first research question was "*What is the best technology to measure parking occupancy?*" The answer to this appears to be nuanced, whereby the traffic sensors appear to score less well, barriers score quite well, as do parking sensors (if there is no overcrowding). This answer is based on a detailed technical evaluation of measuring methods for the dynamic occupancy rates of truck parkings. We made a comparison between the automatic measurements and the manual counts, in which the absolute values were set off against each other. We then determined for each manual count the absolute and percent error, and the mean absolute percent error (MAPE) with respect to the different measurement methods. For each type of count, we also looked at the statistical distribution of the errors, and whether there were any outliers.

Impact analysis

For the impact analysis we first elaborate on the experimental setup, followed by analyses of the parking occupancies, the variable message signs (VMS), and the parking durations using the trucks' OBU data, after which we provide the conclusions.

Experimental setup

To measure the impact of the different incentives on the occupancy rate, we organised three successive phases:

- **Phase 1**: this is the baseline measurement (there is no app and the VMS boards are not active)
- **Phase 2**: an app is available to the truck drivers (Truckmeister, on Android and iOS)
- **Phase 3**: the app is available and the VMS boards are active

These followed each other chronologically, as can be seen in Table 2.

Table 2 – Chronological overview of the different fases for the impact assessment.

		W38	W39	W40	W41	W42	W43	W44	W45	W46	W47
Fase	Info	14/sep	21/sep	28/sep	5/okt	12/okt	19/okt	26/okt	2/nov	9/nov	16/nov
Fase 1	Nulmeting										
Fase 2	App										
Fase 3	App+VMS										
				(1/10)			*(22/10)*				

For each of these phases, we performed an analysis of the parking occupancies, the impact of the VMS, and the results from the OBU data.

Analysis of parking occupancies

To find out how parking behavior depends on the day of the week, we look at the average parking occupancy across all car parks, broken down by day of the week as shown in the left part of Figure 2. The right part of the figure shows the day profiles per phase.

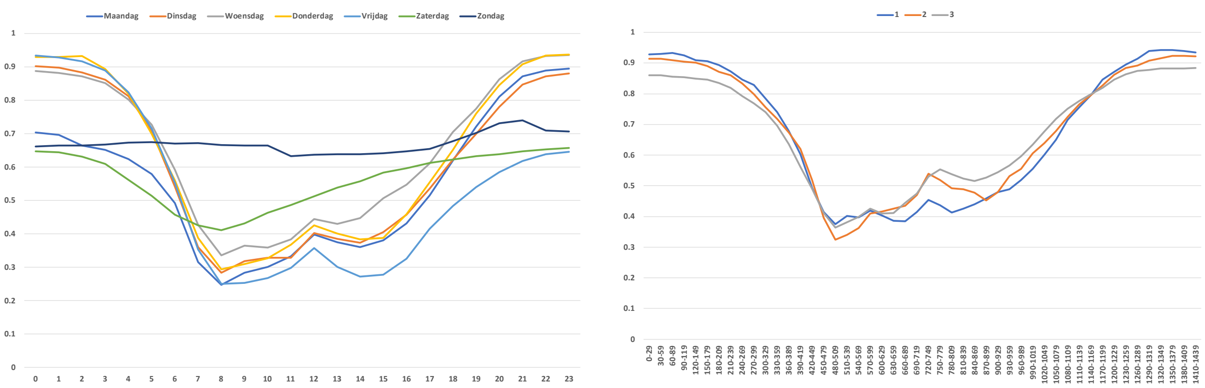

Figure 2 – Left: Average parking occupancy throughout the day per day of the week for all car parks together; right: Day profiles for all car parks together (except Rekkem) separately for each phase.

It is striking that Saturday had a lower average occupancy rate at night and a higher than usual during the day. This difference was even more pronounced on Sundays, where the average occupancy rate was almost constant. This had an effect on Monday, where the average occupancy rate was low at the start, but ended at the same level as the other working days. In addition, the average occupancy rate on Friday evening was also correspondingly lower during the transition to the weekend. On further investigation, these effects occured in all three phases. The foregoing shows that the working days (Monday to Friday) had very similar day profiles. In our further analyses, we therefore worked with day profiles based on these working days and the weekends separately.

