White Book of the **Sustainable Mobility** in the early XXI century

ceec
Clúster d´Eficiència Energètica de Catalunya

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Foreword

At the Catalonia Energy Efficiency Cluster, we are strongly backing the promotion of energy efficiency in all daily aspects of society. However, the transport sector is a very important sector because it is the greatest consumer of final energy, providing a huge challenge for the future and positioning sustainable mobility as a great opportunity for the business fabric and, specifically, for more than 110 companies forming part of CEEC.

The greatest number of journeys for people and goods take place in cities, a fact which leads us to search for intelligent solutions which allow us to organize these journeys and, as a consequence, reduce emissions and optimize the available resources. At CEEC, we believe that the electric vehicle is a good example, because it can help to manage the electrical system more efficiently: charging the vehicle during the period of low demand promotes the integration of renewable energies such as wind power and allows the demand curve to be flattened during peak hours.

For this reason, inefficient mobility has become a key factor in energy savings and efficiency, and that is what has led to the development of this book by a group of experts from the CEEC Efficient Mobility Working Group.

Throughout this document, various experiences are presented regarding the efficient use of mobility in large cities, covering everything from new pilot projects to reduce the use of private vehicles in cities to the use of alternative fuels and low emission transport means.

Carles Xavier Albà
President of the Catalonia Energy Efficiency Cluster (CEEC)

Introduction

"We all have our house, which is our private home;
and the city, which is our public home."
Enrique Tierno Galván

"Progress and development are impossible if one
continues to do things as they have always been done. "
Wayne W. Dyer

Transport has become an essential element in both the social and the economic development of societies, and thanks to the evolution of the motor car a huge growth in mobility options for citizens has come about. However, it must be taken into account that the external effects caused are not always positive.

It is also necessary to understand that the current expansion of cities poses a challenge for urban transport, as every day more people are making journeys, and we must not forget that, whether we like it or not, we share a common and limited space. This growth which cities are being subjected to is all the more obvious when it is seen that only 30 % of the world's population lived in cities in about 1950, while this percentage had already risen to 47 % by 2000, and it finally surpassed 50 % in 2007. Faced with the rapid expansion of urban centres, and given that it is currently estimated that around 60 % of the world's population will live in cities in 2030, it is clear that humanity will have to adapt to the era of the metropolis and megalopolis in the future, while at the same time confronting the need to generate different mobility models [1].

The current mobility model was based on individual freedom and the advantages which the private vehicle provided (work and residence freedom in various parts of the world, free trade and leisure, among others), in such a way that now it is necessary to adopt strategies which allow the more and more serious conflicts which this freedom has generated to be resolved, but without jeopardizing urban behaviour and organization; that is to say, given that mobility has become a collective necessity, effective management is inevitable.

This document came about by taking into account this concept, and intends to establish a strategic framework in which a set of measures and guidelines are brought together which help cities address questions such as: What can we do to make our cities more attractive for their inhabitants and their businesses?, How can we obtain an efficient, sustainable transport infrastructure?, How can technology help us to achieve this?

The main reason to follow this route is the optimization of the cost and benefit function for transport. In order to obtain this, a series of procedures are outlined in this study which will attempt to address, firstly, the problems of congestion and the resulting inconvenience (lost time, accidents, environmental impact, deterioration of health, among others) by mainly establishing short-term standards, but without losing sight of medium and long-term actions.

In order to achieve said standards, meetings have been organized with the key agents involved in mobility in the metropolitan area of Barcelona to debate the current problems and compile observations, points of view and ideas which will resolve them.

Specifically, the White Book for Efficient Mobility attempts to present new mobility proposals which allow city managers to have solutions available in order to improve the quality of life of the inhabitants.

[1] United Nations, World Urbanization Prospects,
The 2007 Revision

Conflicts and problems associated with mobility

For societies these days, mobility has become a basic necessity that must be satisfied in such a way that it does not have negative repercussions for the development, whether economic, social, educational, etc. of said society, nor on quality of life.

The main problem centres on "does not have negative repercussions". The most deeply rooted mobility culture among people is that of "door to door": less time and greater comfort. All this has brought us to a mobility model based on the private vehicle, with this being the least suitable for densely populated areas, and this is leading to a reduction in the competitiveness of these areas.

In this section, the intention is to offer a global vision of what the conflicts are and how they are interlinked and accumulate to the point where they cause the current problems in urban mobility. In this way, it will be possible to glimpse the situation in which we will find ourselves in the future if it is not possible to convert this model into one which is more sustainable and efficient.

Of the numerous conflicts, the following are worth highlighting:

- The strong growth of demand, both from people and goods, has been channelled towards road transport, which has caused serious congestion problems. These hold-ups do not only affect the private vehicle users, but also have a negative impact on public transport because they reduce its effectiveness.

- The increase in energy consumption in the transport sector, with an almost total dependence on fuels which are petroleum derivatives. The consumption of the vehicles in circulation themselves, the energy used in their manufacture and the maintenance of vehicles and infrastructures make up 36.2 % of the total in Spain [2].

- Highly populated zones with deficient transport infrastructures and low connectivity. Once again this is the result of the private vehicle.

- Urban dispersion, both residential and industrial, has increased the mobility problem as the low density makes offering quality public transport impossible and, for that reason, the use of the private vehicle has been unstoppable in these zones.

- Atmospheric pollution. The emission of greenhouse gases, the loss of air quality and the noise produced cause, among other factors, a deterioration in health and the environment.

- Loss of quality of life and a sedentary lifestyle. New social habits, among them the increase in motorized transport, could have a negative impact on the health of persons and cause illnesses such as obesity.

- Traffic accidents. In Spain, there were 2,130 and 584 fatalities recorded on the road and in urban areas respectively during 2009, and likewise 62,928 injuries on roads and 62,038 in urban zones. [3]

- Social exclusion. Transport policies, which have favoured private transport over public, have caused a loss in autonomy of specific social groups (children, those with reduced mobility, the elderly, etc.) with respect to their journeys.

- The consumption of space. The predominance of the private vehicle supposes increasing occupation of public space for circulation and parking which was for other urban uses and functions.

- The diminishing of opportunities for socializing in cities due to the volume of traffic infrastructures, the traffic itself, the noise, etc.

[2] IDAE

[3] Series statistics regarding accidents and victims. DGT, 2009

As can be deduced from the conflicts and problems mentioned, the current mobility model generates a series of economic, social and environmental costs which are not borne by the user, but which fall on the whole of society in the form of economic losses, deaths and illnesses, and material and environmental damage, among others, which generate a series of externalities, or external costs, which have a negative impact on the whole collective.

This project revolves around all these inconveniences and, as has been previously mentioned, attempts to address and discuss new mobility ideas through the promotion of a quality transport system and more effective, sustainable alternatives in order to reduce the local and global impacts deriving from road transport.

1

Incentive Parking And Bus-Hov Lanes

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"The bus-HOV lanes are more useful for buses
than for increasing car occupancy,
and they are convenient provided their cost is reasonable
and the route provides differential advantages."
F. Robusté

1.1 Introduction

The work introduced in this chapter will carry on the line of reflection regarding metropolitan mobility which has been presented up to now, and will attempt to analyse it taking into account a policy change which allows a more rational use of the private vehicle.

In the journey made by any user by motor vehicle, three phases can be differentiated: the origin, the itinerary, and the destination. As will be seen throughout this document, it is necessary to act on these three phases to obtain more effective, sustainable mobility. This section in particular will go deeper into one of the short and medium-term measures which would affect the first phase, the origin of the journey.

It must be borne in mind that one of the main problems detected in cities is that for decades they have been planned for and adapted to the needs of the private vehicle. It is necessary to extend and improve the public transport networks in order to make inter-modality one of the key pieces in addressing possible changes to the journey needs of the public.

This chapter puts forward the study and development of incentive parking, or as it is widely known Park and Ride, and the possible combination of these with Bus-HOV lanes or rail systems.

In this way, it is worth pointing out that inter-modality linked to public transport is often related to the use of the motor car at some stage in the modal chain. For example, in the case of residents on the outskirts of the city, as these areas have a lower population density, they cannot be served by quality public services with respect to frequency and timetable. This demand shows greater dependence on the private vehicle, and it is the aim of this chapter to present more efficient alternatives in order not to increase, among other things, congestion on the access routes into large urban agglomerations.

It is worth highlighting a double objective: on the one hand to resolve the lack of connections, and on the other to substantially reduce the journey times on the various access routes. From this perspective, and with the aim of maximizing success, the following breaks down a series of considerations and actions which must accompany the implementation of this type of parking.

1.2 Incentive parking ("Park and Ride")

Incentive car parks could be defined as areas of public parking linked to a public transport station or stop, normally located on the access routes into the city, in order to encourage drivers to park their private vehicles and access the city centre using public transport.

1.2.1 Criteria for location and design of Park and Ride

Location

As everything which is related to a transport strategy, the location of these car parks must be studied exhaustively, because the usefulness of the creation of this type of space is dependent upon it. Thus it is important to evaluate a series of factors, for example:

- Traffic flow
- Congestion levels
- The entire public transport network
- Expected demand
- Space availability
- Foreseen growth

Another factor which could be taken into account is the experience of each individual city. Currently, there are already many cities which have established park and ride schemes, but not all of these have returned the expected results. Faced with this fact, it is useful to study the specific reasons in each city with respect to the choice of location. An example which may justify this prior analysis of ideal locations is the implementation of some Park and Rides within the urban area, rather than on the edge of the metropolitan area. In order to access these spaces, the users would already have suffered some congested stretches, and thus opt to not access the stations and simply continue their journey by private vehicle.

Furthermore, evidence shows that the desire for door to door journeys continues to predominate in today's society.

In addition to the previously mentioned factors, the following lists others which should be considered, as it must be taken into account that for greater success the proposals for perimeter car parks must be complemented by other measures. Some of these points will be developed in greater depth throughout this chapter:

- Ease of access to the car park from the local transport network
- The proximity of access to collective transport
- The possibility of using existing car parks for park and ride when the timetable is compatible (for example, shopping centres, leisure centres, shows, sports, etc.).
- Tariff integration
- Access to reserved platforms (bus, Bus-HOV)
- Location in zones which could serve more than one corridor
- The setting up of citizen participation programmes in the surroundings of each location

Design

The general design of Park and Ride is also an important factor to take into account, as users could decide to use it or not depending on the perceived quality of the car park. With reference to the functional design of these spaces, aspects such as the following should be evaluated:

• The provision of safe parking areas for bicycles and motorcycles.
• The optimization of the vehicle route in order to avoid accidents and delays due to parking manoeuvres.
• The availability of space, both for the parking of vehicles and for bus stops and "loading and unloading areas" for passengers, in such a way that the operation of the car park is not disturbed.
• The creation of possible waiting zones which are safe, accessible and comfortable for users who are changing from private vehicle to public transport.
• The creation of walkways for pedestrians
• Information signage for the car park itself and for public transport: timetables, estimated arrival times, itineraries, etc.
• Facilitate and make its use attractive by working on the surroundings and ease of use, correct lighting, safety, surveillance, pavements, etc.

1.2 Incentive parking ("Park and Ride")

Selecting adequate surroundings and designs for the park and ride will help to promote clearer templates for sustainable mobility, while improving accessibility to urban centres and all the advantages that this brings.

1.2.2 Tariff integration

As previously mentioned, for the adequate and profitable operation of a Park and Ride, the proposal should be accompanied by other measures such as, for example, creating tariff integration.

The tariff framework for these car parks must be lower than those in the centre of the city in order to reward their use. Taking into account that the costs must be low, the mode of pay per use provides various alternatives:

- Single tickets per use
- Discounts for the number of occupants in the vehicle (high occupancy)
- Tickets where the use of the car park exempts from payment on the public transport, or in which the use of the public transport reduces the parking tariff.
- Tariffs based on a timetable which encourages parking during times where there is less demand.
- Entitlement to subsidised transport (children, youth, the elderly).

It is worth pointing out that the more difficult it is for users to find a parking space at their destination, or the greater its cost, the greater will be their willingness to change their mode of transport via the use of park and ride. For this reason, it would be useful to combine this measure (concerning the origin) with actions regarding the destination.

1.2.3 Signage

The use of one means of transport or another is determined when the user is prepared to start the journey. Correct and efficient information regarding the level of saturation on the roadways, the public transport options, and the status of parking at the destination, could influence the decision regarding which transport to take, as they could choose the most suitable means of transport at any time.

One example could be the availability of an information system via signage or sent directly to a smartphone, which informs the driver about the envisaged difference in time between the car and public transport to get to the centre (for example "10 minutes by train, 30 minutes by car"). From this perspective, it would be important to not only set up information about the present, but also about the future, with congestion forecasts, etc.

Furthermore, the degree of user knowledge with respect to these car parks could also influence their decision to use them, and it could happen that a user does not use the Park and Ride simply because, as it is not correctly signposted, its existence is not known. Therefore, it is very important to have informative signage regarding the park and ride system on the outskirts of cities on the various access roads, and establish possible itineraries on the main entrance roads to the city.

Furthermore, it would also be relevant to offer information, both in said car parks and on various web sites, about the nearest means of transport and stops to each car park, leaving times, estimated waiting times until the next public transport service, availability of spaces, etc.

For the adequate operation of the Park and Ride, it is essential that users can access information in real time, both on the access routes to the car park and in the interchange zone itself, in a visible, simple and homogeneous way throughout the territory, while using new technologies such as variable message panels or communication via the mobile telephone.

1.2 Incentive parking ("Park and Ride")

1.2.4 Examples of signage and information

Figure 1.1 Specific message to promote the use of public transport, Salamanca and Mataró [1]

Figure 1.2 Park and Ride linked to special operations [1]

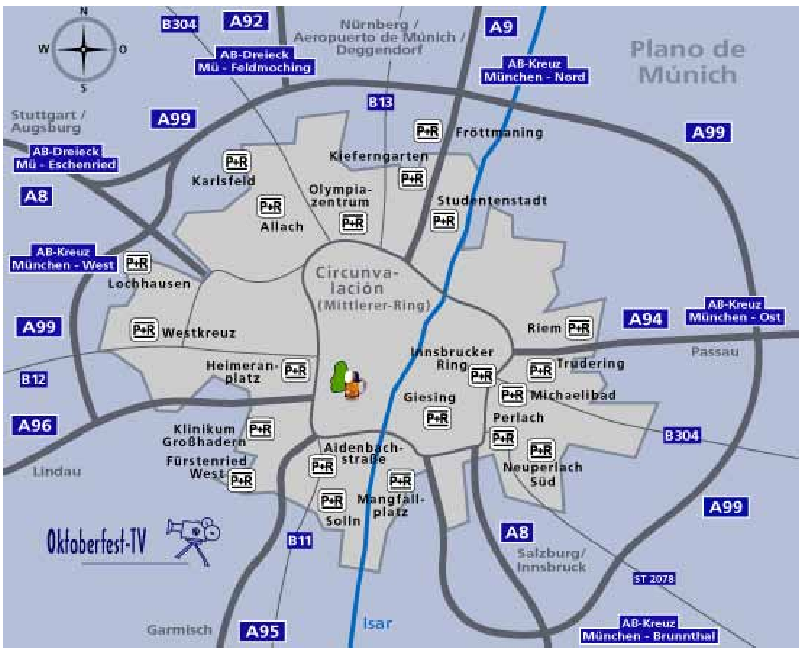


Figure 1.3 Plan showing the location of Park and Ride in Munich [3]

1.2 Incentive parking (“Park and Ride”)

Figure 1.4 Example of dynamic signage to give information about the location of Park and Ride and its connections with public transport. Source: Siemens

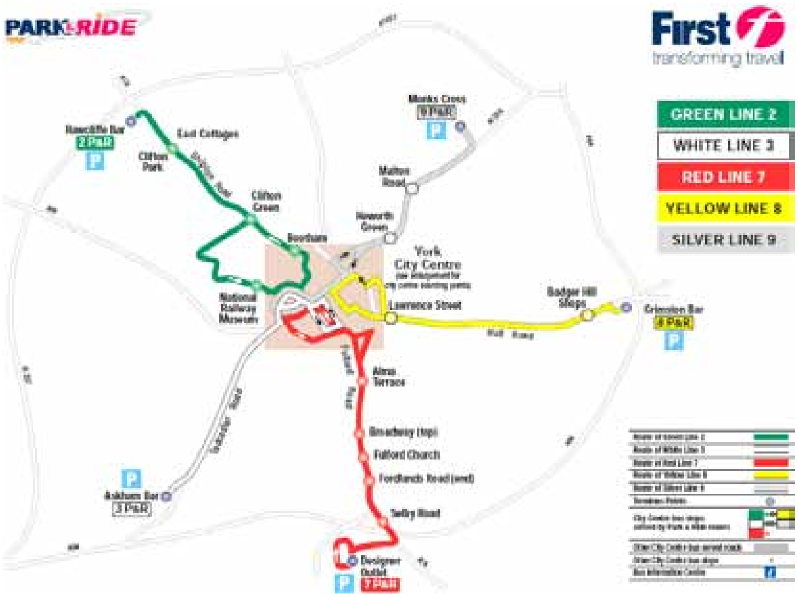


Figure 1.5 Location of Park and Ride and associated bus routes, York, United Kingdom [4]

1.2 Incentive parking ("Park and Ride")

YourNextBus

Get real-time and scheduled bus departure times on your mobile when you need them!

How to find yournextbus on your mobile phone:

1. Create a text message
2. Enter the 8-digit bus stop number on the bus stop flag or timetable display e.g. 32900094
3. Send the text message to 64422.
   A charge of 12p plus your standard network SMS rate applies. You will receive a reply within about 30 seconds which will tell you the times for the next bus departures from your stop.
   - If the time is in minutes e.g. 3 mins, this is a real-time prediction.
   - If the time is shown as a 24-hour clock e.g. 15:10, it is a scheduled time.

Save standing in the wind & rain! Why not save your usual bus stops in your phone so you can find out when yournextbus is due before you set off.

Figure 1.6 Example of the communication of information regarding bus times via mobile telephone, York [4]

minsterCard

If you use Park & Ride on a regular basis why not take advantage of our **minsterCARD**, exclusive to Park & Ride customers.

minsterCARD offers discounts on weekly and monthly travel, plus the convenient 'Stored Value' version provides the ultimate in flexibility, enabling you to use your minsterCARD as and when you need it without worrying about your card expiring.

For daily users

Whether you want to budget on a weekly or annual basis we've got just the ticket.

- Weekly - £9.20
- Monthly - £36.80
- Yearly - £368

Figure 1.7 Example of information regarding payment methods on the Park and Ride, York [4]

1.2 Incentive parking ("Park and Ride")

Figure 1.8 Example of payment via mobile telephone [5]

1.2.5 Visual examples of other experiences

The following shows some examples of Park and Ride:

Figure 1.9 Mixed use Park and Ride in Madrid: The Park and Ride is located beneath the public square, leisure and rest area close to the railway station [6]

Figure 1.10 From left to right, Park and Ride in Toledo [7] and Cardiff [8]

1.2 Incentive parking ("Park and Ride")

Figure 1.11 From left to right, Park and Ride in Mexico [9] and Cambridge [10]

Figure 1.12 Park and Ride linked to buses and bicycles in Clifton [11]

1.3 Park and Ride associated with public transport

As previously mentioned, the Park and Ride concept links private vehicle parking areas with collective transport stations. In this way the Park and Ride can be associated with:

- Local trains
- Metros
- Trams
- Buses

The most widespread and well-known scheme is that associated with railway stations. This type of car park linked with the railway takes its strength from being safer and faster than other modes of public transport, and enjoys a large passenger-carrying capacity. Furthermore, the car parks linked to local railways and metros are sometimes financed by the same public transport operator.

If the plans for Park and Ride with bus connections are linked to reserved platforms and priority circulation measures, the results can be similar to systems based on the railway.

1.3.1 Experiences with Park and Ride

- Park and Ride linked to the railway

Station: (FGC) Vulpelleres (Sant Cugat del Vallès)

Launched: 2010

Description: Exterior single level car park at street level.
The car park has two charging stations for electric vehicles. It is managed by TABASA.

Capacity: 173 passenger vehicles, 9 motorcycles and 10 bicycles.

Timetable: 24 hours per day

Price: TABAS permits a reduction to 2.56 €/day in the parking tariff, although this tariff depends on the mode of public transport taken.

Table 1.1 Park and Ride at the Vulpelleres station, Sant Cugat del Vallès. Source: [12]

1.3 Park and Ride associated with public transport

Station: (Railway) Colmenar Viejo, Madrid Launched: 2008

Description: Underground car park around a public square.
The upper square, in addition to having gardens, children's play area and leisure areas, includes two buildings which, in the future, could house shops or restaurant establishments.

Capacity: 1.850 vehicles over 3 floors

Timetable: from 6 in the morning to midnight

Price: 1.10 €/day

Comments: This car park was free until the signing of an agreement between the Colmenar town hall and RENFE, through which the council handed over the operation of the installation to the railway company (for at least two years). The price was later linked to the local railway network ticket, but this link was subsequently removed, as a result the price is the same for those users who take the train and those who do not.

When the car park was launched, the timetables were extended and adjusted in order to improve coordination between buses and local trains.

Table 1.2 Park and Ride at Colmenar Viejo station. Source [13] and [14]

1.3 Park and Ride associated with public transport

- Park and Ride linked to the underground

Station: (Metro) Leioa, Bilbao	Launched: 2006

Description: Three floors connected to the hall via a lift. It is managed by Metro Bilbao S.A.

Capacity: 254 places

Timetable: The use of the car park is limited to the metro service timetable, with parking or removal of the vehicle being impossible outside this timetable.

Price: It permits integration of the metro ticket with the car park ticket, or the payment of 0.65 €/ day.

Comments: This metro station will become intermodal in the future, as it will connect with the UPV – Leioa – Urbinaga tram, which will make the car park associated with this station very useful.

Table 1.3 Park and Ride at Leioa station. Source [15]

- Park and Ride linked to the tram

Station: (Tram) Olivares, Jaén	Launched: 2011

Description: Surface car park

Capacity: 650 places

Timetable: Not defined

Price: It is possible to use the public transport ticket to remove the vehicle with no additional parking cost.

Comments: To publicize it, promotion and diffusion campaigns were set in motion among the collectives and citizens in the various municipalities making up the metropolitan area of the capital. The campaign included 15,000 folded pamphlets which were distributed at the transport ticket acquisition points.

Table 1.4 Park and Ride at Olivares station. Source [16]

1.3 Park and Ride associated with public transport

- Park and Ride linked to the bus

Pear Tree Park and Ride, Oxford	Launched: not defined
	
Description: Surface car park, close to a transport junction.	**Timetable:** 24 hours per day
Capacity: 1.084 places	**Price:** 2 £/day, 10 £/week

Table 1.5 Park and Ride at Pear Tree station, oxford. Source [17] and [18]

1.4 Advantages and drawbacks of Park and Ride

Advantages	Drawbacks
They combine the flexibility of the motor car (providing accessibility to disperse origins for which public transport cannot provide efficient transport) with the effectiveness of public transport (providing accessibility to heavily populated destinations, where the motor car is very inefficient) [6]	Previous management of parking in the urban centre itself is necessary. A large part of the population perceives transport tariffs as a mere tax-raising measure.
They increase the service frequency for the associated public transport.	Some experts are of the opinion that these intermodal areas reduce the use of the private vehicle in the city centre at the cost of promoting its use on the outskirts.
They improve accessibility to urban centres and increase the attraction of old city centres by promoting templates for sustainable mobility.	The correct location. They must be located away from queues caused by congestion during the rush hour.
They conserve the environment, reduce acoustic pollution, improve air quality, and reduce impact on residents and visual impact.	Their success is not always that which is expected. There are various key factors which encourage their use: the imposition of adequate and integrated tariffs, management of urban parking, better public transport services, better punctuality and safety guarantees.
They prevent congestion in transit along the main corridors.	In some situations, they can cause an increase in traffic: • They can encourage users to make journeys which they did not previously make. • The vehicles which remain parked in the Park and Ride leave spaces in the centre which could be occupied by new vehicles.
By reducing congestion in urban centres, they increase the commercial speed of buses.	They cause a break in the journey. The user will only accept them if the advantages are greater than these facts.

1.4 Advantages and drawbacks of Park and Ride

Advantages	Drawbacks
They prevent the tension suffered by users when driving through highly congested zones and reduce the cost involved in finding parking (both economic and in terms of time).	Slowness of implementation (coordinate the work, manage the price in conjunction with public transport, establish jurisdiction, provide information regarding how to find them and timetables in real time, etc.).
There are variations in use to improve the efficiency of these spaces: adaptation to parking for motorcycles and bicycles, meeting car parks where users leave their private vehicles and use the motor car of another person.	The parking provision must be large and directly linked to the use of public transport. On occasions these spaces end up becoming neighbourhood car parks, and thus the end for which they were conceived is lost.
They improve road safety.	On occasions it may be necessary to expropriate land.
They allow improvements in the areas of energy and the environment.	Costs of execution and maintenance.
	Establishing the manner of financing: Costs could be charged to the administration, to the users, or to both. If the tax-payer bears the cost, it minimizes the cost to the user, and may thus increase demand, but in general the effectiveness, especially in the exploitation of the car park, is lower. If the total cost falls on the user, it is possible that the demand is displaced towards the private vehicle [6]

1.5 Bus-HOV lanes

1.5.1 Description

Together with the creation of Park and Ride, in order to obtain alternative mobility to the private vehicle, it is possible to promote actions via reserved infrastructures which are especially dedicated to collective transport, such as lanes for the exclusive use of collective transport vehicles (bus) or private vehicles with high occupancy (HOV, minimum of 2 or 3 occupants depending on the type of road), which increase both the commercial speed and regularity of public transport and road capacity, as they also produce an increase in the ratio of passenger to vehicle.

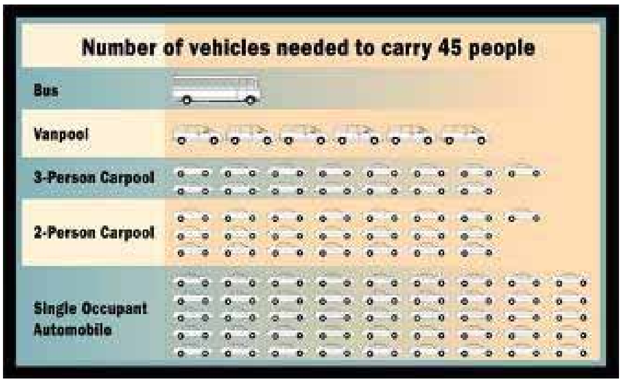


Figure 1.13 Number of vehicles necessary to carry 45 persons [19]

The linking of Park and Ride to this type of lane is an effective way to promote modal interchange, as the user can make their journey without losing the perception of a door to door journey, at a more economical cost and within a shorter time.

It is necessary to ensure not only an adequate infrastructure but also reliability, availability and sufficient frequency to be able to respond to the user needs.

Through the creation of Bus-HOV lanes linked to Park and Ride, the following would finally be achieved:

- The promotion of intermodal connectivity between the various modes of public-private transport.
- A reduction in congestion on the access routes to the urban centres.
- A saving of journey time.
- A saving of energy.
- A reduction in the polluting effects.

1.5.2 Possible alternatives for the implementation of Bus-HOV lanes

There are various solutions or alternatives which would allow this type of lane to be implemented. For example, it is possible to create a lane segregated from the main roadway, reducing the width of the pavements and the existing lanes or by substituting one used for normal traffic.

The following is a brief outline of the implications of each solution:

- Create lanes segregated from the main roadway.

This alternative consists of constructing service roads on the sides of the roads, which would then be designated Bus-HOV lanes. This type of project normally includes numerous overpasses and underpasses in order to keep the existing access points, necessary land-grabbing for the new side lanes, rearrangement of the infrastructure, etc.

- Advantages: If high occupancy vehicles move faster, this will encourage users to follow this pattern.

The creation of segregated lanes avoids the removal of space from cars on roads which are already congested.

1.5 Bus-HOV lanes

- Drawbacks: The construction of new roadways implies a very high execution cost, and on occasions it is not very efficient, as it encourages more vehicles to join the road.

More land is occupied by roads.

- It reduces the width of pavements and lanes.

It would involve a reduction in width for the existing lanes and pavements in order to add the dedicated Bus-HOV lane.

- Advantages: The road capacity is significantly increased and it is clearly beneficial during rush hours as it improves the flow of traffic.

Reduced costs by avoiding new infrastructures, expropriations, connections with other routes, etc.

It also avoids the occupation of land for road use.

- Drawbacks: This solution could only be implemented on some stretches due to lack of space.

