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COMPETITIVE AND SUSTAINABLE GROWTH
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PROGRAMMES

MIRACLES Project GRD1 – 2001 – 40047

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MULTI INITIATIVE
FOR RATIONALISED
ACCESSIBILITY
AND CLEAN LIVEABLE
ENVIRONMENTS

Deliverable D 4.2

REPORT ON EVALUATION RESULTS

Annex 3 – 2nd Implementation Report for Barcelona

Version N°4.0
31st March 2006

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MIRACLES DELIVERABLE n°4.2

Annex 3 – 2nd Implementation Report for Barcelona

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1. Introduction

This document is Annex 3 to D4.2 and also forms the MIRACLES deliverable "2nd Implementation Report for Barcelona". The Annex is a compilation of the detailed Measure-Level templates (MLTs) produced for Barcelona as part of the evaluation process within MIRACLES. See the main body of the D4.2 deliverable for a summary and interpretation of the template results within this annex.

For the Barcelona site, there were 5 individual Measures in all, each reported within a separate MLT. Within this document, each chapter corresponds to a MLT.

2. Measure 5.1

MEASURE-LEVEL RESULTS	
Measure number and title: **WP5 Access control**	**Project: MIRACLES** **Site: Barcelona**

The Measure – what is it about?

M1: Measure objectives

Barcelona Municipality seeks to reduce the flow of vehicles passing along the Rambla, including motorised two-wheelers, and thus to improve the pedestrian amenity of this world-famous promenade.

The aim is to control the time, speed and type of vehicle that travels the section from Pg. Colom to Pça Catalunya, using a system of cameras to ensure an efficient enforcement. The success of this scheme is expected to determine whether cameras can replace existing control points using retractable bollard and thus reduce maintenance costs.

M2: Description of the measure

Some 11,600 vehicles per day use the Rambla to travel from Pg Colom to Pça. Catalunya. Whilst the proportion of service vehicle traffic is too great for the Municipality to consider a full, immediate pedestrianisation of the street, the vehicular traffic is small in comparison with (two-way) pedestrian volumes which exceed 56,000 persons per day, along the busiest sections.

This measure restricts access during the times of high pedestrian activity (from 11.00 to 20.00) to authorised classes of vehicles (buses, taxis, residents and special service vehicles) whilst maintaining open access for vehicles using any of the 3 off-street car parks located along the Rambla. The aim is to reduce the traffic during the hours of restriction, so as to improve pedestrian conditions. In order to ensure that the lower flow of vehicles do not travel at higher speed, and to maximise the safety of pedestrians, 30 km/h “traject control” (using cameras, the speed is deduced from the times of matched plate registrations of a vehicle travelling the known distance between the entry and exit control points) is also introduced.

The work undertaken within MIRACLES required the trialling of the enforcement and detection scheme using ANPR technology, before the full system could be introduced. Cameras were installed to record the movements of vehicles passing along the Rambla. Automatic Number Plate Recognition (ANPR) technology was used to identify the passing vehicles. If the vehicle had a number recognising it as an authorised vehicle (on a “white list”), then the recorded image was erased, with no action being taken.

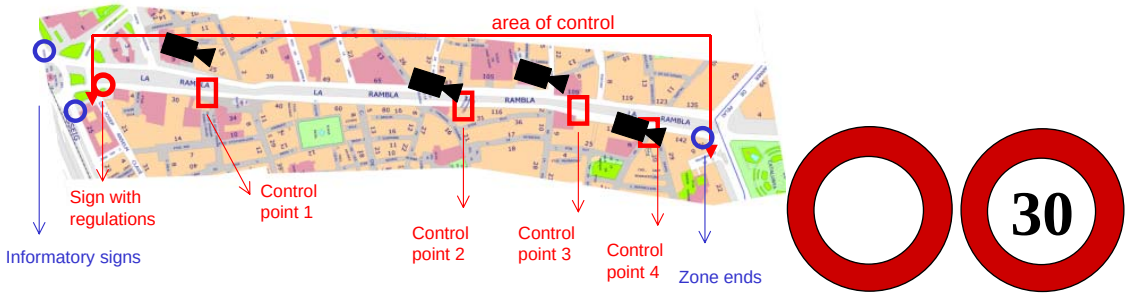

Figure 1 Schematic of Rambla access and speed control system.

Following the positive ANPR trial results, the full system is being implemented. Any vehicle travelling at more than 30 kph, or does not belong to a “white list”, or does not use one of the car parks has its

recorded images archived for use as evidence and a penalty fine imposed (to the owner of the vehicle). The automated system uses “black lists” to identify habitual offenders, so that police could use the system to catch and prosecute habitual offenders or vehicles not showing a legal number plate. Due to the high noise nuisance caused by motorised two-wheelers, and to ensure a sufficient reduction in the conflict with pedestrians, the restrictions are being applied to 2- as well as 4-wheeled motor vehicles.

The work in MIRACLES goes beyond the setting up and realisation of the ANPR trials. The contract for full implementation has been awarded following approval by various Municipal commissions, and the works are proceeding within a complex programme of interventions that precede the 2007 municipal elections.

The Implementation – how was the measure implemented?

M3: Innovative aspects

This is the first time that the Municipality has realised traject speed control using ANPR technology.

It hoped that ANPR technology would also enable the plates of powered two-wheelers to be read. The trial results were satisfactory for the newer larger plates of larger motorcycles, but the read levels were low for smaller plates of mopeds. Nevertheless, the 2005 surveys indicate that the high volumes of PTWs (24.1% of the actual daily traffic volume) require that these vehicles be restricted in order to achieve a real improvement in pedestrian amenity. This is the first time that a policy of prohibition of PTW access is considered, and marks a new step in municipal traffic policy.

Figure 2 Reading number-plates of small powered two-wheelers remains a big challenge.

M4 Situation before CIVITAS

Street configuration: In the late 1990s, the District authority widened the pavements and narrowed the circulating road space to a single lane in each direction.

Access control gates (retractable bollards) control the movements at side roads along the Rambla. These control points form part of the integral management known as “Barnacentre zone”, for which residents with vehicles have been issued with a card and vehicle movements controlled using a centralised database (white list). Prior to CIVITAS, a proposal had been made to the District authority to install retractable bollards at the Pg Colom entry to the Rambla, identifying the off-street car parks within the controlled area.

Camera technologies; the use of video to identify and provide evidence of fraudulent entry of access control zones had been demonstrated in the INTERCEPT project, and video-based control of red-light jumping had been installed at 6 locations; both of these systems are operated directly by the urban police tele-sanctions centre. However, the Municipal Traffic Control Centre had not installed cameras connected with vehicle plate recognition technologies when the project started.

M5 Design of the measures

Early design work investigated elements to overcome the new challenges of installing retractable equipment on primary roads (systems for equipping buses, to deal with higher traffic volumes that would lead to increased maintenance problems with local road system, and including the possibility to

lower/raise the outstation ticketing machine on occasions).

The proposal using retractable equipment contemplated the issue of tickets to drivers intending to use car parks. This was the main factor that led to this design being considered inappropriate by the traffic authority on the grounds that the time to control vehicle entry would be excessive and would lead to congestion problems on the primary road network.

Following the change in Traffic Councillor, work concentrated on developing an equipment configuration based solely on cameras using ANPR technology. How to deal with vehicles using the three off-street car parks along the Rambla was a major challenge. The solution involved collecting evidence of non-entry at each point. This, and other legal issues, was investigated to determine scheme feasibility. The “2003 configuration” that gained technical approval of both administrations integrates ANPR for both access control (including powered two-wheelers) and speed-over-trajectory management.

It was also decided during the preliminary stage that low-emission vehicles would be managed via white lists (of vehicle number plates) and that emission sensor equipment (such as that trialled in Winchester) was not required at this stage (problem orientated to improving local pedestrian amenity rather than motivated by air quality concerns – see for instance the MIRACLES project in Rome).

Different technologies (both cable-based and mobile telephone technologies) were considered in order to provide a high-capacity, secure transfer of data between roadside controllers and the Municipality’s Traffic Control Centre. The consideration of mobile phone technologies was developed and shown to be competitive, but the problems of ducts servicing the lower end of the Rambla were considered to be resolved and the decision was taken to install fibre optic links.

M6 Actual implementation

Following a series of delays, the scheme was implemented, initially as a series of experimental trials of ANPR technology during 2005, and more recently as a permanent implementation.

The political decision to go-ahead (taken in November 2004) was conditional upon a satisfactory outcome from a series of consultations with neighbourhood associations, car park operators and hotels. These consultations were satisfactorily resolved during the spring of 2005.

The initial “trial” installation involved the fibre-optics connections required for camera locations at both ends of the Rambla, and at the Municipal Traffic Control Centre (TCC), with cameras being located on existing street lights. An operator work station was established at the TCC. During the first half of 2005, in turn, four different contractors (ETRA, SICE, INDRA and TELVENT) installed their cameras and ANPR controllers at the two roadside locations, demonstrating the operability of their equipment.

An open tender was then made to contract the supply and installation of the roadside control points (at car park entries as well as the finalised entry and exit points) and the TCC control software and interface to the municipal sanctions system. The contract was awarded to SICE toward the end of 2005. The first phase of system operation, concerning the installation of the roadside equipment, and the demonstration of the plate-reading performance. is expected to be operational before the end of March of 2006, with full operation planned for September after important improvements have been realised at Liceu mtro station (works that will temporarily close the Rambla).

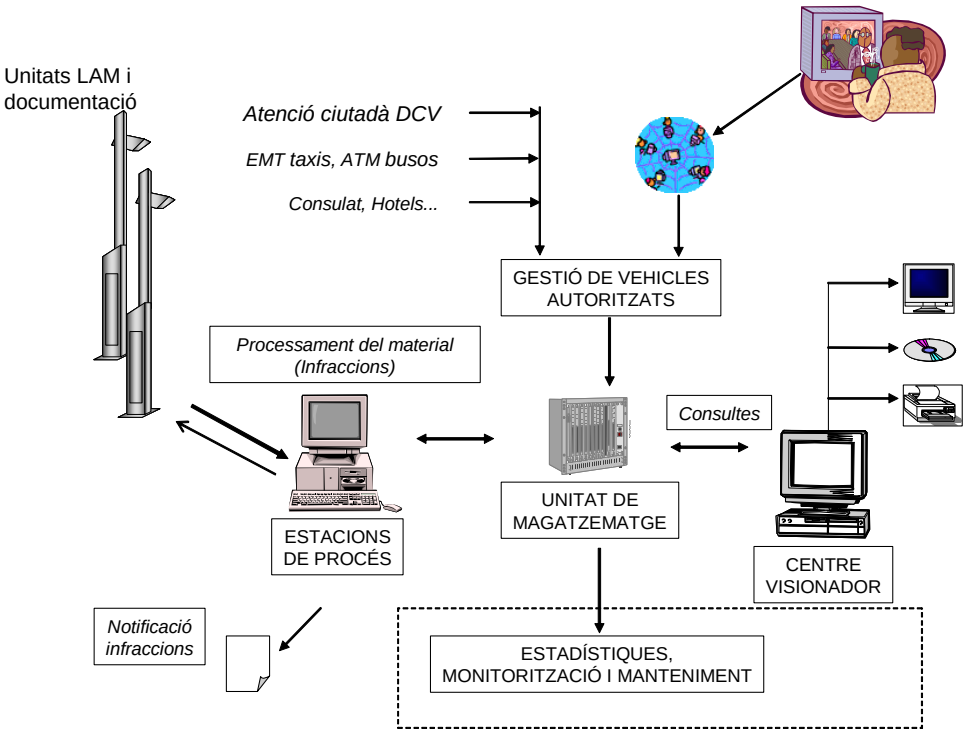

Figure 3 System architecture of Rambla access and speed control system.

M7 Deviations from the plan

Considerable design work was undertaken on configurations using retractable equipment. Following the change in Traffic Councillor (Spring 2003), the decision was taken to opt for a solution with enforcement based entirely upon ANPR camera technology.

Further delays occurred during 2003 and 2004. Changes in key staff associated with the municipal election (held in May of 2003, but with changes in key posts finalised in May 2004) led to revisions in priorities (e.g. the implementation of the residential parking scheme across the central districts of the city). The Madrid bombing of March 2004 led to further revision of the policy of access control in the central area – with new options being studied.

The political decision to accept the technical proposal and to go ahead with the implementation was taken at a meeting of the Traffic and District councillors held in November of 2004, shortly following the site technical audit. Important results demonstrating the performance of ANPR technology were achieved by the technology trials held during the first half of 2005, and this led to the tender for supply of the permanent system.

Additional work was undertaken on the initial design tasks, and on algorithm development to realise both access control and traject speed control. Additional work was incurred in explaining and revising the scheme following changes in key staff, and in conjunction with other traffic management plans concerning the city centre. In spite of the initial work on prototyping retractable bollard technologies, and the need to include additional camera control points, the total cost of the supply contract is less than originally planned.

The work on implementing the control system is underway and, although problems with the fibre optics connections have been encountered, it is expected that site acceptance of the roadside installation will be achieved before the end of March 2006. However, the full system commissioning

will be influenced by traffic diversions that will operate during the improvement of access at the Liceu metro station (works programmed from April to September 2006). Full implementation requires additional effort to communicate the regulation of Powered Two-Wheelers, and to enforce this part of the control (extra police effort is required, due to the inability of ANPR to read a sufficient number of PTW number plates).

The Evaluation – how was it done and what are the results?

M8: Methods of measurement:

	Activities	Data Source	Notes	Main results
1)	Traffic counts, OD survey, car park inventories, pedestrian exposure counts	Fieldwork surveys contracted by Municipality, 2002	Traffic by composition & hour of the day. Direction Pça Catalunya only	Definition of closure hours, estimate of traffic reduction.
2)	"Before" acceptance (citizens, car park operators, traders, Friends of the Rambla)	Telephone survey, 2003. Consultation meetings, 2005		Acceptance of proposals by key actors. Poll of citizens' opinions.
3)	"Before" accidents analysis	Municipal police	3 years of data, up to 2003	Comparative accident levels (Rambla cf. Other streets)
4)	Number plate reading & journey speeds	Trials of ANPR suppliers, 2005	Technologies of 4 systems suppliers	Car plate reading levels, travel time measurements.
5)	Traffic counts, pedestrian volumes and crossing times surveys	Fieldwork surveys contracted by Municipality, 2005	Both directions (Pça Catalunya & Pg. Colom)	Estimate of pedestrian benefits, design of maximum traffic levels, confirmation of the need to restrict PTWs.

M9 Achievement in terms of quantifiable results

The initial estimates of traffic reductions formed a key part of the presentations that led to decisions to go ahead with the ANPR trials.

The ANPR trials showed that camera-based enforcement could automatically capture sufficient data to enable access control and speed control to be enforced.

From the counts realised in 2005, it became evident that Powered Two-Wheelers (PTWs) would have to be included in the access restrictions in order to achieve a significant improvement in pedestrian amenity, but that this control would require manual enforcement by police; ANPR technology is not able to read small plates of mopeds.

Observations of pedestrians have quantified the delays experienced crossing the existing traffic, as well as the total volume of pedestrian crossing movements. Estimates of pedestrian delay savings are quantified to be some 2,515 hours per day. Applying standard values of travel time savings, such benefits are quantified at 7.92 M Euro per year, giving a benefit / cost ratio exceeding 10.

M10 Achievement of evaluation-related milestones

M1: Before survey results: Mth 15 traffic and car park surveys, and pedestrian exposure counts realised mth 8, with proposal for hours of closure agreed mth 14
M2: Tender: planned for mth 24, following ANPR trials, an open tender procedure was completed in mth 46.
M3: Site acceptance tests: planned for mth 30, the report on suppliers' trials was completed in mth 43, roadside equipment site acceptance: mth 50.
M4: After survey result: planned for mth 40, the scheme impacts are comprised of roadside equipment performance (mth 49), and estimates derived from surveys in mth 47.