Analysis of variable message signs

There were four VMSes available along the motorway corridor, showing both traffic information and parking-related information (in case this was no urgent traffic information needed to be displayed). In our study we carefully analysed the location, type, frequency, and duration of each message displayed during the three experimental phases. Considering the number of parking-related messages per hour of the day for the various VMS signs, we saw an inverse relationship between the showing of parking-related and non-parking-related messages. The latter appeared throughout the day (there is therefore less traffic and incidents at night), while the former appeared earlier in the morning and evening. Our analyses also uncovered that in the majority of cases the duration of a message fell under five minutes. This seemed to be ok if we look at the extent to which the occupancy rate of a parking fluctuated.

It was not possible to find a direct link between the messages on the VMS signs and the parking occupancy. Nevertheless, the VMS boards were the only variable across the three phases, excluding other factors such as seasonal effects and not being able to observe other measures taken or behavioral changes. The activation of the VMS signs in phase 3 may therefore have had a positive effect, with the indication of the current occupancy rate presumably leading to a better distribution in the car parks.

Analysis of parking durations using OBU data

Using the on-board units of individual trucks (which is a different data stream than the one mentioned in Table 1), we were able to analyse the parking durations at the various truck parkings. This OBU data stems from the mandatory kilometre charge in Belgium. Our data samples contained for one part 240 467 722 records in a 18 GiB data file, filled with GPS positions for 6 consecutive days (see also Figure 3), as well as 4 weeks of data totalling over 1 billion records and about 120 GiB. All data was GDRP-compliant pseudo-randomised such that individual identification was no longer possible. After careful filtering of the data (including statistical outlier detection and remediation), we used geofences around the truck parkings' entrances, parking areas, and exits, to detect when trucks were entering and leaving the parkings.

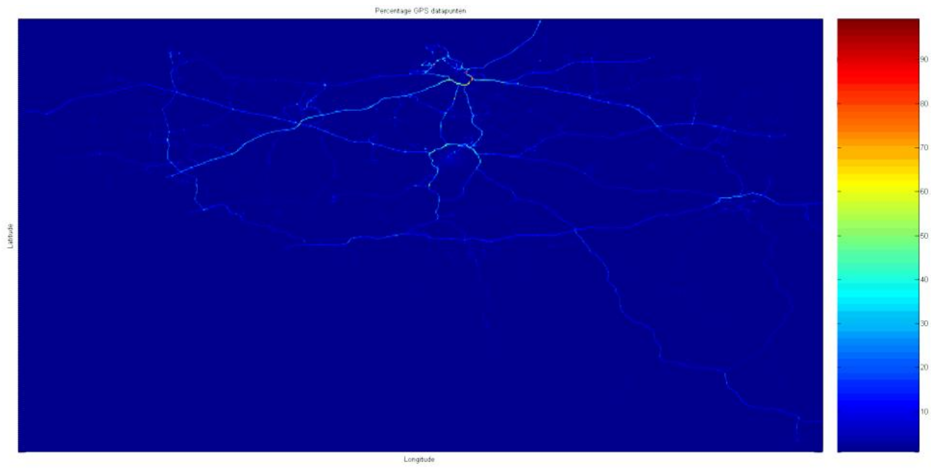

Figure 3 – Overview of the GPS locations of all trucks in Belgium based on their OBU data.

Using the data, we were able to calculate the trucks' parking durations on the parkings in the first pilot study, as shown in the distribution plot in Figure 4. There was a large spread of local maxima. The majority of the trucks appeared to be in the parking for only a very short time (less than 10 minutes), followed by two groups for around 35 and 50 minutes. In this we recognise an interruption of at least 45 minutes after 4.5 hours of driving (driving and rest times regulations), which can be replaced by an interruption of at least 15 minutes, followed by an interruption of at least 30 minutes. The daily rest (> 11 hours), reduced daily rest (> 9 hours), weekly rest (> 45 hours), and reduced weekly rest (> 24 hours) are not visible based on the passages because the of data's pseudo-identification process. These rest periods take place at the first departures (those who were already parked from the previous day and left the car park) and the last arrivals (those who entered a car park but did not leave the same day).