If the width of the lanes and pavements is reduced, it is necessary to reduce the circulation speed in order not to compromise road safety.

Furthermore, there is the risk of causing congestion in the case of incidents on the road.

It would be necessary to incorporate new technologies in order to guarantee that drivers respect these lanes.

- It converts a normal traffic lane into a Bus-HOV lane.

- Advantages: In the same way as in the previous alternative, it would reduce costs by avoiding the need to construct new infrastructures, and it would not be necessary to have more space available for roads.

A flexible solution is obtained as it is possible to use the lane as Bus-HOV during rush hours and as a normal lane for the rest of the day, via variable signalling.

It clearly promotes the use of public transport or high occupancy.

- Drawbacks: It undermines the private vehicle in terms of congestion.

In this case, it would also be necessary to incorporate surveillance on the Bus-HOV lanes.

1.5.3 Catalan success story: C-31 North bus lane

In November 2006, the C-31 stretch of bus lane was launched on Gran Vía between Sant Adrià and plaça de les Glòries. The infrastructure was created during the remodelling of Gran Vía.

It is estimated that the infrastructure handles some 900 buses and coaches daily, 400 of which are regular bus services providing a service to over 15,000 users every day. The infrastructure signifies a journey time saving of some 5.5 minutes.

The link between the interurban bus lane and the urban stretch at Les Glòries operates via a two speed intelligent traffic light which gives priority to vehicles on the bus lane.

1.5 Bus-HOV lanes

Figure.14 Map showing the infrastructure location (the Bus-HOV lane is in red). Source: Google Maps.

Figure 1.15 Roadway reconversion project for Gran Vía (on the left in 2000, on the right in 2007). Source: FECAV.

In 2011, the Institut Cerdà analyzed for the Metropolitan Transport Authority the real impact of the infrastructure on mobility (in terms of demand and change of mode) based on user questionnaires regarding the interurban lines used by the infrastructure.

In terms of demand, the balance is very positive. In the period between 2006 to 2010, the set of interurban lines analyzed coming from Maresme show an increase in demand of over 20 %, which places it well above the 6 % growth in demand on the set of interurban lines in the metropolitan region.

Work in the field has determined that 38 % of users have increased their use of the bus as a result of the new infrastructure. Although in the majority of cases the increase in use is due to new journeys, 40 % of these users have come from other modes.

That is to say, 15 % of the total number of bus users previously made the same journey by other means.

The results of the survey in question are reflected in figures 17 and 18.

1.5 Bus-HOV lanes

Therefore, the main reason for using the bus on this route is comfort (63.3 %), followed by difficulty in finding parking within the city (23.9 %).

The main reasons for the journey are shown in Figure 20.

Therefore, work (49.8 %) and studies (25.5 %) are the main reasons for the use of the service.

It is clear that the increase in commercial speed due to the creation of the C-31 bus lane has contributed towards increasing the competitiveness of public road transport and has resulted in new users, as the time saving on the route is 5.5 minutes, and the percentage of modal shift has been 15 %. In addition, the main reasons for use of these bus services are comfort and the difficulty in finding parking within the city, and they are mainly used for journeys to place of work or study.

Figure 1.16 Image of the C-31 North bus lane. Source: ATM.

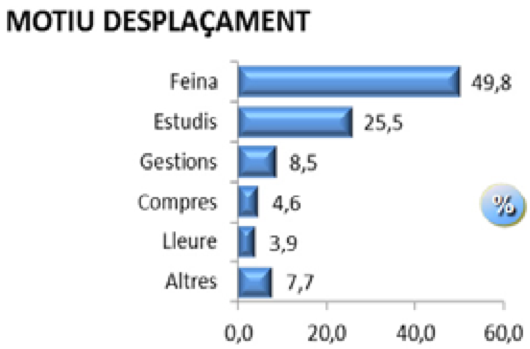


Figure 1.17 Reasons for using the service for this journey. Source: Institut Cerdà.

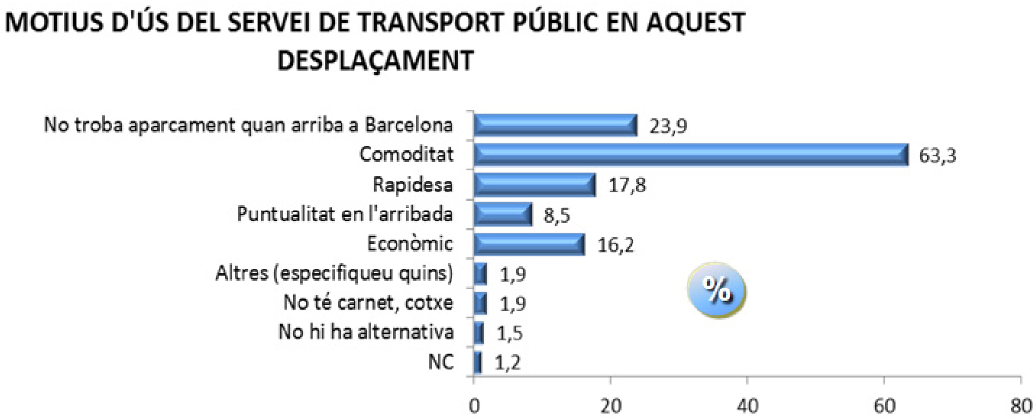


Figure 1.18 User habits on the C-31 North. Source: Institut Cerdà.

1.5 Bus-HOV lanes

1.5.4 European experiences

In Europe, the first Bus-HOV lane was implemented in 1993 on the A-1 motorway in Amsterdam (Holland). However, 10 months later the lane was closed due to legal problems. Currently, the oldest operating Bus-HOV lane is the one on the A-6 Madrid.

It is worth pointing out that the majority of implemented European Bus-HOV lanes are relatively short, and with the exception of the one in Madrid, the Bus-HOV lane projects currently operating in Europe are found in metropolitan regions or medium to small towns and cities.

The following table presents a summary of the main European experiences, and following on from that a more detailed description of the HOV projects in Madrid, as it presents a similar situation, in terms of typology, surroundings and behaviour, to the forecast implementation for the Metropolitan Region of Barcelona.

	Madrid (ES) A6	**Amsterdam (HO) A1**	**Linz (AU) B127**	**Graz (AU) A2-A9 intersection**	**Leeds (UK) Stanningley Rd A-647**	**Leeds (UK) East Link**
Regional population (in millions)	5.6	7.5	1.4	1.2	1.5	1.5
Operating period	1995-	1993-1994	1998-	2004-	1998-	2009-
Length (km)	16.1	7	2.85		1.5	3.9
Occupancy	2+	3+	3+	3+	2+	2+
Effects / time saving		Reduction in journey time: 10-30 min	Reduction in journey time: 23 min (from 30 min. to 7 min.)		Reduction in journey time: 4 min (HOV lane) and 1.5 min (other lane)	
Effects / average occupancy	1.36 ->1.53				1.35->1.43 in 2 years 1.35->1.45 in 6 years	

1.5 Bus-HOV lanes

	Bristol (UK) Avon Ring Road A4174	Sommerset (UK) Long Ashton Bypass A370	Birmingham (UK) A47 Heartlands Spine Road	Stockholm (SE) 261 Ekerövägen	Trondheim (NO) Elgeseter gate	Kristiansand (NO) E18
Regional population (in millions)	1.0	1.0	2.3	1.9	0.4	0.1
Operating period	1998-	2005-	2007-	2000-2006	2001-2008	2001-2005
Length (km)	1.75	1.5	7	9	0.85	3
Occupancy	2+	2+	2+	3+	2+	2+
Effects / time saving	Reduction of 50% in journey times in 2 years		Minimum reduction	Reduction in journey time: 5-8 min.	Reduction in journey time: 2.5-3 min.	Reduction of 50-70% in journey time
Effects / average occupancy	Number of vehicles with + than 2 people: 20->35% in 7 years		Slight increase	Number of vehicles with + than 3 people: 2->4%	1.33->1.38	1-27->1.31 (morning: 1.20->1.27)

Table 1.6 Compilation of HOV lane projects in Europe. Source: [20]

1.5 Bus-HOV lanes

Among the previously presented experiences, there are four examples of Bus-HOV lanes which closed or were changed to bus lanes: Amsterdam, Stockholm, Trondheim and Kristiansand. In the case of Amsterdam, as has been mentioned, the closure was due to legal and not operational reasons (the legal framework would not allow the application of traffic discrimination based on occupancy). In the case of Stockholm, the cause was the reduced use of the lane together with the high incidence of violations. In the case of Trondheim, the reason was a too high use of the reserved lanes, which led to problems of congestion and significantly reduced the commercial speed of buses. In Trondheim, the strategy was replaced with the creation of "Buses with a High Level of Service".

Figure 1.19 Bus-HOV lanes in Leeds (United Kingdom). Source: Institut Cerdà.

Figure 1.20 Bus-HOV lanes in Bristol, Avon Ring Road (United Kingdom). Source: Institut Cerdà.

1.5 Bus-HOV lanes

Figure 1.21 Bus-HOV lanes in Graz, left and Linz, right (Austria). Source: Institut Cerdà.

Figure 1.22 Bus-HOV lane in Stockholm (Sweden) which in 2006 was converted into a bus lane. Source: Institut Cerdà.

Figure 1.23 Bus-HOV lane on the route into Trondheim (Norway), now converted into a bus lane. Source: Institut Cerdà.

1.6 Innovation proposal: Adaptation of public transport to the real demand

As has already been seen, the factors making up a mobility model are numerous; in this chapter an elementary breakdown of possible solutions to the problems presented has been established, making reference to specific aspects which affected the origins of the user's journey in the first place.

Based on these possible directorates, the following is a possibly more global solution, complemented by small suggested actions.

In the first place, it must be said that a recurrent problem to date is the need to adapt the demand curve to the supply curve, as demand for public transport is not constant and it is thus common to see this transport very overcrowded or very empty. This inconvenience could be resolved, for example, through the creation of buses which allow dynamic coupling between convoys; thus the demand curve would adapt in an extremely flexible manner.

Organizing a single meeting point, where these convoys would be prepared, and with the implication of a single person as the driver, it would be possible to increase or reduce the bus capacity based on the expected demand at any moment.

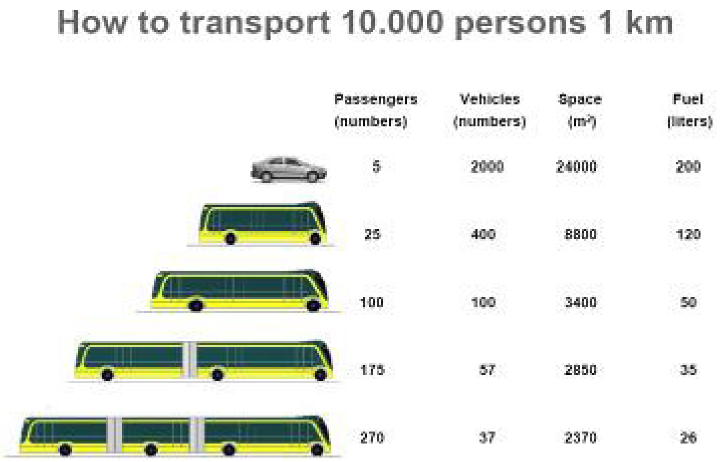


Figure 1.24 ------------

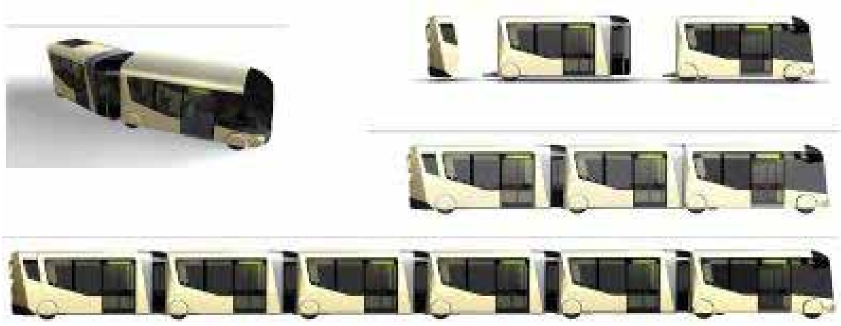


Figure 1.25 The described vehicle concept. Source: [20]

1.7 Advantages and drawbacks of Bus-HOV lanes

The following shows the main advantages and drawbacks of the Bus-HOV lanes, together with those for the proposal for a bus service adapted to demand.

Bus-HOV lanes

Advantages

Benefits in terms of efficiency and safety.

An increase in the average occupancy of the private vehicle.

An increase in the road capacity.

A reduction in costs to the user.

They help with the promotion of sustainable mobility patterns by increasing modal exchange without losing the perception of a door to door journey.

An increase in the commercial speed and regularity of public transport.

They reduce congestion on the access routes to the urban centres.

Energy savings.

A reduction in the polluting effects.

Drawbacks

Execution costs.

The need for an improvement to infrastructures, timetables and punctuality of collective transport.

An increase in surveillance costs: incorporation of technology which detects the presence of vehicles so that drivers respect the lane and do not use it.

Problems when deciding the manner of implementation:

- If circulation lanes are replaced then the private vehicle already suffering congestion is further undermined.
- The creation of new circulation lanes implies large costs in addition to encouraging more vehicles to use the road instead of changing the mode of transport.
- If pavements were reduced and the number of lanes increased, it would be necessary to reduce the circulation speed in order not to compromise road safety. There would also be the risk of causing congestion due to incidents on the road.

1.7 Advantages and drawbacks of Bus-HOV lanes

Advantages	Drawbacks
They promote the rational use of the motor car by favouring public transport and those vehicles which transport more persons, with the corresponding savings in fuel and time.	
A reduction in accidents associated with mobility.	
With respect to the manner of implementation for this type of lane: • If a circulation lane is replaced with a Bus-HOV lane, a flexible solution is obtained, as the lane can be used as a bus-HOV lane during rush hours and as a normal lane the rest of the day. • If segregated lanes are created then the commercial speed of collective transport is increased considerably. • If the pavements are reduced and the lanes are made narrower, the capacity of the road is increased considerably.	

To link the parking zones to the Bus-HOV lane, accesses would allow the benefits of both to be seen.

1.7 Advantages and drawbacks of Bus-HOV lanes

Buses adapted to real demand

Advantages	Drawbacks
Adaptation to the demand curve in an extremely flexible manner.	The costs associated with the adaptation or creation of these new vehicles.
The implication of a single driver.	Location of the meeting points for these convoys.
A huge increase in the capacity of the bus.	The need for very reliable information in real time.
A reduction in polluting emissions and greenhouse gases.	
A reduction in the consumption of resources.	

1.8 Conclusions

Park and Ride

A car parked in a Park and Ride not only is one less car parked in the city, but also two less journeys in the urban environment [6].

The creation of Park and Ride has been proposed in order to help solve one of the problems of mobility which most affects the city: congestion on the access routes and the interior, and likewise all the environmental consequences this implies.

It has been demonstrated that financial support from the public administration for the promotion of the Park and Ride schemes is one of the leitmotiv of the cases studied. This fact resides in the fact that in the majority of cases the economic balance for exploitation does not cover the depreciation costs. However, the social and environmental benefits are clear: a reduction in the number of accidents, which is a direct consequence of the transfer of users from the private vehicle to public transport, together with a reduction in environmental pollution and a more efficient use of transport.

Following the observations broken down into the various sections, for an adequate operation of a Park and Ride it is important to take into account a series of considerations:

- A co-modal vision for the location of the car parks is needed with respect to the urban layout and the transport network. That is to say, it is necessary that the use of the car park and public transport is the optimum for each means of transport.
- There is a need for signage integration and the interaction of information with the user on the transport network.
- It is considered essential that the tariff setting for public transport user groups is integrated.
- Preliminary studies regarding dimensions are necessary for the implementation of Park and Ride.
- The policies of positive discrimination towards more efficient vehicles (urban tolls, regulation of destination parking, among others) and the policies for the promotion of public transport become useful tools for increasing demand for the Park and Ride.

Bus-HOV lane

It is evident that it is already necessary to manage mobility in order to promote a more efficient transport model. In this way, the prioritization of the vehicles via the implementation of Bus-HOV lanes is a useful tool for increasing the capacity of roadway infrastructures and moving towards a more competitive mobility model. However, in order to guarantee the success of the development of Bus-HOV lanes as an instrument to improve the efficiency of the transport network, it is necessary to direct our actions in accordance with specific technical criteria.

The following gives the conclusions of the main criteria2 for the development of Bus-HOV lanes:

- It is necessary to join the implementation of Bus-HOV lanes within the overall framework of the transport network (urban hubs, park and ride, tolls on access routes, railway network, etc.).
- For the implementation of Bus-HOV lanes, a minimum flow of buses is necessary. As a reference figure a minimum of seven expeditions during the rush hour could be considered.
- The use of dynamic management must be directed to take into account the criteria for efficient mobility.
- The management of intersections in favour of the most efficient vehicles becomes a key factor. Advances must be made in intelligent traffic light prioritization which allows an increase in the commercial speed of the most efficient vehicles and the regulation of public transport services.

1.8 Conclusions

- The efficient, safe use of the Bus-HOV lanes requires good vehicle compatibility. It has been demonstrated that the shared use with motorcycles or bicycles compromises road safety.

- For the smooth operation of the bus lanes which are not segregated, a high level of control is necessary in order to guarantee the efficient use of the infrastructure.

2

Urban Mobility Management

Index

"Comparing the air of cities to the air of deserts and arid lands is like comparing waters that are befouled and turbid to waters that are fine and pure.

In the city, because of the height of its buildings, the narrowness of its streets and all that pours from its inhabitants and their superfluities [...] the air becomes stagnant, turbid, thick, misty, and foggy...

If the air is slightly altered, the psychical spirit will also be noticeably altered"

Maimonides (Rabbi Mosheh Ben MAIMON)
Cordoba Sephardic Medic, 1135-1204

2.1 Introduction

Around 75% of the European population live in urban areas, where 85% of the Gross Domestic Product (GDP) of the European Union is generated. Currently, urban areas are facing the challenge of making transport efficient in terms of the environment (CO2, air pollution, noise) and competitive (congestion) without losing sight of the social dimension. This involves: providing an answer to health problems and demographic trends, strengthening social and economic cohesion, and taking into account the needs of those people with reduced mobility, families and children.

The “Action Plan on Sustainable Mobility” from the European Commission (COMO (2009)490) and the subsequent “Sustainable Energy Action Plan to reduce emissions” (SEAP) respond to this challenge, initiatives which enjoy the support of over 4,500 Spanish local governments.

With regards to transport, the SEAP offers municipalities various possibilities when drawing up their own action plans:

- Reduce transport needs
- Increase the attraction of “alternative” means of transport
- Make journeys by private car less attractive
- Take action regarding information and marketing
- Reduce emissions of the fleet of municipal and private vehicles
- Install urban traffic control systems

This chapter puts forward proposals for the two last families of actions suggested in the SEAP; the reduction of emissions - through areas known as low emission zones (LEZ) or protected atmosphere urban zones (ZUAP) - and traffic control - through the application of systems known as ITS (intelligent transport systems).

2.2 Traffic and atmospheric pollution

The daily limits for values of NO2 put forward in current legislation are surpassed in Catalonia and the rest of the State to a relatively high degree.

As described in the “Scientific-technical basis for a National Plan for Improvements to Air Quality” from 2012[1] “The vast majority of said exceedances are almost exclusively due to road traffic (especially diesel motors, including those currently being manufactured). Thus around 50% of the Spanish traffic monitoring stations do not meet the future annual limit for NO2 (...) while only 10% of the urban-industrial monitoring stations fail to meet said value. Therefore, the measures which must be introduced in order to reduce NO2 levels in the air have to focus outside those areas with high industrial emissions, in road traffic (...).»

This situation is aggravated by two main facts:

1. Some of the large Spanish cities have a traffic density (vehicles/km2) of between 1.7 and 4.1 times greater than the vast majority of central European cities.

2. The proportion of diesel vehicles (much more polluting with respect to NO2 than petrol) in the Spanish city vehicle fleet is extremely high (50%, and 70% of vehicles registered in 2010) when compared with cities such as London, Stockholm or Oslo (<15%).

[1] Scientific-technical basis for a National Plan for Improvements to Air Quality, Xavier Querol, Mar Viana, Teresa Moreno, Andrés Alastuey, CSIC, 2012.

2.3 Low emission zones and flow control

We shall now introduce the idea of low emission zones (LEZ), through which a series of actions will be taken which will simultaneously regulate the type of vehicle entering the zone and the density of vehicles moving within it. The type of vehicle determines the nominal level of emissions and the density of traffic determines the effective level of emissions and the efficiency of energy use.

In order to favour sustainable, efficient mobility, models based on allowing or denying access to the said zone will be put forward (or as a complement the penalization of unauthorized access) and it will be shown that other more elaborate schemes can be explored with the same material configuration, such as the active management of the supply and demand of access to the zone.

Thus the first model which will be shown will be one in which Europe has been gaining ground over the past few years: that of the low emission zone (LEZ) which limits emissions and not traffic, as entry is restricted to those vehicles with a high emissions level, thus improving health and the quality of life for those who live, work or visit the city.

Furthermore, in addition to the low emission zones, some of the possibilities which flow control can offer in these managed mobility zones or ECO-zones will be shown, given that through effective management it is possible to determine various uses, such as programmable access, regular access and distribution, car parking management, dynamic tolls, etc., which will not only help to reduce emissions, but will also reduce congestion in said zone.

2.4 Low emission zones (LEZ)

Often the most radical and perhaps the most effective solution to solve air quality problems is to establish low emission zones.

This measure includes the problem of social acceptance, as it means that some car users have to change their vehicle, make modifications for which they must bear the cost, or even pay access taxes to said zones. The opposition on the part of the citizen to initiatives such as this can be reduced through information and awareness-raising campaigns. There must also be a sufficiently long transition period.

It is necessary to understand that the main objective in establishing these zones is to confront air pollution and, if they are not accompanied by other complementary measures, they would reduce emissions but not the large volume of traffic.

2.4.1 LEZ operation in Europe

According to the experience of various European cities, there is no single operating method for these areas providing some minimum requirements are met, although there are some differences in application.

Firstly, it is necessary to delimit the zone which will be affected by the restriction. Normally barriers and toll booths are not set up, but there is a series of informative panels on the sides of the access roads to indicate that a LEZ is being entered.

These signs should also include information about which vehicles are allowed to enter and which, on the other hand, are restricted. Significant emphasis must be placed on the publicity campaign so that the users do not have any problems understanding the meaning and process of said restrictions.

The possibility of access will be determined based on the degree of pollution of the vehicle based on emissions set out in European regulations. These European regulations set the limits for gas emissions originating from the exhaust pipe for all new vehicles sold in Europe.

In addition, it is also important that users can access information regarding these regulations in order to know whether their private vehicle meets them or not; although in principle the emissions regulations for a vehicle can normally be determined from the date of registration as a new vehicle.

Once the perimeter and the vehicle limits are delimited, respect for the low emission zone can be enforced via various methods, establishing penalties and fines for cases of non-compliance with the regulations via the competent body for each city.

2.4.1.1 Congestion charge

Some European cities, for example London and Stockholm, have established, together with the application of the LEZ, the charging of a tax for vehicle use. This tax, normally called “congestion charge” is set based on the degree of pollution of the vehicle, according to European standards (so that vehicles meeting the regulations will be exempt from the charge), and the time band in which access to the restricted zone is desired.

In addition, fixed and mobile cameras are installed to capture and process images. This allows for the identification of those vehicles entering the zone. Authorized vehicles simply appear as recorded on a database (where the vehicle is checked for compliance with the established emissions regulations, or whether the user has paid the corresponding charge), and the offending vehicles are detected and identified automatically.

Thus, prior to the installation of this system, it is necessary to create a powerful database which also includes foreign vehicles, not solely those registered within the country.

This measure would act as a conventional urban toll, but without some of the associated drawbacks, as it would not be necessary to develop a booth and barrier infrastructure and would thus avoid the queues which normally form; it would also be different in

2.4 Low emission zones (LEZ)

that the charge would be based on how polluting the vehicle is. In relation to this tax, it would be necessary to facilitate the possible forms of payment and allow, for example, various methods: via mail, in petrol stations or offices, via mobile telephone, internet, etc.

The inconvenience of establishing these taxes as a way of accessing urban centres is the social discrimination it entails, as it allows those with high purchasing power to continue to use their private vehicle without being worried by the obligation to pay taxes, and it thus only affects those with lower incomes. Another of society's objections is that the charge is seen as another way the government charges the population more in taxes. Even so, the negative effects on drivers with a lower income can be minimized if the collected resources are invested in an improvement in the public transport system.

Therefore, the use of taxes for vehicle use will lead to a reduction in air pollution, as the most polluting vehicles would in some cases have access prohibited, and others would have to pay elevated charges. Thus some of the population would change or modify their vehicles in order to be able to enter the zone or reduce the tax to be paid. A reduction in traffic volume can also be foreseen with the congestion charge, as another section of the population would exchange the private vehicle for public transport due to being unable or unwilling to pay this tax.

2.4.1.2 Ecological emblems

One alternative, such as in Germany, Sweden or some Italian regions, is the use of ecological emblems. This entails attaching stickers on windscreens to distinguish between the various emission groups. In total, there are five emission categories according to NOx and PM emissions. Vehicles which have access and those which do not are indicated via a colour code. In principle, it could be stipulated that Euro I or lower vehicles will not have the sticker, and Euro II vehicles will have the red sticker, and thus will not be able to access the environmental zones. In accordance with this criterion other colours are established for Euro III and above (with the possibility to move to higher categories if modifications are applied to the vehicle[2] and distinguishing between petrol or diesel vehicles), in a way that each city, based on the degree of pollution, can decide which categories can access each zone.

In this case, it would also be necessary to draw up a register to include those vehicles which meet the requirements for each zone, differentiating between the European emission categories in accordance with those which have been approved, together with those which have been modified in order to adapt to the requirements of the European emission regulations.

The use of this method allows for easy monitoring to prevent unauthorized vehicles entering the zone; both the local police and the blue zone wardens can check that the vehicles are carrying the correct sticker. Users, both foreigners and residents, should be able to acquire the stickers in the easiest way possible.

2.4.2 Which vehicles are affected by the LEZ?

The low emission zone should affect all vehicles which are established in the city, as it is possible to restrict vehicles to a greater or lesser degree based on the recorded pollution.

In any case, this measure will not only act against the private car, but trucks, buses, vans, ambulances, refuse collection vehicles, etc. will also be affected.

The first table shows which vehicles the LEZ applies to and from when they must meet the relevant emission regulations for the metropolitan area of London, and what follows is a more general table for Europe. Each particular city must draw up its own classification according to its restriction requirements.

[2] See paragraph 2.5.3 Available options for vehicles which do not meet the regulations

2.4 Low emission zones (LEZ)

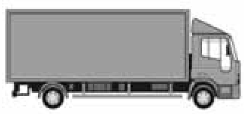
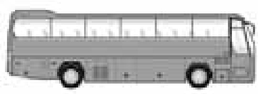
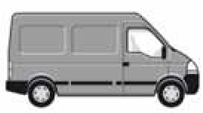
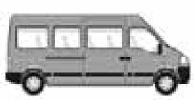
Types of vehicle and definitions	Date they become affected	Required emission standards
Heavy trucks Heavy diesel vehicles which exceed 12 tons in gross vehicle weight, including goods vehicles, motor caravans, horse transportation vehicles, and other specialist vehicles.	February 2008, Euro III January 2012, Euro IV 	All Euro III vehicles meet LEZ standards. Vehicles registered as new vehicles on 1 October 2001 or on later dates are considered Euro III and meet the LEZ emissions standard. Vehicles which do not meet this emissions standard could be obliged to meet it by being modified in order to respect Euro III regulations regarding particles.
Light trucks Heavy diesel vehicles between 3.5 and 12 tons in gross vehicle weight, including goods vehicles, motor caravans, horse transportation vehicles, and other specialist vehicles.	July 2008, Euro III January 2012, Euro IV 	Vehicles which do not meet the emissions standards will have to pay a daily quota if used within the LEZ. From January 2012 the applied regulations regarding emissions will be Euro IV. All Euro IV vehicles meet LEZ standards. Those vehicles registered for the first time on 1 October 2006 or on later dates will be considered as meeting the Euro IV regulations and, as a consequence, also meeting the LEZ emissions regulations.
Buses and coaches Diesel passenger vehicles with more than eight seats plus the driver's seat, and which exceed 5 tons in gross vehicle weight.	July 2008, Euro III January 2012, Euro IV 	Vehicles which do not meet this emissions standard could be obliged to meet it by being modified in order to respect Euro IV regulations regarding particles. Vehicles which do not meet the emissions standards will have to pay a daily quota if used within the LEZ.
Large vans Diesel vehicles between 1.205 tons without cargo and 3.5 tons in gross vehicle weight, and motor caravans and ambulances between 2.5 tons and 3.5 tons in gross vehicle weight.	January 2012, Euro III 	All Euro III vehicles meet LEZ standards. Vehicles registered as new vehicles on 01 January 2002 or on later dates are considered Euro III and will meet the LEZ emissions standard. Vehicles which do not meet this emissions standard could be obliged to meet it by being modified in order to respect Euro III regulations regarding particles.
Minibuses Diesel passenger vehicles with more than eight seats plus the driver's seat, which are under 5 tons in gross vehicle weight.	January 2012, Euro III 	Vehicles which do not meet the emissions standards will have to pay a daily quota if used within the LEZ.