M11 Report on the measure results:

Estimates of reductions in vehicular traffic: By comparing the traffic volume over a typical day with an index of the evolution of street use by pedestrians, the hours of closure to through traffic were defined. Having defined the hours of closure, and taking account of those elements of the traffic anticipated to be affected by the restrictions, the change in traffic load over the day was estimated. The initial estimate of traffic volume reduction during the controlled hours was 40%. The overall daily traffic was expected to be reduced by between 10 and 15%, with higher traffic levels prior to access control at 11.00 hours. These estimates were later revised based on counts in 2005; the revised estimate of the daily traffic reduction was 43% (from 11,656 vpd); the target level of admissible traffic during access control is set at 80 vph, compared to measured levels of 630 vph (11.00 – 20.00). The difference (with respect to earlier estimates) is explained by the inclusion of PTWs in the access prohibition, higher estimates of traffic suppression, and the evolution of the traffic counts.

Results of ANPR trials: The ANPR trials achieved car plate reading levels at a single point exceeding 90%. This result was consistent with read levels achieved by a system installed on the Ring Road in 2003. Measures of journey speeds have been made using data provided by two of the participants in the ANPR system trials. Based on a total of 3716 measurements, the average speed during the proposed control period (11.00 to 20.00) was 12.0 km/h (both sets of measurements), and speeds outside the proposed controlled hours were higher (average values of 13.1 and 15.8 km/h). The percentage of vehicles exceeding the 30 km/h speed limit was zero during the proposed controlled hours, and less than 5% for the hours from 20.00 to 11.00; the important result was that the different systems were able to demonstrate a reliable detection of speeding vehicles, see Table 1. However, the trialled systems were able to detect only a small fraction of Powered Two Wheelers (those recently registered motorcycles with larger plates).

Time period	Nº Vehicles	%	Average speed (km/h)	Mínimum speed (km/h)	Maximum speed (km/h)	Nº vehícles >30 km/h	%
11:00 a 19:59	635	95,06%	12,03	3,36	25,63	0	0,00%
20:00 a 10:59	33	4,94%	13,08	3,75	36,00	1	3,03%
Total	668	100%	12,08	3,36	36,00	1	0,15%

Time period	Nº Vehicles	%	Average speed (km/h)	Mínimum speed (km/h)	Maximum speed (km/h)	Nº vehícles >30 km/h	%
11:00 a 19:59	1359	44,60%	12,01	3,38	28,53	0	0,00%
20:00 a 10:59	1689	55,43%	15,28	3,37	56,00	43	2,55%
Total	3047	100%	13,83	3,37	56,00	42	1,38%

Table 1 Measures of traject journey speeds for time periods with/without access control: results from ANPR trials with trialled systems A (above) and B (below).

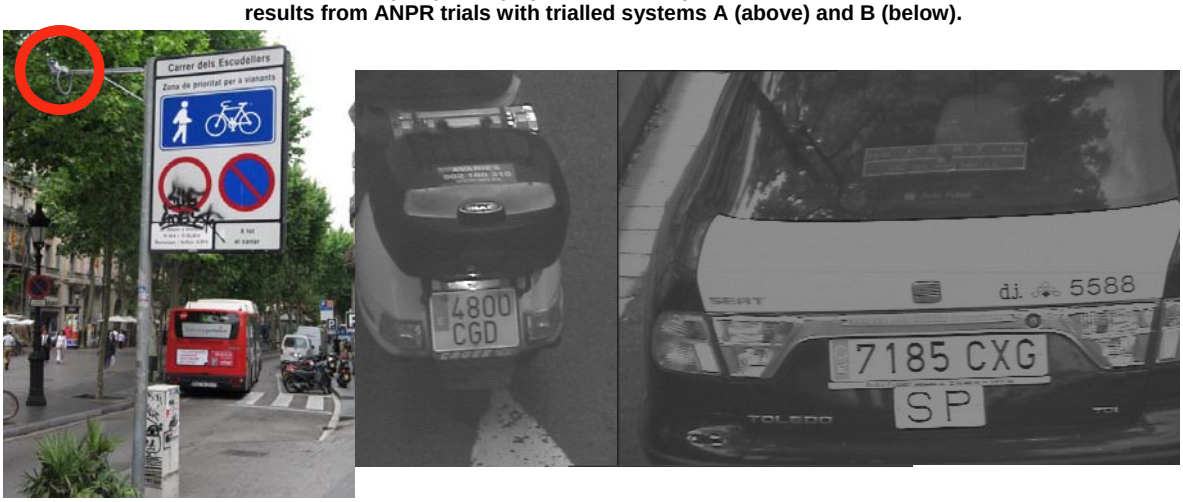

Figure 4 ANPR trials using provisional camera locations, ("entry" control point shown left) achieved sufficient read levels for car plates, but only a small fraction of PTWs. Source: SICE.

Pedestrian benefits: The surveys realised in 2005 include counts of pedestrian crossing volumes and the delays experienced by these road users. A total daily volume of 77,100 pedestrians cross the circulating traffic (11,656 vehicles). Observations of 200 pedestrian crossing movements at the four signalled crossings estimate the delays to range from 2.2 to 4.6 seconds. As a result of the reduction in the conflict, it is estimated that the delay saving could be of the order of 3,800 hours each day. The annual benefit is quantified to be 7.92 M Euro (based on travel time savings of 9 Euro/hour). However, it is difficult to carry out reliable measurements of pedestrian behaviour, and the computed figures should be considered an approximate measure of the improvement in amenity. A full cost-benefit would require quantification of delays to vehicular traffic, as well as an assessment of changes in pedestrian accident rates.

Figure 5 More than 56,000 pedestrians walk the Rambla every day; pedestrian crossing volumes are quantified to be 77,000 movements, more than 6 times the daily traffic level.

This measure will continue to be supported by the local authority after the MIRACLES project has ended.

Up-scaling:

The scheme to restrict vehicle access along the Rambla involves the application of ANPR technology both to deter car traffic and to detect and control those vehicles that inappropriately drive along it, in the direction toward Pça Catalunya. If the scheme successfully discriminates between those vehicles accessing off-street car parks and those making an inappropriate use of the road, then the scheme can be proposed to control the “outbound” movement as well as the inbound movement that constitutes the first implementation.

If the scheme demonstrates that the technology is efficient in terms of the detection (and the penalization) of users making inappropriate use of the road, then there is the possibility that this technology would offer benefits in terms of reduced maintenance costs and could be progressively applied to substitute the existing access control systems (some 50 gates) based on retractable bollards, cards and video ISDN technologies. Whilst the up-scaling procedures appear relatively straightforward, much depends upon whether the scheme performs satisfactorily in terms of sanctions and deterrence of illegal entries, something that will not be known until 2007.

MIRACLES Summary WP 5.1 Access control, Rambla, Barcelona				
Indicator (units) Meteor code		Baseline	After Miracles	
Econ.1	Purchase & installation costs (Euro)	n. a.	500,000 Eur.	Includes Fibre Optics & S/W improvements
Econ.2	Annual maintenance cost (Euro, per control gate)	Retractable bollard estimate: 7000 Eur.	n.a.	More time needed to assess cost of processing camera fines
Econ 3	Benefits in terms of travel time savings to pedestrians	n.a.	1) 7.92 M Eur.	Based on Indicator S3, applying minimum value (9 Eur/h) of travel time reported in Odgaard et al., for Spanish TEN projects
System efficiency E.1	Plate recognition efficiency: % of car plates read / total cars	Trial report indicates 90% note 1	Pending site commissioning	1: temporary camera position
System efficiency E.2	ANPR traject speed control Nº of drivers exceeding 30 km/h speed limit (% of total volume: 1: 11.00-19.59 2: 20.00-10.59	n.a.	A: 1) 0% 2) 3.0% B: 1) 0% 2) 2.6%	A: ANPR Trial supplier A B) ANPR Trial supplier B
System efficiency E.3	Deterrence performance: nº illegal access entries per total entry flow (%)	Retractable bollards: note 1	See note 2	1: less than 5% 2: estimated at 20%, will depend upon level of manual control of Powered Two-Wheelers …
System efficiency E.4	Plate recognition efficiency: % of PTW plates read / total PTWs (Powered two Wheelers)	ANPR trial: Only new large plates readable.		It is accepted that manual police controls will be required
Soc 14 a	Acceptance citizens (ratings on 0 to 10 scale)	5.97	n.a.	Base: telephone surveys with 800 respondents
Soc S.1	Pedestrian crossing volumes (persons per day)	Observed: 1) 29,700 2) 18,900 3) 13,800 4) 14,700	Estimated: 1) 29,700 2) 18,900 3) 13,800 4) 14,700 Total crossing peds.: 77,100 per day	For 4 sections before, on and after signalled crossings at: 1) Canuda/ Sta Ana, 2) Porterferissa 3) Pla d'Ors (café d'Opera), 4) Ferran.
Soc S.2	Pedestrian crossing time delay (sec)	Observed: 1) 4.55 2) 2.23 3) 3.50 4) 3.40	Estimated 1) 3.64 2) 1.78 3) 2.80 4) 2.72	50 observations at each of the 4 sections: 1) Canuda/ Sta Ana, 2) Porterferissa 3) Pla d'Ors (café d'Opera), 4) Ferran.
Soc S3	Savings in pedestrian crossing time (hours)		From S1 and S2, it is estimated that 2,515 hours of time would be saved by pedestrians every day	Observed values applied to 1 in 6 of counted pedestrians, 20% delay reduction assumed
Trans 20	Nº of injury accidents	1) 75 accidents, 55 involving injury	not available.	1) 2002
Trans 21 a	Traffic volume (vph) average during controlled hours	1) 630 vph	Estimated to be 80 vph	1) dec 05 .(11.00-20.00)
Trans 21 b	Traffic volume (vpd) during day	11656	Estimated: 5000	1) dec 05
Trans 21 c	cars volume (vph) average during controlled hours	76	Estimated. 10	1) dec 05 .(11.00-20.00)

Trans 21 d	cars volume (vpd) during day	4384	Estimated: 2150	1) dec 05
Trans 21 e	PTWs volume (vph) average during controlled hours	48	Estimated. 5	1) dec 05 .(11.00-20.00)
Trans 21 f	PTWs volume (vpd) during day	2804	Estimated. 600	1) dec 05
Trans 21 g	Goods vehicles volume (vph) average during controlled hours	71	Estimated. 5	1) dec 05 .(11.00-20.00)
Trans 21 h	Goods vehicles volume (vpd) during day	1432	Estimated. 1500	1) dec 05
Trans 21 i	Bus volume (vph) average during controlled hours	8	Estimated. 8	1) dec 05 .(11.00-20.00)
Trans 21 j	Bus volume (vpd) during day	268	Estimated: 268	1) dec 05
Trans 21 k	Taxis (occupied / unoccupied) volume (vpd) during controlled hours	15/ 24	Estimated: 20/32	1) dec 05 .(11.00-20.00)
Trans 21 l	Taxis (occupied / unoccupied) volume (vpd) during day	861/ 908	Estimated. 861/ 908	1) dec 05 .
Trans 21 k	Bicycles volume (vph) average during controlled hours	26	Estimated. 30	1) dec 05 .(11.00-20.00)
Trans 21 l	Bicycles vehicles volume (vpd) during day	997	Estimated. 1200	1) dec 05
Trans T.3	Nº vehicles entering car parks (Contipark, Palau Nou)	505	Estimated. 505	1) dec 05 .(11.00-20.00)
Trans 23 a	Traffic speed (km/h) average during controlled hours 11.00 – 19.59	ANPR Trial supplier A: 12.0 B: 13.1	Pending final system commissioning	A: based on 635 matchings B: based on 33 matchings
Trans 23 b	Traffic speed (km/h) during rest of day 20.00 – 10.59	ANPR Trial supplier A: 12.0 B: 15.3	Pending final system commissioning	A: based on 1359 matchings B: based on 1689 matchings.

M12: Barriers and drivers of the measure implementation

Barriers:
The barriers that the scheme has faced include:

- opposition from car park operators concerned that the scheme could jeopardise their business
- the need for continued collaboration between Municipality (traffic) and District (local) authorities with respect to the disruption caused by changes in key staff in these organisations following elections at regional and local levels, and by the programming of other actions in the city centre
- concern that the scheme is sophisticated and “high-tech”, vis-à-vis its likely impact.
- The need to remove more than half the traffic (in order to achieve notable pedestrian benefit) implies restricting access not only to cars and commercial vehicle through traffic, but also to Powered Two-Wheelers (for which manual enforcement is required to supplement ANPR).

Drivers:

The scheme design, although complex, was required to overcome the concerns of car park operators. Extensive consultation was a further requirement to ensure scheme progression.

The measure forms part of the Municipality’s Programme for Traffic Calming; being part of the mandate has helped ensure continued efforts to implement the measure. This programme has

already introduced more than 40 access control gates as part of measures to restrict access to local streets in historic areas of the city. The need to further reduce the intrusion of vehicle traffic – including PTWs - upon pedestrians is undoubtedly a main driver for this measure.

The scheme includes number plate reading technology that could lead to a substitution of some of the existing control gates (if the deterrence is proven to be effective) so as to reduce the on-going maintenance of retractable bollards. This driver is secondary to the improvement of pedestrian amenity. Realising ANPR technology trials has helped to overcome concern about technological sophistication.

M13: Interrelationships with other measures

CNG buses serving the Rambla are subject to similar access authorisation as other types of bus.

M14 Lessons to consider for replication and take-up by other cities

The first lesson learned is that restricting vehicle access to a level that improves pedestrian conditions, on a road of this type (10,000 vpd) is not an easy task. In order to achieve a sufficiently low level of vehicular traffic, Powered Two-Wheeler traffic needs to be restricted (as well as cars and goods traffic).

ANPR technology provides a tool for controlling different elements of traffic which provides a more flexible solution that retractable bollard systems (bus movements on primary roads, access to car parks and traject speed control.

In order to control Powered Two-Wheelers, it is recommended that large registration plates be adopted across Europe (national legislation for this has been established in Italy, following the access control experience of Rome). Since this will take time, tags may be required to recognise authorised entry by PTW users who are residents of the controlled central area.

It is important that efforts are made to quantify tangible benefits for pedestrians; given the difficulties of defining and applying indicators to reflect improvements in amenity, crossing times of pedestrians was found to be a useful indicator. Using published values of travel time, the scheme is shown to produce first year benefits that substantially exceed scheme installation costs.

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3. Measure 7.2

MEASURE-LEVEL RESULTS	
Measure number and title: **WP7.2 Multi-operator real-time passenger Information**	**Project: MIRACLES** **Site: Barcelona**

The Measure – what is it about?

M1 Measure objectives:

The objectives were to:

- Improve the quality of public transport information;
- Demonstrate real-time messaging based on a multi-operator system using (6) standardised information panels; and
- Display messages at bus stops to promote usage of bus services integrated with a new tramway.

M2 Description of the measure:

The measure comprised:

- A common AVM (Automatic Vehicle Monitoring) system for the 20+ medium and small bus operators active in the Barcelona metropolitan area
- A system for interchanging information about the location and arrival times of buses of the main bus operator
- A control centre at ATM offices that processes information from the AVM and other information sources and emits messages about the arrival times of next buses at certain stops
- Information panels installed at selected stops.

The Implementation – how was the measure implemented?

M3: Innovative aspects:

The new AVM system incorporates GPS technology to give a more accurate vehicle positioning than the existing AVM systems of the city's larger operators. The initiative to develop and provide a modern AVM system for the small / medium bus operators was an action that ATM has taken in order to promote a new standard specification for such equipment for all operators in the region, and to ensure interoperable systems for smaller operators who would not have invested in such equipment without ATM's intervention aimed at achieving economies of scale and standardised systems.

The measure was implemented in the Trambaix tramway corridor as part of an initiative to improve the collective transport service within and between the municipalities adjacent to the city of Barcelona. Bus services in this area are supplied by several different operators, and this demonstration was the first time that bus arrival information for services run by a multiple number of operators was displayed to passengers in Catalonia.

Work undertaken for the main bus operator TMB included the migration of the web trip planner to XML and improvement of multimodal search algorithms, and development work to integrate the various on-bus embedded systems. This work contributed to TMB publishing an SMS message service which eventually became the means for demonstrating information interchange in MIRACLES (connecting the TMB and ATM servers via GPRS).

