Dynamic Speed Control in the metropolitan area of Barcelona

Final Version

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REPORT TEMPLATE

Project Reference (From EasyWay Work plan):

ES2-04

Project Name:

Dynamic Speed Control in the metropolitan area of Barcelona

EasyWay Region:

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1. Key Evaluation Results

This section should present a brief summary of the key results related to the EasyWay objectives and any other key results.

The key evaluation results after application of Dynamic Speed Control in the metropolitan area of Barcelona are briefly summarized in next paragraphs. It corresponds to the first deployment on C-32 and C-32 highways in 2009. It has been implemented a second phase on AP-7, AP-2 and B-23 highways, but evaluations are being carried out now.

1.1. Impact on Traffic Flow

The Dynamic Speed Control project in the metropolitan area of Barcelona has improved the main parameters of traffic flow. These are: improvement of travel times, less congestion (reduction in length and duration of congestion), homogenization of speeds, decrease of number of “stops & go”, improvement of the driver’s comfort, increase of the capacity of the infrastructure and improvement in the level of service.

1.2. Impact on Safety

The impact of the project on road safety results in an important reduction of accidents, casualties with seriously injured people, and injured.

1.3. Impact on Environment

The Dynamic Speed Control in the metropolitan area of Barcelona has reduced air pollutant emissions. Particularly, this environmental evaluation has focused on CO₂, NOₓ and PM₁₀ emissions.
2. Description of the Problem

On July 10th 2007, the Catalan Government passed an action plan in order to improve air quality, in which 73 measures were taken into account. 14 of them dealt with road transport. One of the 14 measures was to fix the maximum speed limit to 80km/h in part of the metropolitan area of Barcelona (2008). From January 2009 onwards, the Catalan traffic authority sought to manage the maximum speed limit of the main metropolitan roads, according to the pollution levels and traffic conditions.

For this reason, the Catalan traffic authority decided to carry out two dynamic speed control projects in this metropolitan area. The main goals were the following:

a) To improve traffic management
b) To improve air quality
c) To improve road safety

2.1. Site

We shall distinguish three scenarios within the project:

1) Prior to 2007, any traffic management measures which had been taken to reduce congestion and pollution and to improve safety.
2) In the first stage (2007-08) two areas have were defined: the southern area, which is the area where the pollution levels were highest, and the northern area surrounding Barcelona city. There were maximum speed limits in both sections: it was mandatory to drive no higher than 80 kilometres per hour for the former, and it was recommended no higher than 90 kilometres per hour for the latter.

3) In a second stage from 2009, the dynamic speed control system was implemented on the C-31 and C-32 highways, in the southern area, near Barcelona Airport; it will be extended to the whole network in the following years, progressively. There are two main aims: to reduce pollution levels so as to get to acceptable levels of clean air and noise and to manage traffic congestion, also improving road safety conditions.
2.2. Issues Addressed

The project mainly aims to manage traffic in a concrete zone of the metropolitan area of Barcelona, optimising the speeds of the vehicles in order to reduce the worst instances of congestion and to improve the traffic flow. It also includes enforcement with speed cameras adapting to speed limits on each stretch and time.

Secondarily, weather and pollution measures are taken by environmental stations, in order to know the emissions of traffic in the areas of the project and the relationships of all the variables involved. ITS equipment for each of these goals has been implemented.
3. Description of the ITS Project

3.1. Service Area

For the present project, the key working areas are Traveller Information Services, Traffic Management Services and ICT Infrastructure.

3.2. Key Words

Key words of this project are:
- Traveller Information Services
- Traffic Management Services
- ICT Infrastructure
- Variable Message Signs
- Variable Speed Limits
- Traffic Monitoring
- Speed Control using ANPR
- Control Centres
- Automatic Incident Detection
- Use of CCTV
- Enforcement

3.3. Objectives

For the present project the objectives are the following:

- Information about the mobility process on the road: License Plate Recognition to calculate Travel Time, and Data Capture Stations to obtain intensity and speed data.
- Enforcement by installing speed cameras whose speed limit threshold is synchronised with the Dynamic Speed control.
- Automatic Incident Detection by using a specific system for that purpose.
- Information capture about weather and pollution conditions by installing 2 weather and pollution measure stations.
- Traffic control and safety by installing television cameras (CCTV).

3.4. Systems and Technologies Applied

The components needed to meet the objective suggested are as follows:

- Universal Remote Stations (URS)
- Signalling Gantry
- Closed-Circuit Television (CCTV)
- Automatic Incident Detection System
- License Plate Recognition Cameras
- Pollution and Weather Measurement Stations
• Data Capture Stations
• Variable Message Signs (VMS)
• Enforcement with Speed Cameras
• Communications Systems
• Management Centre

3.5. Costs

No information currently available on this question. It will be provided in a later version of the report.