Table 2.1. Information regarding LEZ in London [1]

2.4 Low emission zones (LEZ)

Type of vehicle	LEZ	2011 emissions regulations	Future emissions standards
Trucks	The Nederlands	Euro IV (PM)	Euro IV (01/07/2013)
	Austria	A12 Motorway	Euro II, III
	Mont Blanc Tunnel France/Italy	Euro I	-
Heavy vehicles	London (UK)	Euro III (PM)	Euro IV (PM) (03/01/2012)
	Denmark	Use o filter if below Euro IV	-
	Sweden	8 years / Euro III	-
	Prague (CR)	Euro II	-
Vehicles with 4 or more wheels	Germany	Euro II-IV (PM) and Euro I for petrol	Euro III-IV (PM) and Euro I for petrol
All vehicles	Italy	Euro I-IV (not for 2-stroke motors)	Euro II-IV (not for 2-stroke motors)
Local buses (with agreements)	Norwich (UK)	Euro III (NOx)	-
	Oxford (UK)	-	Euro IV (01/01/2014)
Vans	London (UK)	-	-
	Germany	Euro II-IV (PM) and Euro I for petrol	Euro III-IV (PM) and Euro I for petrol
	Italy	Euro I-IV (not for 2-stroke motors)	Euro II-IV (not for 2-stroke motors)

Table 2.2 General restrictions affected by the LEZ in Europe [2].

2.4 Low emission zones (LEZ)

2.4.3 Available options for vehicles which do not meet the regulations

Faced with the implementation of low emission zones in some metropolitan areas, there are various alternatives for vehicles which do not meet the regulations, and thus it will not always be necessary to change the vehicle for another. The following gives a breakdown of a number of possibilities which not only includes the operators of private vehicles, but also owners of vehicle fleets [1].

- Install a new motor: it is possible to change the vehicle motor for a more recent model.
- Install particle reduction equipment: it is possible to install a certified pollution-reducing device in order to reduce vehicle particle emissions and meet the LEZ emissions standards. This usually consists of a particle trap or a partial filter.

  A particle trap is a filter which is installed within the vehicle exhaust pipe in order to reduce particle emissions. This trap can effectively increase the Euro standard for vehicle particle emissions by at least two Euro levels (for example, from a Euro II to a Euro IV motor).

  On the other hand, partial filters are not designed to trap or filter as many particles as the traps, and normally eliminate half the material emitted by the vehicle (from a Euro II motor to a Euro III standard).

  For this measure, it is essential that each city draws up a list of certified equipment, so that the user does not install unauthorized equipment.
- Convert vehicle to hybrid: it is possible to opt for converting the vehicle so that it works using gas or electricity [3].
- Change the vehicle.

2.4.4 Complementary measures

Once again it must be pointed out that it is necessary to support additional measures so that the overall objectives are achieved. The installation of low emission zones should be accompanied by:

- Awareness and publicity campaigns.
  - Public information of a general nature through various media: information regarding the existence of zones, implications, benefits, etc.
  - Operational public information on the web regarding use of the zone, access to the zone, etc.
  - Signs around the LEZ providing the status and operation of the zone and indications, for example, of whether it is using image recording or if automatic fining systems are in operation.
  - Signs indicating entry to/ exit from the zone.
  - Signs on-line for navigational aids using telematics to obtain traffic information.
  - Information regarding the use of taxes collected in the LEZ in improving public transport.
- Promotion and improvement of public transport.
  - Renewal and modernization of the bus fleet.
  - Aid and incentives for vehicle fleets in order for them to be adapted as clean vehicles (taxis, goods transportation, etc.)
  - Taxis:

[3] See chapter 5, «Alternative fuels» from this White Book for Efficient Mobility

2.4 Low emission zones (LEZ)

        - Establish routes with heavy demand during rush hours.
        - Promote the use of taxi ranks so that the user goes there instead of using taxis in circulation. In this way it is possible to reduce the number of vehicles in circulation and fuel consumption.
        - An increase in the use of the radio transmission service (both on the part of the users and the taxi drivers).
        - Use new technologies to manage fleets (SatNav and sms, among others)
        - Promote applications for smartphones such as “My Taxi”, which allows for the hire of taxis quickly and easily via a telephone, and also allows payment to be made through it.
    - An improvement to infrastructures (charging points, car parks, reserved platforms, etc.)
    - Provide information on public transport about other means of transport, together with where to find it, timetables, etc.
- Promote and provide incentives for the use of clean vehicles as private vehicles (electric, hybrid, gas, filters, etc.)
- Adaptation of the public service fleets to meet environmental criteria; street-cleaning vehicles, refuse collection, parks, etc.
- Parking regulated on the periphery of the LEZ in order to prevent large-scale parking on the zone limits.
- Aid and discounts for residents within the LEZ.
- Political commitment to respect the emission standards established by the EU.
- Traffic control and management measures.

2.4.5 Other considerations

Apart from those aspects which have been mentioned, there are other factors which must also be taken into account:

2.4.5.1 Characterization of the vehicle fleet

In order that the competent administrations can push effective measures against air pollution and decide on a strategy to follow, it is important to identify the truly polluting hot spots on the road transport network. If not, it is possible that the application of low emission zones in specific populations will not have a direct effect on emission levels due to the structure of the vehicle fleet circulating in the zone.

Thus it would be important to precisely characterize the real fleet of vehicles in circulation and their polluting emissions.

2.4.5.2 Low emission certificates

The criteria approved by the Government of Catalonia in order to determine whether a vehicle can be accredited as a low emissions vehicle are the following:

- Type of vehicle: passenger car.
- Vehicles registered in any EU member state.
- Technical requirements by type of fuel:
    - Electric vehicles, LPG, Natural Gas, hydrogen: all.
    - Diesel and bio-diesel vehicles: CO_2 emissions below 108 g/km.
    - Petrol, bio-ethanol and other fuels: CO_2 emissions below 120 g/km.

2.4 Low emission zones (LEZ)

- And in order to enjoy discounts on toll motorways:
    - Payment using VIA-T.
    - Discount applicable Monday to Friday, not on public holidays.

2.4.5.3 Exemptions

Exemptions must be few and temporary for LEZ to work well.

In principle, this category could include vehicles designed and constructed principally for off-road use: agricultural and forestry tractors, mowers, farm machinery, etc. Classic or military vehicles could also be considered.

Secondly, the owners of small businesses or commercial vehicles would be seen to be affected, together with the residents themselves, as they could have more difficulties in meeting the costs of any changes.

Finally electric, NG, LPG, etc. vehicles should be exempt, and the possibility of including public transport vehicles and fleets (such as taxis) should be considered providing there is a plan for change.

2.4 Low emission zones (LEZ)

2.4.6 Visual examples from other European cities

City: London

Body: TfL (Transport for London)

location: When entering the delimited zone

Information:
A reminder that it is necessary to pay a charge if you enter the zone.
Hours of application

Figure 2.1: Informative panels for Congestion Charging, London. Sources from left to right [3], [4] and [5]

City: London

Body: TfL (Transport for London)

Description: A mobile camera captures the vehicle registration plates and compares them against the database to check if they are signed up and paying the charge.

Figure 2.2: Mobile camera at the access to the central zone in London [5]

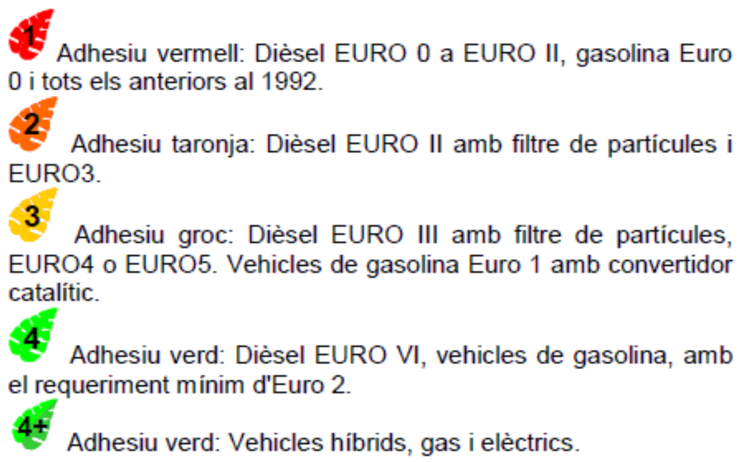
2.4 Low emission zones (LEZ)

Web: http://www.lowemissionzones.eu

Body: Joint EU work, LEEZEN (Low Emission and Environment Zone in Europe Network), cities with LEZ, ministries and regions.

Information on the web page:
Definition and the need for LEZ implementation.
Scope of application and standards in each city.
Starting dates

Figure 2.3 Cities with LEZ throughout Europe [2]



1 Adhesiu vermell: Dièsel EURO 0 a EURO II, gasolina Euro 0 i tots els anteriors al 1992.

2 Adhesiu taronja: Dièsel EURO II amb filtre de partícules i EURO3.

3 Adhesiu groc: Dièsel EURO III amb filtre de partícules, EURO4 o EURO5. Vehicles de gasolina Euro 1 amb convertidor catalític.

4 Adhesiu verd: Dièsel EURO VI, vehicles de gasolina, amb el requeriment mínim d'Euro 2.

4+ Adhesiu verd: Vehicles híbrids, gas i elèctrics.

Country: Spain

Name: Creation of urban zones of protected atmosphere (ZUAP).

Description:
Spatial delimitation of an urban area for the application of a set of measures aimed at improving air quality.
Labelling of vehicles by the Ministry for Industry, Work and Trade, based on their NOx and PM10 emissions.

Figure 2.4: Measures executable under State competence in the period 2010-2015 [6]

2.4 Low emission zones (LEZ)

Clase de polución	1	2	3	4
Pegatina	No tiene derecho a una pegatina	2 S-UM43	3 S-UM43	4 S-UM43
Requisito sobre emisiones (vehículos diesel)	Euro 1 o anterior	Euro 2 o Euro 1 + filtro de partículas	Euro 3 o Euro 2 + filtro de partículas	Euro 4 o Euro 3 + filtro de partículas

Country: Germany

Cities:
Berlin, Hanover, Stuttgart, Nuremberg, Frankfurt, Cologne, etc.

Description:
Colour coding by distinguishing ecological criteria.

Implementation:
These zones were started in 2008
There were 40 by the end of 2010

Information: Informative panels at the entries to and exits from the environmental zone.

Figure 2.4: Measures executable under State competence in the period 2010-2015 [6]

2.4 Low emission zones (LEZ)

2.4.7 Advantages and drawbacks of low emission zones

LEZ

Advantages	Drawbacks
Significant improvement to air quality in cities.	Big problems with social acceptance. The affected users must change their vehicles or carry out modifications to them, bearing a part or the entire cost, or pay daily charges.
Accompanied by complementary measures, city traffic can be reduced.	The need for strong information and awareness-raising campaigns.
They promote the use of fuels which are more respectful towards the environment.	The creation of technology for the detection of emissions in real-time.
Recovery of urban space for the pedestrian.	The correct characterization of the vehicle fleet is very important. Otherwise, the LEZ is not being implemented to solve the real problem.
Improvements to public transport (less traffic volume implies greater speed).	The need to create powerful databases which classify those vehicles which are in fact polluting.

2.5 Flow control

If up to this point the scheme put forward was based on permitting or restricting access for vehicles into a specific zone, now, in contrast, various models for the control and regulation of traffic circulating within the managed mobility zone are offered, as controlling the vehicle flow can be just as important as restricting vehicles.

A large part of this document points out the importance of a change in the mobility model, and proposes, above all, measures so that users stop using their private vehicles. However, it is very difficult to convince the population to do this, and that is one of the reasons why it is also important to develop other management mechanisms. Therefore, technologies and mechanisms which bring about a more effective use of the car are necessary[4].

2.5.1 Delimitation of the zone

As mentioned in the section on low emission zones in this chapter, the first step is to delimit the zone which is to be affected, both by access restrictions and by the various proposals given in this section, together with ways to ensure respect for the managed mobility zone or ECO-Zone.

The current alternative put forward is, just as was explained for the case of London, a system based on the capture and processing of images which allows all registered vehicles which enter the zone to be identified. Authorized vehicles would appear simply as recorded on a database, and the offending vehicles would be detected and identified automatically.

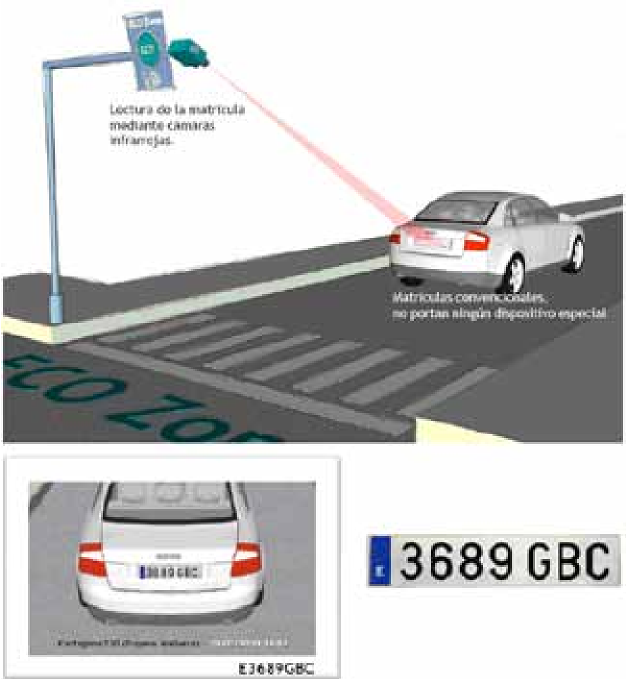


Figure 2.6 Registration plate reading mechanism [12]

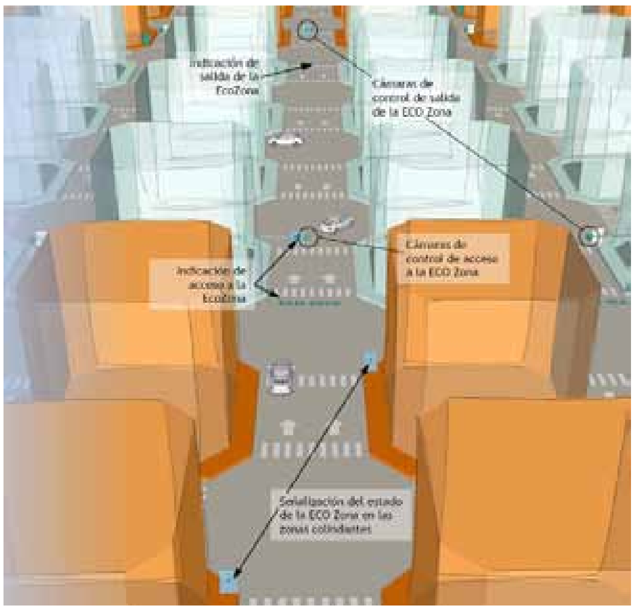


Figure 2.7 Delimiting, signalling and control in the managed mobility zone or ECO-Zone [12]

[4] This part has been prepared based on a joint proposal from Siemens España S.A. and GTD Sistemas de Informacion, S.A.

2.5 Flow control

2.5.2 Dynamic management of public street configuration

This model would consist of dynamic alterations to, depending on the circumstances, public street configuration.

- Number and direction of the lanes.
- Traffic light frequencies.
- Typology of the parking zones: alternating between loading and unloading zones, school bus stops, and parking zones, reserving spaces based on the demand for places from disabled persons, changing the parking configuration (parallel or perpendicular), etc.
- Action regarding the maximum speed on the streets.

According to this model, one of the key moments when specific areas become congested in the city is when children are being dropped off or picked up from school. During these specific times, both the access roads to schools and surrounding roads collapse. For this case, there is another way to manage the access supply. The proposal consists of delimiting, during these times, a perimeter of access streets restricted to school transport, in a way that the rest of the traffic is diverted towards alternative corridors with higher circulation speeds and thus the accumulation of cars is avoided.

This measure can also be complemented through the deployment of other active management mechanisms which are available. The idea would consist of dynamic alterations to, depending on the circumstances, public street configuration: studying, for example, the possibility that specific streets, which are initially two-way streets, are adapted so that one lane is for driving and the other for stopping the car (in this case to be able to drop off the children).

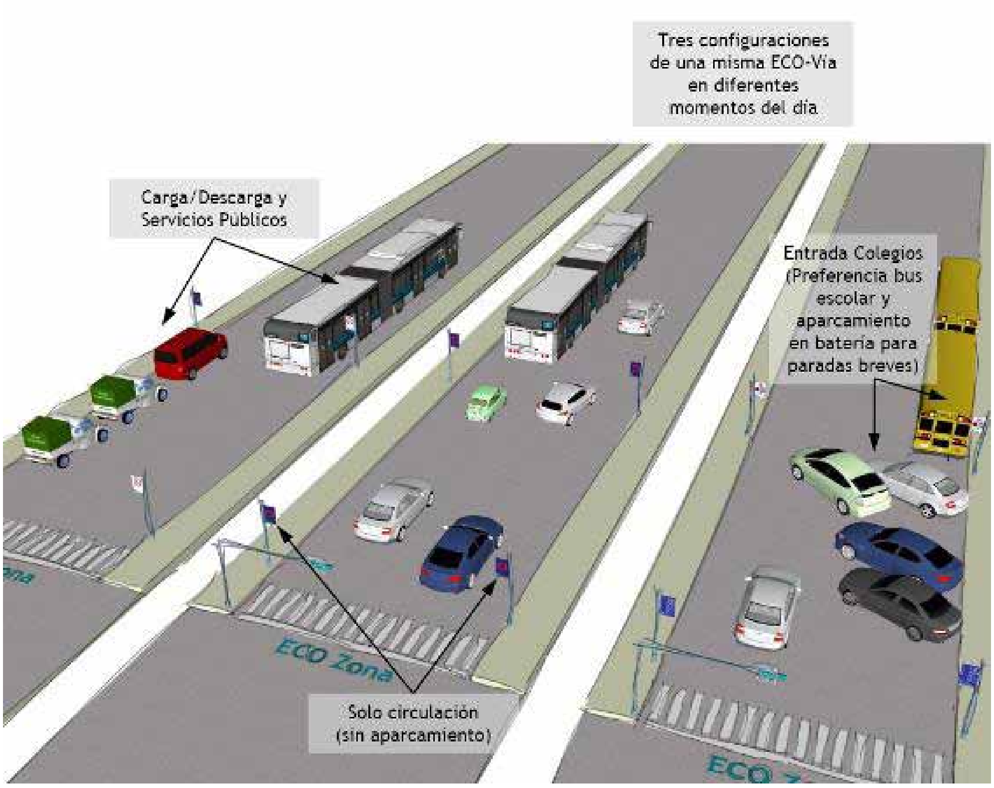


Figure 2.8 Examples of various public street configurations [12]

2.5 Flow control

2.5.3 Car parking management. Guided parking

As mentioned in previous sections, despite proposing measures to reduce the volume of vehicles, it must not be forgotten that the private car will continue to play an important role and, as such, its inclusion in new mobility models will be undeniable.

For this reason, systems, technologies and mechanisms which lead to a more effective use of the car will end up being essential.

With that in mind, the concept of guided parking is presented, both on the public streets and in covered infrastructures (such as, for example, shopping centres or leisure and sports centres), as any streamlining in the search for parking implies, among other things, a better use of energy and a reduction in polluting emissions.

Initially, some of the basic elements that would have to be installed are:

- Information panels regarding the operation of parking zones.
- An indication at the start of the street of the number of spaces available.
- Sensors in the parking space.
- Space available indicator.

And in order to manage and reprogram the information in real-time:

- Communications network.
- Control centre.

In this way, the users could find free spaces in an easy, visual manner.

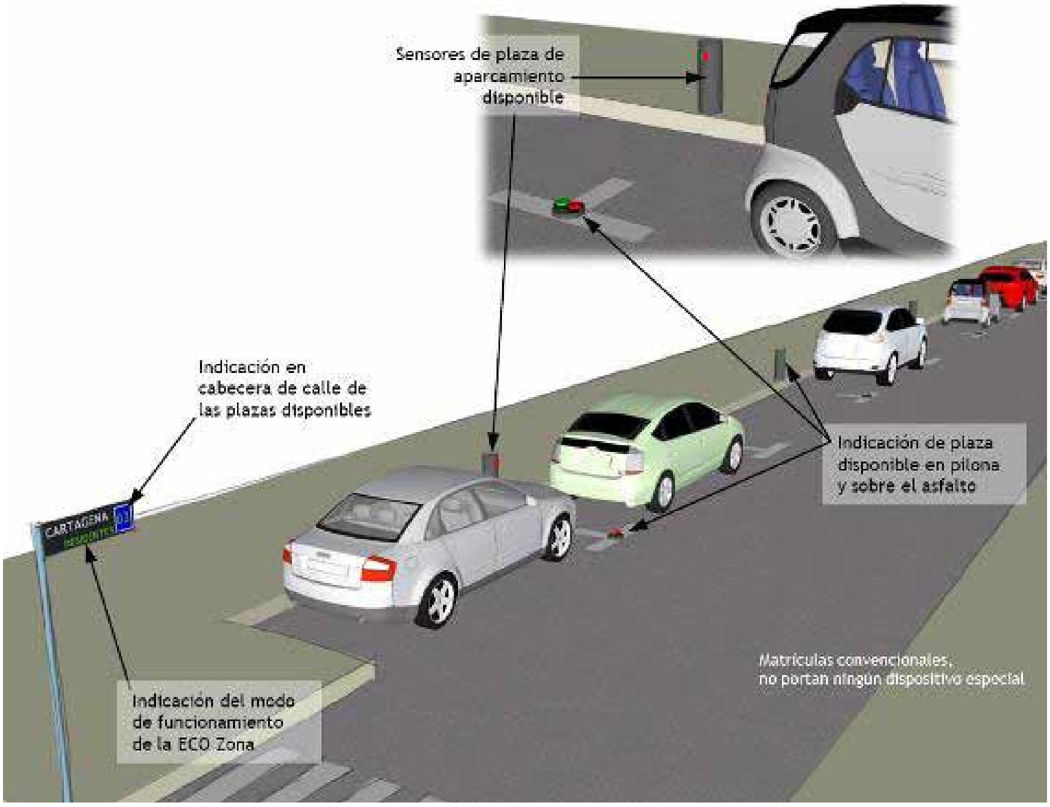


Figure 2.9 Car parking management concept on public streets [12]

2.5 Flow control

Figure 2.10 Free space indicators on the street [16] and in a covered car park [17]

2.5.3.1 Solved problems

Through systems which improve the effectiveness of the parking process, the basic problems which can be resolved (or partially resolved) are:

- Pollution: the accumulation of pollution caused by the search for a parking space is very large and has a greater impact in urban environments. If cars are guided towards parking spaces, the degree of pollution can be significantly reduced.

- Congestion: each parked car is one less in circulation.

- Lost time: the amount of time lost searching for a parking space can become productivity, time with the family, etc.

- Safety: attention to driving, on the part of drivers, is diminished when they have to think about finding a parking space, and this causes additional accidents.

- Inefficiency: parking spaces are not used efficiently from the moment the user is unaware of where they are or whether there are any free.

2.5.3.2 Benefits for those implicated

The fact of having to search for a place to park and the consequent driving by the user until one is found has an impact on various factors. Thus the benefits that those implicated can enjoy are:

- Citizens: both for those who use the private vehicle and residents of the zone.

    - Drivers: each minute used looking for parking implies an extra cost in fuel consumption (with the consequent economic implications) and wear to the vehicle.

      Likewise, when users reduce this search time they can appreciate the benefits in terms of “state of mind” (stress or tension associated with a lengthy search for parking).

    - Residents: they see fewer cars and less pollution, and this leads to benefits which improve health.

- Environment: the car has a significant impact on urban pollution (both atmospheric and acoustic) and thus, as has been mentioned, the parking management processes for cars would lead to an improvement in the quality of the city environment.

- Town Halls:

    - High occupancy: parking faster increases occupancy. This in turn can imply greater income for the Town Hall.

    - Fines: in addition to detecting the typical infractions such as staying for longer than the time paid for, it is possible to install sensors in zones where parking is not permitted so that infractions are detected immediately.

Likewise, it allows control and validation of correct regulated parking which is not charged for (loading and unloading zones, high rotation zones, parking for persons with reduced mobility, etc.)

- Pollution: when pollution is reduced, the Town Halls can comply with the established air quality limits.
- Greater citizen satisfaction.

- Car park operators; companies and public or private bodies dedicated to managing and operating car parks can benefit (airports, shopping centres, etc.).
  - The statistics for car park occupancy can facilitate various urban planning exercises. Likewise, they can obtain income from the infractions committed by users.
  - If the efficiency of use for parking spaces is increased, a greater number of customers using them is obtained (increasing customer productivity).
  - Long queues often form in large car parks because drivers do not know where the free spaces are, and thus both these delays and minor accidents could be reduced.
  - Using these processes produces an increase in comfort levels when using the installation and thus increases user satisfaction, leading to a higher probability of return.
  - The possibility to introduce variable charges and reserved spaces.

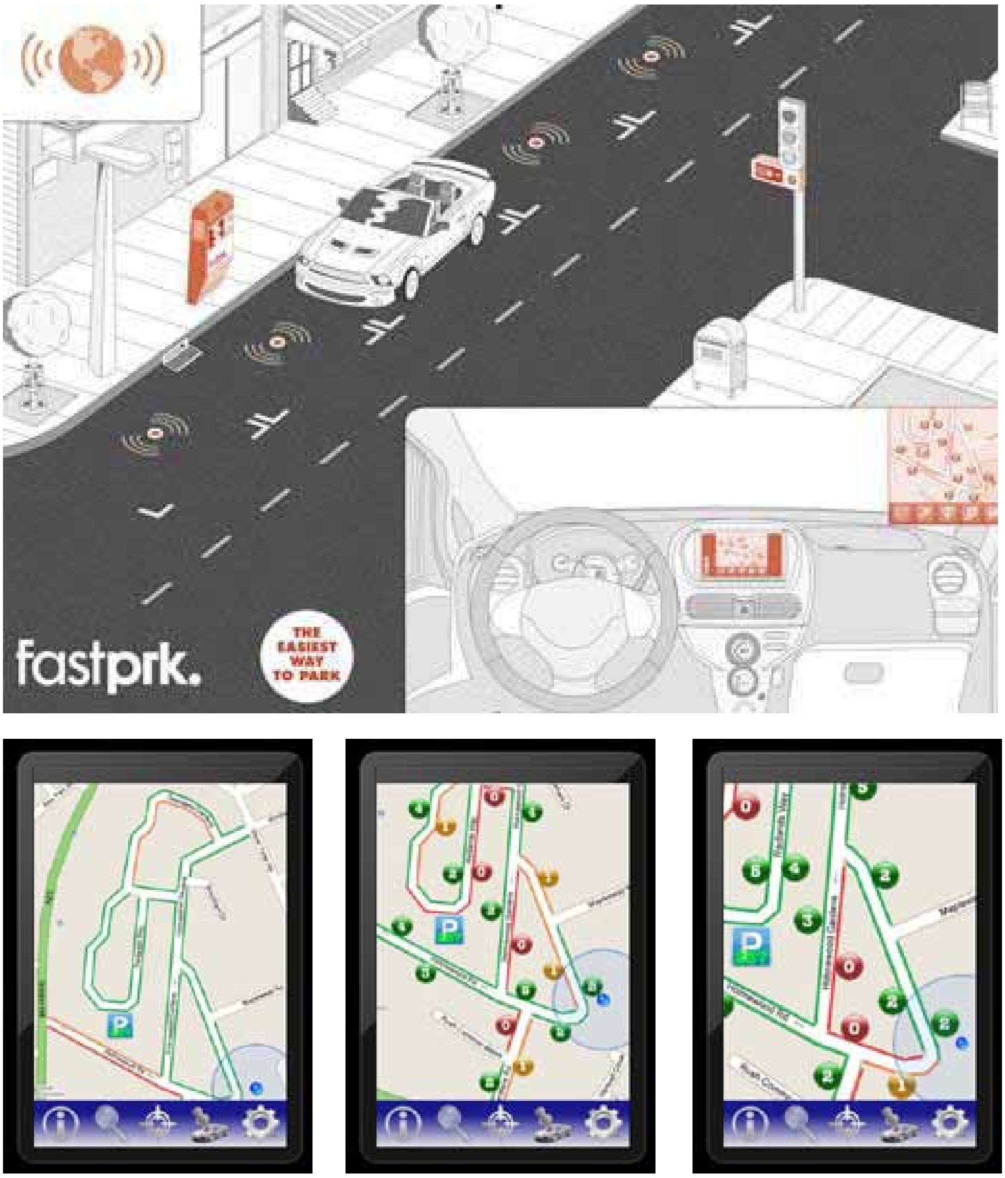
2.5.3.3 New business models. Innovative applications and services

Firstly, parking management does not have to be limited to private vehicles, but could also include, for example, goods loading and unloading zones[5], using the idea of reserved time periods. In this way, by fitting said zones with sensors, the delivery companies could be offered charging based on real occupation time. Or, on the other hand, it would be the users of private vehicles who could reserve parking spaces for a specific period of time before starting their journey.