M4: Situation before CIVITAS:

A (beacon-based) AVM system was operated for buses of TMB the main bus service operator in the city of Barcelona, and by EMT who run night bus services in the city. But none of the other, smaller operators in the metropolitan region had equipped their buses with an AVM system. As a result, it

was not possible to offer complete, integrated information about bus arrivals to passengers at stops served by a variety of bus service operators. Thus, before MIRACLES, the provision of information about bus arrivals was only feasible inside the 100 sq. km of the city of Barcelona (the region comprises 203 municipalities covering 3,200 sq. km.).

Travel demand is increasing for movements between the hinterland municipalities and the city as part of a decentralisation that is making it difficult for collective transport to maintain it's modal share. When MIRACLES started ATM had just introduced a zone-based Integrated fares and tariff system across the metropolitan region as facilitate the use of collective transport at the regional level. ATM has also been promoting the re-introduction of the modern tramway, and the first scheme ("Trambaix") of 15km planned to link 5 of the municipalities to the south with the City of Barcelona. This was under construction when CIVITAS started and, as a complementary measure to the general integration of the tramway (see measure 7.5) it was proposed to demonstrate improved multimodal real-rime information in the Trambaix corridor.

M5 Design of the measure

The design of the ATM AVM system had been largely completed when MIRACLES started. This meant that work on equipment acquisition and implementation for the first of the small-medium operators could proceed smoothly. It was decided to initially install the AVM equipment (supplied by GMV and INDRA) with operators running services outside the Trambaix corridor; the services inside the corridor were subject to disruption and possible revision due to the implementation of the tramway itself. ATM's AVM system enables each operator to use the GPS location system to track its' own vehicles, and issue commands via its own control centre. The modules serving each operator are integrated at ATM's server. Messaging was originally supported by an analogue radio trunking system with capacity for up to 450 buses, see Figure 1.

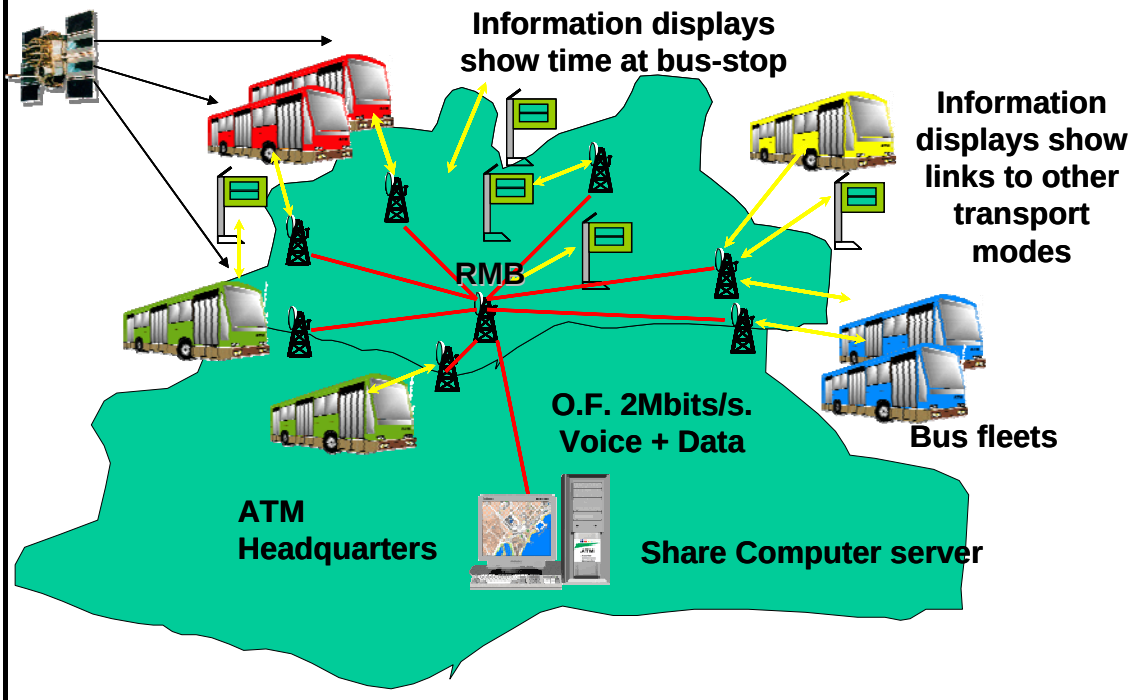

Figure 1 Schematic description of ATM's AVM system architecture.

It was clear that local bus services needed to be reviewed in the light of the implementation of the tramway. ATM made a proposal to rationalise services with buses acting as feeders / distributors to extend the tramway catchment. Relatively modest, these proposals met with considerable local opposition and were subject to intense negotiations that delayed the identification of those bus stops along the tramway that had potential to demonstrate real-time information about arrivals of buses run

by different operators. These proposals were then presented to the (three) municipal authorities so as to achieve agreement on finalised locations, to agree responsibilities for electricity supply and panel maintenance, and to determine the timetable for installation.

Whilst work on AVM equipment continued, ATM made proposals to the main operators (city buses, metro, suburban trains) for the interchange of information between their AVM systems and the new ATM AVM. Differences between ATM and TMB were only settled following the changes in key staff that accompanied the chain of political elections in Spain (national, local and regional) in 2003 – 2004. The outcome was a change in the system architecture with ATM accessing information of TMB bus arrivals using a mobile GPRS-based SMS web service. The agreement concerning information exchange included the design of the bus stop panels and the protocol for rotation of messages.

M6 Actual implementation

A substantial number of information panels were acquired in the first year of the project as part of the implementation of the AVM Guide Plan project. These could only be implemented after the procedures described under “Design of the Measures” had been finished. The AVM system was demonstrated working in the ATM environment, and for bus operator Soler & Sauret, during the 2004 project audit.

The progress with implementation of ATM’s AVM system was influenced by the coverage of the radio trunking service. Within the project time-frame, improvements were introduced to the panel hardware and system software so as to support messaging via GPRS. This work not only improved coverage but also achieved considerable savings with respect to the cost of communications.

ATM has established agreements with local municipalities for the implementation and operation of panels at 4 stops before the end of 2005, with a further implementation in 2006. The locations of the stops where integrated bus arrival times are being demonstrated is shown in Figure 2.

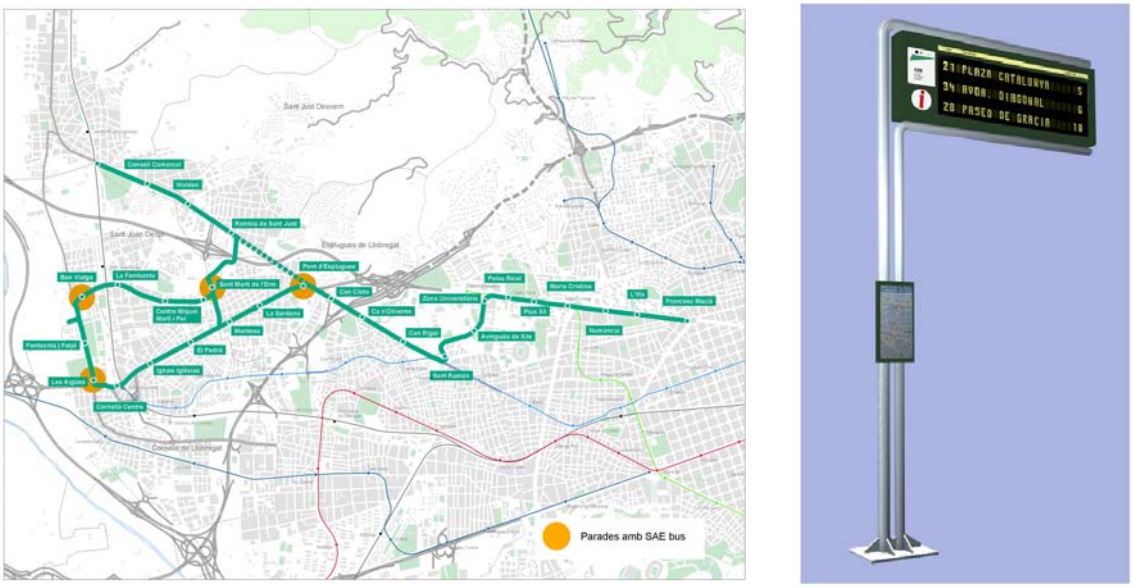

Figure 2 Information panel and locations of bus stops where panels have been implemented

M7 Deviations from the plan

The main delay experienced by this measure concerned the agreement between the authority (ATM)

and the main bus operator (TMB) regarding the interchange of information required to display complete information about all the buses serving the bus stops located in Esplugues municipality. This was finally resolved in late 2004.

Figure 3 Pont d'Esplugues bus stop, showing operation of multi-operator bus arrival Information.

Another consideration is that bus operators have had to realise the development of bus stop database describing the name and location of each stop, so as to support AVM-based applications. An additional factor was the need to agree revisions to the bus services following the implementation of the tramway. Both of these issues were caught up in the process of a switch in political power following the national and regional elections during 2004, and the changes in key staff at ATM that followed thereafter.

The collaboration between the key actors improved following the staff changes and the revised solution for information interchange was presented by both partners at the technical audit held in late 2004. The same audit accepted the reasons for concentrating the measure on the demonstration of multi-operator information. (Multi-media diffusion had originally proposed as part of the local Guides Plan project which has been under review since the change in ATM management). It is recognised that the consolidated operation of ATM's AVM system requires further development work before information diffusion to passengers is considered (i.e using media other than bus stop displays).

Further developments of ATM's AVM.system have been implemented, beyond those originally planned in the MIRACLES project. The first concerns the implementation of GPRS-based communications as a more economical solution (and with better coverage) compared to the initial analogue radio trunking deployment. Another improvement is the development of a web-based application such that operators can manage their fleet via the web, rather than a dedicated PC, and with a simplified user interface. These developments are motivated in order to convince those small operators who run a fleet of only a handful of buses that participation in the AVM system is easy and does not require additional equipment and staff.

The MIRACLES contract annex states that 6 information panels would be demonstrated. Whilst it is still planned that 6 information panels be installed in the tramway corridor, 2 locations are delayed; the first because the tramway serving Sant Just Desvern municipality awaits the extension to the tramway service currently under construction but not now planned to be operational until the end of 2005; the second because the chosen stop is subject to roadworks that have led to service diversions. (With one exception, the stops are the same as those proposed at the 2004 project audit).

The Evaluation – how was it done and what are the results?

M8 Methods of measurement:

	Activities	Data Source	Frequency	Form
1)	Passenger profiles, acceptance & behavioural change	On-tram surveys *	7 months after service start, Nov. 2004	Apolda, face-to-face interviews with passengers
2)	Monitor of passenger volumes at stops with / without information panels	Integrated tickets & tariffs system	Average of 2 months of data (Before & After info displayed at stops)	ATM database

1) The on-tram survey comprised 1818 interviews and assessed the profile of users of the new tram service. A series of questions quantified the proportion of tram users who used connecting bus services, and asked about the usefulness that passengers attributed to the provision of real-time bus information.

2) The analysis of ticket transactions provided a monitoring of changes in passenger travel at bus stops equipped with information panels. The analysis compared the transactions at the Pont d'Esplugues stop for the months of October and November of 2004 (Before) with the same months of 2005 (After).

Corresponding figures for the other tramway stops were compared. (The total number of transactions at Pont d'Esplugues was 104,000 during the 8 weeks, and compares with 2.04 M transactions for the rest of the Trambaix line).

Explanatory Note: Surveys with bus operators were considered in order to consolidate the implementation of AVM across the metropolitan area, but these were only carried out for a small number of operators due to the initial difficulties of radio coverage and costs, as well as the need to establish bus stop databases. Further consideration to a survey of operators will be given once the web-based application is completed, and experience with bus arrival information has been achieved.

M9 Achievement in terms of quantifiable results

The main results were as follows:

i) All the operators, who serve the stops where the four panels have been displayed, have installed AVM equipment (Soler & Sauret, and Mohn, Oliveras & Rosanbus) or have made bus arrival times available (TMB) ia an integrated, automated way.
ii) the increase in passenger usage at the Pont d'Esplugues stop (equipped with panels showing real-time bus arrivals) is 2.2%. This compares with an overall growth in multi-stage journeys of 1.6% for all tramway stops. Taking account of the general growth in multi-stage usage, the growth at the stop with demonstrated information amounts to some 48 extra passengers per working day.

M10 Achievement of evaluation-related milestones

M1 Information panels acquired by ATM: Mth 16
M2 On-bus AVM equipment verification tests completed by ATM (2 independent suppliers): Mth 22
M3 Information exchange agreement (ATM and TMB): Mth 33
M4 Completion of tramway passenger survey Mth 34
M5 Panel implementation at selected bus stops, messaging operational:Mth 44
M6 After data collection completed: Mth 46

M11 Report on the measure results:

Intermodality

Surveys were undertaken 7 months after the tramway came into operation with face-to-face interviews conducted with some 1800 passengers using the tramway service, based on a random, stratified sample (see WP7.5 for further details).

Concerning intermodality, the responses identified that:

- 32% of the trips are single mode (tram) journeys, 44% involve two modes and 22% involve 3 modes
- around half of the trips involve a combination of walking (of more than 5 minutes) plus tram
- other important interconnecting modes are metro and bus (both accounting for 10% of combined mode trips)
- 75% of connecting bus services are lines run by the main city operator, and five operators account for 95% of the connecting bus trips.

The intermodality rate for the whole public transportation system is about 21%, well below these figures.

Motivators of passengers' use of the tram

Interestingly, "information about times of next tram arrival" ranked only 6th in customers' views on tram system features that motivated them to use the service (1.3% of responses) with a much lower score than features of the tram system itself "faster" (52.7%), "closer" (26.7%), "adapted access" (12.6%) etc., or integrated service features such as "less interchanges" (8.1%), or personal motives such as "change of home address" (3.5%).

Bus stop patronage levels

The year-on-year comparison of the trends in passenger usage at the Pont d'Esplugues stop, equipped with panels showing real-time bus arrivals shows a higher (than the line average) growth in multi-stage validations. Comparing October and November figures for 2004 and 2005 the growth at the Pont d'Esplugues stop is 2.2%, compared with an overall growth in multi-stage journeys of 1.6% for all tramway bus stops. As Table 1 shows, the difference between rates is significant because of the large size of the samples.

	Overall tramway network	**Pont d'Esplugues stop**
Oct & Nov 2004	1.50 M passengers 32.66% multi-stage trips	75,317 passengers 15.24% multi-stage trips
Oct & Nov 2005	2.04 M passengers 34.28% multi-stage trips	104,480 passengers 17.27% multi-stage trips
Growth of multi-stage trips	+1.63%	+ 2.03%
95% confidence interval	± 0.10%	± 0.34%

Table 1: Comparison of passenger ticket validations for the Pont d'Esplugues bus stop and the overall figures for the Tram line.

Note that while the survey stated than more than 66% of trips involved at least two modes, the figures in the table for the overall network are only some 32% to 34%. There is no contradiction in these figures because the definition of "transport mode" is different in both sources. While the survey considered that "walking more than 5 minutes" was a mode, the table only takes into consideration the multi-stage trips in public transport modes, i.e. bus+tramway or metro+tramway, but not walking.

These figures have not been estimated from a survey but from the integrated ticket system. This

system permits to know **all** the stages of **each** journey in public transport so that the "sample" is indeed the whole population.

If the multi-stage rate in 2005 had been the same than in 2004, the amount of multi-stage journeys at Pont d'Esplugues would have been 15,922 (=104,480 passengers * 15.24%) with a 95% confidence interval of ±228 passengers. But it actually was 18,045 passengers which yields a net increase of 2,123 journeys, clearly outside the confidence interval, indicating that the increase is significant. Assuming 44 weekdays in the two months period, the growth can be estimated at some 48 extra passengers per weekday.