3.6. Status of the Project

The project has been operating on the C-31 and C-32 highways since 2009. The Catalan traffic management authority, Servei Català de Trànsit, has extended this traffic management system to AP-7, AP-2 and B-23 highways, since January 2012. It is planned to expand the project to other areas of the metropolitan area of Barcelona in the next years. Specifically it will be implemented on the B-20 and C-32 in the northern area of the metropolitan region, and on the C-16 highway.
4. Evaluation Planned

4.1. Timing and Type of Evaluation

The Catalan traffic authorities carried out in 2009 an evaluation of the Dynamic Speed Control project after its implementation. Also, they designed in 2009 a simulation of the project.

4.2. Objectives for the Evaluation

This evaluation aimed to analyse the results in daily traffic of the implementation of the Dynamic Speed Control in terms of:

- Traffic flow:
  - Comparison of journey times between different situations, with and without dynamic speed management.
  - Study of the length and duration of congestion through the congestion factor analysis.
  - Number of “stops & go” by using floating car data.
  - By using micro simulation tools.

- Pollution (emissions):
  - Analysis of CO₂, PM₁₀ and NOₓ pollutants emissions and relationship between their total costs and speed.

- Road safety:
  - Comparison of accidents, casualties, seriously injured and injured for the period of 2007-2008-2009, on the 80 km/h zone and dynamic speed control roads.

4.3. Research Questions

No information currently available on this question.

4.4. Study Area for the Evaluation

The study area of the evaluation was centred the C-31 and C-31 highways where the project is implemented and all the ITS equipment is installed. Also the B-23 and A-2 highways took the whole 80 speed limit area as reference roads which include the previous roads mentioned.
The following graph shows C-31 and C-32 highways and the ITS services where data are collected and project has been evaluated.

<table>
<thead>
<tr>
<th>Service</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollution and weather measurement station</td>
<td><img src="image1" alt="Image" /></td>
</tr>
<tr>
<td>License plate recognition cameras</td>
<td><img src="image2" alt="Image" /></td>
</tr>
<tr>
<td>Data capture stations</td>
<td><img src="image3" alt="Image" /></td>
</tr>
<tr>
<td>Signalling gantries</td>
<td><img src="image4" alt="Image" /></td>
</tr>
<tr>
<td>CCTV cameras</td>
<td><img src="image5" alt="Image" /></td>
</tr>
<tr>
<td>Variable Message Signs</td>
<td><img src="image6" alt="Image" /></td>
</tr>
<tr>
<td>Speed cameras</td>
<td><img src="image7" alt="Image" /></td>
</tr>
</tbody>
</table>
The next image shows the videowall at the Traffic Management Centre (CIVICAT) in Barcelona which displays in real-time the dynamic speed control system. It shows the current average speed measured by the Data Collection Stations and the current speed limitation adopted in each stretch.

4.5. Expected Impacts

The expected impacts before the implementation of the project were related to:

- Traffic flow: improvements in journey times, the length and duration of congestion, reduction of number of “stops & go” and its duration and speed homogenisation.
- Pollution: reduction in pollutant emissions and fuel consumption.
- Road safety: reduction in the number of casualties seriously injured and injured.

All these expected impacts have been identified and assessed in the evaluation and all of them are related to EasyWay objectives.
4.6. Expected Methods

The procedures that have been used and/or will be used are the following:

<table>
<thead>
<tr>
<th>FORESEEN EVALUATION METHODS</th>
</tr>
</thead>
</table>
| **Indicators**              | • Traffic flow parameters: journey times, congestion parameters, stops & go, speed vehicles.  
|                             | • Pollution: pollutant emissions and fuel consumption.  
|                             | • Road safety: number of casualties and injured. |
| **Approach**                | Before and after surveys  
|                             | Simulation |
| **Scope**                   | Influence area of the ITS equipment. |
| **Expected performance**    | Although originally the project was part of a range of measures to reduce pollution, later there were expected relevant improvements in traffic flow mainly. Also improvements in road safety. |
| **Technical consultancy for specifications / provisions** | Catalan traffic authority members visited the main implementations in this area in Europe, e.g. the Mestre Beltway in Italy. |
| **Data collection**         | Traffic flow parameters are taken by the data capture stations and enforcement carried out by the speed cameras. Weather and pollution data are taken by the environmental stations. Also, accident data is provided by the Traffic Police. |
| **Data selection**          | All the data available is selected. |
| **Analytical techniques used** | Congestion and pollution algorithms were designed to optimize the speed in order to achieve the objectives.  
|                             | Also micro-simulation software |
5. The Impact of the Project - Results

5.1. Technical Performance

The dynamic speed control system calculates the optimum speed to be displayed in the different signalling gantries installed on the roads. The system receives data from the traffic data stations (i.e. intensity, average speed, average occupancy and classification of vehicles by speed and length) and runs two algorithms: the congestion one and the pollution one in order to obtain the speed proposed by each algorithm on each road stretch.