At the same time, the incorporation of new technologies to this system would allow (both for private users and delivery companies) for an increase in the parking space stay from, for example, a mobile telephone. Or, on the other hand, via these new technologies (for example, through smartphone apps, or web navigators) the driver of a vehicle could use a guiding system to find a specific parking space. The system would receive information regarding free spaces and send this information to the navigator as the final destination.

[5] See also section 2.3.2. Channelled delivery for small goods

2.5 Flow control



Company:
Worldsensing

Product:
FastPrk

Company studies:
Between 18% and 25% vehicles in circulation through European cities are permanently searching for parking spaces.

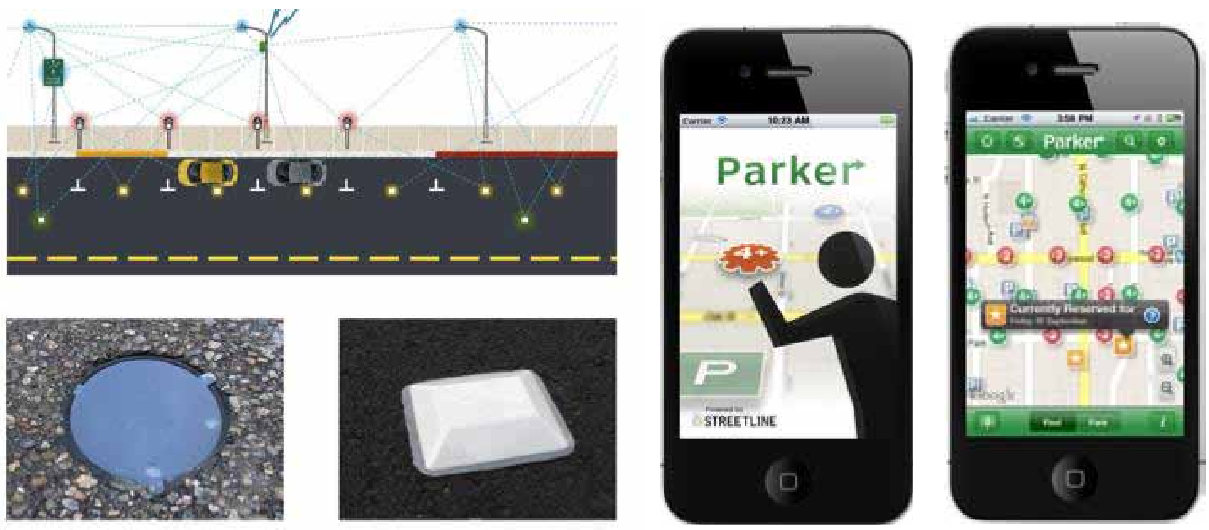
Description:
Parking occupation sensor
Magnetic detection
Adapted for interior or exterior use
Wireless communication

Figure 2.11 Example of guided parking application for iPhone, based on the FastPrk sensor. References [15] and [16]

2.5 Flow control

With respect to covered car parks, if wireless network connection infrastructures are used, businesses in shopping centres can send information about offers to customers who have parked their cars, or even reserve the spaces nearest to the entrances and exits. It is also possible to include, in large car parks, an option for users to enter their vehicle registration in order to see where the car is parked.

To succeed in managing parking for the various vehicles can provide, apart from all the benefits already mentioned, new investment possibilities aimed at improving vehicle security, controlling access and internal mobility via guidance systems and vehicle location, and thus develop and establish various applications and business models.



Company:
Streetline

Application:
Software based on GPS technology which allows drivers to find parking spaces in the city.

Company studies:
30% of city traffic corresponds to cars looking for parking spaces.

Cities:
System deployed in San Francisco and Los Angeles; awaiting introduction in New York and Washington (November 2010).

Figure 2.12 Example of surface guided parking [18]

2.5 Flow control

The Urbiotica proposal

Our main reference with respect to intelligent parking and mobility solutions is the project we are deploying in Nice (France). The objective of the Urbiotica project in Nice is to provide citizens with the tools which allow them to take decisions regarding their mobility by combining traffic information, parking availability and the use of information regarding alternative transport (public transport, bicycles, electric car services, etc.), in order to reduce illegal parking, increase the security, quality, and availability of services and coexistence in the city centre, and to offer the citizens a better quality of life and health via an improvement in environmental conditions (control and reduction of pollution).

The implemented solution

- A network of sensors which provides real-time information regarding the availability of parking spaces, traffic density, and air quality.
- A multi-service kiosk which allows overall control of public services within the public network.
- Integration with public and alternative transport (bus, tram, shared public bicycles and electric vehicles)
- A set of electronic services in order to facilitate the flow of information to users and to the municipal administration through diffusion technologies, such as smartphones, etc.

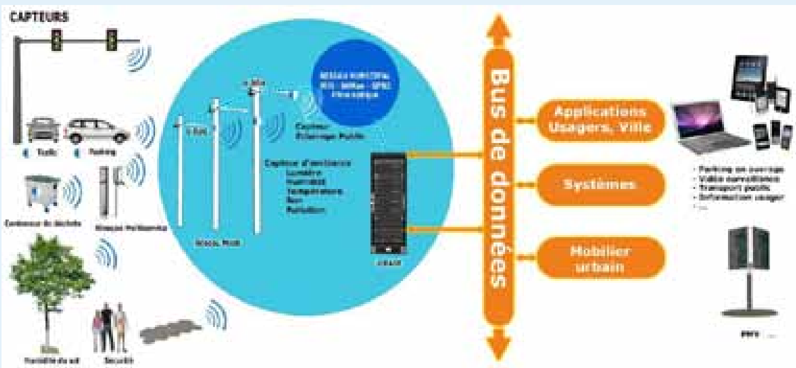
Some key figures:

- 8,500 parking spaces with sensors in the street by the end of 2014
- 10,000 off-street parking spaces connected to the information delivery system in real time.
- Delivery of a guidance service to 344,000 citizens

Architecture of the Urbiotica solution

To address the challenge which the growth of cities represents, URBIOTICA and its partner company SUDE have designed a modular system using electronic components and communication protocols. This system consists of:

- A set of sensors in order to know in real time the status of parking, the traffic and the environmental quality.
- An infrastructure and communication network in order to be able to provide information regarding transport and send it to the information systems.
- A services platform which comprises of a set of e-Services to better inform users and municipal service operators.



2.5 Flow control

2.5.4 Service vehicles

Another question which must be addressed is the reduction in managed mobility zone access requirements for service vehicles. Through monitoring the status of these resources and the infrastructure, it would be possible to simplify maintenance and actions in these zones.

There are numerous aspects which can be monitored remotely or which can be inspected in a coordinated way which is in line with the objective of limiting on site visits.

- Refuse collection. Currently the refuse collection trucks always follow the same route independent of whether it is necessary or not. While they are in circulation they cause hold-ups because they block the movement of other vehicles and travel at a lower speed. The proposal provides the containers with sensors, so that it is possible to receive information from a control centre as to whether the containers are full and need to be emptied. Thus routes and optimum times can be established; managing the mobility associated with these trucks and thus avoiding unnecessary journeys (also contributing to a reduction in fuel consumption).
- Likewise, it could be possible to control the status of street lighting, flowerbeds and green zones, the public streets and the signalling, etc.

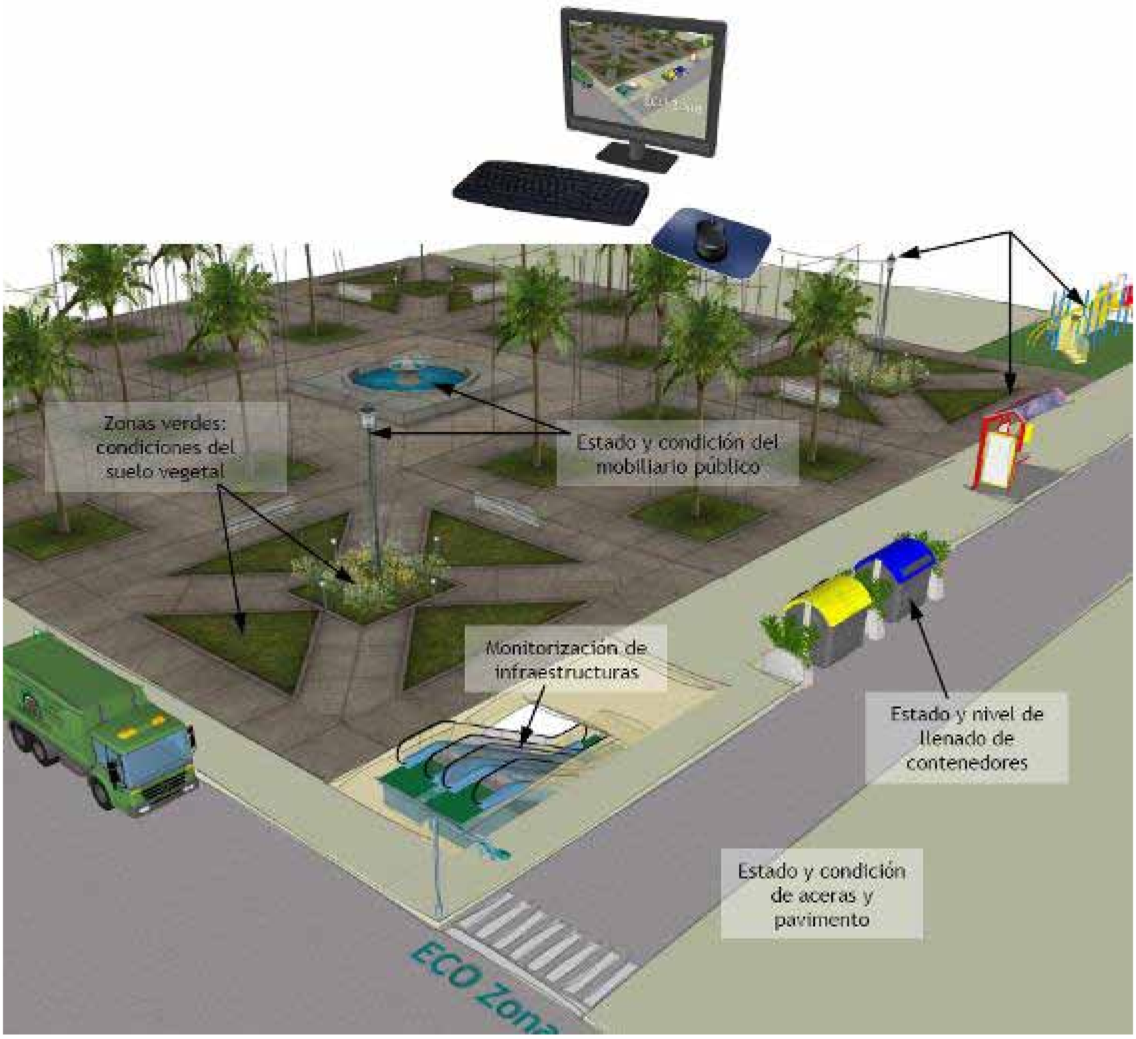


Figure 2.13 Examples of monitoring in order to reduce on-site need [12]

2.5 Flow control

2.5.5 Dynamic tolls

Experience tells us that an increase in street capacity leads to congestion problems[6]. An improvement in the quality and capacity of streets causes an initial reduction in journey time, which attracts more users, and the point is reached at which the initial advantages disappear, and the end result is an increase in private vehicles and thus an increase in journey time. Therefore, because of factors such as economic viability, low effectiveness, environmental problems, etc. the solution is sought by exploring new alternatives which allow for a more efficient operation of the current transport network.

For this reason, another control tool which some cities are starting to opt for is the implementation of dynamic tolls. In contrast to the other proposals mentioned in this "Flow control" section, this measure would serve to manage the flow of vehicles accessing the managed mobility zone, not those circulating within it; that is to say that the tolls would be created as alternative lanes subject to a certain charge, on stretches of motorway or main roads which have serious congestion problems, with the intention that on the one hand the traffic volume would be lightened, and on the other the reliability of public transport circulating via those roads would be increased.

The challenge of these installations is to guarantee the effectiveness of these roads and obtain maximum use of their capacity.

It is important to bear in mind that factors such as the capacity of the road infrastructure, climate, population and traffic density, etc. vary in each city and thus the characteristics of these tolls must be established based on the specific requirements of each city, taking into account and applying different perspectives for tolls which could be based on:

- Traffic levels (congestion).
- Number of occupants per vehicle (incentives for high-occupancy vehicles- HOV).
- Time period.
- Typology of vehicles.
- Emissions produced.
- Etc.

Depending on the aspect to be made a priority, it is possible to establish various models:

- Fast Lane

  This option consists of the creation of alternative lanes which are normally known as Fast Lanes, which allow constant driving speed and optimum use of the road capacity, with a price set to guarantee traffic flow.

  In this sense, the challenge is to set the price correctly in order to prevent hold-ups.

  As an example of this application, a system devised by Siemens Mobility is shown in Figure 14.

- Selective toll for high occupancy vehicles

  The objective of the HOV 3+ selective toll is to reduce the toll charge for high occupancy vehicles (2 or more travellers). The selective toll carries out automatic processing of images obtained from the vehicle interior to recognize the number of occupants in each vehicle.[7]

  The implementation of this type of toll favours the shared use of vehicles and helps to reduce road traffic in large cities, streamlining mobility, and reducing emissions and acoustic pollution.

[6] This phenomenon is known as the Braess paradox

[7] Emte sistemas, part of the COMSA EMTE group, in conjunction with the UPC and TABASA, has developed the detection system for persons inside the vehicle.

2.5 Flow control

To date, the system has been implemented in the Vallvidrera Tunnels on the route into Barcelona. HOV 3+ is the first semi-automatic HOV toll which has been implemented at European level, and has won the X Barcelona Mobility Pact Prize. In order to use it, a button must be pressed during payment and, after verification by the system, a discount is applied to the normal charge.

- HOT Lanes

This alternative option would be a union of tolls and high occupancy lanes (HOV). HOT is the acronym used for High Occupancy Lane.

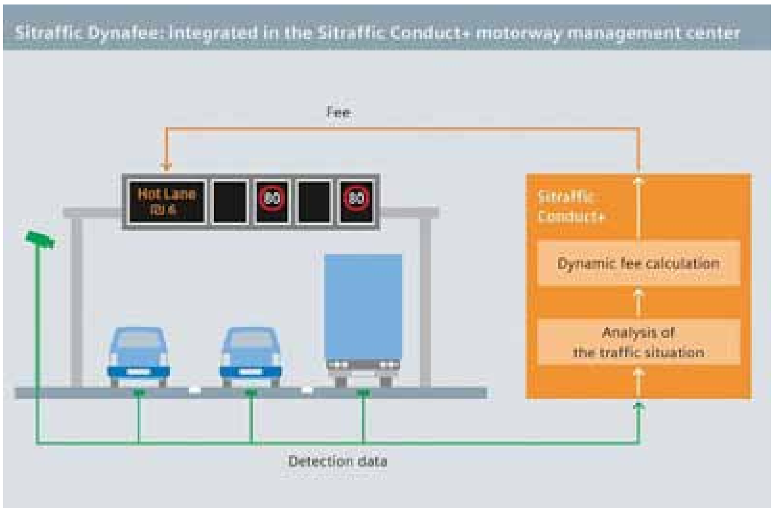
HOV lanes on motorways, for when the whole road capacity is not used. This system of managed lanes maximizes the capacity because it ensures availability for all vehicles. The HOV lanes, which in principle can only be used by vehicles with more than two or three persons or public transport, are structured so that all private vehicle users can use them if they pay a certain charge.

As mentioned previously, this charge can be set based on the time of the day, the traffic in circulation, the typology of the vehicle, etc. depending on the needs of each city.

These lanes have been implemented with success in various cities in the United States, such as San Diego, Miami, Minneapolis, Salt Lake City, Denver, etc. As an example, the first HOT Lane used in Texas is shown in Figure 16.

Figure 2.14 Image of discounted toll for vehicles with three or more occupants. Source: EMTE SISTEMAS

2.5 Flow control



Description: The system is made up of induction circuits distributed throug-hout the road surface which records the speed and the number of vehicles on the main roads and toll lanes. Using the obtained data a complex algorithm is developed which calculates the toll charges to be applied at each moment.

Result: Light traffic: the toll charge goes down. It provides an incentive for users to use the lane.
Heavy traffic: the toll charge goes up. It puts some drivers off and prevents hold-ups.

Signalling: The charges are displayed on luminous signs at the beginning of the HOT Lane.

Payment: vehicle registration plates are recorded at the beginning of the lane to determine the applied charge. This charge will be made via the bank account of the vehicle owner, which was previously recorded, and if not, an invoice would be sent.

Successful trials carried out in Israel.

- 12 km lane on the motorway connecting Jerusalem with Tel Aviv.
- Journey at peak time on the main roadway: from 30 to 60 minutes.
- Journey on the HOT: 12 minutes.

Figure 2.15 Dynamic toll developed by Siemens to reduce the bottle-necks on motorways [13]

2.5 Flow control

TIPO DE VEHÍCULO	LUNES - VIERNES HORAS HOV 5 am - 11 am	LUNES - VIERNES HORAS HOV 2 pm - 8 pm	TODAS LAS OTRAS HORAS INCLUYENDO FINES DE SEMANA
VEHÍCULOS EXENTOS Autobuses METRO y autobuses de escuela	Gratis	Gratis	Gratis
MOTOCICLETAS	Gratis	Gratis	$0.30 a $0.40 por plaza de peaje
HOV carro, camión, van o camioneta (SUV)	Gratis	Gratis	$0.30 a $0.40 por plaza de peaje
SOV carro, camión, van o camioneta (SUV)	$0.30 a $1.60 por plaza de peaje	$0.30 a $1.60 por plaza de peaje	$0.30 a $0.40 por plaza de peaje
3+ EJES vehículos comerciales o vehículos de remolque	$7.00 por plaza de peaje	$7.00 por plaza de peaje	$7.00 por plaza de peaje

Date: set up from 18 April 2009

Description: a combination of HOV lanes (high occupancy and collective transport) with variable toll charges. There are two managed lanes in each direction, offering more reliable journey times for public transport and making available the capacity on unused lanes for those driving alone who pay a toll, and thus saving time.

Characteristics: totally electronic toll. An EZ TAG (or TxTag) is required

Location: between Highway 6 and the East Interstate Highway 610 in Houston (Texas).

Information system: Variable charges at the beginning of the lane on electronic signs.
On the web page there is an explanation of the entire operation, charges, fines, etc. while it also provides links to help find people with whom to share the car.

Body: Harris County Toll Road Authority (HCTRA)

Budget: 250 million dollars collected in tolls (approximately 180 million euros).

Web:
www.hctra.org/katymanagedlanes

Independent of the parameters which define the established toll, its main drawback is the population's sensitivity to a price increase and low levels of awareness on the part of the public regarding this type of lane. Thus it must be highlighted once more that there is a need for complementary measures such as those which have been mentioned: publicity campaigns, Park and Ride at the end of the lanes with these dynamic tolls, investment of the money raised in improvements to public transport, etc.

2.6 Conclusions

In this chapter, managed mobility zones or ECO-Zones have been presented, that is to say the creation of specific zones in cities which allow the control of both vehicle flow and the emissions originating from them.

Thus the first application which has been described is the definition of low emission zones (LEZ), the main objective of which is to reduce pollution within the urban nucleus. According to the experience of many European cities, the positive impact foreseen is clearly evident, as the obligation to meet certain standards obviously limits the circulation of the most contaminating vehicles, and thus it is to be hoped that emissions of CO2, PM and nitrous oxides are reduced. However, there are studies which conclude that the application of low emission zones in specific areas does not have a direct effect on emission levels due to the structure of the vehicle fleet circulating in the zone.

This measure is directed towards improving air quality, and thus during the first years of its implementation the additional improvement of a reduction in traffic volume can be seen, as some vehicle owners that don't meet the standards cannot or does not want to purchase another vehicle or install filters, and thus the percentage of vehicles in circulation in the ECO-Zone falls; however, as the vehicle fleet is renewed it is possible that the environmental quality has improved in the LEZ but the traffic density continues as before.

It must not be forgotten that the application of these zones could meet with strong initial opposition from the population, and so it is necessary that their creation is accompanied by massive publicity campaigns, incentives and aid, and above all by a significant improvement to public transport (renewing and modernizing fleets, improving infrastructures such as charging points, car parks or reserved platforms, providing real-time information and reliable timetables, etc.)

It must also be remembered that the implementation of the LEZ carries the need to adapt the technical inspection of vehicles to new procedures, such as the detection of real emissions (including the calculation of PM and NOx) and the evaluation of modified vehicles.

In the second part of this chapter it has been explained that it is not necessary to limit zones solely to the restriction of polluting vehicles, however they can establish a system to explore new more elaborate mobility management schemes for the city. Following this concept of managed mobility zones, and via these new models, it is possible to control not only the typology of vehicle, but also to reduce vehicle traffic and improve the flow within said zones.

3

Improvements in Public Transport and Sharing Systems

Index

3.1 Introduction

Public transport provides a solution to mobility in a more sustainable way than the private vehicle; this is one of the reasons why the evolution of this type of transport must be continuous in order to improve and complete deficient or inefficient networks, and integrate and expand the various means to provide better cover.

Many of the ideas and measures covered in this White Book for Efficient Mobility must be accompanied by significant improvements to collective transport so that these improvements can be transformed into improvements in quality of life, time savings, and greater productivity and effectiveness.

In order to achieve this new mobility culture which is being put forward, substituting means of transport which cause the most externalities should be promoted, taking into account that public transport is not the only alternative to the private vehicle.

With the aim of promoting public transport in cities and the use of shared vehicles or bicycles, two specific cases of new urban transport models are presented in this chapter; a solution for the management of a fleet of trams and a summary of experiences regarding sharing, both for bicycles and cars or motorcycles.

The first model presented is focussed on a traffic management system for trams which enables an increase in capacity, a reduction in the journey time between stations, and energy savings.

Secondly, the project for the implementation of a high-performance bus network in Barcelona which provides surface transport with similar characteristics to the tram is presented. This makes the bus competitive when compared with the private vehicle, taking into account that it is a new transport system designed to offer a differential service based on operational measures, traffic management, and new technologies and as a non-intrusive action to infrastructure while respecting its integration with the urban design of the city.

With respect to the bicycle, a summary of experiences regarding public bicycle systems is presented, together with an overview of the use of bicycle in cities. In Spain, this means of transport has been gaining ground progressively in recent years, and is little by little becoming consolidated as an ideal means for urban journeys, as has already been shown in many European cities. Public administrations are increasingly backing policies for the management and promotion of the bicycle in order to improve the quality of life of people and urban spaces.

Therefore, the objective of this chapter is to show that progress linked to an improvement in public transport is essential, and that initiatives for vehicle sharing have become key to the promotion of more sustainable mobility.

3.2 Improvements in public transport

Today, one of the most used means of public transport is the railway. The railway is currently understood as the leading collective means of transport as it revolutionized mass transport from the outset. Its superior capacity and efficiency in terms of energy consumption per passenger make this system one of the best for the transportation of persons over short and medium distances. Reference is made to this means in various chapters of this book, above all with respect to improvements in intermodality with other transport systems, the use of new IT systems, etc., but it is unnecessary to develop this further as it is a highly studied transport means. What does seem innovative is the application of new Information technologies to the railway, as explained in the following system.

3.2.1 Tram traffic light timing

3.2.1.1 Introduction

In recent years, tram lines have become more significant as a means of urban transport, as in addition to being compatible with concepts such as sustainability and respect for the environment, they represent one possible solution to some of the problems which public transport is currently facing in cities, such as congestion and commercial speed.

A large number of cities have opted for its implementation and, in the majority of cases, it has enjoyed considerable demand. Spanish cities such as Valencia, Bilbao, Madrid (Parla), Malaga or Barcelona have successfully implemented tram systems. On a European level, Vienna, Milan, Berlin (east), Prague, Budapest, Warsaw, Stockholm and Munich stand out.

This section will show how, through carrying out certain modifications to the tram management system, it is possible to increase the benefits of this means of transport even further, which will provide greater energy savings, greater capacity and shorter journey times between stops.

3.2.1.2 Current problems

As mentioned previously, one of the significant problems currently perceived with regard to trams is the low commercial speed, which is often a consequence of a lack of coordination between the operation of the tram system and the accompanying traffic. This problem in turn leads to energy losses and an increase in journey time.

In any tram operation, the main protagonist in ensuring the correct driving operation is the driver, which leads to irregular timekeeping. This situation leads to an increase in consumption, which could be reduced to a large extent if there was an optimisation in tram driving which took into consideration the traffic lights controlling the accompanying traffic.

Due to its characteristics, the tram frequently runs parallel to lanes for the use of traffic vehicles, which is why it must fight against interference which is produced at junctions. This means that it is conditioned by external factors which can make operation difficult, whether by pedestrians or vehicle traffic and the associated incidents.

The following shows some images which illustrate situations in which the tram suffers interference and must delay its passage.

3.2 Improvements in public transport

Figure 3.1 From left to right, interference in Victoria (Australia) and Zaragoza (Spain). Sources: [1] and [2].

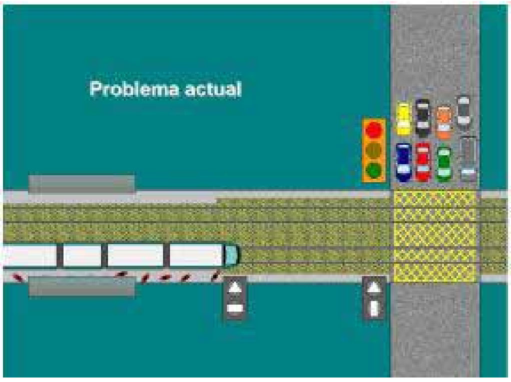
Figure 3.2 Interference from pedestrians and vehicles in the stretch which runs along Diagonal avenue in Barcelona. Source: House production

Figure 3.3 Interference from other transport on the stretch which runs along Diagonal avenue in Barcelona. Source: House production

All the situations which have been shown highlight the importance of adequate traffic light settings between tram stops and the accompanying traffic.

At the same time, on numerous occasions, this interference suffered by the tram is not so evident, but even so has significant repercussions for both consumption and the timetable. This is the case in the following:

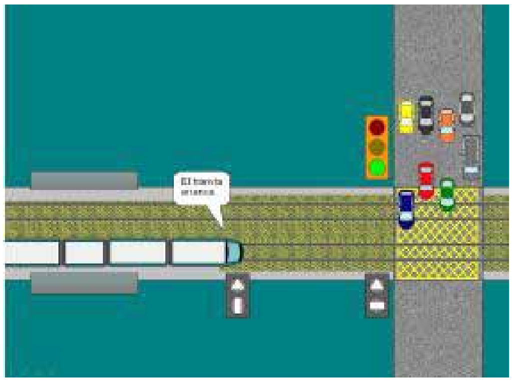
3.2 Improvements in public transport



1. The tram is stopped at the station for passengers to board.

2. At the same time the perpendicular traffic light changes to green.

3. While the vehicle traffic is flowing, the tram cannot proceed.



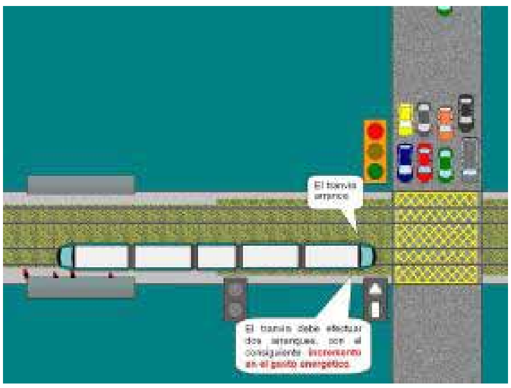
4. The stop stay time comes to an end.