NOTE: The binomial law has been used to calculate the confidence intervals. However, given that the information about the whole population is known, the appropriate law to use is the hyper geometric, with a resulting confidence intervals of 0 length. Therefore, all the conclusions stated before are significant.

This measure will continue to be supported by the local authority after the MIRACLES project has ended.

Upscaling

ATM is committed to improving the quality of service for passengers of collective transport across the metropolitan region, including passenger information. In total it is planned to install information panels providing real-time bus arrival information at 50 bus stops. A plan for implementing the stops has been devised. Currently, including the 4 stops of the MIRACLES project, 20% of the target implementation has been achieved. The number of bus stops will continue to grow after MIRACLES has finished, based upon the devised plan and subject to variations introduced by changes in service concessions, high-level requests from Mayors of the different municipalities, etc.

M12 Barriers and drivers of the measure implementation

Barriers:

Institutional / integration of existing systems: Achieving an integration of relevant information from all bus operators is the main challenge to providing real-time information about bus arrival times to all travellers in the Barcelona metropolitan region. Part of the challenge is technical, and the MIRACLES approach (based on equipping smaller operators with a common modern AVM system) can lead to institutional difficulties, where larger operators (with older AVM systems) feel threatened by the initiative. (e.g. that the arrival times of other services are more reliable). Cooperation in the case of the tramway corridor was complicated by resistance from bus operators involved in discussions about changes to rationalise the bus services (to feed/distribute tramway passengers).

Economics of small/ medium operators' participation: The cost of operating ATM's AVM system has initially been met by ATM. With the implementation of GPRS-based communications, the costs have been reduced. ATM is now seeking contributions from the bus operators to finance the maintenance of the system, and this inevitably generates resistance….

Drivers:

Door-to-door multimodal traveller information: The overall driver of the project is the objective of providing travellers with integrated door-to-door information about journeys using all modes of public transport for any locations within the metropolitan region. This conceptual framework was converted into the practical proposal of equipping all bus services with AVM equipment, with ATM providing incentives to smaller operators to participate. This driver overcomes the initial barrier that smaller operators did not have AVM equipment, and it resolved it in a way that established a "de facto" common specification.

Database of bus stops: the creation of a common database of bus stops forms an integral part of the system. The management of this information provides catalyser for organisation of operators / municipalities, and operators recognise the added value provided by the authority…

Authority commitment & programme flexibility: The large size of the project requires sustained commitment on the part of the authority. There has to be sufficient flexibility to introduce technological upgrades to counter the length of large-scale implementation (as has been achieved with GPRS communications, with web-based application).

M13: Interrelationships with other measures

Measure 7.5, the integration of the tramway in the public transport network forms the other part of WP7 measures demonstrated in this corridor.

M14 Lessons to consider for replication and take-up by other cities

The implementation of an AVM system for small / medium bus operators requires a large-scale commitment that can only be assumed by an authority with responsibilities for integrating passenger services across a metropolis or a region.

Such a system achieves fleet management benefits for operators in the short-term, but the authority only sees benefits in the medium and long term. Installing information panels and communicating bus arrival times at interchange stops has been demonstrated to have a positive impact, leading to a relative growth in multi-stage trips, and representing some 48 extra passenger journeys per day at the monitored bus stop (to be reviewed as further data becomes available). The effort expended in equipping smaller operators, and from the full integration with TMB, needs to be exploited via web and SMS media to reach passengers before they reach a stop.

It is not recommended to demonstrate bus arrival information in association with tramway or other implementations that cause a rationalisation of the bus services since such service changes undermine the basic cooperation of operators. It is possible that the MIRACLES demonstration would achieve larger impacts in the hinterland areas where bus frequencies are lower.

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4. Measure 7.5

Measure title: Integration of the Tramway in the CPT Network	**Project: MIRACLES**
Measure Number : 7.5	**Site: Barcelona**

The Measure – what is it about?

M1 Measure objectives:

The objectives were focused on:

- Integrating the new tramway service within the Barcelona metropolitan Collective Passenger Transport (CPT) network,
- Achieving an operational performance in running speed of at least 20 km/h
- Quantifying the operational, energy and environmental benefits of the tramway, and
- Reporting of best practice regarding tramway implementation.

M2 Measure description:

Barcelona's *Diagonal-Baix Llobregat tramway scheme* ("Trambaix") combines the latest tram vehicle technologies with a radical re-allocation of street space to offer accessibility for all Barcelona's citizens in a way that reduces the city's future dependency on petroleum. The tramway comprises three suburban spur lines that join to serve a single radial route into Barcelona via the UPC University and new commercial developments along the Diagonal highway. It has a total length of 15km, and (currently) 25 stops.

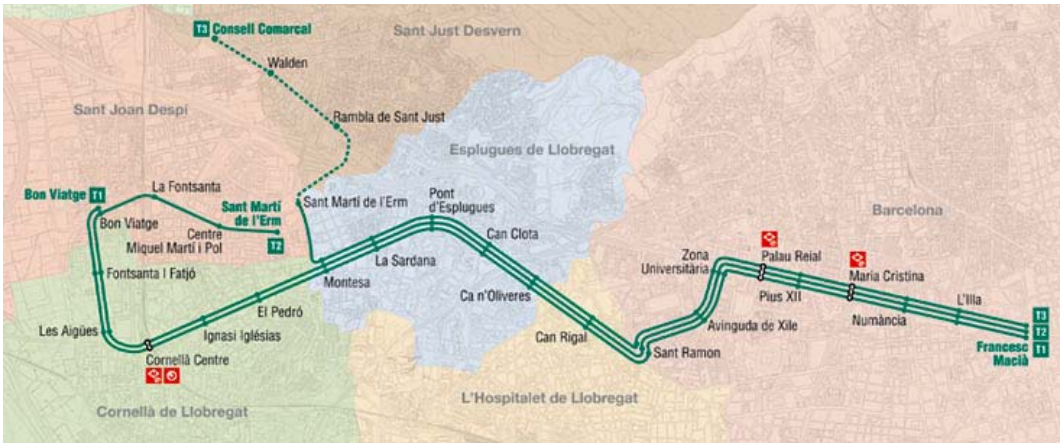

Figure 1 Plan showing the "Trambaix" tram lines, stops and municipalities, as operated during 2005.

The rolling stock is Alstom's Citadis 302, bi-directional, with 5 modules in aluminium and steel, having a capacity of 218 passengers and a maximum speed of 70 km/h. The trains are equipped with AVM (Automatic Vehicle Monitoring) equipment and signal priority is given at some of the 25 junctions along the route.

The funding from the MIRACLES project has provided ATM, the Metropolitan Transport Authority, with additional resources to oversee design aspects during implementation, to study aspects of integration such as bus lines rationalization, and to effectively monitor this new mode of transportation in the city (no equipment or infrastructure works have been charged to MIRACLES).

The Implementation – how was the measure implemented?

M3: Innovative aspects:

The BOT (Build, Operate & Transfer) contract is an **innovative Public/Private Partnership** which has provided the main impetus to implement the tramway. The scheme constitutes a new form of public transport offer which extends the city's rail-based network into the city hinterland areas avoiding the cost of tunnelling works associated with metro systems.

The high level of attention to integrated urban design is particularly aimed at promoting multimodal travel with softer modes (of walking and cycling).

M4: Situation before CIVITAS:

The municipalities surrounding the city of Barcelona contained a large number of derelict buildings and land associated with former heavy industry. Constructing the tramway was both an opportunity to develop new axes for mass transportation as well as a catalyst to promote urban renewal.

Prior to the tramway implementation, mobility was concentrated within each of the 6 municipalities, with walking as the predominant mode, accounting for two-thirds of all trips (figure from the 2001 "EMQ" household survey). Bus travel accounted for 10% of all trips, and similar percentages were made by rail (metro and train) and by car.

Figure 3 Avinguda Xile, in 2002 before the works started. Typically, most of the carriageway is allocated to (circulating and parked) cars.

Trials had been realised on a short (1km) section of the Diagonal in 1998/1999. These trials allowed citizens to use a modern tramway for the first time, and proved very popular as a means of accessing the recently-constructed "Illa" shopping development.

Within the important Diagonal corridor, prior to the tramway, public transport was achieved by bus services with running speeds of 13 to 14 km/h.

M5 Design of the measures

ATM - *Autoritat del Transport Metropolità* (the metropolitan transport authority) administers public transport subsidies and plans new infrastructure investments. It has worked with *Tramvia Metropolità*, the new company established to build and operate Tram, and with the six municipalities (local authorities) to:

- define the 15km route,
- integrate elements such as signal priority, bus stop information, the revision of bus lines, etc.,

- oversee the works and
- monitor operational performance.

ATM had already carried out the route planning before MIRACLES started. Continuous liaison has been necessary to coordinate public transport services during the works (concerning both the tramway implementation and related re-urbanisation of streets and roads). This process has seen the conversion of 162,500 m2 of road space into pedestrian spaces and new cycle routes, and 135,000 m2 of roads into green planted areas. The integrated design is particularly evident at key stations for modal interchange.

Figure 2 Cornellà station, where 4 modes of transport interconnect (RENFE Suburban trains at the upper level, Tramway and buses at the intermediate level and Metro at the lowest level).

ATM has also worked with the operator *Tramvia Metropolità* on the design of the stops with the view to facilitating access by wheelchair users, those with baby chairs or cycles. The tram stops are also designed with a view to attracting first-time users and passengers from other public transport services; tickets available for the whole transportation network can be purchased at terminals integrated within each tram stop.

Figure 3 Aspects of the “Trambaix” tramway design: left; wheelchair access at stops, right; road space allocation showing tramway and cycle lanes.

Figure 4 Aspects of the “Trambaix” tramway design: information and ticket vending at stops.

M6 Actual implementation

Construction commenced shortly before the start of the MIRACLES project. It took more than 15 months and involved significant roadworks.

Line and depot construction were followed by more than 6 months of works installing control systems and commissioning rolling stock.

The tramway commenced operation in April of 2004, month 27 of the MIRACLES project.

Figure 5 Avinguda de Xile, in 2004 after works were completed.

Comparing Figures 3 and 5, it can be seen that, typical of many sections along the tramway, general traffic circulation is restricted to one lane and on-street car parking has been removed with one lane being occupied by the tramway, and the others dedicated to cycling lanes (in this case), or widened pavements.

M7 Deviations from the plan

The service started operation on 3rd April 2004 only a few weeks behind the original plan, following changes to junction designs to eradicate collisions caused by those private vehicle drivers (initially) unwilling to accept turn prohibitions.

The Evaluation – how was it done and what are the results?

M8 Methods of measurement:

	Activities	Data Source	Frequency	Form
1)	Monitor of passenger volumes	Integrated tickets & tariffs system	Continuous, from April 2004	ATM database
2)	Tram running speeds	Tram AVM	Monthly, , from April 2004	Connex
3)	Passenger profiles, acceptance & behavioural change	On-tram surveys *	7 months after service start, Nov. 2004	Apolda, face-to-face interviews with passengers

Activities 1 and 2 are continuously monitored (using ticketing and tram AVM systems, respectively).

* counts of boarding / alighting passenger taken from 25 to 29 October & 2 to 26 November of 2004 are used to weight the survey results. The On-tram survey comprises 1818 interviews, a randon sample of 6.06%, stratified by stop and hour of the day.

M9 Achievement of quantifiable targets

Tram running speeds

The observed commercial speeds derived from the AVM (Automatic Vehicle Monitoring) system during a typical day of October 2004 are presented below for the three main sections. The results indicate higher running speeds in the line sections in the suburban area and lower ones along the section along the Diagonal within Barcelona city.

The average **tram running speed** realised after 6 months of operation shows the overall average of 16.5 km/h to be below the target of 20 km/h. Measures subsequently undertaken to increase the running speed have raised this to 18.5 km/h by the end of the MIRACLES project. Running speeds are higher in the suburban outer line sections than along the Diagonal main road access.

	Length (m)	**Run time (min:seg)**	**Speed (km/h)**
Francesc Macià-Zona Universitària	2,547	10:45	14.23
Zona Universitària – Pont d'Esplugues	2,992	10:26	17.21
Pont d'Esplugues – Cornellà Centre	2,644	08:35	18.46
TOTAL	**8,183**	**29:46**	**16.50**

Table 1 "Trambaix" tramway running speeds after 6 months operation, source Tram.

M10 Achievement of evaluation-related milestones

M1 scheme operation (month 27)
M2 completion of tramway passenger survey (month 34)

The on-tram survey was carried out in November, seven months after operation started (one month of

operation was lost due to a technical problem).

The fuel saving from modal switch has been estimated using the passenger survey results. This estimate has not been further developed since the changes in bus-kms are not available, and the energy consumption of the tramway is also not available. Further elaboration of changes in fuel consumption to quantify pollutant emission savings is pending guidance on the application of Coppert factors, from METEOR.

M11 Report on the measure results:

Overall

The tramway has exceeded expectations in terms of passenger volumes and the share of generated trips. This has been achieved in spite of lower-than-expected overall running speeds. The good overall performance is attributed to the higher generated traffic due to associated new building development on the one hand and, on the other, to the strong connection achieved between walk and tram modes of travel.

1) Passenger volumes:

Based on the ticket validations, during average workdays, the levels of use show a general pattern of progressive growth with latest figures for November 2005 showing a peak of over 41,000 passengers per day. In the second semester of 2004, monthly passenger volumes were higher than the operator's first year forecasts.

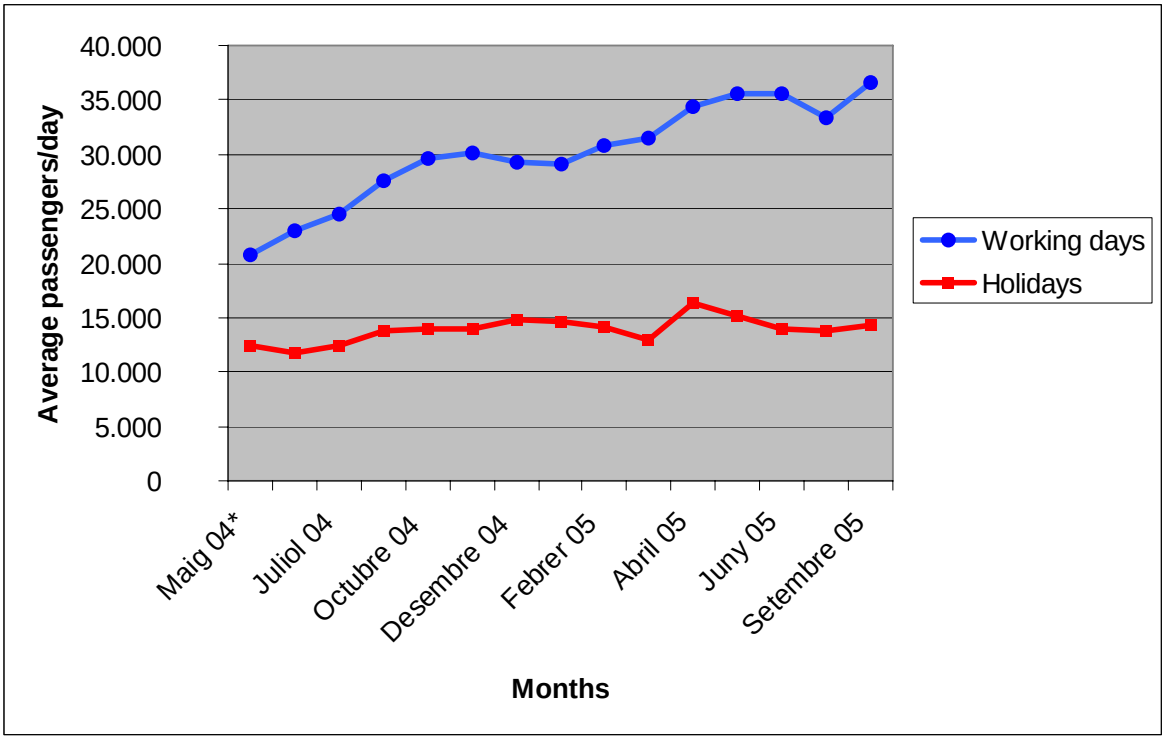

Figure 6 "Trambaix" tramway passenger volumes (to September 2005), source ATM

Concerning intermodality, the responses from the on-tram passenger survey identify that:

- 32% of the trips are single mode (tram) journeys, 44% involve two modes, including walking, and 22% involve 3 modes
- around half of the trips involve a combination of walking (of more than 5 minutes) plus tram

- other important interconnecting modes are metro and bus (both accounting for 10% of combined mode trips)
- 75% of connecting bus services are lines run by the main city operator, and five operators account for 95% of the connecting bus trips.