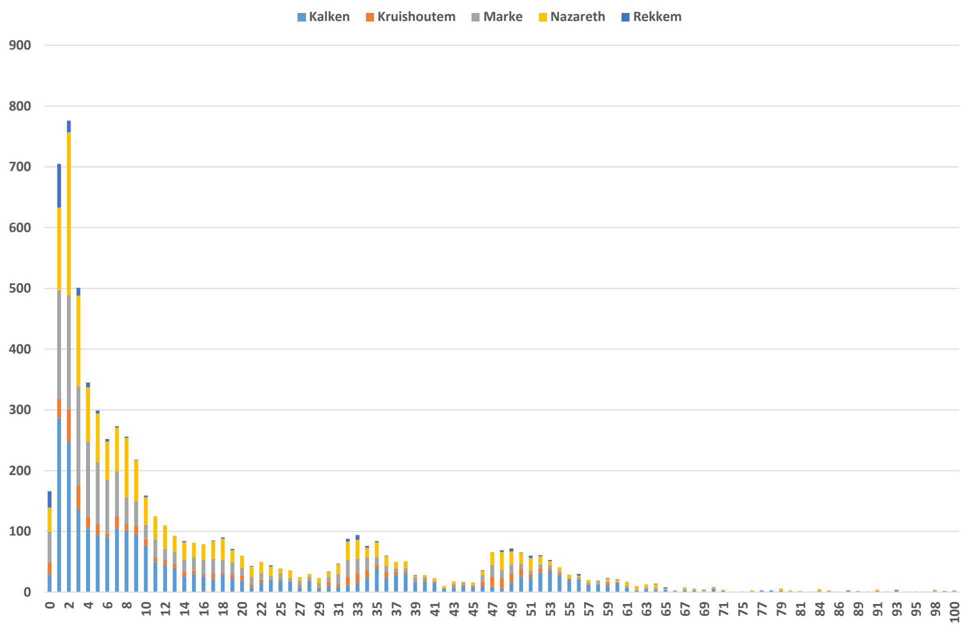

Figure 4 – Distribution of the parking durations (in minutes) of the registered trucks using their OBUs.

In similar spirit we also analysed a much larger data sample (that formed part of a second, follow-up study) that contained four consecutive weeks of data (from 2022). Note that due to the nature of truck traffic and transportation, there were no significant differences observed between different working days in a week, implying that any working day is representative for the entire week. In our study we then analysed all the GPS traces to detect when and where trucks were stopped for longer durations. For this we mapped all GPS points to hubs, private terrains, public parking terrains and service zones, and even map-matched them onto the full Belgian road network. Our analyses gave deep insights into whether or not capacities of motorway parkings were sufficient, and at which locations trucks are typically stopping (both domestic and foreign truck drivers). An example of a motorway parking that does not have enough capacity to serve all truck parking demand in shown in Figure 5, where they start to park on the entrances and exits on the motorway. This information will be used by the Flemish government in order to further define their vision on truck parking and to take appropriate actions.

Figure 5 – Example of trucks parked for longer durations at entrances and exits of motorway parkings.

Conclusions

The most difficult research question to answer was "*What is the impact of providing information to the truck driver on the occupancy of the parking?*" To measure the impact of the different incentives on the occupancy rate, we organised three consecutive experimental phases: phase 1 (two weeks, this is the baseline measurement, there is no app and the variable message signs (VMS) are not active), phase 2 (three weeks, an app is available), and phase 3 (five weeks, the app is available and the VMS boards are active). In general, we can say that, compared to the baseline measurement in phase 1, making the Truckmeister app available in phase 2 had a negligible to nonexistent effect on the parking behaviour of truck drivers (due to the very low penetration rate).

It was not possible to uncover a direct link between the messages on the VMS and the parking occupancy. Nevertheless, the VMS were the only variable across the three phases, excluding other factors such as seasonal effects and we were unable to observe any other measures taken or behavioural changes. The activation of the VMS in phase 3 therefore probably had a positive effect, with the indication of the current occupancy rate probably leading to a better spread over the parkings.

Finally, analyses of the OBU data of the kilometer charge for trucks showed that most trucks that were already parked leave before 7:00, routinely arrive at a parking throughout the day, with a slight dip around 8:00 in the morning. The parking peak is in the morning / morning at the normal passages. The majority of trucks stay in a car park for a very short time (less than 10 minutes), followed by two groups around 35 and 50 minutes. These two local peaks occur around 10:00 – 11:00.

