SUMMARY OF THE p-TEMPS 2 PROJECT

In view of the imminent termination of the p_TEMPS 2 project, it would seem to be the right moment to prepare a document summarising the objectives desired and the results obtained from the project. We should point out that this document does not aim to be exhaustive or exact, but to be simple and schematic. This may mean that in places it is excessively simplified, in order to offer a clear vision at a strategic level of what line Abertis could follow in the future in terms of travel time and of research into operations in general.

This document is structured in two parts:

1. Objectives desired and results obtained in the p_TEMPS 2 project.
2. Main conclusions and methodological assessment.

1. OBJECTIVES DESIRED AND RESULTS OBTAINED IN P_TEMPS 2

1.1. Objectives

The objective of the p_temps project was **to learn to measure travel times on a toll motorway with a closed pay booth**. To achieve this objective, the work was developed following two lines of research:

1. Information provided by the pay booth **tickets**.
2. Information provided by the electromagnetic spiral **detectors**.

In each case, the work consists of two highly differentiated parts:

- **Data processing** that permits the use of the data collected to calculate travel time.
- **Algorithm to calculate** the travel time from a certain kind of data.

In addition, two complementary objectives were considered:

3. **Long-term planning of travel time,** using the historic series of the tickets available.
4. **Merging of data** from tickets and detectors that permits the most to be made of the synergies existing between both sources of data.

1.2. Results

The four objectives desired (listed in the previous part) were successfully fulfilled. The results that have been delivered to Abertis and that support this statement are the following:

Objective 1. Travel time based on tickets

1.1. Algorithms of filtering and toning down the data from the toll booth tickets, eliminating mistaken data, en route stops, motorcycles that skip the congestions, etc. and giving greater reliability to time periods and routes with not much data.
1.2. Algorithms to estimate the travel time based on the tickets, permitting the main road travel time between junctions and the time off the motorway at each junction to be determined. The algorithm limits the time delay to the travel time between consecutive junctions and with regard to other methods to achieve the same objectives, it avoids the installation of OBE readout bridges in main sections. The algorithm is updated every 15 minutes.

Objective 2. Travel time based on detectors

2.1. Analysis of the calibration of the detectors, recommendations for improvement in the fields of data collection from the detectors, validation of the entries and reconstruction of missing data.
2.2. Algorithm of calculated travel time based on the speed measured in the detectors, achieving a toning down of the intrinsic variability of the data every 3 minutes and a fast response in the face of sudden changes in the state of the traffic. The algorithm is updated every 3 minutes.

Objective 3. Long-term planning of travel time

3.1. Planned traffic timed intensity patterns and their confidence interval for any day on the calendar, including working days, public holidays, long holiday weekends, etc.
3.2. Planned travel time patterns for any main trunk section between junctions and for any other route, with their confidence interval for any day on the calendar, including working days, public holidays, long holiday weekends, etc.

Objective 4. Data merging

4.1. Data merge algorithm which, based on the two calculated travel times using the algorithm of the tickets and using the algorithm of the detectors and the respective errors, provides a calculated travel time with an error lower than any of the previous calculations (or, in the worst case, the same).

Each of these results are presented as closed products, programmed in Access or Excel applications, and tested with pilot data provided by Abertis and especially selected for its particular interest in terms of travel time.

2. MAIN CONCLUSIONS AND METHODOLOGICAL ASSESSMENT

Below, we offer the main conclusions concerning the two technologies for obtaining data that permit the calculation of travel time (tickets and detectors) in the form of a comparative table. They include concepts of functioning, precision and reliability of the algorithms, as well as aspects of territorial extension that could help in the decision making.

DETECTOR SYSTEM (SPEED)	TOLL BOOTH TICKET SYSTEM
Information provided	
Main trunk travel time between detectors.	Main trunk travel time between junctions. Time off-road at each junction. Route time for all the routes.
Functioning in free circulation	
Correct functioning that would not involve problems. In addition, under these conditions probably the most suitable dissemination policy would be that of disseminating "free circulation" or free travel time, set and annotated. Considerations in detail: • Travel time slightly slanted downwards, as the detectors are located in privileged points of the toll motorway where the speeds are higher than the average (e.g. far from junctions). • Slight lack of precision in not being able to directly discriminate from the average speed data in the section only for light vehicles.	Correct functioning. Idem as for the detectors. Considerations in detail: • Slight lack of precision due to the lack of data in certain time periods and on specific stretches.

Functioning in the presence of congestion	
Serious lack of precision, in these states of transit in which the information on travel time takes on maximum value. • Generalisation of a one-off measurement throughout a complete stretch. If the queue messes up the detector: the entire stretch is congested; if the queue does not mess up the detector: the entire stretch is free. The reality in many cases would be a weighted average between these situations. • In the specific case of the AP-7 toll motorway between Maçanet and La Roca, with detectors approximately every 5 km, this lack of precision is serious. Clearly, the higher the density of the detectors, the more precise the calculations will be. This simple but expensive solution may not be the only one. • The speed measurement provided by the detectors in a stop & go situation is highly imprecise and very highly slanted, resulting in travel times that are lower than real ones.	Correct functioning, that would provide a sufficiently precise calculated travel time every 15 minutes. Considerations in detail: • It can present more significant lack of precision in times of very sharp change in travel time (e.g. accidents) as, in this case, part of the vehicles in the time period considered could present free travel time and part could be subjected to a very significant delay. • In the event of a total stoppage in the toll motorway, lack of precision due to lack of data.
Reliability of the system	
The detectors are technology that requires calibrating and intense maintenance. They are particularly sensitive to work on the motorway and to faults in the communication. All this leads to a high frequency of faults, that partially deprives them of their data.	The data on the toll booth tickets, as it is centralised in the junctions, depends on the operative functioning of the toll motorway and on the data collection technology itself, meaning it is data that is very robust and reliable.
As off-line information (monitoring the travel time *a posteriori*)	
Very little precision in the case of a congested state of traffic.	Correct, precise functioning in all the states of transit.