2) Generated trips and the switch from the private car

The on-tram passenger surveys reveal that slightly more than one-third of passengers are making trips they did not previously make. Of the two-thirds of tram users who previously made the same journey, 18% used to travel by car, and 3% by motorcycle. The forecast modal shift from car was 7%. The Tramway has achieved a shift of at least 3,800 car journeys, based on May 2005 passenger volumes, and this represents a saving of 14,000 motorised veh-km per weekday.

The generated volume of traffic exceeds 13000 trips per day; at almost 40% of patronage this is higher than the expected forecast (around 20%).

3) An investment to keep trip lengths short

Land redevelopment associated with the tramway project has generated over 11,000 passenger trips per day. These are short-distance trips of typically 5km associated with compact urban renewal; they could not be accommodated if all the passengers were to use cars on the local road network. Had an out-of-town land development been promoted as an alternative, this would have provoked longer-distance commuting of, say 12km, with a more dispersed OD pattern – the type that is reliant upon use of the private car. So, in terms of the 10 to 20 year perspectives often used to economically justify road investments, the private road traveled saved by the tramway lies somewhere between 40,000 and 100,000 car-km per day, according to the way the generated travel is accounted, and taking into account the average car occupancy level.

4) Social inclusion

The responses from on-tram passenger survey identify that, each day

- some 17 wheelchair users travel by tram unassisted;
- around 50 cyclists use the tram to extend their trip-making distance;
- parents push some 385 baby chairs into and out of the trams.

5) Improved street amenity

The re-urbanisation of streets and roads has seen the conversion of 162,500 m2 of road space into pedestrian spaces and new cycle routes, and 135,000 m2 of roads into green planted areas.

This measure will continue to be supported by the local authority after the MIRACLES project has ended.

Upscaling

The Trambaix is one of the two tramway schemes installed by the new operator *Tramvia Metropolità,* with the second scheme (Besòs) opening one month later and being subject to similar design standards, assessment and monitoring. Of the various proposals to further extend tramways, a key feature is the proposal to link these two schemes by running trams along the central section of one of Barcelona's primary roads, (the Diagonal). Of the different alternatives that have been considered, street-running (rather than costly grade-separation in tunnel) would be the more natural upscaling scenario. However the political decision as to which options should be progressed is pending, and

estimates of impacts are not available.

Summary WP 7.5 Integration of Tramway in CPT network				
Indicator (units)		Baseline	After Miracles	
Econ.1a	Operating revenue (Euro/year)		6,400,000 Eur	Oct 04- Sept 05
Econ.1b	Purchase & installation costs (M Eur)		230.8 M. Eur	
Econ.2	Operating costs (M. Eur.)		22.6 M. Eur.	Oct 04- Sept 05
Ener.3	Vehicle fuel efficiency (litres fuel saved p.a.)		1) 57,000 2) 163,000	1) Concerns saving from car switching excluding generated trips 2) ditto, including generated trips See indicator Tran.28
Soc 14 b	Acceptance citizens (on 0 to 10 scale)	1) 4.26	2) see tramway survey…	1) May 2002 phone survey of 800 citizens
Soc 15	Impact for vulnerable groups (Users per day)		Wheelchairs 17 Cyclists: 50 Baby chairs: 385	
Tran.18	modal split / switch (% of pax)	PT from EMQ 2002..	18% switch from private modes (car & m'bike)	After mode split not available until EMQ survey repeated (after MIRACLES completion)
Tran.21 / 22	Trips (nº per day.)	See comment	41,000 on tramway	November 05. 6-month survey indicates that around 13000 (of 32000) passenger trips per day have shifted from other PT modes (primarily bus)
Tran.24	Average speed (km/h)	13.5 (bus)	18.5 tram	Tram figures achieved at November 2005
Tran.28 a	total amount of km saved (veh-km per day)	N/A	1) 14,000 2) 40000	1) Figure excludes generated trips, 2) Figure includes conservative estimate of generated trips.

M12 Barriers and drivers of the measure implementation / Process evaluation:

Barriers:

Historical legacy: this line represents the implementation of the first modern tramway in the city. The re-introduction of a street-running rail-based mode of transport after many years without trams was a matter that provoked a lot of debate, and considerable resistance to the scheme. One aspect of this was **private vehicle drivers' intolerance of movement restrictions:** the suppression of private vehicle turns at traffic signals caused some drivers to disobey restrictions and this led to several accidents in the latter stages of system commissioning, and the initial weeks of operation.

Drivers:

1) **Successful organisation** – both in terms of planning the works, and in financing their construction.

2) **Successful pilot**: In the late 1990s, a pilot track of 1.5 km was used to test different candidate supplier's proposals. The pilots were open to the travelling public and generated a higher-than-expected level of use.

M13: Interrelationships with other measures

Measure 7.2 is a demonstration of real-time information of connecting bus feeder lines.

M14 Lessons to consider for replication and take-up by other cities

The tramway rolling stock is performing well.

The ticketing and automatic vehicle monitoring systems work well and provide the means to monitor the principal performance indicators (passenger volumes and running speeds).

The tramway is the only mode of surface transport that is respected by private traffic; its segregation is designed for the overall route in a way that is not achieved by lanes reserved for bus lanes. Barcelona has yet to find a way to make car drivers really respect bus lanes and this reduces bus commercial speeds.

The stop design and the vehicles facilitate easy access, and promote social inclusion.

The high level of urban design is visible in terms of the re-allocation of street space as well as in the design of the interchanges with rail, metro and bus services; Trambaix helps citizens to walk or cycle extended trip distances more than it facilitates interconnection with bus and rail modes.

Passenger volumes exceed 40,000 persons/day, and are above the level forecast for the first year. The Trambaix scheme has achieved a substantial increase in passenger transport patronage due to its integral design as part of urban renovation and street amenity improvement.

The first-year switch from private travel modes (mainly the car) is around 20% for those passengers who make the same journey as prior to tramway implementation; the associated weekday saving in motorized travel is estimated to be at least 14,000 veh-km.

The high-density urban redevelopment has stimulated a high level of generated tramway trips. This helps to prevent an increase in trip lengths and improves the CPT capacity for serving local travel, and it is highlighted that half of all trips include walk times of mode than 5 minutes

Running speeds at 18.5 kph are currently slightly lower than was aimed for, although improved from th 16.5 km/h peed after 6 months of operation. Measures to improve running speeds concern segregation of tram and pedestrians as well as reduced cycle times at key signal junctions; the movement conflicts caused by introducing the tram are not easily resolved and require changing some streets to one-way so as to relocate car queues. 53% of surveyed passengers cited the higher speed (then 16.5 km/h) as the main motivation for using the tramway, showing that the achieved speed is appreciated by citizens.

A tramway scheme is more expensive than a series of bus lines having continuous priority in the stream of road traffic. It is debateable whether or not an alternative of high-speed bus lines could achieve a similar 20% switch from private car to that achieved by the tramway. However, further to the car switch to CPT achieved by the tramway, local practitioners highlight other improvements that the alternatives to the tram could not achieve, namely:

- the tram as a help to walk or cycle extended trip distances
- the better social inclusion of those with mobility difficulties
- improved street amenity (although there is no view as to how this could be quantified)
- the capture of a substantial trip generation for public transport

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5. Measure 9

MEASURE-LEVEL RESULTS	
Measure title: New concepts for the distribution of Goods	**Project: MIRACLES**
Measure Number : 9	**Site: Barcelona**

The Measure – what is it about?

M1 Measure objectives:

The objectives were focused on:

1. Improving Municipal management of vehicle circulation on the main and local road networks.
2. Reducing delivery times and costs.
3. Developing mechanisms to self-finance the successful scheme elements.

M2 Measure description:

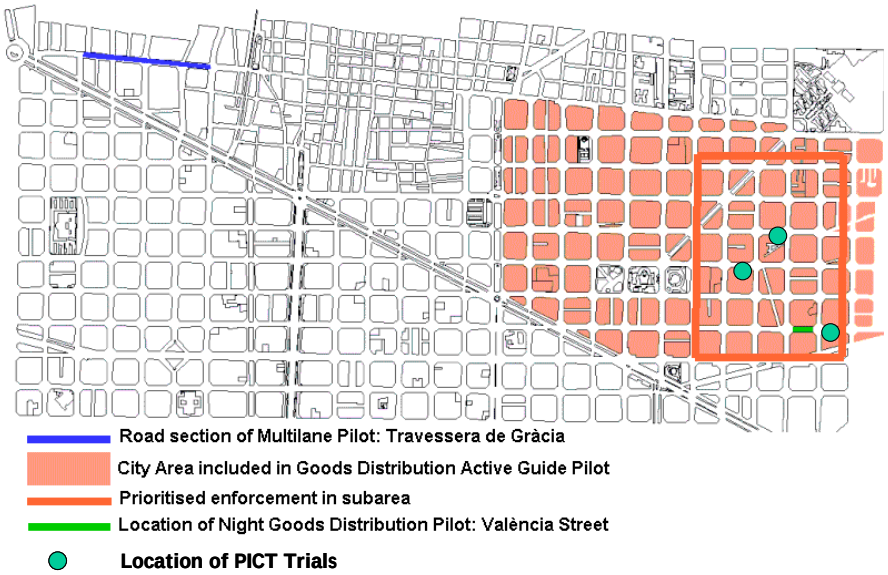


Figure 1 Map showing locations of MIRACLES goods delivery experimentation in Barcelona

The implementation comprises a series of measures:

1) Multi-use lane:

Addressing Objective 1, a multi use lane was installed along Travessera de Gràcia Street, a primary road comprising 4 lanes, having a total length of 1500m. One lane was allocated to bus priority during peak hours, and to goods deliveries during between peak hours (with on-street parking allowed overnight). Variable Message Signs (VMS) were installed along the section to clearly communicate the regulations to road users, with illuminated studs providing horizontal delineation of the multi-use lane.

2) Night-time deliveries:

Addressing all three objectives, goods operator Mercadona has trialled adapted 40T lorries and special equipment and operations for quiet deliveries at night. To do this, the Municipality has introduced experimental traffic regulations. Traffic police have collaborated with the Municipality to measure noise levels in residences close to the supermarket sites.

3) `Loading /Unloading' (L/U) Active Guide: web info & targeted enforcement.
Addressing Objectives 1 and 2, and covering a pilot area of some 0.5 sq. km. (with 230 reserved spaces serving a potential demand of 1085 premises), 8 supermarket operators + 3 distribution companies exchanged information via the web with the Municipality. The Municipality produces aggregated information to registered operators to enable them to plan to avoid hot spots (times and locations of congested delivery). The information analysed from the first 9 weeks was used by the municipal police to prioritise on-street enforcement action for a further 12 week period.

4) PICT Trials (special kerbside regulations)

It consists of temporary short -term loading /unloading spaces with special regulations restricting access to the kerbside directly in front of the supermarket to vehicles "authorised" by the 3 participating operators (Caprabo, Sorli, SuperSol). The supermarkets are located at more than 25m from the existing reserved spaces.

Note: measures 2 to 4 evolved from the original proposal to provide guidance using an electronic device which was to substitute the actual cardboard disc.

The Implementation – how was the measure implemented?

M3: Innovative aspects:

Multi-use lane

Unlike earlier schemes (with peak hour clearway regulations favouring the general circulation of car traffic), the MIRACLES measure provides bus priority at peak hours with bus lane regulations being produced and displayed on a new Variable Message Sign. The between-peak hours are dedicated to goods delivery unloading.

Figure 2 Left: new VMS message for bus priority
Right: Trav. De Gracia lane on the left, joins with the earlier Muntaner scheme, showing a peak-hour clearway.

Night-time deliveries

Operators had never previously worked with the Municipality / traffic police to trial quiet night-time deliveries; this is an innovative collaboration where operators have become active in introducing quieter and more ecological vehicles.

L/U Active Guide: web info & targeted enforcement

Eleven operators provided common data to set up the trial, with ten of them participating in further data exchange up to the end of the trial. This level of cooperation, involving two enforcement agencies, achieved through a series of 10 meetings over two years had not been previously achieved. The collaboration included a formal consensus on the trial specification (measure 4 was included at the request of the operators and in response to the results of the user needs surveys), pilot participation and acceptance rating of results..

PICT Trials (special kerbside regulations)

The agreed trial specification included new experimental kerbside regulations, providing reserved time-windows of 2 to 4 hours – much smaller than current regulations and for which the police expected difficulties regarding enforcement.

M4: Situation before CIVITAS:

The Municipality successfully introduced the **multi-use lane** concept for primary roads in the late 90s, with installations that reserved the between-peak hours for goods deliveries, but only with peak-hour clearways (see SMILES project report in ELTIS). Prior to MIRACLES, the length of implemented multi-use lanes across the city was 1.8km.

Barcelona Municipality had realised city-wide surveys of samples of commercial premises and operators which quantified more than 47,000 commercial premises generating some 100,000 un/loading operations per day. Based on this, in the period 1998-2002 the total of number of **reserved spaces for goods** deliveries was increased to 8,432 spaces.

Figure 3 Vertical signing of goods delivery regulations;
(lower captions indicate days and times, obligatory use of disc and limit of stay to 30 minutes)

Some 22% of these spaces are concentrated in the Eixample district which has a grid network of streets with junctions every 100m. Reserved spaces are located within the junctions with a capacity for 4 or 5 vehicles per reserved space, operating from 08.00 to 20.00. The number of space-hours available is designed to meet the overall measured demand derived by the city-wide survey. A cardboard disc is provided to those vehicles authorised to use the reserved spaces, and this disc is used to control / enforce the maximum stay limit of 30 minutes.

Night-time deliveries had never been previously experimented in the city.

M5 Design of the measure:

The design of the multi-use lane was realised by the Municipality Traffic Department in collaboration

with TMB, the largest bus operator in the city, and local Intelligent Transport System (ITS) suppliers.

For the rest of the measures, operators' needs were determined through a series of Mobility Pact (an open "Freight Partnership" led by the Municipality covering policy objectives & steering of freight-related actions in the Municipal Programme) meetings where initial proposals for information systems were discussed, and through which a user needs survey was defined, responses obtained and results presented.

Through this Forum, one of the operators initiated bilateral discussions to realise a trial of quiet nocturnal delivery using an adapted 40T truck to serve one of their supermarkets located in Valencia St. in Eixample District. This trial was designed in collaboration with staff of Mobility Services and traffic police.

A key result of this User Requirements phase was the demonstration that the location (and/or times) of the reserved spaces does not match the precise detailed requirements of the operators. This was demonstrated to the Municipality by pooling data from eleven operators on delivery schedules corresponding to an area of 1.3 sq. km. (containing 505 reserved Loading /Unloading spaces and some 3500 commercial premises) and by using G.I.S. tools to determine the percentage of reserved spaces within distances of 25m, 25-50m and 50+m of the store doorsteps.

The user survey also confirmed that operators have only limited possibilities to use real-time congestion information to alter delivery itineraries. In the case of B2C (home deliveries) the pattern of deliveries is devised outside the city, and the ability to deliver depends highly upon the availability of the end-customer.