5. The passengers have boarded the tram.

6. Therefore it starts up.

7. The tram must remain stationary until the perpendicular traffic light changes to red.

8. This means that new passengers arriving at the stop can no longer board.



9. When the car traffic lights change to red, the tram starts its passage.

Figure 3.4 Images of the current operation of trams at junctions. Source: Siemens.

3.2 Improvements in public transport

As a consequence, the tram has started up twice, with the corresponding energy cost, in addition to having reduced its commercial speed, commercial capacity and journey time. This situation, in which the tram has to make unscheduled stops, undermines to a large extent the effectiveness of this means of transport.

Thus one of the main problems which the tram driver faces is having to leave specific stops without knowing what will be encountered ahead, whether the journey between stops can be made without stopping or if stops must be made due to the crossing traffic. This aspect occurs randomly because there is no system which regulates the timetable of the trams.

3.2.1.3 Traffic light timing and priority

In order to avoid problems such as those mentioned in the previous section, it must be understood that urban transport systems (in this case trams) have to coexist on the same level as pedestrians and motor vehicles and, as such, it should be organized and coordinated in order to create the most fluid mobility possible.

The tool which performs this function is traffic light regulation.

In order to control junctions, all flows which may have an impact must be controlled: main vehicle flow, crossing flow, and tram system.

Apart from being aware of the various flows which may have an impact on circulation, priorities must be established for each means of transport:

- Null priority: the tram does not have priority; it will cross when it coincides with the green wave of the main flow in such a way that it will have to wait until the end of the crossing cycle in order to start up from the signalled point and complete the junction.

- Micro-regulation: extend the duration of the green wave of the main flow in such a way that it can accommodate the passage of the tram; in this way the order of the flows does not change abruptly, and only a few seconds are added. It requires prior detection of the arrival of the tram and synchronization with the traffic lights.

- Dynamic priority: the tram enjoys absolute priority. In this management model, the tram imposes the signalling in the direction of its trajectory, which stops the crossing flow. Through a system of beacons already installed on the tram, the traffic light system can govern the intersections so that the tram always finds them open to its passage. This system must be regulated with great precision to prevent times which are too short for the crossing flow.

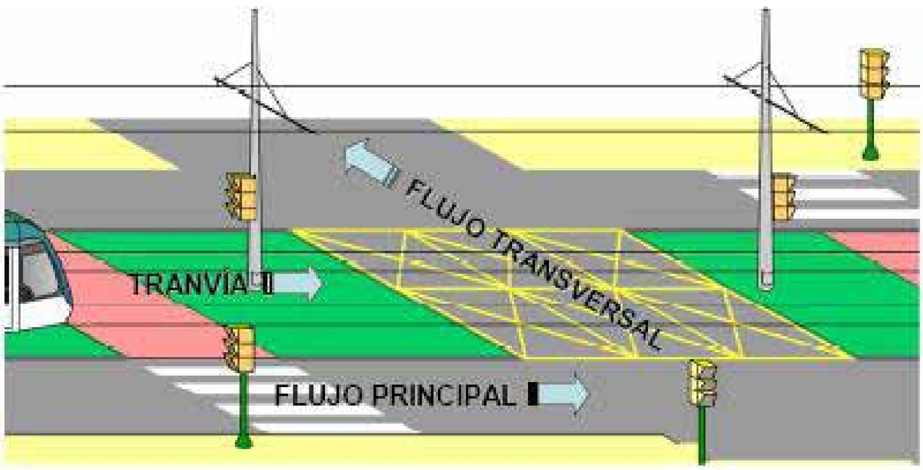


Figure 3.5 Diagram of traffic flows present at a junction. [3]

3.2 Improvements in public transport

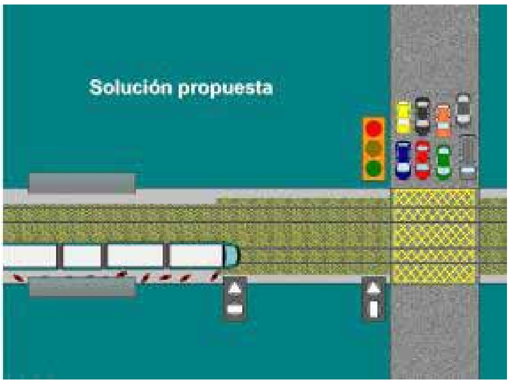
3.2.1.4 Proposed scenario

The scenario proposed in the following aims to give one possible solution to the traffic light problem presented in section 3.1.1.2. Current problem

An alternative which has the least possible repercussions to the current traffic has been considered, starting from the basis of not modifying the traffic priority and incorporating a micro-regulation model.

Thus for the development of this model it is necessary to provide the tram driver with a system which reports the time available to start up.

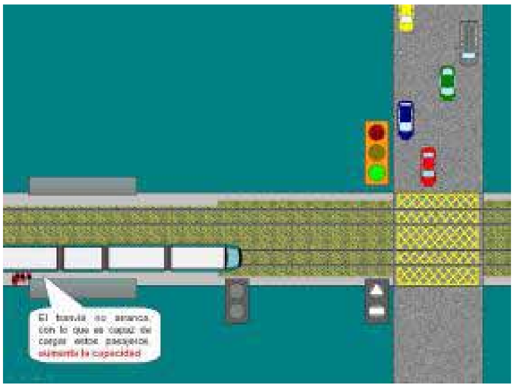
The following illustrates the proposed solution graphically:



1. The tram is stopped at the station for passengers to board.

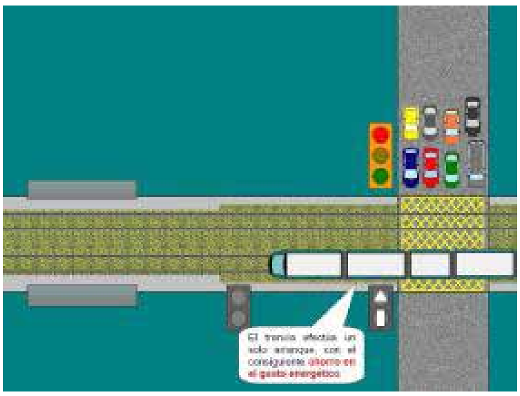
2. At the same time the perpendicular traffic light changes to green.

3. While the vehicle traffic is flowing, the tram cannot proceed.



4. The tram does not start its passage because it KNOWS the status of the following traffic light.

5. On lengthening the time at the stop, boarding is possible for those passengers who are continuing to arrive.



6. When the car traffic lights change to red, the tram starts its passage.

Image of the proposed solution. Source: Siemens.

3.2 Improvements in public transport

As a consequence, the tram has started up only once, which avoids the energy cost of an additional start up, in addition to not having reduced its commercial speed, and increasing its commercial capacity and reducing journey time.

Expected benefits of the proposed scenario.

1. In relation to the proposal to improve the traffic light timing for the tram system, the benefits of implementation would be the following:

2. A reduction in the time required to cover the same route. It does not have to start up and stop twice, the time is reduced and the commercial speed is increased.

3. A reduction in the energy required for the same route. A reduction in the required traction energy. To cover the route it would not be necessary to stop at crossroads, which would minimize the associated energy costs at the moment of start-up traction.

Commercial capacity is increased as the tram stays longer at the stops.

3.2 Improvements in public transport

3.2.1.5 Advantages and drawbacks of the tram system

Advantages	Drawbacks
It is quieter (vibration and noise levels) and less polluting than the bus.	As it cannot overcome obstacles, the rigidity of its route implies that it can be affected by incidents on the route.
The construction of its infrastructure is more economical than for the metro.	The infrastructure and vehicle construction is more expensive than for the bus.
Highly accessible. It travels on the surface, with fast, direct access, with no staircases, tunnels or obstacles. Low platform, access for persons with reduced mobility.	It has less capacity and speed than other types of rail travel.
The platforms are perfectly integrated within the pavements.	There is a greater risk for pedestrians and private vehicles if they do not respect the traffic lights and cross the rails.
The low centre of gravity of the vehicle reduces the sensation of dizziness or movement.	There is an aesthetic impact on the area, although there are tram systems without overhead cables which have a reduced visual impact.
Versatility. It can follow tight curves in order to adapt to specific population centres which are inaccessible underground.	If they are given traffic light priority and users do not exchange the private vehicle for other means of transport, then they can contribute to increasing the congestion even further for traffic circulating in the city.
When a reserved platform is available there is an improvement in journey times, regularity and safety.	It is a transport network which does not cover the whole city.

3.2 Improvements in public transport

Advantages	Drawbacks
It is possible to recover a part of the braking energy through regenerative brakes.	A high level of precision and control for traffic light timing is essential in order to avoid traffic congestion, accidents and ineffectiveness.
It has an elevated passenger transportation capacity, which allows more platform savings than with other means of surface transport.	
It allows a reduction in transport congestion.	
As it works using electrical energy, it doesn't generate polluting emissions and therefore doesn't contribute to air pollution in cities.	
It permits the use of alternative energies coming directly from fossil fuels; hydro-electric, solar, wind, wave, etc.	
Easy adaptation to renewable energies.	

It is worth mentioning that, by avoiding unscheduled stops, it also achieves:

- Greater timetable dependability.
- A reduction in energy consumption.
- An increase in commercial speed.
- Greater fluidity in the interaction between tram traffic and automobile traffic.

3.2.2 High service level bus network

3.2.2.1 Introduction

A specific project for the city of Barcelona is presented in this section, which will attempt to demonstrate that surface public transport can also be fast, dependable, punctual, economic, effective and clean; in conclusion, attractive for users.

Although what will now be shown is a plan for a specific city, it must not be forgotten that there are now other cities throughout the whole world which have Bus Rapid Transit (BRT) systems or buses with

3.2 Improvements in public transport

a high level of service (BHLS) which achieve high performance thanks to segregated platforms, passage priority, high occupancy vehicles and specially designed stops. For example in America, theTransmilenio in Bogota, or in Europe the TVM in Paris and the BusWay in Nantes.

Likewise, it should be mentioned that the proposal put forward is the result of work in conjunction with TMB, the city hall of Barcelona, and CENIT (Transport Innovation Centre) in the UPC, which united in order to achieve the design for a new bus network model which is more hierarchical and totally oriented towards demand, with the separation of services into three types: high performance lines, restructured conventional lines, and a neighbourhood network. The initial approach has been modified and lines have been added to the first proposal. The version which was finally implemented began operating on 1 October 2012, and is described here in detail.

3.2.2.2 Mobility in Barcelona

ETAPES	Interns	%	Connexió	%	TOTAL	% modal	%10/09
TRANSPORT PÚBLIC	1.690.815	34,20%	1.408.471	49,33%	3.099.286	39,74%	0,86%
TRANSPORT PRIVAT	907.036	18,35%	1.239.501	43,41%	2.146.537	27,52%	-0,46%
A PEU I BICICLETA	2.346.250	47,46%	207.321	7,26%	2.553.571	32,74%	2,15%
TOTAL	4.944.100	100%	2.855.293	100%	7.799.393	100%	0,91%

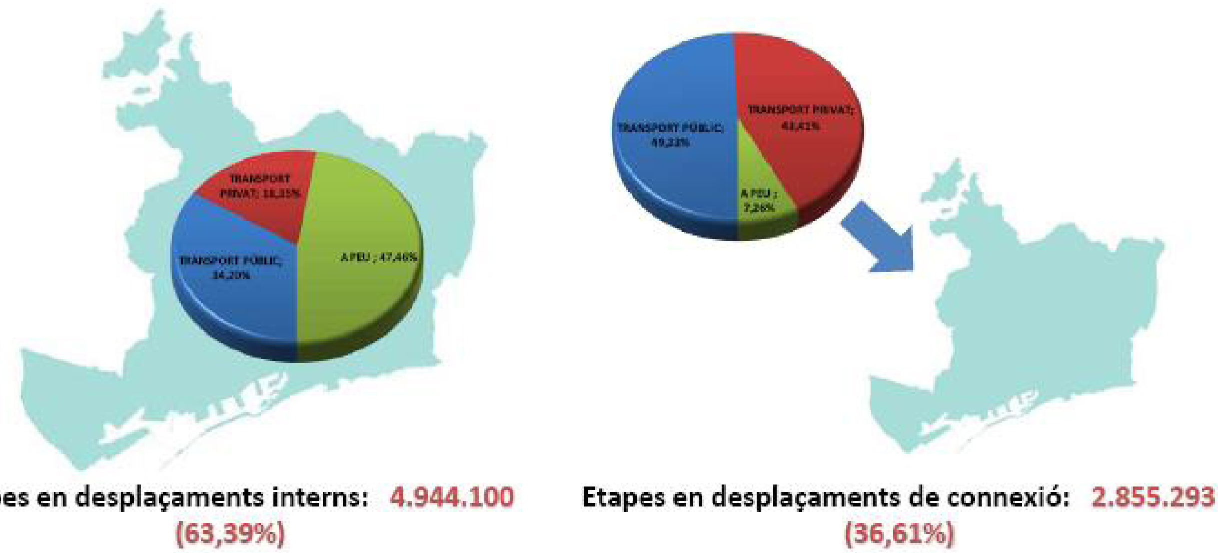


Figure 3.7 Modal distribution for the stages (working day) in 2010. [4]

OPERADOR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	%10/09	nous viatgers	%10/07
METRO	280,9	286,7	294,1	305,9	322,0	332,0	343,3	345,3	353,4	366,4	376,4	381,6	381,2	5,4%	19,62	4,1%
TB (autobús BCN)	169,8	171,3	172,3	187,2	189,8	203,7	205,1	205,0	207,7	210,5	194,9	196,0	189,4	-3,3%	-6,56	-10,0%
TOTAL TMB	450,7	458,0	466,4	493,1	511,8	535,7	548,4	550,2	561,1	576,9	571,3	557,6	570,7	2,3%	13,06	-1,1%
F.G.C.	52,7	57,0	60,7	63,2	70,0	73,0	75,8	74,9	78,0	79,1	80,9	79,8	79,8	-0,1%	-0,04	0,9%
RODALIES RENFE	88,8	90,4	95,4	103,6	110,9	111,9	113,8	122,6	122,2	117,1	114,4	110,1	103,7	-5,8%	-6,41	-11,5%
ALTRES BUS	83,2	85,1	87,1	99,5	107,3	114,1	120,1	125,9	132,0	140,9	144,6	142,6	138,4	-2,9%	-4,18	-1,7%
TRAMVIA							7,7	13,0	16,9	20,9	23,2	23,9	23,8	-0,4%	-0,09	14,1%
TOTAL	675,4	690,5	709,6	759,4	800,1	834,6	865,8	886,7	910,2	934,8	934,4	914,0	916,3	0,3%	2,34	-2,0%

Table 3.1 Evolution (in millions) of the number of passengers using public transport on the RMB. Source: [4]

3.2 Improvements in public transport

As can be seen in figure 3.7 a large percentage of journeys (both internal and connecting) take place on public transport.

It can be deduced from table 3.1 that 35.8 % of public transport users used the bus for their journeys during 2010 on the RMB (TMB buses and other buses).

This data once more points out the importance of continuous improvement in public transport services, and one of its main branches; the bus.

3.2.2.3 Current bus network in Barcelona

The current bus network in Barcelona is made up of a group of lines inherited from the tram system from the first half of the twentieth century, although it has been subsequently influenced by new metro and tram lines and by urban development. Today, it consists of 160 lines served by some 900 vehicles during rush hour on working days.

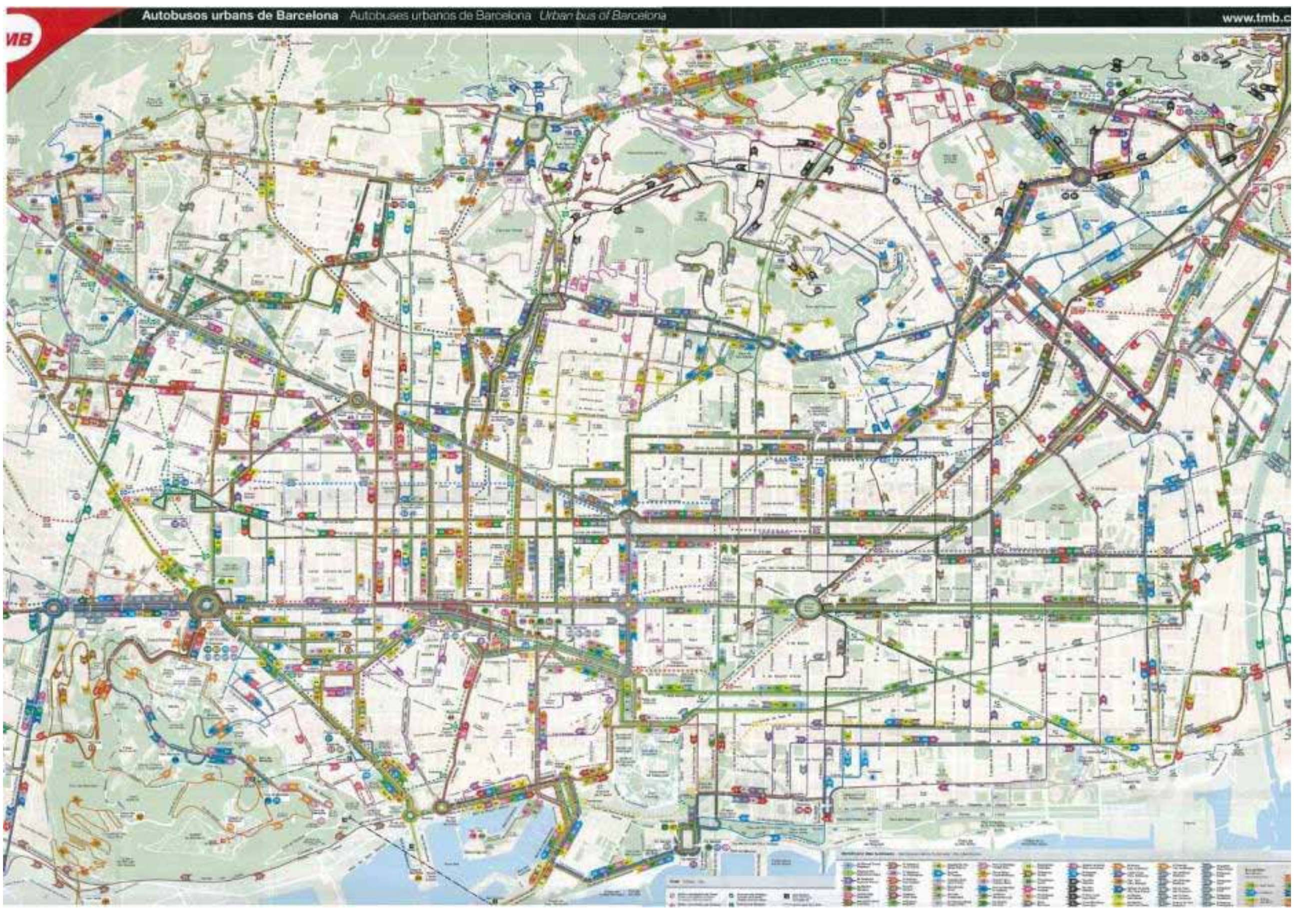


Figure 3.8 Conventional bus network in Barcelona [5]

3.2 Improvements in public transport

3.2.2.4 Project definition

The proposed bus network model is a BRT Bus Rapid Transit) type system which aims to provide performance levels which are close to the metro and similar to the tram, and overcome the limitations of the conventional bus. However, despite sharing similar characteristics to the BRT systems in other cities, the proposed system has been created based on the characteristics and needs of Barcelona and has become the first BRT network.

a) Theoretical model

Based on various studies (carried out by the Transport Innovation Centre and UC Berkeley Center for Future Urban Transport in 2009), it is thought that the optimum structure for a bus network in Barcelona is one known as a semi-alternating hybrid network:

- Hybrid: it combines radial and orthogonal characteristics.
- Semi-alternating: the distance between the horizontal axes will be half the separation of the vertical axes.

At the same time, the branches cover the extremes with continuous accessibility, but reduce the frequency at junctions.

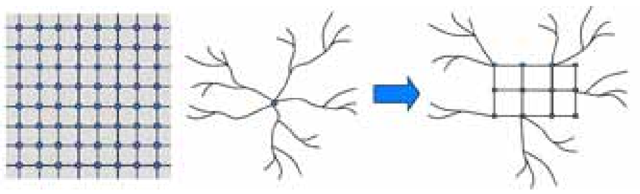


Figure 3.9. Diagram of the hybrid network (right) as a combination of the orthogonal and the radial. [5]

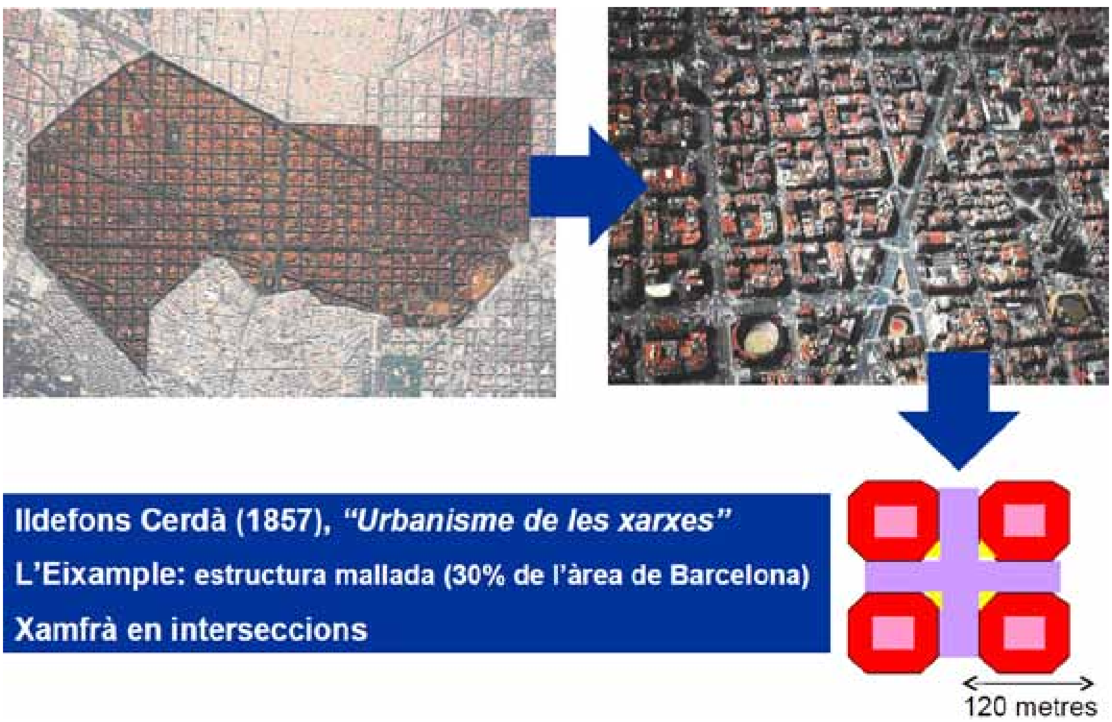


Figure 3.10 Current road network in Barcelona. [6]

3.2 Improvements in public transport

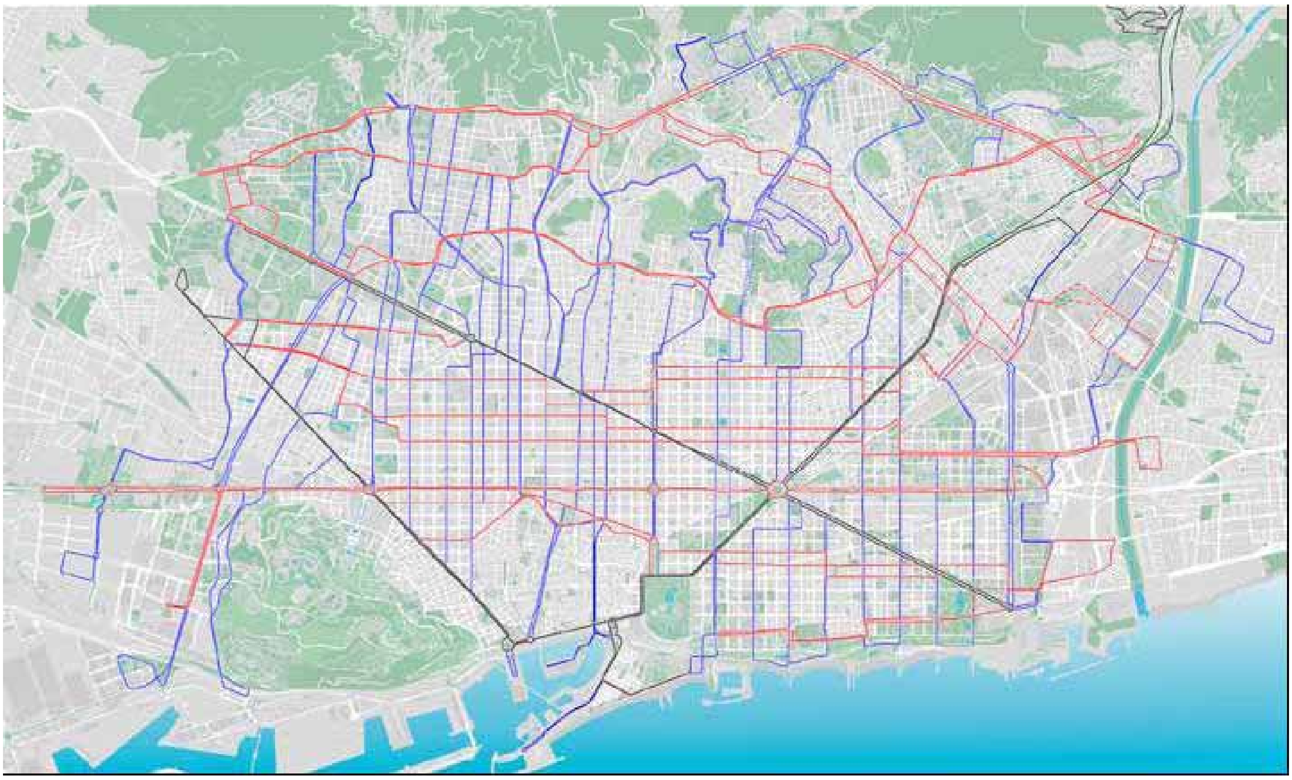


Figure 3.11 Distribution of the 28 proposed axes. [7]

b) Proposed design
The following shows the design of the proposed bus network for Barcelona, as a consequence of its structure (shown in figure 3.15).

The proposed network consists of 28 corridors:

- 17 vertical axes (sea-mountain)
- 8 horizontal axes (Llobregat-Besòs)
- 3 axes oriented radially

It can be seen that adaptation to the specific conditions of the road system in Barcelona has been a priority when defining the axes.

c) High performance network characteristics
The basic characteristics of this surface transport model in Barcelona can be summarized as:

- A high service level bus system designed for the specific conditions in Barcelona in line with the public transport network in the metropolitan area.

- The configuration is in the form of a grid with hubs at intersections.

- 25 corridors: 17 in the sea-mountain direction and 8 in the Besòs -Llobregat direction.

- The service is complemented with neighbourhood buses and inter-urban bus routes which circulate within the city.

- It features special priority and segregation measures with respect to private traffic and conventional buses.

- Passing frequency of three minutes (rush hour) on the grid zone. This high availability will make timetables unnecessary, as all users will be able to go to the stop in the knowledge that waiting time will be short.

- All citizens will be less than 300 metres from a high performance stop.

3.2 Improvements in public transport

- Distance from transfer less than 100 metres.
- 90 % of journeys are direct, or only require a single transfer.
- Integrated fares.
- Reduction in the average door-to-door journey time (estimated at around 13 %).
- Distance between stops of 350 to 400 m.
- Commercial velocity of 15 km/h.
- Constructed without adding buses to the existing TMB fleet.
- Articulated buses which are not too full.
- Maximum network capacity: 60,000 passengers/h.
- Legibility: the network geometry has been kept simple and logical so that even occasional users have no difficulty using it.

d) Hierarchical global network
Implementing this system encompasses three network levels: high performance network, conventional network and neighbourhood network.