There is enforcement of dynamic speed limits: the system synchronises speed cameras and dynamic speed limits on gantries. There is a time lap when the speed limit changes in order to be sure that drivers are aware of the new limitation.

**Congestion algorithm**

The congestion algorithm has as main purpose to modify the maximum speed of the road before the point of congestion so as to achieve a harmonizing effect of speeds, reduce the number of stops and starts and improve the overall driving. This algorithm is activated at peak traffic conditions. Thus, the algorithm analyzes the abrupt decreases of speed and reduces the speed upstream of these decreases in order to harmonize the traffic flow and reduce the number of stops and starts and sudden changes of speed.

**Pollution algorithm**

There is also a pollution algorithm which aims to modify the maximum speed limits in order to minimize the emission of pollutant agents such as NO\textsubscript{x} (nitrogen oxides) and PM10 (particulate matter). In principle, this algorithm only works outside the periods of congestion, since the congestion algorithm prevails over the latter. Therefore, the congestion algorithm proposes maximum speeds in peak hours (low speed) and the pollution algorithm does it in the remaining daylight hours.

The pollution algorithm calculates for each measurement section the speed which provides a lower emission factor, based on the classification of vehicles by speed and length and the speed at that moment indicated on the gantries. From these data the algorithm calculates the emission factor of NO\textsubscript{x} and PM10, and the total emission factor for the speed indicated at the time of calculation. Once the system has the current emission factor, then it calculates the emission factors assuming that the speed is 10 km/h higher and assuming that the speed is 10 km/h lower.

The change of speed due to pollution occurs when the new speed represents an increase of more than 10 \% compared to the factor calculated with the current speed for three consecutive integration intervals. Thus, the system avoids frequent changes for slightly substantial improvements. So far, the pollution algorithm has been operating but the Catalanian Traffic Service have not taken any traffic management decisions, as they are still making functioning check-ups and evaluation of results.
Next figure shows how the congestion and the pollution algorithms work, based on the registered speeds.

\[\text{Speed}=f(\text{congestion}) \rightarrow \text{pollution decrease}\]

The congestion algorithm should allow speed variation and anticipate its sudden drops. A proposal of anticipation to these sudden drops could be as follows:
5.2. Results

- Measurement of the three main indicators: congestion, safety environment
- Results from questionnaires, models etc
- Comparison with reference case and expected performance

5.3. Reliability of Results

- Sample and measurement details
- Statistical significance of results and accuracy of model simulation
- Sources of bias in results

5.4. Research Questions Answered

With reference to the research questions set out before the evaluation started (summarised in Section 4.3), describe how the evaluation provided answers to the questions posed.

5.5. Overall Assessment

The main results of the overall assessment are summarized below:

5.5.1. SAFETY

The next image shows a comparison in terms of road safety for the January-October period of 2007-2008-2009, on the 80 km/h zone and on the Dynamic Speed Control roads.

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>552</td>
<td>423</td>
<td>352</td>
</tr>
<tr>
<td>Casualties+ seriously injured</td>
<td>61</td>
<td>28</td>
<td>35</td>
</tr>
<tr>
<td>Injured</td>
<td>708</td>
<td>532</td>
<td>436</td>
</tr>
<tr>
<td>Variation</td>
<td>-23.4%</td>
<td>-25%</td>
<td>-21%</td>
</tr>
<tr>
<td>DSC (C-31 C-32)</td>
<td>190</td>
<td>123</td>
<td>111</td>
</tr>
<tr>
<td>Casualties+ seriously injured</td>
<td>29</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Injured</td>
<td>241</td>
<td>144</td>
<td>143</td>
</tr>
<tr>
<td>Variation</td>
<td>-35.3%</td>
<td>-40.2%</td>
<td>-64.2%</td>
</tr>
</tbody>
</table>

Note: all data for January-October period

There is a clear positive evolution of road safety parameters from 2007 when any specific speed regulation measure was implemented, to 2008 (80 km/h restriction was mandatory) and to 2009 (dynamic speed control was deployed).