The following scheme summarises how the actors utilise and manage on-street Loading / Unloading (L/U) spaces in the scheme:

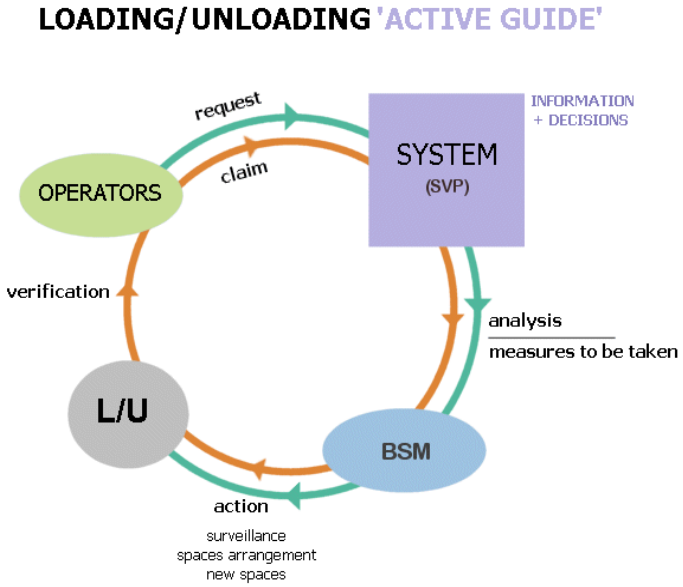


Figure 4 Functional scheme of stakeholder involvement

The trial design was agreed through meetings with the operators. As part of the second phase (with targeted enforcement) the Municipality agreed to operators' proposals to trial experimental "PICT" regulations directly in front of certain supermarkets.

M6 Actual implementation:

The **Multi-use** scheme was implemented under a contract awarded to ETRA in spring / summer of 2002. A significant police enforcement effort was made at the commencement of operation. 44 on-

street car parking spaces were replaced by the multi-use lane regulations, such that the capacity for unloading was significantly increased (approximately 30 spaces allowing 30 minutes per operation gives a capacity of over 400 slots between 10.00 and 17.00).

The first **night-time quiet delivery** trial was made at the Mercadona supermarket in Valencia Street in 2003, with an adapted 40T truck. To do this, the Municipality had to introduce experimental traffic regulations. Traffic police collaborated with the Municipality to measure noise levels in residences close to the supermarket sites. The trials with 40T trucks were extended to 5 other locations around the city during 2004. In addition to the adaptations to the vehicles, staff were trained to realise the unloading operations using a set of procedures aimed at minimising verbal communication and other noise.

Figure 5 Quiet night-time unloading using adapted 40T truck at Mercadona's Valencia St outlet.

The web-based L/U Active Guide was trialled between March and June of 2004 for a pilot area covering 40 junctions. It involved 8 supermarket operators + 3 distribution companies exchanging information via the web with the Municipality during a 16 week period. The following figure shows an example of the output achieved using the input page (also shown).

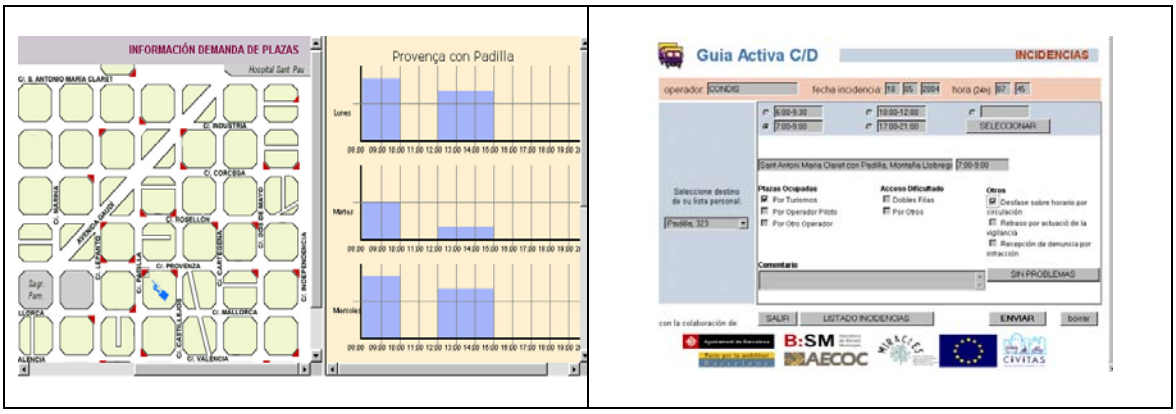


Figure 6: Map of the Active Guide pilot area, showing the delivery zones used and their occupancy level (by day of the week); on the right is the web page for incidence reporting

Traffic police from three different jurisdictions were involved in the enforcement of the second phase of the Active Guide trial. To facilitate monitoring, operators' vehicles carried an identification card.

Figure 7 Lorries participating in the Active Guide pilot showing identification card.

The traffic police also participated in the PICT trials of special kerbside regulations. Different road types were included in these trials; one primary road (4 lanes in total, peak-hour clearway giving 4 circulating lanes) and two secondary roads (one having a total of 4 lanes, two for circulating traffic, the second having 4 lanes, one being a dedicated cycle lane, one for circulating traffic).

Figure 8 PICT scheme experimental signing

M7 Deviations from the plan:

The proposal to pilot an electronic device as a substitute for the cardboard disc was presented to operators, but was modified to better solve their actual problems. The operators negotiated with the Municipality to include the PICT trials, delaying the completion of pilot specification by one month.

The opportunity to trial quiet night-time deliveries also arose during the needs definition phase of the project, and this was incorporated as a new Milestone in the revised Site-Measures Annex.

The functionality of the information system was adapted in light of the results of the user needs survey, and in view of the willingness of the operators of the B2B distribution sector to participate in collaborative trials under the coordination of the AECOC (national operators association).

Work expected to be realised under sub-contract (Internet database) was finally realised as labour with the incorporation of the sub-contractor in revised Contract Amendment 1.

Resources initially allocated to the supply of kerbside identifier units were re-allocated to additional design work for the active guide and quiet nocturnal delivery trials, and to the provision of related policing services. As a trial, the Active Guide application was loaded on a third-party server rather than the Municipality's server.

The Evaluation – how was it done and what are the results?

M8 Method of measurement:

Activities	*Data Source*	*Frequency*	*Form*
1) Multi-use lane	Street surveys of circulation speeds and parking activity	pre/post	excel/word documents
2) Night-time deliveries	Noise measurements (GU)	pre/post	dBa
3) Active-Guide	field measurements (DSD)	once	GIS (data+maps)
	Web Service (operators)	daily*	web site database
	Enforcement agencies reports	periodical	excel/word documents
	on-street controls (DSD)	periodical	excel/word documents
4) PICT Trials	control measurement (DSD)	pre/post	excel/word documents
	information report (GU)	once	excel/word documents
	activity report (operators)	pre/post	excel/word documents

*pilot lasted for 18 weeks, finishing on June 16, 2004.

Additional surveys of users needs were carried out, using “post-back” questionnaires, at the onset of the project. On the one hand this provided evidence that most operators’ operations were not organised in a way that could avoid congestion by changing delivery schedules in a dynamic way. On the other hand, it collected information about actual delivery patterns that could be used to determine the level of service achieved by the reserved spaces provided by the Municipality.

The acceptance of operators was also recorded using a common scale at the end of the pilots to determine relative acceptance of the Nocturnal unloading, Active guide and PICT trials.

Multi-use lane

The main indicator that the Municipality uses to assess Multi-use lane performance is the journey speed of the general traffic as recorded by floating car surveys. Approximately 30 “runs” were completed during a one week period prior to installation, with a similar measurement being made in the month following implementation. In addition, the municipality commissioned surveys of the legal / illegal parking activity (hour-by-hour, over the day, on the same working day in a week before and after scheme implementation). Bus journey time data along the Multi-use lane were not available for the before situation due to technical problems with the AVM system of the main bus operator.

Night-time deliveries

The Municipality’s main concern regarding the extension of goods unloading beyond 20.00 is the possible noise nuisance to residents (shops are serviced from the street, with commercial premises as the ground floor of apartment blocks typically 6 stories high). Noise measurements at the Valencia St nocturnal un/loading site were realised by Municipal police during the months of April, May, June and July of 2003. The measurements were realised outside within the street environment as well as inside 6 occupied residences close to the supermarket. The measurements were realised at different time periods (23.00, 03.00 and 05.00 hrs, with measurements at residences recording minimum and maximum values in dB(A) between 23.00 and 23.30 hours (total of 22 sets of measurements).

L/U Active guide

Over the 17 week trial period, 1772 communications from 11 operators were received and registered

in the web database. These communications were reported for 460 vehicles, estimated to represent between 15% and 39% of the goods vehicle activity in the trial zone (depending upon whether company service vehicles and vehicles of associated suppliers are included with those delivery vehicles belonging directly to the participating operators).

In addition, on-site observations were made for circuits designed to give observations of space occupation, duration of stay, identification of participating vehicles, etc. at least once every half-hour for each set of reserved spaces, over the period of regulated use (08.00 to 20.00). These measurements were made both before the trial (in February) and during the trial first phase (March) with 14 sets of measurement in total. Additional on-site observations were made by police and traffic enforcement agents, and the number and type of sanctions issued was recorded.

PICT trials

Observations of deliveries were recorded at the supermarket frontages before and during the operation of the special kerbside regulations, both by staff commissioned by the Municipality and by the participating operators. The measurements recorded the type of delivery made, the type of vehicle making the delivery, incidences affecting space availability and the time taken to make the delivery and vacate the space. By comparing the observations made (nearest space available before the trial with space facilitated in front of the supermarket) the reduction in delivery times and space occupation were derived. Additional on-site observations were made by police and traffic enforcement agents.

M9 Achievement of quantifiable targets:

There are no quantifiable targets for this Measure.

M10 Achievement of evaluation-related milestones:

M1 Agreement on prototype application was signed in June 2003 (month 17)
M2 (First) Quiet night-time delivery trial (month 17)
M3 Loading of the Active Guide prototype was realised in March 2004 (month 26)
M4 Demonstration with kerbside identifier units realised (Active guide & PICT trials), months 26 to 29

M11 Report on the measure results:

Multi-use lane

The main result is a reduction in travel time along the section of (generally) between 12 to 15% – see M11. This achievement reflects a reduction in overall illegal parking activity for both cars and goods vehicle), with the latter being associated with the increase in unloading kerbside capacity. The changes reduce the possibility that the second lane becomes blocked due to double parking, and this leads to improved circulation. What is especially encouraging is that journey times were still lower after the special police enforcement (supporting scheme introduction in May) had been completed.

Date/Time	9,00 h	11,00 h	13,00h
3 may 2002	100%	100%	100%
22May 2002	83%	88%	87%
18 Oct. 2002	88%	47%	84%

Table 1 Reduction of travel time (Casanova St. /Via Augusta), Before, 2 weeks After, and 5 months after introduction of the combined-use lane

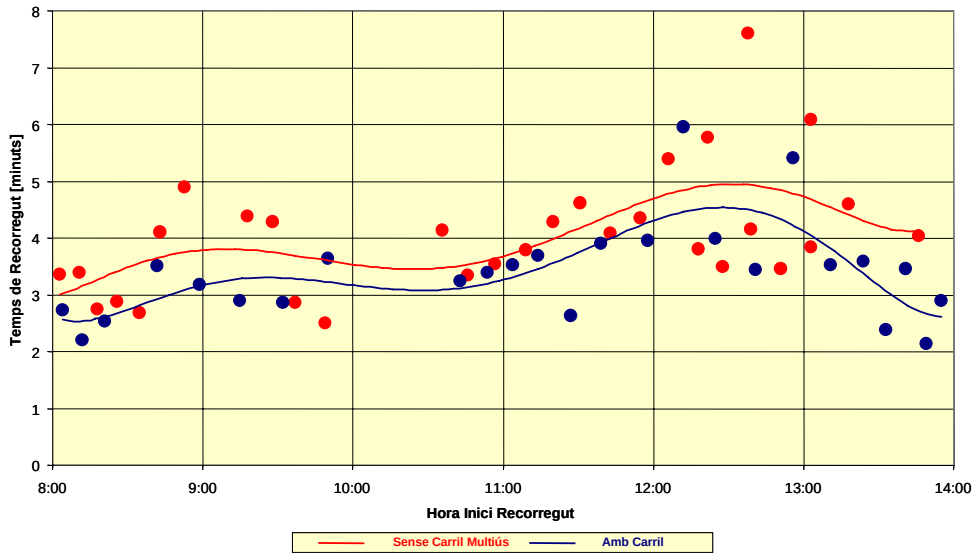


Figure 10 Journey times Before (red) and After (blue) the implementation of the multi-use lane in Travessera de Garcia.

The observations goods show that incidences of illegal goods unloading are reduced to below 10 vehicles per period of observation (continuous on-street counting) from previous levels of around 25 vehicles during the late morning and 20 vehicles during the afternoon. For cars, parking during the late morning is reduced, and the afternoon incidences become more concentrated around the time of closure of a local school. The intensity of the loading / parking action is reflected in the journey time results.

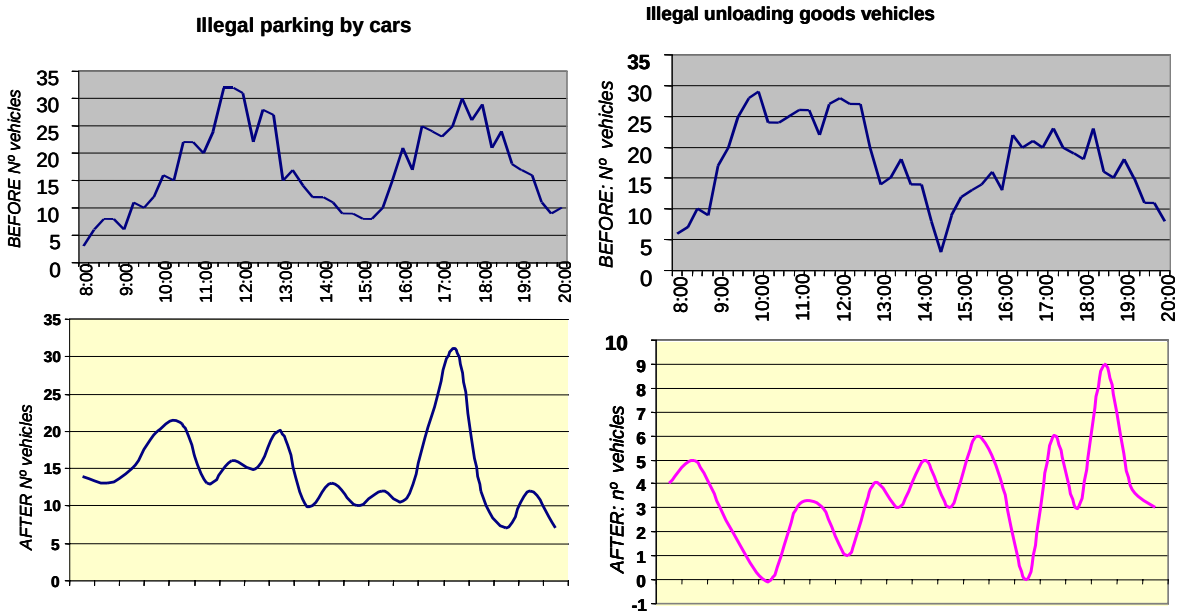


Figure 11 Before (top) and After (bottom) observations of on-street car parking (left) and illegal goods unloading (right) for the Travessera de Gracia multi-use lane.

Night Time deliveries

Operator Mercadona has demonstrated that quiet delivery is possible with a 40T lorry serving supermarkets with a rather large capacity and with substantial refrigeration facilities. The result is quantified in terms of noise measures compared to ambient noise levels on nights when the delivery was not being made; the average of the minimum values recorded during unloading inside buildings (23.5 dB(A)) was 0.3 dB(A) greater than those recorded before loading started; for maximum values no difference was recorded for measurements inside buildings (33.4 dB(A)), and the maximum values recorded in the street varied by only 0.1 dB(A), average with unloading of 52.2 dB(A).

The delivery characteristics in this trial indicate that 2 trips/week at night can save 7 trips using smaller lorries during day-time traffic.

Operator Mercadona estimates that full investment in vehicle adaptation is recoverable within 3 years.