Analysis of user acceptance

For the analysis of user acceptance we will first elaborate on the survey rolled out to the truck drivers, followed by the conclusions.

Surveying truck drivers

We rolled out a survey after the end of phase 3, containing an extensive questionnaire. The survey could not be conducted in the car parks themselves due to the COVID-19 pandemic and the associated measures. As such, we created it digitally. Because the truck drivers had to be reached on the route, the concession holders of the car parks were approached for this, advertisements were posted in specific Facebook groups of truck drivers (both those of the government and others), via LinkedIn posts, and finally it was also distributed among the truck drivers of a specific local distribution company. In addition, QR codes were also made available, which referred to the survey. The survey was available in Dutch, French, English, and German. The survey was closely monitored week after week, with appropriate actions taken to receive statistically significant feedback and a high response rate. In total we had 256 complete (42 %) and 349 (58 %) incomplete answers for a total of 605 together.

Conclusions

Another research question was "*How do users deal with the information (user experience)?*" For this, we rolled out our own survey after phase 3, which contained an extensive questionnaire. Almost all respondents (239 of 256, 93 %) drove on the A10 / E17 towards France, which gave relevant results. There were 164 respondents (69 %) who used the information from the VMS. Almost all (89 %) found the information offered useful to very useful. Most of the respondents (76 %) thought that the information on the VMS was usually correct, and if this was not the case, it turned out that there was no space left while the signs indicated the opposite (just like with the app). In the future, a large proportion of truck drivers (80 %) would find an app useful to very useful, and a smaller proportion (20 %) rather useless. We observed a similar trend for the VMS (81 % useful to very useful, 19 % rather useless).

Interviews with stakeholders

As a final step in our evaluation, we held interviews with nine relevant stakeholders from the ecosystem: transport sector organisations, private concession holders, public stakeholders, service providers, and stakeholders from policy. Through the interview we wanted to gauge the use, the possibilities, and the findings about services that provide information about the occupancy rate. Each interview included the following three main parts that were surveyed from all stakeholders:

- In the first part, we asked about more general aspects of service zones and the extent to which the interviewee or the organisation has knowledge about the services to communicate occupancy rates to truck drivers or others.
- In the second part, we mainly asked how the organisation feels about this service.
- In a final part, we discussed the specific aspects of this service: to what extent is it effective? What impact can it have on the organisation? How do you see the costs and benefits? Etc.

Conclusions

After conducting interviews with the stakeholders, we noted that the problem of overcrowding of parkings and the need for a better spread of use is almost unanimously endorsed. The service provision, as in the pilot project, will certainly make a contribution, but should be seen as part of a more global approach: better legislative framework, enforcement, more parking facilities including (private) facilities that are not located along motorways, etc. A parking policy / vision therefore imposes itself on both a regional and a European level. There is certainly the will of the organisations to contribute to tackle the problem. How far you want to go as an organisation to facilitate this service is closely related to the business potential of the service and what role one should take as a stakeholder (facilitator, data provider, etc.).

Some caveats and recommendations

It is not clear whether VMS or the app can guarantee a better service: VMS appears to be necessary if one gets closer to the car parks. An app allows for more options and can, if necessary, be more complete. The reluctance to an app is more about the use of a mobile phone and road safety. If this service is integrated into the truck itself, the reluctance is less. Providing the service is mainly placed in the hands of the government by some stakeholders, one expects that the government will outline the guidelines and assume responsibility for both the detection facilities and the provision of data.

The first study had a very broad approach, in which a number of aspects were highlighted in great detail. To answer the three research questions, various analyses were performed, experiments were set up, and groups of users were questioned. There are consequently a number of comments with regard to the implementation of the study and the interpretation of the results. Before such a study like this can be started, the technical systems to be considered must already be operating under good conditions. This was not always the case, which meant that certain analyses had to be repeated several times. Various problems occurred during the study, including detection methods that were set over time with different parameters, problems with technical installations, missing measurements, manual counts that were partly incorrect, etc. Further research could be useful, given that a significant number of manual counts are available. This would then make it possible to determine whether data is best fused or not, or recalibrated regularly, and to what extent raw data is suitable for achieving a good fusion. A larger amount of data and a greater mutual comparability of the various locations are strong pluses.
Another caveat to the impact analyses is that more data would in any case lead to more stable results.

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