The reduction of all the parameters about road safety has been more important on the Dynamic Speed Control zone (C-31 and C-32 roads).
5.5.2. EFFICIENCY

The efficiency of this traffic management measure has been analyzed evaluating its impacts on the traffic flow. Some fluidity indicators have been studied and the results for each of them are the following:

a) Travel times

A comparison of the minimum and maximum travel times for the peak hour period 6:00-11:00 am, between 2007, 2008 and 2009, was performed. There is a smaller difference in travel times with Dynamic Speed Control (2009) between the maximum and minimum values than in previous periods (2008, fixed 80 km/h or 2007, any variable speed regulation).

Comparing average travel times every 15 minutes from January to June, for three scenarios 2007, 2008 and 2009, from Tuesday to Thursday, as shown in the figure:

The average of travel time on 2008 (for the 7:15 to 9:15 period) has improved 72 seconds regarding to 2007. But on 2009 it has increased 34 seconds regarding 2008. However, we shall take into account the differences on demand: the demand on peak hours is higher than 24 h demand (2009 vs 2008-2007).

b) Length and duration of congestions
This parameters are studied by an indicator called ‘Congestion Factor’, obtained multiplying the average length of the congestion by its duration, on C31 and C32 roads. Next figure compare this indicator for all the periods, 2007, 2008 and 2009:

The congestion factor in 2008 (fixed 80 km/h speed limit; brown line in graph) is clearly better than the congestion factor in 2007 (no actions; green line in graph). From January to April 2009 (DSC; blue line in graph), 55 % of values of congestion factor are below than the 2008 ones. It should be taken into account the consideration about demand.

c) Number of “stops & go”

The number of stops & go has been evaluated by using floating car data on C32 road, only for the peak hours (from 7:00 to 11:00 am). There was 50 % of trips without any stop in 2008, while this percentage increased to 67 % in 2009. So, it represents an improvement of 33 % in the number of stops & go from 2008 to 2009.

Conclusions:

The reduction to 80 km/h in the zone 1 has many positive outcomes: less congestion, reduced journey times during rush hour, higher throughput. Obviously, travel times have increased under a free flow scenario.

The evolution from fixed 80 km/h restriction to Dynamic Speed Control gets smaller improvements:

- Depending on traffic conditions (scenarios), travel times increases during rush hours, and also under free flow scenario.

- The number of “stop & go” decreases, which improves the driver’s comfort feeling.

- An important problem is to compare traffic parameters under different demands. For these reason, the Catalonian traffic authorities are carrying out micro simulation analysis.

- It would be wise to consider complementary measures, such ramp metering or hard shoulder running.
5.5.3. Environment

The environmental evaluation has focused in the analysis of CO$_2$, NO$_x$, and PM$_{10}$ emissions comparing different scenarios. For a given traffic composition in the metropolitan area of Barcelona, we can make a graph with the total costs of these pollutants versus speed.

In 2008, the reduction from 120 to 80 km/h represents a big improvement. In 2009, with the Dynamic Speed Control operating on C-31 and C-32 roads, the algorithm is working between 40 and 80 km/h, near the minimum area. It tries to reduce the number of “stops & go” moving dots from the red area to the green.

The reduction to 80 km/h in zone 1 of the metropolitan area of Barcelona caused a decrease of 10% in PM$_{10}$ and NO$_x$ during the first six months of 2008. For the same period of 2009, the decrease was about 13%, but there was 6.8% less demand of traffic.

The evolution from 80 km/h to DSC on the C31 and C32 roads didn’t lead to a relevant improvement on emissions. Servei Català de Trànsit (SCT) is studying carefully the improvements on emissions due to reduction in the number of “stops & go” during rush hours, in the DSC zone.
Annex 1: Technical Annex

Selected Indicators

Wherever possible standard indicators should be adopted for the evaluation of project impacts, related to EasyWay objectives. Guidance on appropriate indicators is included in the EEG’s ‘Euro-Regional Project Evaluation Guidelines' available via the EEG’s website (http://www.easyway-its.eu).

Other Technical Aspects e.g. Modelling

The Servei Català de Trànsit commissioned to an external traffic engineering consulting the making of a simulation of the project, before its deployment. This consulting simulated in a stretch of the roads in which the system had been implemented some traffic parameters and obtained good results. Next figures show some issues of this simulation:

Simulation of travel times (blue line); red and green lines represent the maximum and minimum travel times obtained from real flow data.
Simulation of comparison between travel times before implementing DSC, with fixed 80 km/h restriction in 2008, and after its deployment in 2009 (Variable).

Simulation of comparison between number of “stops & go”, between the same scenarios.
Simulation of speed diagram between both scenarios. It shows the anticipation of speeds, and thus the homogenization of flow.

Simulation of flows with and without DSC, showing speeds. There is a clear difference in speeds and congestions comparing both scenarios. In both figures, the line up represents the application of DSC, while the line down represents any specific speed restriction.