L/U Active Guide

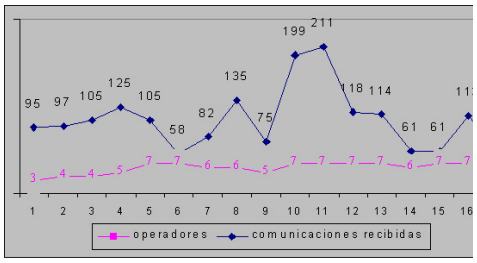
From the analysis of the data supplied about operators' deliveries in the area containing 505 reserved spaces it was discovered that:

- only 36% of the deliveries could be made using reserved spaces within 25m distance of the store, and in half of these cases the operator using the reserved space would have to cross a street.
- 11% of deliveries are further than 50m from the reserved spaces; in all of these cases the operator using the reserved space would be obliged to cross at least one street.

It is thus not surprising that the initial user survey identified the main problem as being a lack of reserved spaces.

For the pilot area, with 230 spaces available, the observations from circuit surveys quantified the demand/supply ratio to be 112% (after taking into account levels of illegal parking by cars). Ratios of demand to supply exceeding 85% typically result in degraded levels of service. When the circuit observations are compared with the detailed reporting of delivery problems via the web, it was found that operators encountered difficulties on 553 of the 1772 (67% of) occasions when deliveries were made during the 17 weeks of the trial.

Information received about operators' schedules (for the area containing 230 spaces) was aggregated to identify locations / times where unloading actions are concentrated (i.e. the "hot spots" for enforcement). It was demonstrated that this information can be published to encourage operators to voluntarily re-schedule deliveries at congested locations to less-busy times of day (such behaviour was not observed during the limited time of the trial, and the concentration of early-morning deliveries for this (food distribution) sector suggest that operators are most interested in more and better located spaces).



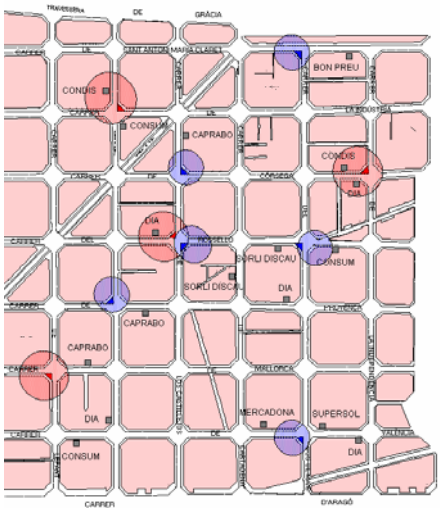


Figure 9 Active Guide trial.
Above; evolution of operator participation & reported incidences
Right; identified "hot-spots" where enforcement was targeted during Phase 2 (pink; incidence reported by more than one operator, blue; incidence reported by one operator).

One of the results is the way that monitoring of reported incidents can identify those locations where problems are concentrated, and also measure temporal changes following targeted enforcement (see M11).

Another result is that operators' reports show deliveries ("entregas") to be concentrated in the early morning (some 36% of all deliveries are made between the hours of 07.00 and 09.00) and more than a third of incidence reporting occurs in this time period, see Figure 10.

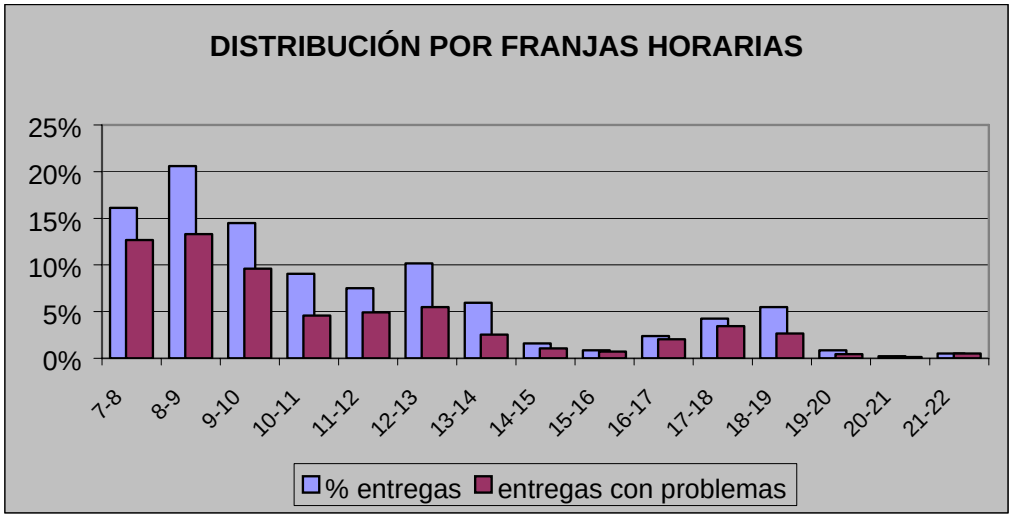


Figure 10 Hourly distribution of deliveries and deliveries experiencing problems in the Active Guide trial

The comparison of those spaces with highest occupancy levels according to conventional on-street "circuit" surveys with the operators' reported incidences are broadly similar once the reports for 07.00 to 08.00 are excluded (circuit surveys are realised for the hours of regulation which start at 08.00).

In week 9, enforcement was targeted at 3 "hot spots" where particularly high levels of problems had been reported (by at least two of the 10 participating operators). As a result of the enforcement an average reduction in problem-reporting of 18,6% was achieved at these location / time periods during the second phase of the trial:

		% of comms. reporting problems with un-loading	
nº of operators	zona ref.	Before	After
2	3	85	67
3	11	63	40
2	19	82	67

Table 2 Active Guide: results of targeted enforcement

The difference between zones with more early deliveries (zones 3 and 19) and those without (zone 11) is noted; to achieve the higher reductions of zone 11, either the regulations would need to start earlier (07.00 instead of 08.00) or operators would have to re-schedule their deliveries later in the day.

PICT customised unloading trials

3 types of location were trialled: a) primary road (high density transit), b) secondary road + free parking lane, c) secondary road + free parking lane + bike lane. An important factor was the police assessment as to whether regulations giving just a couple of hours of unloading could be enforced; this was assessed by the Municipal traffic police; based on their own reports and site observations, no additional problems were encountered.

Although the measurements of delivery operations and times were realised to different degrees at the different sites, the estimates of delivery times that have been computed indicate that this measure achieves significant reductions in times for operators compared to the normal city situation. Table 2 provides a summary of the performance of one of the PICT locations.

	Type of Unloading	Distance (m)	Unloading Time (min)	Total time (min)	Trips (num.)	Persons (num.)	goods Volume (m3)	Affected Pedestrians (nº)	(Time/ Volume) Ratio
U/L Zone	Pallet	30	**13,3**	27,0	5	2	15	**13,7**	**0,9**
PICT trials	Trolley	0	**6,5**	8	2	2	11	**8**	**0,7**

Table 3 Comparison of supermarket deliveries; PICT versus usual U/L zone

A local language report of the results was presented and agreed at a meeting of stakeholders held in late 2004.

Comparison of achieved versus expected quantified and verifiable result:

The activities concern new actions that generate new information and/or combine information in new ways. There were no prior estimates regarding how the information might be exploited.

The focus on supermarket deliveries (rather than B2C home deliveries) was a collective decision taken by the project participants, and reported in the Mid-Term Report.

Provided that a high level of participation is achieved, the utility of information exchange is demonstrated as a means of identifying the location and times of more acute unloading problems, and in monitoring the reduction in reported incidences following targeted enforcement. For times when reserved spaces are available (i.e. after 08.00) web-based incidence reporting identifies similar problems to those identified using conventional on-street (circuit) surveys – suggesting that the web could provide a means of extending monitoring beyond the area currently agreed by the municipal – agency contract. In addition, web-based reporting obtains a new intelligence about the problem of early-morning deliveries (i.e. before 08.00).

Unloading times can, in some cases, be halved by an improved location of reserved spaces (PICT trials).

Operators are highly motivated to participate in the trials of new concepts (night-time delivery using adapted vehicles, PICT measures, etc.) that facilitate improved locations of reserved spaces. In the case of night deliveries operators appear to be motivated to invest in new technologies. The possibility of a more general licencing to self-finance new regulations.would need to take account of the general characteristics of operations that are applicable city-wide. Also, the recent AREA (residents' parking) scheme initiative has to be taken into consideration as this alters the supply of reserved spaces in parts of the city.

This measure will continue to be supported by the local authority after the MIRACLES project has ended.

Up-scaling

Multi-use lanes: Barcelona Municipality is committed to extending the kms of multi-use lane covering the city's primary roads. Since the MIRCLES trial, the Fabra I Puig scheme has been implemented extending the total kilometrage to 4.4kms. Additional schemes are under preparation in the Municipal Action Plan (2004-2007) Each scheme is designed to meet varied local conditions such that a simple extrapolation of the impact demonstrated at Trav de Gracia street is not recommended. These measures aim to prioritise goods deliveries, and extend the overall policy of restricting on-street parking for cars, whilst maintaining the general circulatory speed of primary road traffic.

Quiet night-time deliveries: From the operator point of view, upscaling is an essential part of securing the return on investment. A nation-wide upscaling of the Barcelona result has been achieved by Mercadona, the operator using 40T lorries to service atypically large neighbourhood supermarkets; the initial trial at one location in Barcelona has been extended to 4 locations across the city (in addition to Valencia St; Crta de Sants, Calabria St and Casp St) and to over 100 outlets across Spain. However, from the city view point, the upscaling can only be achieved when similar positive results are achieved with the 15T lorries generally used to service the more prevalent smaller supermarkets of other operators. Such trials are on-going, with a second operator Condis involved in a trial using an IVECO truck at its Aragó St outlet, earlier this year, Until such trials demonstrate a solution with medium-size lorries a city-wide upscaling cannot be envisaged. The Municipality and operators are considering possible further trials within the framework of the FIDEUS project.

Figure 12 Quiet night-time unloading using adapted 15T truck at Condis' Aragó St outlet.

Active guide: in order to implement a web-based reporting service across the city, the useability of the application would need to be improved; rather than the manual logging and entry of reports an automated solution based on PDAs needs to be offered to operators. The benefits of such a service would be the collection of intelligence for areas of the city where the authority currently has no means of monitoring delivery needs /enforcement performance, as well as the possible substitution of manual monitoring effort of the area for which an enforcement agency agreement is in place. The technical feasibility of an automated service needs to be proved before estimates of upscaling are contemplated.

Indicator (units)		Baseline	After Miracles	
Econ.1	Purchase & installation costs (Eur).		181,000	1) Multi-use lane
Econ.2	Operating costs: 1) nº of trips 2) unloading / delivery times	1) seven trips / day with 15T lorries, during peak & off-peak 2) Only 18% of deliveries achieved from reserved spaces within 25m, with no need to cross street	1) 2 x 40T trips (night-time) 2) PICT results show unloading time can be halved, overall delivery time reduced by two-thirds if delivery is made from spaces in front of supermarket outlets	1) Mercadona; 40T truck night-time delivery 2) Active guide / PICT pilot
Env. 12	Level of noise (maximum dB(A) level recorded in 30 min. period	43.4	43.5	40T truck night-time delivery (average of 13 observations)
Soc 14	Acceptance operators (responses from 11 participants in Active Guide, 0 to 5 scale):	n.a.	1) 3.0 2) 3.3 3) 4.0	1) Night-time unloading 2) Active guide 3) PICT spaces
Tran.23	average veh. speed peak (%)	100%	88% (12% reduction)	Multi-use lane
Tran.24	average veh. speed off-peak (%)	100%	84% (16% reduction)	Multi-use lane
Tran.28.a	Average Nº of illegal un/loading operations /hour over day	16	3	Multi-use lane
Tran.28.b	Average Nº of illegal parking operations /hour over day	20	12	Multi-use lane
Tran.28.c	Nº of transport operators registered	n.a.	11	Active guide
Tran.28.d	Nº of transactions realised	0	1772	Active guide

Table 4 Summary of indicators for Measure 9

M12 Barriers and drivers of the measure implementation / Process evaluation:

1. Collaboration within the frame of the Mobility Pact and the Municipal Programme for Action is the main driver.

2. Needs were surveyed for 11 operators to identify the tools to solve the problems between supply & demand. This confirmed that although the Municipality provides enough spaces to satisfy city-wide demand, the operators experience a series of problems at microscopic, local level. The survey prioritised these problems, and this was an impulse for the collective design, development and evaluation of the activities.

M13: Interrelationships with other measures:

The demonstrated multi-use lane provides priority for Collective Passenger Transport, but is not linked to the WP7 measures of the city demonstration.

M14 Lessons learned:

The first lesson learned is that the road authority needs to do more than provide a number of un/loading spaces that broadly meets the overall demand; locating such spaces at the most

convenient locations for highway management does not, usually, resolve operators' problems.

A second lesson is that the web can serve as an effective channel to register the times and locations where operators' delivery problems are most severe. To ensure strong operator participation in the short-term, authorities are advised to use this new information to carry out targeted enforcement of the "hot spots"; this can reduce the level of problem-reporting by operators significantly (around 20% in the case of the Barcelona MIRACLES trial). In order to address "structural problems" regarding the improved location of unloading spaces, medium-term actions such as the PICT trials can be incorporated in the collective initiative to good effect. The three operators participating in the PICT trials were satisfied with the outcome (e.g.: elimination of a 30 metre distance reduced overall delivery times from 27 to 8 minutes), and enforcement agents did not encounter an increase in illegal parking.

In dense cities like Barcelona, supermarket operators are interested in more flexible regulations regarding the times of delivery. It has been found that operators using 40T lorries serving supermarkets with refrigeration facilities can realise such operations at night without causing noise disturbance to residents (vehicles with special carpets, electric lift and carry elements, etc.). With a twice-weekly delivery, such an operation can substitute 7 daytime deliveries using smaller vehicles. The success of this trial has led operators of smaller supermarkets, (who use smaller 12T vehicles and cannot adopt a delivery pattern using such large vehicles), to also look for noise-reducing measures; further trials have been made with 15T vehicles. If these are successful, a code of good practice could be established, and the allocation of prioritised kerbside un/loading could be linked to operators' compliance as well as levels of portal participation.

There is interest to continue with the initiative beyond MIRACLES, with a focus on managing PICT requests via the web portal. This work needs to exploit the cost and benefit data gathered in MIRACLES in order to establish a financing mechanism that meets the interests of all actors (authority, operator and enforcement agency), and this will need to take account of recent initiatives such as the AREA resident parking scheme. In taking forward the initiative a means for facilitating automated incidence reporting by operators is likely to be a pre-requisite.

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6. Measure 12.3

MEASURE-LEVEL RESULTS	
Measure title: Extension of the CNG bus fleet	**Project: MIRACLES**
Measure number: 12.3	**Site: Barcelona**

The Measure – what is it about?

M1 Measure objectives:

TMB (Transportes Metropolitanos de Barcelona), the main bus and metro operator in the city of Barcelona, is motivated to integrate Compressed Natural Gas (CNG) buses into the public transport fleet as part of its corporate strategy to achieve the highest environmental standards, and to contribute to the improvement of a more sustainable transport for the city.

The objectives focused upon making a significant demonstration of (at least70) standard gas buses with a view to making a decision for accelerated vehicle acquisition (up to 250 vehicles by 2006).

M2 Measure description:

Between 2001 and 2002, a fleet of 70 CNG buses was acquired in two batches of 35 vehicles, the latter forming part of the MIRACLES project. These are standard length (12 m.) vehicles supplied by IVECO and MAN (and are referred to as the 2001/2002 or first generation of CNG buses in the fleet).

The first part of the measure concerned the demonstration and evaluation of the “first generation” of 70 CNG buses in terms of environmental and energy performance, and under real operating conditions.

A second part of the work involved infrastructure improvements in order to support the operation of an extended fleet of CNG buses as part of the company’s bus operations. Further vehicle acquisition was not charged to the MIRACLES project.

The Implementation – how was the measure implemented?

M3: Innovative aspects:

The measure was undertaken within the framework of the strategic partnership agreement made between TMB and the catalan utility company, Gas Natural s.a..

This project was central to TMB becoming the first bus operating company in Spain, and one of the first in all of Europe to achieve ISO 14.001 certification.