These three networks are managed within the same integrated metropolitan transport system with full transfer freedom between them and other modes of transport, both surface and underground.

e) High performance network implementation
The implementation process includes the corresponding studies and projects covering the details of the necessary infrastructures and operation.

Finally, for this specific model in the city of Barcelona, it was decided that the high service level network would be implemented in three phases (ideally through implementing four corridors per year until the 12 planned are completed, and taking into account that the restructuring of conventional lines would also follow the same rhythm).

The routes will be introduced gradually (together with the operating costs), and the benefits could be seen after commissioning and in proportion to the number of connected routes.

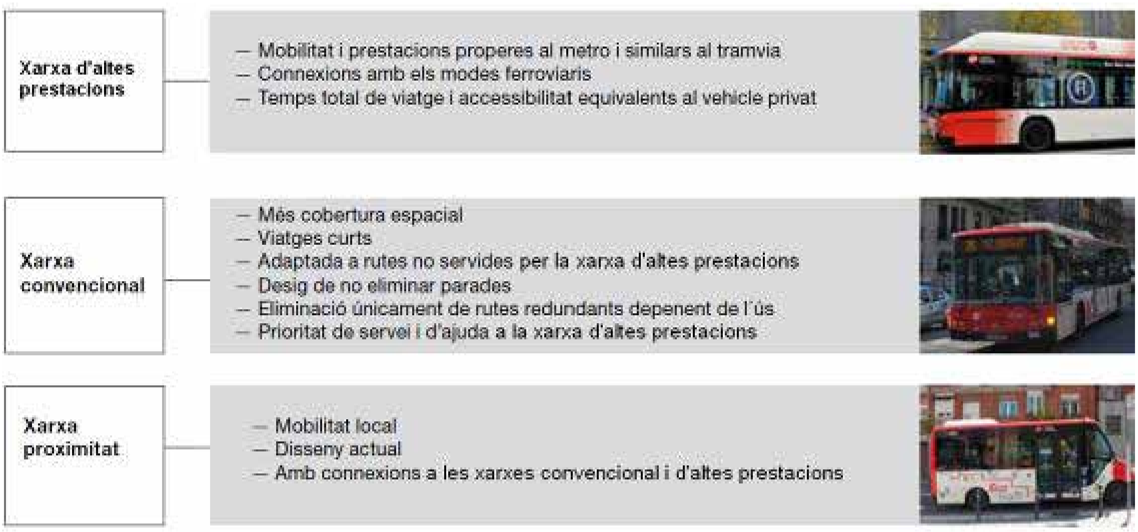


Figure 3.12 The three environments of the future bus network in Barcelona. [6]

3.2 Improvements in public transport

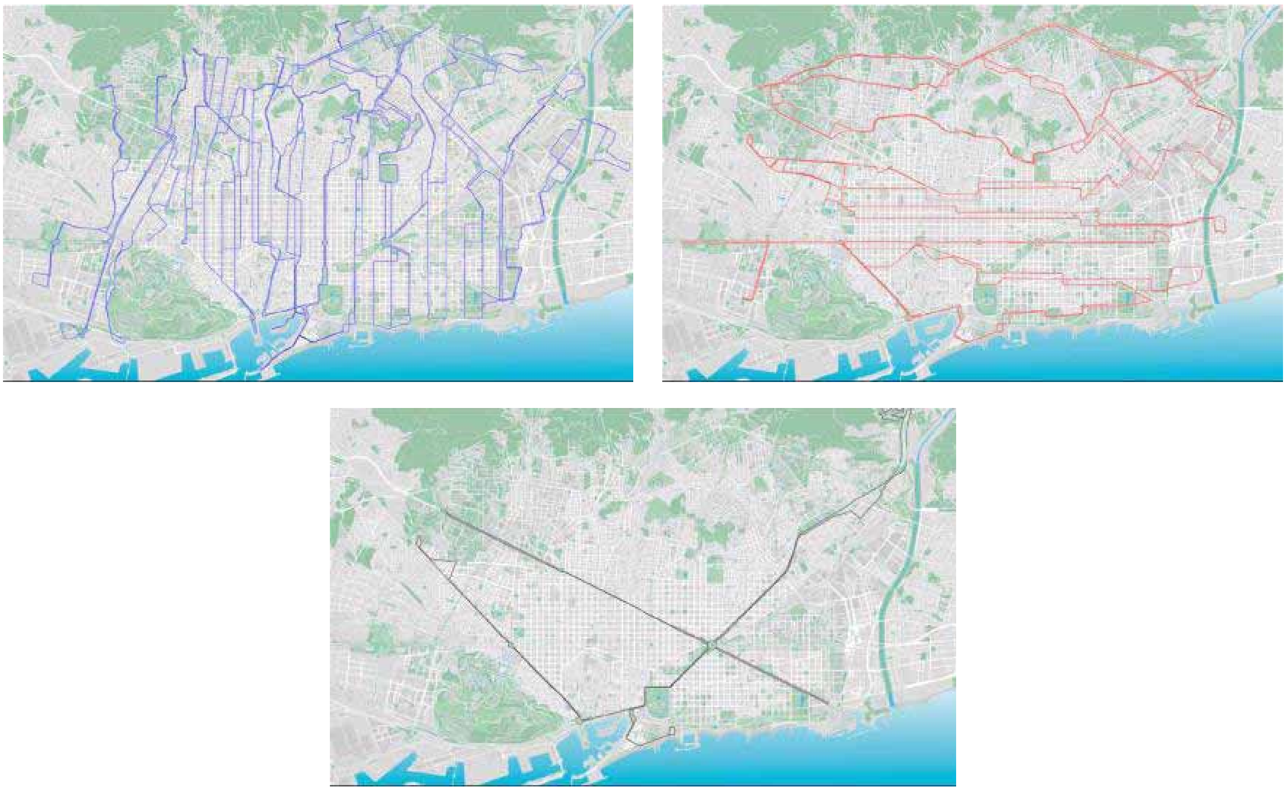


Figure 3.13 The various vertical, horizontal and diagonal axes. Source: [7]

The first step will be to set up five of the routes in the project:

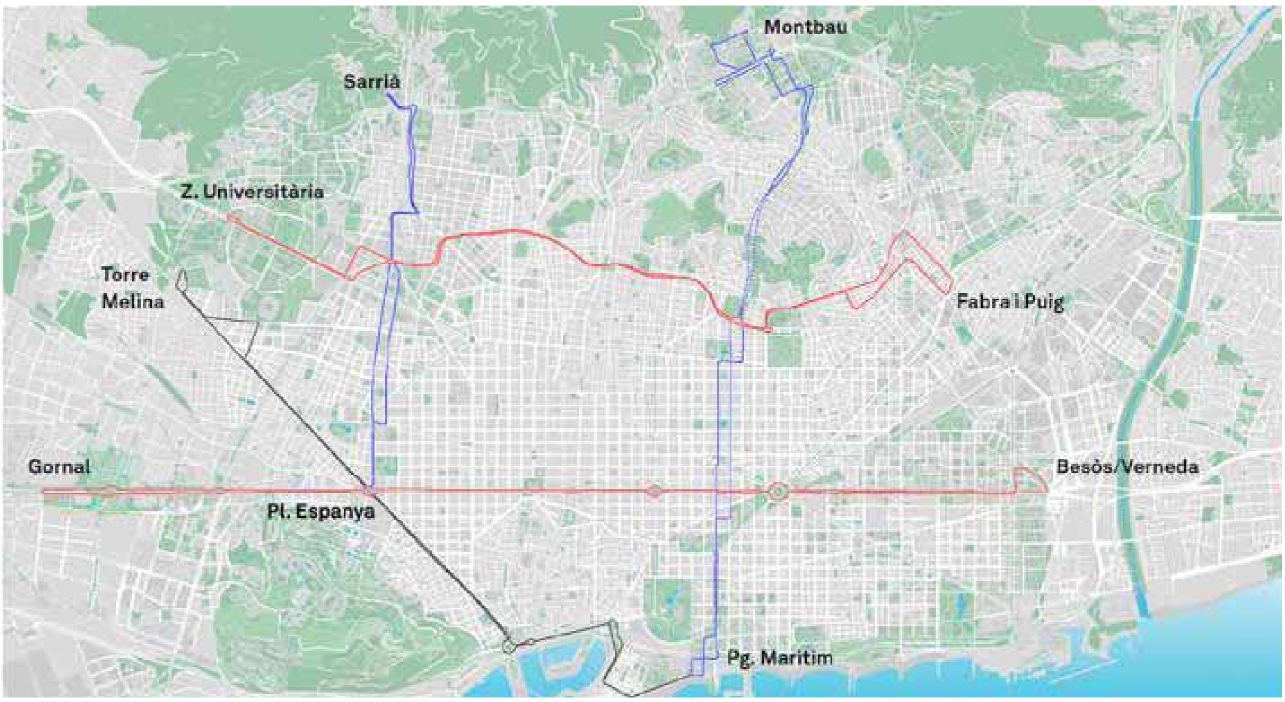


Figure 3.14. The first five routes which will be implemented. Source [7]

These routes cover 88 km, and have provided a service since October 2012.

3.2 Improvements in public transport

3.2.2.5 Distinguishing aspects of the high performance services. Priority measures

A high performance system is defined by a series of characteristics which must be able to provide a higher commercial speed, greater capacity and a reduction in environmental impact, and in order to achieve this the presence of certain priority measures is necessary.

For that reason, aspects which mark out high performance services while at the same time being necessary in order to ensure the effectiveness of the system will be discussed in this section.

- **Infrastructure**
  - Segregated bus lane, or bus lane with intermittent priority where a permanent bus lane cannot be constructed.
  - Colour difference for the bus lane on common stretches.
  - Optimum circulation width.
  - A limit on right turns.
  - The creation of specific zones beside the stops in order to prevent the blocking of the adjacent lane and allow a high performance bus to overtake a conventional bus in order to guarantee priority. It is essential to ensure that these zones are always free of cars.
  - An improvement to bus stops: more real-time information (both for arrivals and incidents), ticket sales machines, information about other means of transport, etc.
  - Specific vertical signalling on the public highway in order to direct the user towards the high performance bus stops and facilitate connections.
- **Operation**
  - Green wave phenomenon with the passage of the bus.
  - Traffic light macro-regulation (dynamic priority) for the high performance bus at specific crossroads.
  - Double stops on corridors operating conventional and high performance routes. They must allow two buses to stop simultaneously.
  - Regulation of the corridors or public transport route axes, as opposed to route by route regulation, so that those bus routes with two branches (forking at a specific point on the route) which run along a high performance corridor do so in a regular manner, in accordance with the passing frequency.
  - Awareness-raising for citizens, the media and users.

Figure 3.15 -------------------

3.2 Improvements in public transport

- **Vehicles**

As with other means of transport, it is important to introduce new designs and image changes which help the bus to be considered a modern, effective and sustainable means of transport.

  - In general, articulated or bi-articulated vehicles (high occupancy).
  - Environmentally improved (CNG, hybrids, etc.)
  - With the incorporation of more advanced technologies: information systems for imminent stops, incidents in real time, connections with other modes of transport, temperature on the route, etc.
  - Sliding electric doors in the centre and at the rear.
  - Interiors suitable for intensive use.
  - Differentiated interior and exterior aesthetics (distinctive for the high performance service).

Figure 3.16 Sufficient space for a double stop. [6]

Figure 3.17 On the left, BusWay vehicles in Nantes, similar to how the high performance buses in the proposal may appear. On the right, possible bus interior. [7]

- **Stops**

  - Further apart than for the conventional bus in order to be able to increase the commercial speed and reduce journey time.
  - Stops differentiated from other bus services.
  - Modern, contemporary stops:
    - Transport ticket vending machines.
    - Touch screen which allows the customer to access powerful information tools.
    - Information to plan the journey by taking advantage of the possibilities across the entire public transport system, making connections and locating points of interest in the surrounding area.
    - Indicators of arrival time and route.
    - QR code for mobile devices.

3.2 Improvements in public transport

  - Solar energy capture device so that the information panel is self-sufficient.

- As with conventional stops, they must also have seats, plans, a thermometer for the route (indication panel for bus stops), etc.

- As has been covered in the operation section, in zones where the conventional and high performance buses coincide there should be, wherever possible, two differentiated stops.

- Provide each means of transport with connection stops such as:

- **Hubs or connection zones**

  - Ease of connection (in this specific case, the routes are located at a separation of less than 100 m).

  - As mentioned, the location of the stops must facilitate inter-modal connection (with metro, tram, railway and conventional bus routes).

  - 90 % of users will be able to make direct journeys or have a single connection between two routes.

Figure 3.18 Images of the various stops, vending machines and information screens. Source: [9]

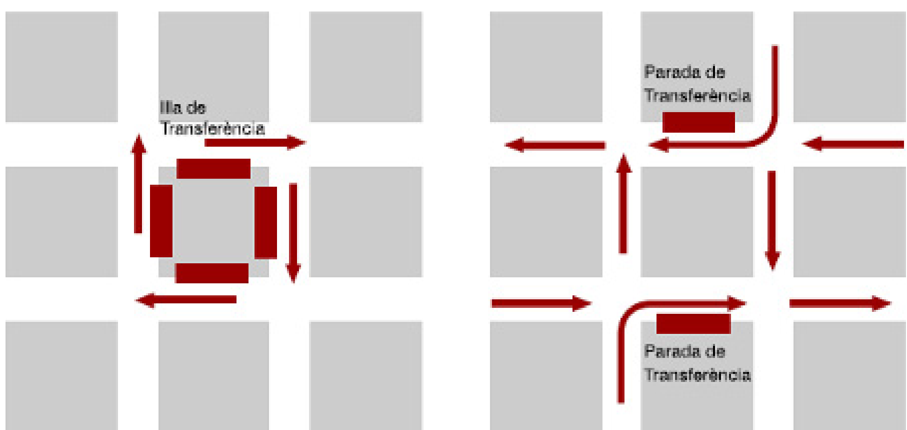


Figure 3.19 On the left, an example of a connecting island on one-way routes (clockwise). On the right, an example of a connecting island where a vertical and a horizontal corridor share the same stop. [7]

3.2 Improvements in public transport

3.2.2.6 Advantages and drawbacks of the proposed bus network

Advantages	Drawbacks
An increase in the efficiency of the bus network. Resources are applied in order to benefit more people. It is estimated that with 30 % of the buses 64 % of places can be covered during rush hour.	Costs: design, management, infrastructure and operation.
An increase in bus network provision. It is estimated that transport capacity could be increased by 28 % once implemented.	An increase in the distance between stops.
Diversification and specialization of services: high performance, conventional and neighbourhood networks. Cover for the whole city.	An increase in the number of connections, although the high frequency of the service reduces the impact of this inconvenience.
An increase in commercial speed. An increase of 40 % is estimated.	Negativity on the part of some users to accept the new bus system, as many routes will disappear and the new stops could be further away than the previous ones.
ICT could increase the commercial speed by another 30 % if the cruising speed is increased (without stopping).	
The network topology is adapted to the orthogonal configuration of the Barcelona road system in order to construct logical itineraries with multiple connection points.	
It is designed with criteria of accessibility in order to facilitate its use by those with reduced mobility.	

3.2 Improvements in public transport

Advantages	Drawbacks
Green fleet: the vehicles will be the cleanest available at all times.	
Connection with the railway system. Promotion of inter-modality.	
Total journey time and accessibility equivalent to the private vehicle. An average reduction in journey time of seven minutes is estimated.	
Higher frequency of service and lower route time.	
Improvement in the environmental quality: • A saving in the consumption of energy resources. • A reduction in emissions.	

3.2 Improvements in public transport

3.2.3 Innovation in the integration of automatic systems within public transport.

The esTRAUSS and TRainCom systems

The current trend in the construction of new metro lines in large cities is to automate systems in order to improve the effectiveness with which the system is managed. From controlling the position of the trains to automatic driving. However, there are many other systems for which automation greatly improves infrastructure control, such as the control of energy consumption, ventilation, fire detection, etc. and for that reason a system that integrates control from a single centre has been developed.

The esTRAUSS system was conceived within the framework of the Barcelona Metro Line 9 project, which is currently under construction. This line features a series of innovations which will allow public transport to become more efficient and competitive.

The esTRAUSS system, developed by Emte Sistemas, is a suite offering a multi-disciplinary integrating platform for operation and maintenance of the railway line. Thanks to this system, it is possible to manage the following subsystems from the control centre: energy, fixed installations such as air conditioning and ventilation, vertical transport, platform doors, access control, fires via a detection system, communications and mobile material. When the system is operational on the entire line, it will be managing around a million signals.

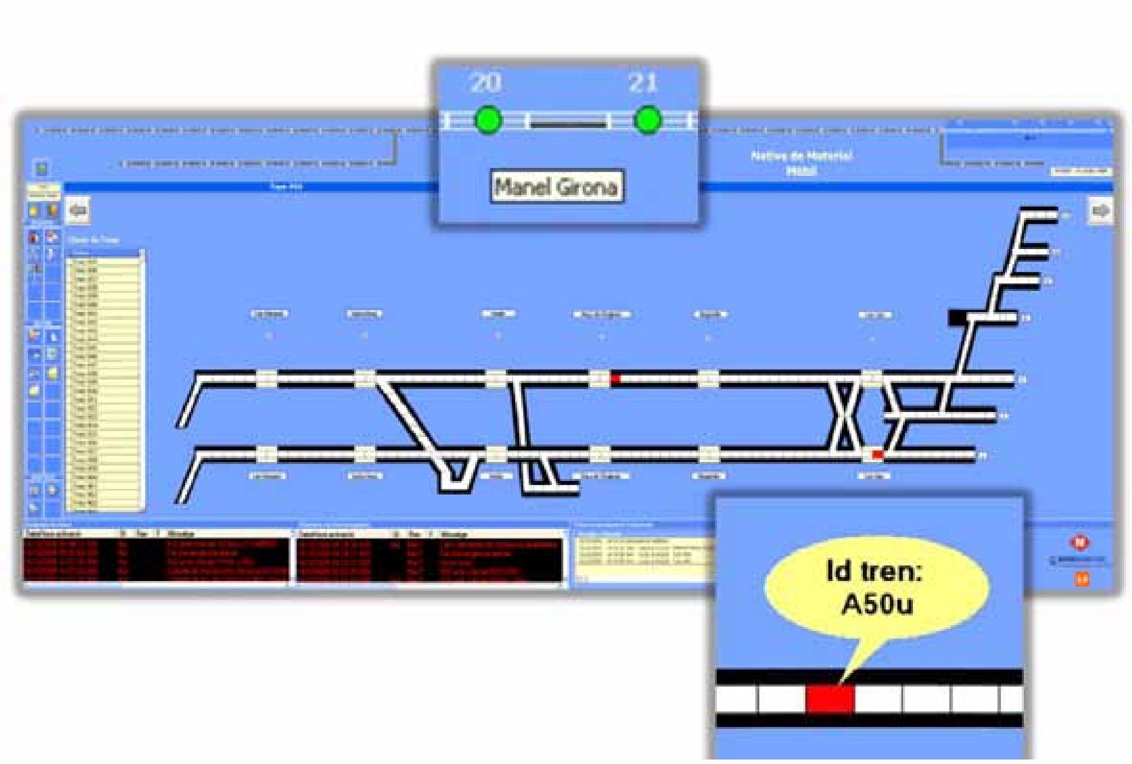


Figure 3.20 Integration of the traffic control system. Source: [10]

Another innovative system is the TRainCom, also developed by Emte Sistemas. It is based on a wireless broadband communications system between mobile material and the operational control centre which responds to the need for having images within trains available in real time, together with those from the platforms and other installations. All the images are managed instantaneously, whether on board or fixed. This solution allows L9 to have the most advanced broadband train-earth radio, specially developed for mobility on a rail network.

The choice of this technology was made with a rail network in mind. For that reason the systems are flexible, modular and scalable, allowing new applications and adaptations to be easily integrated within the future metro control operations.

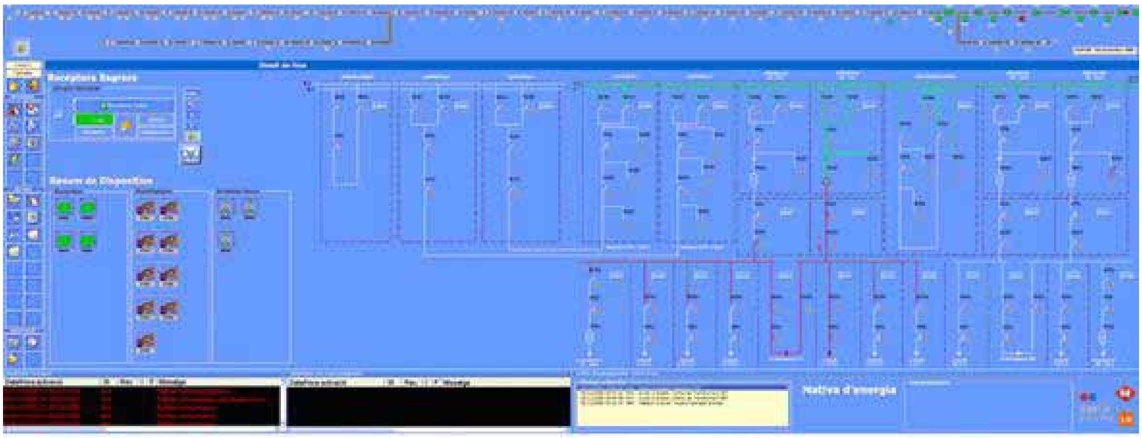


Figure 3.21 Remote controls on esTRAUSS. Source: [10]

Each remote control has its own native application, based on esTRAUSS. However, the platform goes much further and provides an integration suite which facilitates the unified operation of systems for their izationoptimization.

On the esTRAUSS suite, in addition to the previously mentioned subsystems, the following are integrated via TIBCO messaging:

- Traffic
- Validation and sales
- Energy management systems

3.2.4 Conclusions

The need for a change to the current mobility model has been demonstrated throughout this book, and to a large extent this supposes a reduction in the number of journeys made by private vehicle.

For that reason, the main aim of this chapter was to point out the importance that public transport can have within this new mobility model, and the need for continuous improvement.

Following on from that. two specific improvements have been presented for urban public transport: A management system for tram traffic (applicable to any tram route which is crossed by car traffic without traffic light priority) and a new high performance bus network in the city of Barcelona. An innovative system for metro management has also been introduced which allows control of the infrastructure to be more automated.

The first of these was based on synchronization between the tram timetable and traffic light regulation for the surrounding traffic, and established the start-up and braking of the tram based on the existing traffic light timing.

3.2 Improvements in public transport

Thus, when the position of the crossing is determined based on the real location of the tram, when the timetable is recalculated to take into account incidents or interference, and when the rest of the trams are repositioned, a new model of optimized management is achieved which permits a reduction in the energy consumption necessary for the same journey, an increase in tram capacity (due to the management of time slots at the stops), a reduction in the time between stops (with the consequent increase in commercial speed) and greater fluidity in the interaction between the surrounding traffic and the tram.

Furthermore, the second proposal formed part of the re-engineering of urban surface public transport (design, management, operation, ICT, etc.) which would allow the implementation of a new high service level bus network which would overcome the limitations of the conventional bus, evolving with respect to aspects such as high frequency, greater capacity, ease of connection, reduction in journey time, legibility, etc. and making it a means of transport which is sufficiently competitive with the private vehicle in order to make it an attractive option for new users.

Therefore, given that public transport carries significant weight regarding journeys in cities, if they opt for schemes such as those presented, opening up to new methods, an improvement in urban mobility will be achieved which is in turn in line with the current needs of society and the environment.

3.3 The sharing of bicycles and vehicles (cars and motorcycles)

In this section, we will show what role the bicycle and rented vehicles can have within the new mobility model; their advantages, possibilities for improvement, complementary measures, etc. while focussing attention to a large extent on urban public bicycle systems (PBS) and the benefits these systems can provide with respect to the traffic (and its derivatives) in cities.

It is necessary to mention that with adequate planning, the use of the bicycle can cease to be a whim and become a necessity as, while it cannot provide a complete answer to mobility problems, it can form part of a set of solutions which will provide an increase in transport sustainability.

Bicycle sharing

3.3.1 Public bicycle systems (PBS)

According to various studies [11], over 30 % of journeys made by car in Europe are over distances of under 3 km, and 50 % are under 5 km. In these cases, terrain and climate permitting, the bicycle could be an efficient mode of transport which contributes towards an improvement in quality of life and urban spaces.

The Urban Public Bicycles (UPB) systems are rental or free lending systems for bicycles within the urban centres, generally promoted by the public administration. They are different to traditional bicycle rental services, directed more towards leisure or tourism, as they offer a practical, fast mobility service designed for everyday use, set up as a new means of individual public transport which is more flexible for journeys within the city.

3.3.1.1 Criteria to consider in a PBS and main characteristics

Firstly, it is important to consider what should be the basic characteristics of any public bicycle system:

- It must promote inter-modality. That is, the bicycle parks must be around the train, metro or bus stops.
- Users must be certain that there are bicycle parks close to both the point of origin and destination.
- Users must also be safe in the knowledge that there is a bicycle available whenever they need one, and a space to park it.
- The operation of the service must be flexible, dependable and simple in order to guarantee ease of use under good conditions.
- It must be a versatile system, with little urban and planning impact. The infrastructure and location designs must be planned to not constitute physical barriers, above all for pedestrians.
- Various methods of subscription and payment for the different users must be offered.
- The system must be completed with a network of infrastructures reserved for cyclists (cycle lanes, etc.).
- The system cannot cost more than the benefits it can provide.

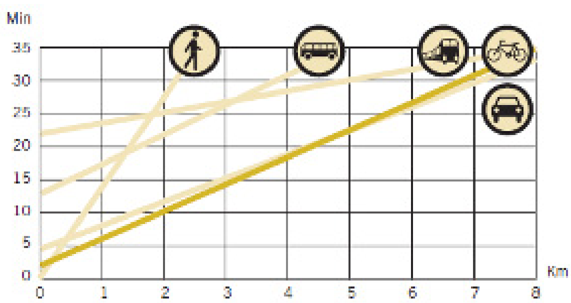


Figure 3.22 On the left, comparative table for journey speeds in an urban environment (time calculated door-to -door). On the right, a 3.5 m wide street which can be used by 2000 people by car during one hour, while seven times this number, or 14,000, can use it by bicycle. [11].

3.3 The sharing of bicycles and vehicles (cars and motorcycles)

- In order to implement it, there must be clearly established lines of financing.
- Publicity and awareness campaigns are essential in order to promote and increase the use of the bicycle as a form of individual public transport.
- Automation of bicycle renting services to avoid the need to use personnel to that end.
- Another common characteristic is the use of fixed stations, in such a way that users take and return bicycles to these stations.
- The PBS should be included within the new mobility plans.

The following provides a series of criteria and considerations which must be taken into account when designing projects to set up these systems in order to guarantee the previous characteristics [12]:

- Population density.
- Strategic positioning of the bicycle points.
- Service timetable.
- Usage time.
- Cost for the user: free service, with some cost, deposit, etc.
- Operation: cash, card, by mobile.
- Restrictions on use: age, everyday/tourist user, ID card, etc.
- Responsibilities of the user: return, damage, theft, accidents, etc.
- Responsibilities of the company or administration: damage, theft, accidents, etc.
- Type of financing.
- System management and maintenance.
- Information and publicity
- Model for bicycles, cycle parks, etc.
- Indicators: number of users, incidents, repairs, complaints, etc.

Furthermore, each city must study its particular characteristics in order to choose or implement the PBS correctly: size of the city, terrain, climate, demographic, urban fabric, etc.

3.3.1.2 Pricing framework for a PBS

In principle, the decision to implement a public bicycle system is motivated by the aim of improving urban mobility, and as such the tariffs must be set so that they are attractive to the user (and thus attract more people to this means of transport) and not as a means of generating income.

Some recommendations are:

- When the system is set up, it should be completely free for the initial period after implementation and the introduction of a tariff (minimum or moderate). Cities with little bicycle culture will get used to it as an option, its use will be promoted and it is possible to capture a greater part of the public.
- For registered users (with a monthly or yearly quota, etc.), there must be a period of free use (usually the first 30 minutes as a minimum). After this time, a rate per minute is charged. In this way the rotation of bicycles and their use as an everyday means of urban transport is promoted (and not leisure use).
- Tariff integration. In order to promote this more sustainable mobility, the system facilitates inter-modality between other methods of public transport (train, metro, bus and tram), with the possibility of a single ticket or card, etc.