<table>
<tr><th colspan="2">Dissemination of the information in real time to vehicles entering the toll motorway.</th></tr>
<tr><td>Slight lack of time synchronisation, as the update time is reduced (3 minutes) and does not need the vehicle to have completed the trip to count its travel time.</td><td>Significant lack of time synchronisation.
• Information that is "out of date" is provided, a time that is the same as the travel time between junctions.
• In situations with sudden changes in travel times, this lack of synchronisation can be critical, as the travel time is long and in a few minutes the conditions can undergo a great change.
• The updating every 15 minutes adds lack of time synchronisation to the information to be disseminated.</td></tr>
<tr><th colspan="2">Detection of incidents that cause a variation in the travel time</th></tr>
<tr><td>Reliable detection of incidents on the main trunk of the toll motorway

The delay in detection can be considerable despite the immediate nature of the data registered by the detector (note that the queue must mess up the detector); see the following point for a more detailed explanation.</td><td>Reliable detection of incidents of the main trunk of the toll motorway or on the branch roads between the junctions and the toll booths.

If the incident causes a sudden change in the travel time of all vehicles, the delay in the detection can be considerable (note that the vehicle must have left to be able to obtain the data).</td></tr>
<tr><th colspan="2">Joint use / Merging data</th></tr>
<tr><td colspan="2">The current configuration of the monitoring of the toll motorway does not allow the maximum added value to be extracted from it.

The schema for merging data is ideal: one of the technologies provides precision and the other immediate data. The problem is that the lack of travel time precision based on the data from the detectors in the case of congested circulation means that the immediate nature of the information is lost. In other words, a detector detects a queue immediately, as long as the queue messes up the detector. The current configuration of monitoring with detectors every 5 km means that delays (the time that the queue takes to grow between detectors) in the information is, in most cases, similar to the information on the tickets. In this situation, the merging of precise data, even with a lack of time synchronisation (tickets) with highly imprecise data and also lack of time synchronisation (detectors), means that the improvement obtained is imperceptible in most cases. The increase in added value provided by the merging of data would increase the precision/immediate nature of travel time calculations provided by the detectors.
Despite not taking full advantage of the benefits of data merging, we should not underestimate the improvements it offers, such as its operational robust nature, as one sensor can provide information while others are non-operational or only partially operational. This is also translated into an extension of time cover and the extension of spatial cover, by using different sensors distributed in different ways in the space.</td></tr>
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Extension to other stretches of the concession	
The extension of the algorithm to other stretches of the concession requires the installation of electromagnetic spiral detectors with high densities. The optimum density will depend on the precision one wants to obtain in the results. The density would not have to be even along all the stretches of the toll motorway, and would depend on the objectives (monitoring travel time in recurrent congestion or monitoring non-recurrent congestion and detection of accidents).	The extension to other stretches of the concession with closed toll booths is direct, without the need for additional monitoring infrastructures. In the case of toll motorways with open-style toll booths, we will need to determine whether obtaining travel times between main trunk toll booths is sufficient or whether the main trunk OBE detector arches provide a sufficient sample of vehicles. Whatever, in this situation, the algorithm of tickets loses its immediate nature for information in real time (as only long routes are available in the calculation of travel times). This means that in relative terms, the immediate nature of the information provided by the detectors (even installed every 5 km) improves, and therefore the added value provided by the merging of data is also greater.

It should be mentioned that the previous comparative table was made taking into account the work developed within the context of the p_TEMPS 2 project. We have been informed that Abertis is currently using an alternative travel time algorithm, based on the speed information provided by the spiral detectors, developed by SANEF, one of the group's subsidiary companies. Despite not knowing the details of the algorithm introduced, it is believed that it is in a position to confirm that the results of this algorithm do not, in any case, solve the overall problems presented in the comparative table.

Conclusions.

In the comparative table presented, in which the main conclusions referring to the two methodologies of obtaining the travel times obtained in the p_TEMPS 2 project are reflected, it is shown that at the present point of development of the research, the information provided by the toll booth tickets is much more valuable than that provided by the spiral detectors in the objective of calculating travel times. In addition, the marginal information provided by the detectors will be reduced in most cases (apart from the case of a failure of the ticket data system or very particular situations with incidents on the toll motorway).

Nevertheless, we are convinced that the potential of the electromagnetic spiral detectors is great, also in terms of travel times, and can offer more. However, this requires additional research and most probably modifications in the structure of the monitoring with detectors, that will not necessarily require great changes or great investments. It is possible that small modifications could produce great improvements.

As you can see from this document, the p_TEMPS 2 project has allowed us to make great advances in the calculation of travel times on a toll motorway using data from the toll booth tickets and data from the spiral detectors.

In addition, the project, as a collateral result of the work with these two kinds of data, has provided a joint vision of the enormous potential of these sources of information to improve the operations that are carried out on the toll motorway and the information that can be obtained from it.

In this sense, the data from the tickets is privileged, as it provides, in real time, an origin-destination matrix that includes the travel time. This valuable information, with immense potential, is practically impossible to measure and even to calculate in other transport networks. The electromagnetic spiral detectors offer a different vision and are able to measure microscopic variables of the traffic, such as the distance between vehicles, which are key variables when modelling the flow of traffic. This microscopic vision of the detectors has been enormously boosted with the new functionality of recording vehicles at an individual level that is incorporated in the Abertis detectors. This information is essential in planning, for example, the evolution of the state of the traffic in the case of an incident on the toll motorway.