The innovation concerns the improvement of maintenance infrastructure, both to minimize CNG bus costs and to support the migration to hydrogen bus trials (CUTE project).

M4: Situation before CIVITAS:

It was 1995 when TMB introduced for the first time two (standard and articulated) CNG buses, demonstrating the viability of that “new fuel” for the public transport vehicles. The test outcomes confirmed the reduction of the polluting emissions and the noise level generated from these vehicles in comparison with the rest of the (diesel propelled) fleet. TMB and Gas Natural s.a. signed in April of 2000 an agreement to use CNG as a regular fuel for the buses.

There are more than 250 Euro 1 diesel (or older) buses in the total fleet of 1008 passenger-carrying vehicles.

M5 Design of the measures

Under the strategic partnership agreement, Gas Natural s.a. became the sole provider of gas energy, and would have exclusive rights to the design of bus livery for marketing and image promotion. TMB received gas supply at a fixed price and Gas Natural s.a. assumed responsibility for the provision of the refuelling station.

Given the positive results achieved with articulated buses (both in energy and emissions) the initial intention was to acquire articulated buses. At the time of initial tendering (1999- 2000) no responses were received from manufacturers, and the decision was taken to proceed based on standard 12m buses.

Infrastructure improvements were made at one of TMB's largest bus depots (Zona Franca I) in order to extend the capacity of the re-fuelling station and to provide specialised, efficient workshops for maintaining vehicles of this type. The Zona Franca depot was chosen because of its location adjacent to the Port of Barcelona; this enabled the refuelling station to receive gas supplied directly by pipeline, avoiding the need for road transportation. The refuelling station was developed with technology to achieve fast bus refuelling within 3 minutes. The station includes a reserve compressor, and initially had a refuelling capacity for 120 buses.

Figure 1 CNG bus refuelling station, at TMB's Zona Franca depot, Barcelona

M6 Actual implementation

Figure 2 CNG bus demonstration in Barcelona; a strategic partnership between TMB and Gas Natural s.a.

The evaluated buses correspond to the following models:

- IVECO City- Class (CNG) Euro 3 VEM
- MAN NL - 233F (CNG) Euro 3
- MAN NL - 233F(CNG) Euro 3
- MAN NL - 243F(CNG) Euro 3 VEM
- M.B. O 405 N2 Euro 1

The evaluation of environmental and energy performance was realised by putting the CNG buses, and those used as a reference (Euro 1 diesel), into operation on a series of bus lines; 22, 57 and 157. Line 22 (with an overall average gradient of 4%) was chosen to represent the hilly lines that run on gradients along the sea-mountain axis. The other lines represent the generally flat conditions of the rest of the city, with one line dedicated to each of the CNG bus suppliers.

Figure 3 Routes used in the CNG bus demonstration: left;Line 22, centre; Line 57 and right; Line 157

The design and construction of the specialised workshops were realised in the first 18 months of the project. In addition to measures to counter risks associated with handling of compressed gas, a transversal crane provides easy access for maintaining gas tanks located in the roof of the bus.

Figure 4 Specialised workshops facilitate the maintenance of buses with new fuels

M7 Deviations from the plan

No deviations occurred during demonstration and evaluation of the fleet of 70 CNG buses.

The target for gas bus acquisition (300 vehicles in the Technical Annex) was modified to 250 vehicles in the report to the Mid-Term Review, and this was accepted at the Review.

The Evaluation – how was it done and what are the results?

M8 Methods of measurement:

	Activities	Realised during:
1)	Measurements of energy consumption & estimates of pollutant emissions (70 CNG buses)	Jan – May 2003 (CNG) Jan – May 2001 & 2002 (Diesel)
2)	Driver & passenger surveys	March – April 2003
3)	Economic costings	2002 – 2003

1) The comparison of CNG with the vehicle type to be replaced is justified in terms of the context of the strategic agreement with Gas Natural s.a, plus the ambition to achieve a leap forward in terms of the environmental performance of the bus fleet. Fuel measurements made for all services run during 5 months of CNG bus operation. The evaluation was made by Formaplan consultants, with technical advice provided by ICAEN, the energy agency of the regional authority. The estimation of pollutant emissions is based on COPERT, with unitary data from vehicle suppliers used instead of CORINAIR (which does not include data for CNG vehicles).
2) Acceptance surveys realised by face-to-face interviews with 82 drivers and 348 passengers

M9 Achievement of quantified targets

During 2005, TMB has presented to the Mayor, 90 new CNG buses acquired this year. This brings the total CNG bus fleet to 160 buses (110 standard (11m. long) buses, plus 50 articulated (18m) buses). It is forecast that the ambition of achieving a fleet of 250 CNG buses will be achieved in 2006.

M10 Achievement of evaluation-related milestones

All the evaluation related milestones (as in the Barcelona Local Annex to Deliverable 4.1) have been achieved. The results were presented locally in July 2003 ("Avaluació de la flota d'autobusos de gas natural comprimit").

M11 Report on the measure results:

Energy efficiency and pollutant emissions

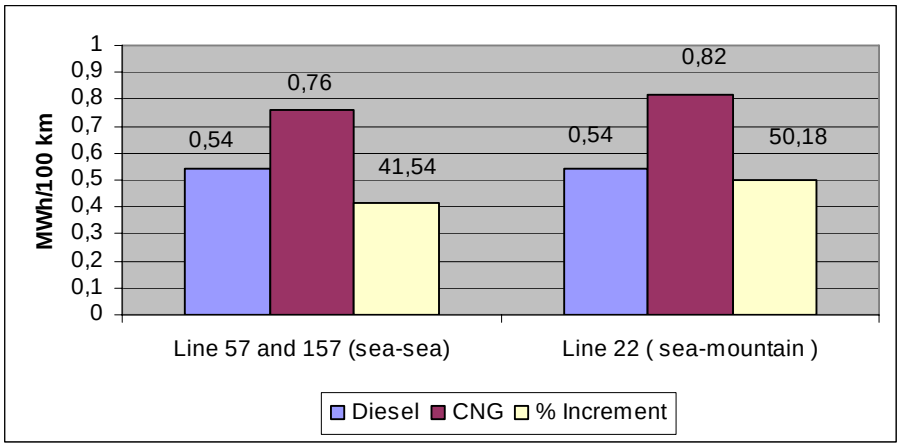

Figure 5 Energy performance of "standard" CNG bus:

42% more than diesel on the flat, 50% more on the hilly route

In terms of the monthly operation of the demonstrated fleet of 70 CNG buses, although the energy consumption increases by 50% (464 MWh), the savings in pollutant emissions are:

- 158 Kg of particles
- 1,2 Tn of HC
- 4,8 Tn of CO
- 7,3 Tn of NOx

Table 1 presents the pollutant emissions of the diesel buses in terms of the numbers of CNG buses required to achieve the ame level of emissions.

	CNG buses
Small Particulates	8
CO emissions	9
HC emissions	14
NOx	16

Table 1 Pollution levels of one diesel bus in terms of equivalent number of CNG buses

User acceptance

A high level of acceptance of CNG buses is found from the survey responses:

- 7 out of 10 drivers value positively the CNG buses
- 9 out of 10 passengers value positively the CNG buses

For drivers, the most highly rated aspects concerning quality of service are the:

- Decrease in engine (93%) & ambient noise (85%),
- Decrease in fuel smell (88%),
- Decrease in vibrations (87%).

For passengers, the most highly rated aspects concerning quality of service are the:

- Decrease in pollution (96%) & fumes (91%)
- Decrease in fuel smell (75%)
- Decrease in vibrations & noise (71%).

Interestingly, the drivers and passengers gave higher ratings for different CNG bus models.

Economic / Financial appraisal

	Surcharge per vehicle	
	Without subsidy	With subsidy
Vehicle	36.000	18.000
Recharge station	14.482	0
Maintenance workshop	5.309	5.309
Training	1.810	1.810
Total	**57.601**	**25.119**

Table 2 Investment costs of CNG compared to Diesel bus

The higher CNG bus investment cost is balanced by a saving in maintenance cost that is quantified as 1,027 Euro per month. (Under the strategic partnership with Gas Natural s.a., although the energy consumption of a gas bus is higher han the diesel bus, there is a saving in terms of fuel cost that exceeds the higher maintenance of the gas bus). This gives a return on investment (without subsidy) of less than 5 years. Efforts were made to quantify the economic benefits associated with the emission and noise savings. The following table summaries the result achieved using two methods. These impacts are not included in the aforementioned rate of return.

	Saving vs diesel buses (€/km)	
	INFRAS / IWW	CERTU
Atmospheric pollution	0,321	0,457
Acoustic pollution	0,083	0,008

Table 3 Cost estimates of environmental benefits of CNG compared to Diesel bus

CNG buses are demonstrated to consume more energy than the diesel buses. Within the framework of the strategic partnership with the utility company, the higher fuel consumption is not a critical issue, and operational savings more than offset the higher gas bus maintenance costs.

Of the two CNG models tested, the one showing lower energy consumption showed a poorer energy performance on the hilly route. Given that different models are found to be most popular for different users (drivers and passengers), and that the results were achieved for "first (2001/2002) generation" CNG buses it is recommended that:

- The model with lower performance is allocated to the flatter service routes,
- An open policy is adopted toward the acquisition of additional new CNB buses (especially considering the original interest in articulated CNG buses).

This measure will continue to be supported by the local authority after the MIRACLES project has ended.

Up-scaling

Current scale

The MIRACLES demonstration of CNG bus fleet expansion was realized with 70 CNG (standard 12m. long) buses, comprising models supplied by IVECO and MAN.

Motivation, Objectives & Scale of measure

Up-scaling of the results achieved for a "test fleet" of 70 CNG buses has been of interest since the local ambition is to achieve a CNG bus fleet of 250 vehicles. The objective was to quantify the relative benefits related to a further expansion of the fleet (from the 70 bus used in the demonstration to a fleet of 250 buses).

Specification

The energy and emission estimates made for the 70 buses in operation are considered to be expandable to 250 vehicles provided the same models are acquired, (and replaced). In practice, new and improved gas buses have become available such that by the end of 2005, 90 new CNG vehicles were acquired (40 standard 12m length but with reduced weight, and 50 new articulated buses).

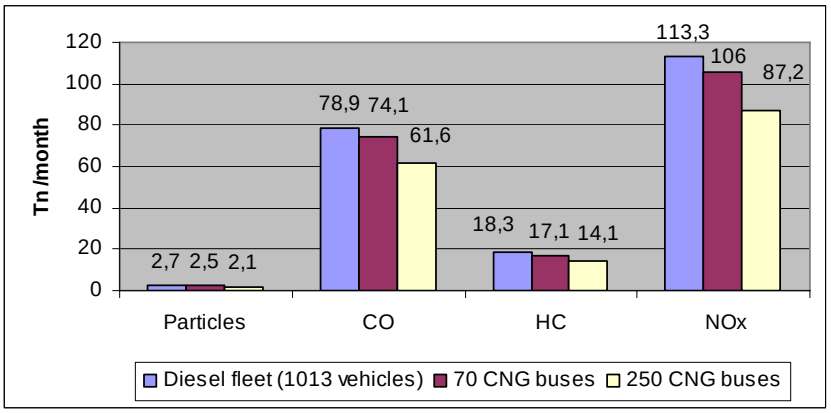

Table 4 Estimated emission savings based on acquisition of "first-generation 2001/002" CNG buses

The question is raised as to whether the initial up-scaling emissions estimates (see Table 4) are relevant given the new developments.

Summary WP 12.3 Extension of CNG bus fleet				
Indicator (units)		Baseline (Euro 1 Diesel)	Miracles CNG	
Econ.1 a	Marginal purchase & installation costs (Euro /	0	1) 25 119 2) 57601	1) with subsidy 2) without subsidy
Econ.1 b	Annual operating cost savings (Euro / veh.)	0	12324	Lower fuel price more than offsets higher gas bus maintenance
Econ.1 c	Estimated annual cost benefit of environmental improvements (Euro / veh.)	0	) 15,159 2) 24,880	1) infras / iww 2) certu
Econ.1 d	Investment recovery period (years)	n.a.	4.67	Excludes subsidy
Ener.3 a	Vehicle fuel efficiency (MWh/100 km)	1) 0.54 2) 0.54 3) 0.54	1) 0.76 2) 0.82 3) 0.79	1) Flat routes 2) Hilly route (average gradient of 4%) 3) average all routes
Ener.3 b	Monthly increase in energy associated with 70 CNG buses demonstrated (MWh)	0	464	
Env. 9 a	CO emissions (Kg/100 km)	2.44	0.38	Saving of 2.06 Kg/100 km
Env. 9 b	Monthly savings in CO emissions associated with 70 CNG buses demonstrated (tonnes)	0	4.8	
Env. 10	NOx emissions (Kg/100 km)	4.34	0.4	Saving of 3.94 Kg/100 km
Env. 10 b	Monthly savings in NOx emissions associated with 70 CNG buses demonstrated (tonnes)	0	7.3	
Soc 14 a	Acceptance drivers (% vauling the experience as “good” or “very good”)	n.a.	70%	82 drivers
Soc 14 b	Acceptance passengers (% vauling the experience as “good” or “very good”)	n.a.	94%	348 passengers
Soc 14 c	Acceptance citizens (on 0 to 10 scale)	1) 7.9		1) May 2002 phone survey of 800 citizens

Table 5 Summary of Measure 12.3 evaluation indicators

M12 Barriers and drivers of the measure implementation / Process evaluation:

Drivers:

The main driver concerns the commitment of TMB and the Municipality to the promotion of the city

fleet as an example of environmental improvement, and a contribution to a more sustainable urban transport. TMB has sought a strategic partnership with an important utility company in order to overcome the barriers described below.

Barriers:

Energy consumption of CNG buses is higher than diesel buses. Within the framework of the strategic partnership set up with Gas Natural s.a., the cost of gas fuel was less than the cost of diesel; the main barrier concerns the higher economic cost of investment required to set up refuelling and maintenance infrastructures, plus the acquisition of more expensive vehicles.

Process:

The evaluation has shown how higher investment costs are offset by lower operational costs. The economic performance could be further enhanced if, as has been demonstrated, values are attributed to the environmental benefits of reduced pollution and lower noise. The evaluation has been based on COPERT emission models and data from gas bus manufacturers, and catalyser suppliers. TMB has recently initiated an emissions inventory based upon its corporate interest to minimise the environmental impact of Barcelona's bus operations. This process involves the collection of data using on-board measurement equipment to give a second-by-second diagnosis of emissions and other relevant parameters. This approach, undertaken in collaboration with IDIADA and the project EU_PEMS of DG ENTR, is expected to provide important knowledge so as to guide vehicle acquisition policy. This process is also able to assess new vehicles such as articulated gas buses, which have only recently become available. Further evaluation, using the improved method, is recommended so as to support the decision-making of further CNG bus acquisition, and to take account of improvements in gas bus performance.

M13: Interrelationships with other measures

Buses are one of the groups of vehicles that are exempt from the access control measure being introduced in the Rambla (WP5).

M14 Lessons learned:

The combination of positive results (environmental, operational and social) justifies the efforts made, in establishing the strategic partnership, and in initial vehicle / infrastructure investments. Thus, a bus operator who has a considerable number of old (Euro 1 diesel and older) buses in the fleet, and who can rely on political commitment to support a policy of bus renovation, should consider adopting the TMB approach, the key features being:

- A strategic agreement with the utility company,
- Attention to infrastructure improvements (especially the minimised transportation of fuel, and improvements to maintenance workshops facilities).
- Appraisal of impacts over a set of service routes representing the overall operation.

It is clear that vehicle technologies are evolving rapidly, and a new generation of CNG buses is available. In principle, the vehicles acquired in the 2005 fleet expansion offer improvements in both energy consumption and in lower maintenance costs, and this would tend to support the policy of progressing to an acquisition of 250 CNG buses within the 2006 time frame established in the project objective. However, other bus technologies are also improving, and some of the CNG bus emission results are dependent upon the sustained performance of catalysers. Hence, further evaluation, using the improved on-bus method now developed by TMB, is recommended so as to support the decision-making of further CNG bus acquisition.

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