3.3 The sharing of bicycles and vehicles (cars and motorcycles)

3.3.1.3 Spanish and European experience

In the European Union, the distance travelled by bicycle every year is over 70 trillion kilometres. Heading the list is the Netherlands, with an average of 1020 km per person per year, while in Spain the average is still only 24 km (2004 data) , [1]).

Thus it is possible to assume that there are many European cities that have established the bicycle as another mode of urban transport, while the phenomenon of implementing public bicycles began in Spain in 2007, and it is currently starting to become consolidated.

The following shows some of the more relevant examples from around Europe, together with the two most significant systems in Spain, which demonstrate that the implementation of public bicycles can be successful.

Spain

Figure 3.23 mmmmmmmmmmmmmmmmm

Name: Bicing
City: Barcelona
Launched: March 2007
Most recent data: July 2009

System: Automatic that works with user's card.
Number of bicycles: 6000
Number of registered users: > 90,000
Target public: resident user.
Model: Clear Channel SmartBike.
Implicated bodies: public: Barcelona City Hall and BSM. Private: Clear Channel (operator).
Integrated railway stations: 13 (renfe and FGC).

Concept and operation: the user must register to obtain a personal card which, when in proximity to the relevant reader, will allow access to the bicycles at any station. This card allows data regarding the use of the bicycles to be recorded in great detail, together with computerized monitoring of the bicycles which are not returned or which do not meet the conditions of use.

The system allows access to information regarding the bicycles available at each station by internet or mobile, route planning, bicycle or parking reservation, etc.

The first 30 minutes are included in the quota. The maximum period of use is two hours. (Tariffs and conditions of use available on the website).

Web: http://www.bicing.cat

3.3 The sharing of bicycles and vehicles (cars and motorcycles)

Figure 3.24 mmmmmmmmmmmmmmmmm

Name: Sevici
City: Seville
Launched: July 2007
Most recent data: July 2009

System: Automatic that works with user's card or code.
Number of bicycles: 2500
Number of stations: 250 (every 300 metres approximately)
Target public: resident or tourist user.
Model: JCDecaux Cyclocity.
Implicated bodies: public: Seville City Hall Private: JCDecaux (operator).
Integrated railway stations: 4

Concept and operation: After registering, the user can choose between a short subscription (seven days) and a long-term subscription (one year). Once the corresponding card has been obtained, the bicycles can be accessed by moving the card within the proximity of the reader or by the introduction of the user's code.

The first 30 minutes are included in the quota, and then the tariffs vary based on the type of subscription. (Tariffs and conditions of use available on the website).

The interactive point allows various operations to be carried out: select and remove cycles, acquire proof of journey, consult information and plans, reload the account, etc.

Web: http://www.sevici.es

3.3 The sharing of bicycles and vehicles (cars and motorcycles)

Europe

Figure 3.25 mmmmmmmmmmmmmmmmmm

Name: Vélo'v
City: Lyon, France
Launched: May 2005
Most recent data: Spring 2008

System: Automatic that works with user's card or code.
Number of bicycles: 4000 approximately
Number of stations: 340
Target public: resident or tourist user.
Model: JCDecaux Cyclocity.
Implicated bodies: public: Grand Lyon
Private: JCDecaux (operator).
Integrated railway stations: 4

Concept and operation: very similar to the previously described systems. Daily, weekly or yearly subscription. Once the corresponding card has been obtained, the bicycles can be accessed by moving the card within the proximity of the reader or by the introduction of the user's code.

The first 30 minutes are included in the quota, and then the tariffs vary based on the type of subscription. (Tariffs and conditions of use available on the website).

Marketing: As part of the campaign to promote citizen participation, from 7 to 10 December 2006, part of the city recreated a bicycle race video game, Vélo'v Racing in Lyon, in which pedestrians could play (for free) on screens installed in Republic Square. Subsequently. the possibility to play on-line was offered.

Web: http://www.velov.grandlyon.com

3.4 Other considerations for the use of the bicycle in urban environments

3.4.1 Bicycle lanes

Just as with other means of transport, in order to consolidate bicycle use on regular journeys it is necessary to promote the creation of reserved infrastructures which are specifically dedicated to that end, as for example with cycle lanes.

It should not be forgotten that the design of these new infrastructures must respect the flow of pedestrians at the same time as leaving necessary space for other transport, and therefore adequate investigation and management is essential.

3.4.1.1 Road types

As specified in the review of the "Law regarding traffic, circulation of motor vehicles and road safety" [11], various types of lanes for cyclists can be distinguished:

- Cycle lane: cycle way running alongside the roadway, in one direction only or in two directions.
- Protected cycle lane: cycle lane provided with side elements separating it physically from the rest of the roadway and from the pavement.
- Cycle pavement: cycle lane marked on the pavement.
- Cycle track: cycle lane segregated from motor traffic and following a different route to the roadway.
- Cycle path: a lane for pedestrians and mopeds, segregated from motorized traffic and which runs through open spaces, parks, gardens or woods.
- After carrying out the relevant studies, each city should determine which type would be the most convenient for its specific case[1].

[1] Henceforth, and in order to simplify the matter, throughout the rest of this document all lanes which can be used by cyclists will be referred to as "cycle lane".

3.4.1.2 Criteria for location and design

In order to adequately design a cycle lane network, there are a number of aspects which must be taken into account:

It must be a coherent, complete network.

- The routes must be as direct as possible (avoiding excessive or useless diversions) and the maximum slope should be less than 6 %.
- It is necessary to establish itineraries which guarantee connection with various points in the city (city centre, universities, stations, leisure centres, etc.).
- The safety of cyclists must be guaranteed. If they are set up incorrectly, they can create a false sense of security and increase the accident risk for both cyclists and for pedestrians or vehicles. Apart from the location, other aspects must also be taken into account, such as signalling, lighting, lane surface, distances and minimum widths of the lanes, etc.
- The crossing of roads should be avoided, and in cases where this is inevitable, the crossing zone and priorities must be adequately marked.
- The space dedicated to cycle lanes must be at the cost of motor vehicles, not pedestrians (as a complementary measure to promote other more sustainable modes of transport and reduce the number of motor vehicles).
- The implementation of cycle lanes is only recommended if there are sufficient resources available to carry out meticulous planning, as, if not, there is the risk that the lanes will be a failure, and if they are not used, the space and investment dedicated to these will have been wasted.

Finally, it must be said that this cycle network should be considered as one more element in the design and planning of sustainable urban mobility, and the following situations must be avoided:

3.4 Other considerations for the use of the bicycle in urban environments

Figure 3.26 Uncivil behaviour on the part of vehicles and the city hall itself. [18]

3.4.1.3 Signage

The first two images show two stretches of cycle lane that to date, although having some drawbacks, have been successful in Barcelona. [15] The subsequent images show different types of cycle lane (signed) in other countries.

- Meridiana. 1.2 km.
- Well marked lanes producing no conflict with pedestrians.
- The outward and return lanes are separated by the Trambesòs.
- Flexibility and constructed banking separates it from other lanes.

- Diputació. 3.1 km.
- Fluid traffic thanks to the rubber separating elements.
- Conflict at crossings with vehicles turning right.
- The bad habit of many cyclists to ignore traffic lights.

3.4 Other considerations for the use of the bicycle in urban environments

Figure 3.27 On the left, stopping refuges: these allow the cyclists to stop ahead of motor vehicles at junctions in such a way that they are visible to drivers and have priority when turning (United States). On the right, the signal shows that motor vehicles must give way to bicycles when they have to cross the cycle lane. Source: [19].

Figure 3.28 Contrasting colours at junctions. On the left in the Netherlands and on the right in Portland. Source: [20].

3.4 Other considerations for the use of the bicycle in urban environments

Figure 3.29 On the left, a warning sign to increase cyclist safety (Caceres). [21] On the right, a pioneering initiative in Spain, traffic lights installed lower so that cyclists enjoy better visibility (Barcelona). [22]

3.4.2 Bicycle parks

As has been mentioned in previous sections, a strong factor which dissuades the user from using the bicycle more often, and specifically with reference to everyday journeys, is the possibility of encountering vandalism or theft. In various studies, it has been shown that a high percentage of cyclists have at some time suffered from bicycle theft, despite the majority of these bicycles having been fitted with padlocks.

If the intention is to promote its use as a common form of transport, this difficulty must be overcome, and one way of doing this is to promote a network of safe cycle parks, that is to create places where bicycles can be left when not in use, taking into account the set of elements it must include: signs, protection, etc. This possible solution would be available for both private bicycle users and users of public bicycles promoted by the administration.

3.4.2.1 Planning

To avoid a situation where the bike parks are not used, and thus become a failure and a cost, they must meet a series of conditions or recommendations:

- Safety: it is important to guarantee bicycle safety through an adequate selection of materials, design, location, lighting, anchoring and surveillance. The option to install protection systems against the climate should also be considered (sun or rain).
- Location and proximity: they must be in visible, accessible places, close to points of interest (stations, leisure centres, universities, etc.) in order to maintain the perception of door to door journeys. It is also recommended that they are associated with reserved infrastructures (cycle lanes).
- Comfort: these bicycle parks must have sufficient space to be able to manoeuvre the bicycle without risking damage to other bicycles or having to perform complicated manoeuvres. Access manoeuvres to these spaces must not at any time have a negative impact on pedestrians or motor vehicles. If in order to access the bicycle park there is a change in level (for example with underground parking), ramps or channels must be provided next to the steps.
- Multi-functionality: they must be capable of housing any type and size of bicycle.
- Aesthetics: they must possess a design which integrates within the urban surroundings and architectonics.

3.4 Other considerations for the use of the bicycle in urban environments

- Capacity: this must be investigated and the relevant calculations made in order to provide sufficient capacity, taking into account that an empty or overfull bicycle park indicates poor planning and unnecessary costs.

- Integration: to allow the integration of parking services from among the public transport operators (transport title) is a good option.

- Monitoring: provide knowledge on the occupancy status of the bicycle parks via the web or mobile applications.

- Complementary services: repair, maintenance, cleaning, guidance, loan, etc. services can make their use more attractive.

- Cost and maintenance: sufficient investment in order to guarantee optimum conditions, while at the same time foreseeing routine maintenance in order to ensure these conditions.

- Modifications: if it is evident that the location is not suitable, then the recommendation is to change it.

3.4.2.2 Examples of long-term bicycle parks

Figure 3.30 Examples of safe bike parks. Upper photographs. [26] Lower photographs. [27]

3.4 Other considerations for the use of the bicycle in urban environments

City: Seville, Spain
Body: Metropolitan Transport Consortium
Location: In the bus station
Characteristics:

- Capacity of 90 spaces.
- The stay must be under five days.
- Timetable: from 6 in the morning to midnight
- Safety: Cameras and anchoring.

Complementary features: loan and maintenance services

City: Barcelona, Spain
Body: Beautiful (private cycle park)
Location: Historical centre of Barcelona
Characteristics:

- Capacity of 120 spaces.
- Registered users: key card and assigned space.
- Timetable: 24 h, every day of the year.
- Safety: Cameras and anchoring.

Complementary features: during the day, rent and sale of accessories and repairs.

Figure 3.31 Bicycle parking in closed units. [26]

3.4 Other considerations for the use of the bicycle in urban environments

3.4.3 Advantages and drawbacks of bicycle use

Bicycle

Advantages	Drawbacks
The cost of acquisition and maintenance of the bicycle as a means of transport is, for the user, much lower than for the motor vehicle. According to studies [26] it can range from 30 to 40 times lower.	Cyclists can be subjected to stress caused by the large number of vehicles which are in circulation (in relation to safety).
With respect to age, the bicycle can be used by a wide range of the population. The fact that the use of the bicycle requires no licence must also be considered, and thus it is the only autonomous means of transport for under-16s.	In cities where the terrain is not flat or it is cold it is more difficult to create a cycling tradition.
As has been mentioned in previous sections, according to statistics [1], over 30 % of car journeys in Europe are made over distances under 3 km, and 50 % under 5 km. In these cases, the bicycle is an efficient form or transport which contributes towards improving the quality of life for people, and the environment.	Due to its size, power and speed the motor vehicle constitutes a danger for cyclists due to the fact that in a crash the car has much less to lose than a cyclist, and often the safety regulations are not observed.
When journeys are made by bicycle, the queuing and hold-ups typical for other means of transport are avoided (reducing time lost and the associated economic cost).	Lack of "bicycle culture". Often the population is not aware that it must share the space with pedestrians and cyclists, and this can lead to various accidents, not only in circulation, but also when cars are parked (for example when a driver opens the door of the vehicle without looking out for passing bicycles).
The bicycle, as a private transport means, provides door to door transport which is at the same time fast and effective.	People are used to not having dedicated bicycle infrastructures (cycle lanes, spaces on public transport, etc.).

3.4 Other considerations for the use of the bicycle in urban environments

Advantages	Drawbacks
It increases the flow of car circulation.	A greater flow of traffic on the road incites new private vehicle users to use the road instead of changing the method of transport.
By bicycle it is possible to reach 15 km/h practically without effort, which allows a distance of approximately 3.2 km to be covered in 10 minutes.	Theft of parked bicycles. It is one of the most significant dissuading factors. This also makes people use bicycles of inferior quality with a lower level of maintenance, and as a consequence they require more effort to pedal, thus reinforcing the feeling of rejection towards bicycle use.
Improvement in physical and mental health as it is moderate physical activity: it reduces the risk of heart attacks, illnesses such as obesity, it strengthens the body's muscles and back and thus reduces aches and pains, it improves the immune system, increases lung capacity, improves the psychological state, etc. (while reducing health costs which may be associated with the problems mentioned).	
Savings on non-renewable energy resources, energy autonomy (greater independence with respect to other countries) and a reduction in local and global impact (noise, emissions, etc.).	
The use of the bicycle does not need fuel supply installations.	
It is a multifaceted tool, and can be used for sport, work or simply as a means of transport.	
Pollution levels within a car are invariably higher than those of the surrounding air [3].	

3.4 Other considerations for the use of the bicycle in urban environments

Advantages	Drawbacks
Better conservation of monuments and green zones (with a lowering of maintenance costs).	
It implies less occupancy of the space, both for journeys and for parking, and thus is a more optimized use of the surface.	
The possible disappearance of the need for a second family car (and the corresponding increase in the family budget).	
Less deterioration on the roadway network, with the corresponding reduction in the need for new infrastructures and roads.	
An improvement in the attractiveness of city centres (shops, culture, recreational activities, social life).	
Bicycles produce little waste and their life cycle is the most sustainable of all vehicles (manufacture, repair, end of use, etc.). However, they are becoming recoverable and reusable (there are recycling projects in which new bicycles are made from pieces and fragments of old ones).	

Apart from all these aspects associated with the bicycle, the following shows the benefits and drawbacks which are specific to the implementation of urban public bicycle systems:

3.4 Other considerations for the use of the bicycle in urban environments

Urban public bicycle

Advantages	Drawbacks
The overall cost of this system is less than for other means of transport.	For its success, it is necessary to apply complementary measures (increase in safety and comfort for the cyclist, citizen information and awareness campaigns, new infrastructures, etc.).
It can act as an incentive to use the bicycle as a normal means of transport in cities with little “bicycle culture”, while at the same time becoming established as an everyday means of transport.	The initial investment, management and maintenance of the system could imply a large cost if it is not adequately investigated, and thus is not useful and coherent.
It provides the citizen with a fast, practical and flexible form of urban transport.	The need to return the bicycle to a point which is not close to the destination will be sufficient reason for the majority of users to not use it, and thus it is very important to adequately study the location of the bicycle stations.
It promotes inter-modality.	The problem of vandalism and theft has become a common factor in many PBS throughout the world.
It improves the image of the city. The incorporation of the bicycle within the urban landscape offers a special attraction which in time becomes widely accepted.	A significant proportion of the UPB systems implemented in recent years have been ceded to publicity service multinationals. In these, concessions agreements are reached for a specific period of time, but their existence is not guaranteed beyond the stipulated period. [27]
Integrated system (parking, public bicycles, public transport, etc.).	In the event of wishing to extend the project (renewal, increase in the number of bicycle parks, etc.), there is not free competition, as each multinational has its own exclusive system which is only compatible with its own models.

3.4 Other considerations for the use of the bicycle in urban environments

Advantages	Drawbacks
It can satisfy a large number of users and a wide range of journeys.	
Optimization of public spaces.	
With new last mile services, urban public bicycles can help to capture new public transport users if the territorial cover of high capacity services is increased.	
Via secure bicycle parking, it is possible to capture new public transport users who are currently reluctant to park in stations due to security reasons.	
Create job opportunities (maintenance and marketing companies, etc.).	
If the bicycle stations are correctly located, it is possible to increase the area covered by a public transport stop.	
The bicycle stations can be put to other uses: points for information, publicity, management of other activities, etc.	
Any municipality can implement a public bicycle service, as there are now various management systems, each with its specifics adapted to each case. This service is characterized by its high degree of versatility, as the scale to which it is implemented depends on the decision of the municipality itself. [2]	

3.4 Other considerations for the use of the bicycle in urban environments

3.4.4 Vehicles for rent in the city: the car and the motorcycle

Car sharing, or multi-user car is a mobility system which consists of a company or organization, which manages a fleet of motor vehicles or motorcycles, making it available to subscribers (from one hour up to various days). A single vehicle can be used by any subscriber to the service.

Car sharing is mainly designed so that people who do not use a vehicle daily do not have to own a vehicle, thus reducing congestion in cities and greenhouse gases. Car sharing is a service which is in operation 24 hours per day with self-service access to a network of vehicles stationed throughout the city which can be reserved for any period of time via a smartphone, from home via a computer, or also by telephone.

This business works because the users save money and can forget the responsibilities and the headaches associated with being the owner of a vehicle without having a vehicle on hand for whatever purpose when necessary.

The first car sharing pilot trials were set up in the sixties and seventies, although the first modern programme was implemented in Switzerland in 1987. In 2011, in the United States alone there were 26 car sharing programmes with over 10,000 vehicles and half a million users.

Car sharing operational structure

Car sharing has a very simple, clear operational structure for users. The system consists on a fleet of vehicles distributed throughout various city car parks. Via an internet reservation portal, the user chooses the hours, vehicle model and the car park from where it will be picked up. The vehicle can be opened with the customer card, and the keys and the cards to leave the car park and fill the fuel tank are inside. The portal software manages vehicle demand and reports the availability of vehicles in each car park. In order to have the right to make a reservation, it is necessary to pay an annual quota, and in order to rent the vehicles a price per hour plus kilometres is paid to cover the cost of the fuel. If use of the vehicle is not excessive, these costs are much more economical if compared to the cost of a new vehicle with all the associated costs.

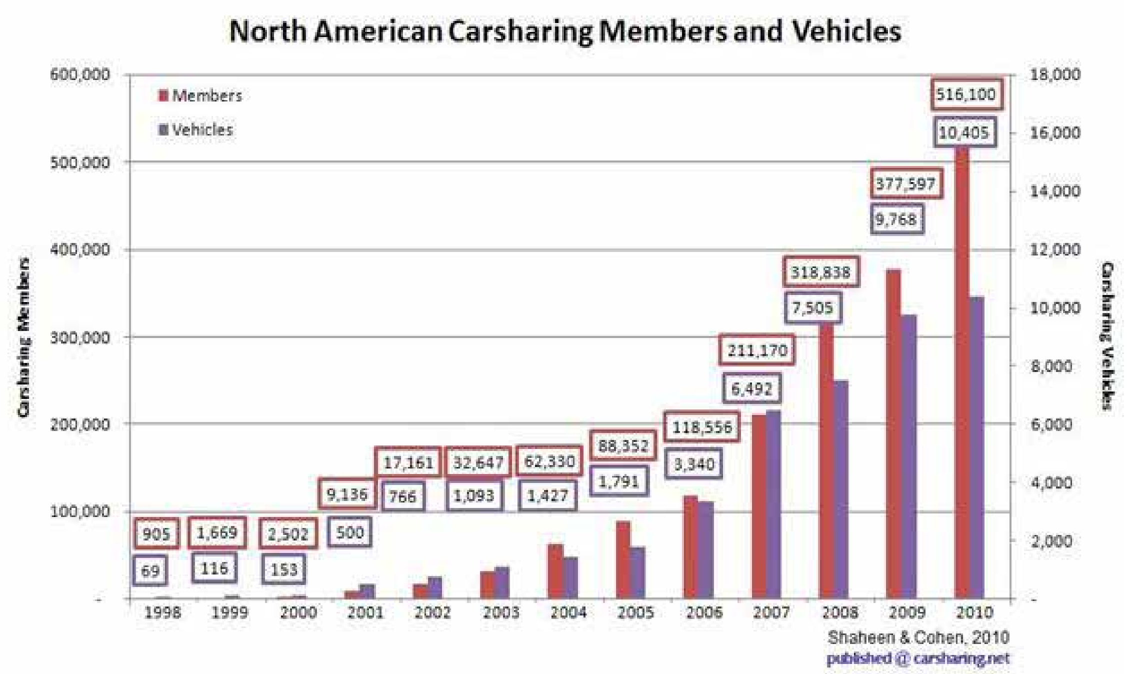


Figure 3.32. Evolution in the number of car sharing members in the United States in the last 12 years. Source: U.C. Berkeley.

3.4 Other considerations for the use of the bicycle in urban environments

In order that a car sharing system works correctly and is viable, it must be implemented in the city with sufficient density and the destinations must not be very far, as the majority of journeys made are within a reduced radius and of short duration.

Figure 3.33 Map of the various points where vehicles can be picked up in the city of Barcelona from the company Avancar. Source: Avancar

In Barcelona, the company Avancar, in conjunction with the Government of Catalonia, the Barcelona city hall and IDEA, among others, manage the car sharing system.

It is possible to distinguish between two profiles contracting these services:

- Professionals: people who need a vehicle for professional reasons. At Avancar, 20 % of customers are professionals.

- Leisure: people who do not have a vehicle, but need one occasionally for leisure or other reasons.

This same system which is applied to cars has also been put into practice with motorcycles. Specifically, a system of sharing is being set up using electric motorbikes in Barcelona, promoted by the Creafutur Foundation (www.creafutur.com). The MOTIT service consists of an open sharing system in which the customer will not leave the vehicle at a specific point, but will indicate via mobile or web where he/she is and the destination, and the system will respond with the exact location of the assigned vehicle.

The following serves as an illustrative case:

- Once registered with the service, the user sends a journey request to the system (via a mobile application or through the web) and specifies the time the service is required, and the location of the point of origin and the destination.

- The system responds with the proposed journey price, and once accepted by the user the reservation is confirmed.

- Five minutes prior to the reserved time, the user receives a notification on their mobile giving the exact location of the assigned vehicle, which is never over 250 m from the desired point of origin.

- The user goes to the place indicated, activates the vehicle using a Smartphone application, and makes the journey to the indicated destination.

- Once there, the vehicle is parked in any of the spaces authorized for motorbikes and the reservation is closed via the mobile application.

- The electric motorbike is then available for other users.

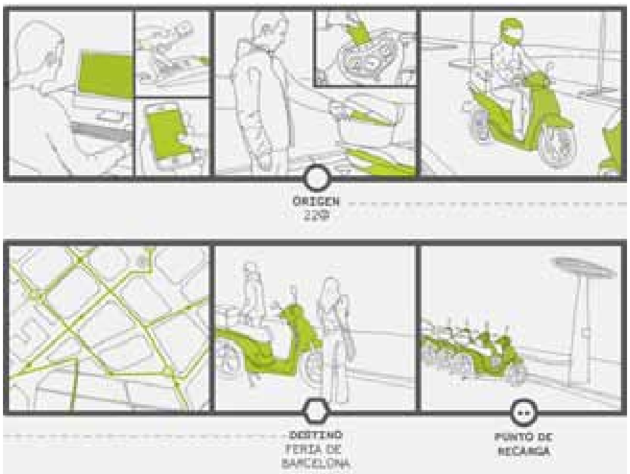


Figure 3.34 Operational diagram of the system created by Creafutur. Source: Creafutur

3.4 Other considerations for the use of the bicycle in urban environments

3.4.5 Advantages and drawbacks of car sharing

Advantages	Drawbacks
It allows for a more efficient use of vehicles as they are working for longer than the average time.	There is the possibility of misuse by the users, and not having a vehicle available when required.
The service operating company purchases, maintains the vehicles, and manages the service. The users do not have to worry about maintenance or paperwork associated with vehicle ownership.	It incites the use of the vehicle in the city centre.
	There is an obligation to return the vehicle at a specific, predetermined time.
Subscribers have access to a vehicle 24 hours a day every day of the year, with only a simple prior reservation by telephone or internet.	The fact of promoting vehicle use within the city does not help to improve air quality in cities.
It reduces the consumption of public space and frees up parking, as the car sharing vehicle substitutes five to eight private vehicles.	The distance between the vehicle park where they must be collected and the user's residence.
It offers an alternative for people who do not want to own a vehicle.	The vehicle must be returned to the same vehicle park from where it was collected, in contrast to hire car companies.
It frees users from the responsibilities associated with vehicle ownership.	
It permits parking in multiple points throughout the city.	
It has a very attractive price.	
The vehicle fleet satisfies a wide demand, from small utility vehicles to vans.	

3.5 Conclusions

Despite its limitations, the bicycle and the new sharing systems can be set up, and in fact they are already in many European countries, as a new means of public transport with great individual and collective benefits.

Throughout this chapter, a series of observations, characteristics and criteria have been mentioned, which in principle should allow cities to improve their "bicycle culture" and the shared use of vehicles, as although an increase in the use of the bicycle for everyday journeys will not solve all the mobility problems facing current society, it can contribute to reducing the large number of externalities which are currently caused by motor transport (mainly the private vehicle).

Therefore, emphasis has been mainly placed on three lines of action: the promotion and implementation of urban public bicycles, the creation and improvement of reserved infrastructures, and the introduction of secure parking.

The public bicycle systems are a powerful tool for the promotion and consolidation of the traditional cyclist, given that with careful planning and implementation the users can observe significant benefits, both economic, social and environmental.

At the same time, it has been explained that the success of this proposal, on the one hand, is based on the necessity to create a coherent, complete infrastructure network dedicated to the bicycle, as in this way an increase in speed, flexibility and safety is achieved for cyclists in circulation, and on the other hand, it is based on the development of comfortable, secure bicycle parks in order to combat vandalism and theft.

In addition, the vehicle sharing systems are being implemented more and more in large cities, and the response from the public regarding these initiatives is positive. The concept of sharing is associated with a new model for consumption because what up to now has appeared essential (to have ownership) is being left behind due to economic, moral and ecological criteria.

Finally, the importance of institutional cooperation and coordination must be pointed out in order to set up campaigns directed towards information, awareness and the education of the population, and in order to be able to draw up mobility plans which will lead us towards a more sustainable future.

4

The Electric Vehicle

Index

4.1 Status of the issue

4.1.1 Introduction

The electric vehicle (EV) represents a future opportunity with widespread implications for energy, the environment, mobility, the use of new technologies and industrial development, given that its promotion is strongly linked both to the transformation of the motor vehicle sector and ancillary industries as well as to the electricity grid.

Various factors of a diverse nature make the incorporation of electric vehicles a suitable complement in the development of sustainable mobility in our cities, and in suburban and metropolitan zones.

- Dependence on fossil fuels. Catalonia's strong dependence on fossil fuels, together with the role played by transport in terms of consumption, prioritizes the introduction of electric vehicles within the energy policy, as it represents an opportunity to introduce other primary energy sources within the transport sector and increase energy efficiency.

- Renewable energies in electrical energy generation. The electrification of the transport sector will allow greater integration of electricity generation from renewable energies, and at the same time will incorporate a greater percentage of renewable energies within the system via the implementation of suitable demand management mechanisms, above all during off-peak periods.

- Energy efficiency. Within the energy sector, if the whole supply chain for the various energy vectors is considered from well to wheel, the electric vehicle becomes on average 50 % more efficient than the internal combustion vehicle (ICV). See figure 4.X. Even for the most inefficient electricity generation power stations, this figure favours the electric vehicle, mainly due to the low efficiency of combustion engines. This improvement is accentuated in urban environments, where the driving cycles give rise to greater inefficiencies for internal combustion engines.

- Progression from the electricity grid to a smart grid. A priori, it can be assumed that the increase in demand caused by the introduction of electric vehicles involves the need to extend the infrastructure associated both with the generation of energy and its transportation and distribution. On the other hand, this challenge can become an opportunity through the implementation of demand management tools which allow the electric vehicle to be used in order to reduce the differences between consumption during peak and off-peak periods. This would increase the economic efficiency of the electrical system, favour the integration of renewable generation within the system, and reduce the need to increase investment in electrical energy power stations.

- Greenhouse gas emissions (GGE). Transport is the main source of GGE diffuse emissions and as such a key sector with respect to strategies for the mitigation of climate change. For this reason, legislative initiatives have been promoted on a European scale in order to reduce emissions from vehicles for the transport of persons and goods by road, and to include the air transport sector within emissions trading. With the current EV consumption data and the electricity generation mix,[1] the EV is an opportunity to reduce GGE emissions within the framework of a sustainable mobility policy. In the future, where the evolution of the mix is predicted to incorporate more renewable energies, greater environmental benefits are foreseen for the EV, depending on the consumption of these vehicles in the future and the efficiency of their batteries.

- Local atmospheric pollution. It is necessary to highlight the role that the EV could play in the reduction of local atmospheric pollution and

[1] Electrical energy is a secondary energy. That is, it is obtained through the transformation of other primary energy sources: hydraulic, fuel/gas, coal, nuclear, wind, etc. The "electricity generation mix" is the proportion of each of the various primary energies which, at a given moment, make up the electrical energy being consumed.

4.1 Status of the issue

- health improvements, taking into account that 40 municipalities within the Barcelona Metropolitan Area have been declared special protection zones. The reason they have been declared special protection zones [1] is that the maximum levels established under European and state legislation for nitrogen dioxide (NO2) and particles with a diameter below 10 microns (PM10) have been surpassed. The traffic in circulation is the main source of pollution in the zone, and diesel vehicles must be highlighted as the main emitters of these pollutants. In this sense, the purely electric vehicle reduces exhaust emissions by 100 % (although it does not reduce the PM10 produced due to the wear of vehicle components or the re-suspension of particles adhered to the ground) and as such contributes to reducing local emissions of CO2, NOx, PM10 and other contaminants where the vehicle will circulate, with the associated benefits to health.

- Acoustic pollution. It is one of the major factors determining the interest of cities and society in relation to the substitution of internal combustion vehicles with electric vehicles. Despite that, it must be taken into account that there are also difficulties with the practical application, as the rest of the circulating vehicles and people will have to be prepared to live with a vehicle causing much less or practically zero noise, with the consequent accident risk.

- Industrial competitivity. Electric vehicles can be presented as an opportunity for the Catalan motor vehicle industry to establish itself in a pioneering position within the new market, taking advantage of the vast industrial fabric available in Catalonia.

Although the EV could be part of the optimum solution for urban and suburban mobility, it must be taken into account that the current range of EV available on the market is very limited, and the performance offered by electric vehicles is not yet approaching that offered by vehicles with an internal combustion engine (ICV). Despite this, for the current mobility model, and particularly for work and everyday mobility with journey distances often under 40 km, the performance currently offered by electric vehicles makes them suitable for the majority of users.

Although public transport must continue to be a priority, the EV could potentially be used in over 70 % of everyday personal intercity journeys currently made using private ICV for distances of under 40 km. It would also be a good solution for the mobility of urban and suburban services managed via an urban distribution fleet, with particular impact on the reduction of local polluting emissions and noise pollution. Furthermore, the efficiency of the electric vehicle in metropolitan environments is greatly superior to ICV, which means a significant economic saving in energy costs for families, companies or public administrations which use them.

4.1.2. Energy diversification in the transport sector

The growing interest on the part of governments and the scientific community with respect to the reduction in energy consumption and the environmental impact of transport has given rise to a search for new propulsion technologies and the promotion of alternative fuels with less polluting emissions than petroleum. Despite the fact that this substitution does not mean a direct energy saving on occasions, the substitution or introduction of new fuels could contribute to a reduction in the dependence on petroleum and a reduction in emissions from the road transport sector.

Among the various alternatives, it should be pointed out that electric vehicles do not cause direct emissions during their use and they allow the use of renewable electrical energy when recharging the batteries.

Furthermore, suitable management of the electric vehicle could contribute towards increasing the

4.1 Status of the issue

economic performance of an electric system, which flattens the load curve and facilitates the integration of a new renewable generation which cannot be managed by the system, particularly during off-peak periods.

Thus, electric vehicles are presented as a viable technological avenue in the short term as an alternative to the use of fossil fuels. However, the promotion of EV implies a series of weaknesses and threats which must be taken into account in relation to the necessary charging infrastructure (strengthening of the electricity grid, standardization, etc.), the vehicles themselves (battery cost, charging time, autonomy, etc.) and electricity generation.

4.1.3 Electric vehicles: classification, charging and efficiency

Within the electric vehicle category, two basic typologies have been considered (figure 4.2) under this strategy: purely electric vehicles (Battery Electric Vehicle, BEV) and the plugged hybrid vehicles (Plugged Hybrid Electric Vehicle, PHEV). The point in common which differentiates these vehicles from the rest is the possibility to charge them via a electrical energy source external to the vehicle, in contrast to the non-rechargeable hybrids (Hybrid Electric Vehicle, HEV) which obtain electrical energy solely from their stored fuel.

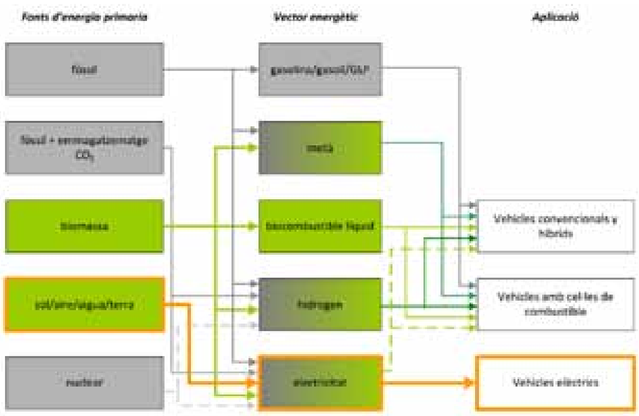


Figure 4.1 Energy cycle for electric vehicles.
Source: House production.

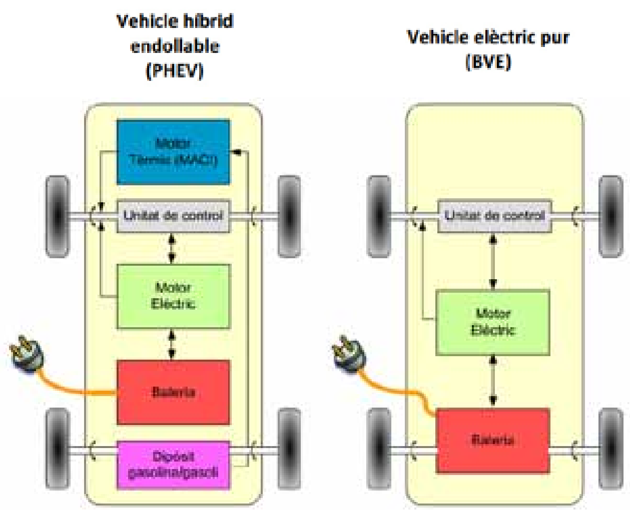


Figure 4.2 Typologies of electric vehicles.
Source: IREC, 2009.

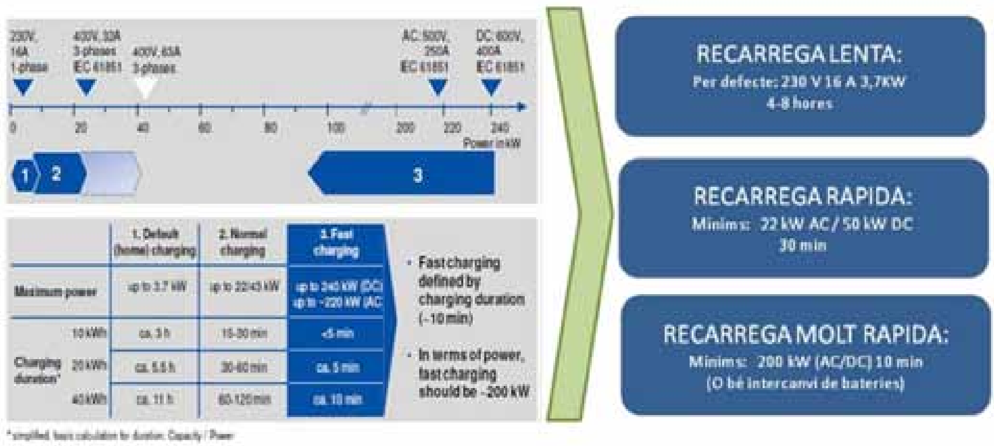


Figure 4.3 Charging options for electric vehicles. Source: [2]

4.1 Status of the issue

Practically all electric vehicles will have to have an associated charging point which means they can be charged during the time they are parked (mainly during the night), which will chiefly be in private locations. Likewise, it will be necessary to have public access charging points which will provide supply security to EV users, and will allow in the future a certain degree of interoperability between urban concentrations at large distances.

With respect to the energy consumption of electric vehicles, they represent a significant saving in primary energy, mainly due to the efficiency of the electric motor itself compared to the internal combustion engine, and the efficiency of the electricity generation mix.

In figure 4.4., a comparative example can be seen of the energy performance for pure electric vehicles compared with conventional internal combustion vehicles, which places an increase in the efficiency of the energy cycle of around 8 % in the least favourable circumstances (very low performance electrical power stations, 30 %). In the case of the Spanish electrical system, the strong presence of renewable generation must be pointed out, which during the first quarter of 2010 has provided almost 40 % of the consumed electrical energy.

[2] WWF (World wide fund)
[3] ICAEN (Catalan Energy Institute)
[4] ICAEN

Although the electric vehicle does not generate local pollution, the emission of pollutants and greenhouse gases can be produced at the site where the electricity is generated. The majority of the emissions associated with EV compared with ICV will depend to a large extent on the generating technology used to produce the electrical energy to charge the EV, the electrical consumption of the vehicle, and the associated mobility. In this sense, emissions of CO2 per kilometre are greatly reduced in the case where the electrical energy used is of renewable or nuclear origin.

With respect to the Spanish electricity system, the electrical generation mix for 2012 contributed to CO2 emissions with a quantity of 273 g of CO2/kW·h[2] (at the point of consumption). These specific emissions per kW·h indicate that an electric passenger vehicle which has a consumption of between 15 and 20 kW·h per 100 km, under the current electrical generation mix, presents emissions of 62 to 82 g of CO2/km[3], a figure which is below that for any current petrol or diesel vehicle.[4]

It is necessary to point out, in the same way as the ICV, the EV consumes energy during the manufacture and scrapping phases which would have to be studied and minimized as far as possible. Therefore, in the future, it will be necessary to develop studies of the complete life-cycles which will be able to address the questions which may arise regarding EV.

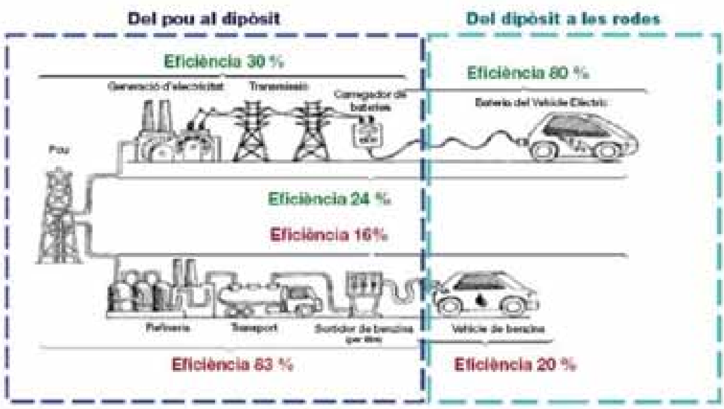


Figure 4.4 Comparative performance of electric vehicles.
Source: NESEA, 2009.

4.2 Vehicle and city

Currently, many cities, together with private and public companies, have incorporated the electric vehicle within their service fleet. Some examples are shown below:

AENA

The public company AENA, which manages airports in Spain, has acquired a fleet of 33 electric vehicles for the airports of Madrid, Barcelona, Palma and Lanzarote. AENA has become the airport manager with the largest fleet of electric vehicles in Europe. The vehicles will be used for activities carried out on the "air side" by the operations, environment and engineering departments, among others. The measure is included within the "Savings, energy efficiency and emissions reduction plan for transport and housing" from the Development Ministry, which has received aid from the Movele Plan [3].

Figure 4.5 Image of a vehicle from the AENA fleet. Source: IDAE.

Correos (postal service)

The public company Correos has the largest fleet of electric vehicles in the country. Its electrical fleet is made up of 100 motorcycles, 90 pedal-assisted bicycles, 15 quadricycles and 5 vans. All these vehicles have substituted others which worked through combustion, distributed throughout various provincial capitals and providing mail and package delivery services.

The electric vehicles used by Correos are to be found in a total of 80 places, where they carry out journeys no greater than 50 km per day. For that reason, they do not need to be charged during the daily route and the battery can be charged in the conventional manner during the night at the company installations.

In addition to a reduction in fuel and environmental impact, the company shows a drop in accidents for electric motorcycles with respect to their combustion counterparts, together with the rapid adaptation and good reception these vehicles have enjoyed from the users.

Figure 4.6 Image of a Correos electric motorcycle. Source: IDAE.

CLD

The company CLD, which is part of the COMSA EMTE group, has also introduced various electric vehicles to its fleet. They make refuse collection tasks more efficient and less polluting to the urban air, while at the same time producing less noise. Since 2003, a total of 28 electric vehicles of various capacities and uses have been added.

Figure 4.8 Image of the CLD fleet. Source: CLD.

4.3 Integration of the electric vehicle within the distribution network

4.3.1 EV charging technologies

As mentioned previously, the penetration scenario for the electric vehicle in the current market is not progressing as expected, but penetration is being reduced due to the global economic situation we find ourselves in, especially in Europe. In any case, the electric vehicle is considered one of the best technologies to reduce Europe's energy dependency and urban pollution. The "Proposal for a Directive of The European Parliament and of the Council on the Deployment of alternative fuels infrastructure"[5], has recently been published, in which the European Commission underlines the fact that the availability of charging stations is not only a technical prerequisite for the operation of electric vehicles, but in addition it is one of the critical components in consumer acceptance. The European Commission has proposed that it could be possible to find a minimum of charging points in each Member State according to the number of electric vehicles available. As a minimum, 10 % of these points must be of public access.

Publicly accessible electrical charging points are considered to be those installations which are complementary to the private charging points (located in the car parks of residences or offices) which promote the urban and interurban circulation of EV. The fuel supply points for EV must provide a short charging time, given that speed in the charging points seems to be the best option for the public access infrastructure.

As can be seen in table 4.1, it is possible to find various technologies for the electrical supply at public charging stations for electric vehicles: rapid charging with alternating current or direct current, battery change, and induction charging. Among these, the rapid DC charging is the most widespread, as it is currently used in various commercial electric vehicles using a Mode 4 DC connector. In the "Proposal for a Directive of The European Parliament and of the Council on the Deployment of alternative fuels infrastructure" it is proposed that connectors will be employed in the near future which permit charging with both alternating and direct current in the same vehicle (a system known as "Combo").

	AC charging	**Rapid DC charging**	**Induction charging**	**Change of battery**
Power	44 kW	50 kW	11 kW	-
Voltage	400 V	400 V DC	400 V	-
Current	63 A	125 A	16 A	-
Duration of 20 kW.h charging cycle	27 min	24 min	109 min	5 min

Table 4.1 Technological alternatives for electric vehicle rapid charging points. Source: IREC.

[5] COM(2013) 18 final

4.3 Integration of the electric vehicle within the distribution network

This directive proposal intends to guarantee the implementation of these common technical specifications for the charging infrastructures for electric vehicles in the European Union. Its objective is to facilitate the work of the market and through this initiative contribute towards promoting economic growth within Europe.

In any case, the interoperability of electrical mobility is not wholly assured with the homogenization of technical standards for charging infrastructures. A framework of protocols and communiques which is commonly accepted and easy to use is necessary for the European market in electrical mobility which will provide support for roaming and guarantee the development of the market for electric vehicles. For that reason, the European Commission initiated a project of European magnitude in March 2011, known as **Green eMotion**, which intends to prepare the European market for the implementation of electric mobility within a period of four years.

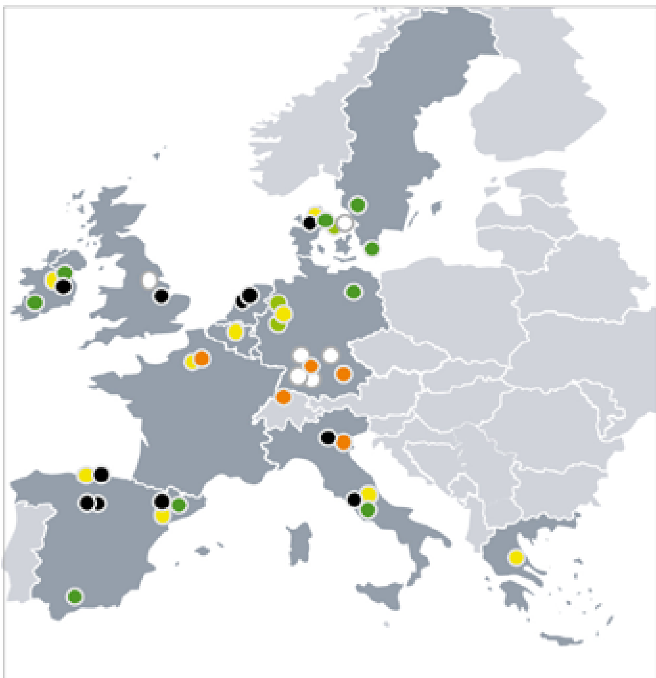
The aim of Green eMotion is to define and demonstrate the concept of interoperability and orientation of the electrical mobility system to the end user, basing it on existing installations and their own experience. For 2015, the intention is to define a series of recommendations concerning ICT tools for the implementation of electrical mobility within the European market which will promote roaming and include the necessary devices and identifiers.

4.3.2 ICT tools for electrical mobility

4.3.2.1 The Green eMotion project

The project defines the application framework for electrical mobility in addition to defining and analysing which components and implementations are currently still necessary. These components will be implemented as an example in 10 demonstrative regions located at various points throughout Europe: Iberdrola (Spain), Endesa (Spain), Italy, Ireland, Strasbourg (France), Stuttgart (Germany), Berlin (Germany), Copenhagen (Denmark), Bornholm (Denmark) and Malmo (Sweden).

The 43 members participating in the initiative -industrial companies, motor vehicle manufacturers, municipalities, universities and technology and research institutions- have provided their knowledge and experience relating to electrical mobility to this project (figure 4.9).



- **Industries:** Alstom, Better Place, Bosch, IBM, SAP, Siemens
- **Utilities:** Danish Energy Association, EDF, Endesa, Enel, ESB, Eurelectric, Iberdrola, RWE, PPC
- **Electric Vehicle Manufacturers:** BMW, Daimler, Micro-Vett, Nissan, Renault
- **Municipalities:** Barcelona, Berlin, Bornholm, Copenhagen, Cork, Dublin, Malaga, Malmö, Rome
- **Research Institutions and Universities:** Cartif, Cidaut, CTL, DTU, ECN, Imperial, IREC, RSE, TCD, Tecnalia, TNO
- **EV Technology Institutions:** DTI, FKA, TÜV Nord

4.3 Integration of the electric vehicle within the distribution network

Green eMotion draws upon the combined knowledge of the various players participating to develop the following:

- Standards selected for an interoperable electromobility system (de facto standards for Europe).
- IT architecture for the interoperable electromobility market which supports roaming, including the necessary interfaces and identifiers.
- Recommendations for the construction of an optimized grid and a charging infrastructure.
- Implementation and validation of an interoperable electromobility system for a trial region.
- Analysis of the operability of electric vehicles under real conditions and the development of policy guidelines as the basis for mass implementation within the market.

ICT system for a European market for electromobility services

For the first time, Green eMotion Business-to-Business is bringing together all participants within the electromobility market: charging service providers, charging point operators, energy suppliers and providers of other related services. The aim is to provide electric vehicle users with pan-European access to an infrastructure network which is very easy to use.

This market will allow the associated services -for example roaming between the various charging point operators- to be provided on a European scale, in a similar manner to those practices which operate for telephone companies. In addition, the B2B market is open to other service providers, which will allow new innovative concepts to appear in a way which is not traumatic.

General vision

GeM EV Services Market

The Green eMotion services market is the virtual domain covering all services related to electric mobility and is characterized by covering all types of contractual service:

- B2B, bilateral agreements between two service providers.
- B2C, charging services for the end user.
- B2G, city hall charging infrastructure management.

Figure 4.10 illustrates the relationship between the various players in the electric vehicle services market. The users are defined as follows:

- Service provider: a service provider is the electric vehicle operator or another value-added services provider such as navigation or route provision.
- Service requester: a service requester requires and uses the services offered by a service provider.
- Service broker: the service broker forms a link between the service requester and provider.
- End user service provider: an end user service provider offers services to the end customer and can use the services offered by other service providers in order to cover these services.

Final observations

Information and communication technologies are considered to be key to allowing electromobility, as they will offer a variety of basic and advanced services to the driver. The integration of these services will allow the electric vehicle to be used without regional limits, and to take advantage of economies of scale for advanced services such as fleet management.

4.3 Integration of the electric vehicle within the distribution network

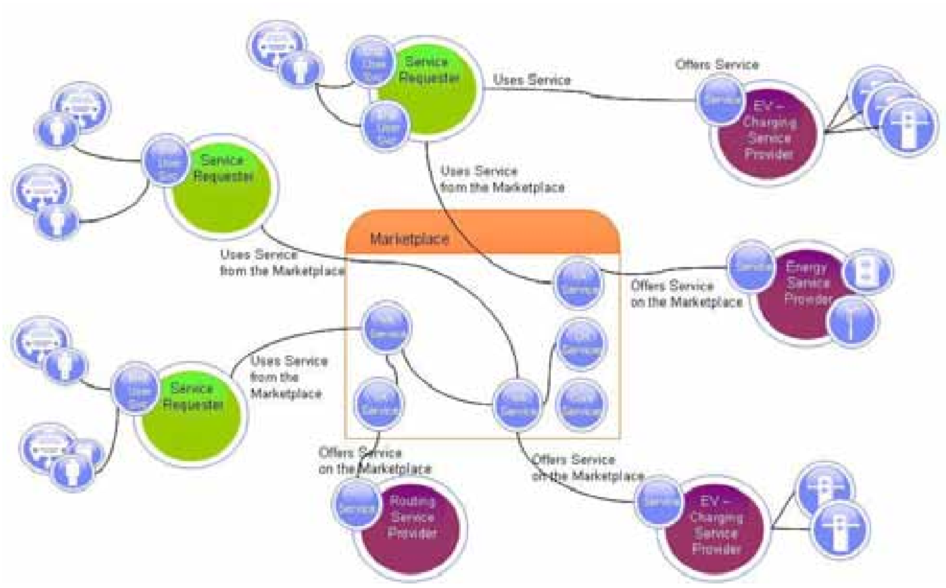


Figure 4.10 Diagram showing the services market architecture for the Green eMotion electric vehicle. Source: Green eMotion project.

Thanks to an open architecture, together with standard interfaces, it will be guaranteed that all participants within this market can develop and market their own services.

One of the main aims of Green eMotion is the creation of an IT system for the European market for electromobility services, and the demonstration of its operability in practice. All information relating to the project can be found at (www.greenemotion-project.eu).

4.3.2.2 Intelligent technologies applied to electromobility: the concept of a vehicle in the grid (V2G)

Introduction

The deployment of electric vehicles, including those which are purely electric and the plugged hybrids, allows electricity to become a source of energy for the transport sector. This transition from petroleum to electricity due to the introduction of the electric vehicle represents a new paradigm for electricity companies.

If electric vehicles are charged during off-peak periods, preliminary studies which have been carried out show that the current electrical grids have the capacity for their connection. However, the most probable situation is that the drivers of electric vehicles charge them at the time which is most convenient, without taking into account the status of the electrical system, which could coincide with peak periods and have a significant impact on the grid. Therefore, electric vehicles must be managed as an intelligent load which consumes when necessary.

Electric vehicles represent a new opportunity to manage energy demand and avoid the reduction in generation from generators based on renewable sources, as the majority of vehicles normally spend more time on the road. In addition, if there is massive EV penetration with millions of deployed units, the energy stored in their batteries could contribute to improving the reliability and quality of the electrical supply.

This opens up an opportunity for new business models which require new devices and new management strategies in order to control the impact of electric vehicles on the electricity system, in addition to facilitating its incorporation as one more element in the intelligent electricity grid. These factors have motivated the development of the Endesa Novare, Vehicle to Microgrid (V2M) project.

4.3 Integration of the electric vehicle within the distribution network

Endesa Novare V2M project

The Endesa Novare V2M project is a project led by CITCEA from the UPC, counting on IREC as a partner, which won the Endesa NOVARE I+D+i internacional prize 2009 , and which has been developed from 2010 to mid 2013. The aim of the project is the design of intelligent systems for the integration of electric vehicles within electricity grids carrying distributed generation from renewable sources, in order to improve the efficiency of the electricity system and its security taking into account electric vehicles as distributed storage.

The tasks and goals achieved within the project are described in the following.

- Design and development of V2G and V2H systems.

The charging points for current electric vehicles are exclusively designed for charging. In order that electric vehicles can be considered as a distributed storage system and thus an intelligent load on intelligent electricity grids, it is necessary that the charging points are bidirectional. This bidirectional charger is known as the Vehicle to Grid (V2G) system if it is connected to the electricity supply, and Vehicle to Home (V2H) if it is connected to an isolated house. Both systems have been designed and developed within the project in accordance with the Japanese CHAdeMO standard for rapid charging using direct current.

The V2H and V2G systems are made up of an electronic converter of external power in the vehicle which communicates with the vehicle via the CAN (Control Area Network). The connection to direct current is used to directly access the battery, which facilitates both the charging of the EV and the input of energy stored in the battery to the grid. The main difference is that V2H is designed to supply a home with the energy stored in the EV battery when there is an interruption to the supply.

These systems installed by Endesa for the ZEM2ALL project, developed in Malaga, can be seen in figure 4.11, in which the capacity and operation of the V2G systems can be put to test in a real environment using electric vehicles.

- Advantages of the V2G and V2H systems

In evaluating the benefits of these systems, it is clear that they will allow an increase in the use of renewable energies, and their integration within electricity systems. Electric vehicles can perform a storage function when there is excess generation of renewable energy, and input the stored energy if there is a lack of generation. Furthermore, with this capacity, the owners of electric vehicles can participate in the electricity markets and obtain income from the sale. For an isolated house with photovoltaic generation, a V2H system could be used as a battery to supply the house when the sun is not shining and store energy when it is.

Figure 4.11 V2G 5 kW points in the ZEM2ALL project installed in Malaga. Source: ENDESA.

4.3 Integration of the electric vehicle within the distribution network

Other potential advantages are the deferral of network infrastructure investment if a system of intelligent management for the charging processes is introduced, and an improvement to supply continuity if the bidirectional charger can behave as a V2H system.

However, in order to obtain these benefits, some drawbacks must be overcome. Currently, regulations do not cover the V2G capacity. It is necessary to define new players in order to adequately manage electric vehicles, with or without V2G. To this end, Spain has recently created the figure of "load manager" who can be considered as one of these new players. In any case, this management could only be carried out if there is the deployment of a communications infrastructure in order to control the operation of the grid in real time, including the V2G points. Effects on supply quality must also be considered, such as variations in the voltage profile and overloads which the simultaneous connection of a large number of electric vehicles could cause, and the harmonics, as the chargers and V2G equipment on electric vehicles are electronic power converters.

- Intelligent management strategies for electric vehicles.

The V2G and V2H equipment could help minimize the previously mentioned impact and help with the deployment of intelligent electricity grids if new management strategies are developed which take them into account. The scenarios detected for which these systems could produce a benefit are:

- A reduction in energy bills through the storage of energy in the vehicle battery during low price periods, and input to the grid when the price is higher.

- A minimization of CO2 emissions via charging of vehicles during a generation mix period with low carbon emissions and input during periods with greater emissions.

- A flattening of the particular demand profile via charging-discharging of the vehicle battery in accordance with fluctuation in demand or their own generation.

- A guarantee of the balance between power generated and demanded via charging-discharging of the battery in accordance with signals from the system operator.

- The operation of a system in isolation with renewable energy generation if excess generation is stored and the stored energy is input when there is a lack of generation.

Although bidirectional chargers have been taken into account, each scenario referred to requires a different management strategy. Within the project, new intelligent management strategies have been proposed and tested on a demonstration microgrid for all these scenarios. In figure 4.12, an example can be seen of the results obtained for the flattening of a demand profile.

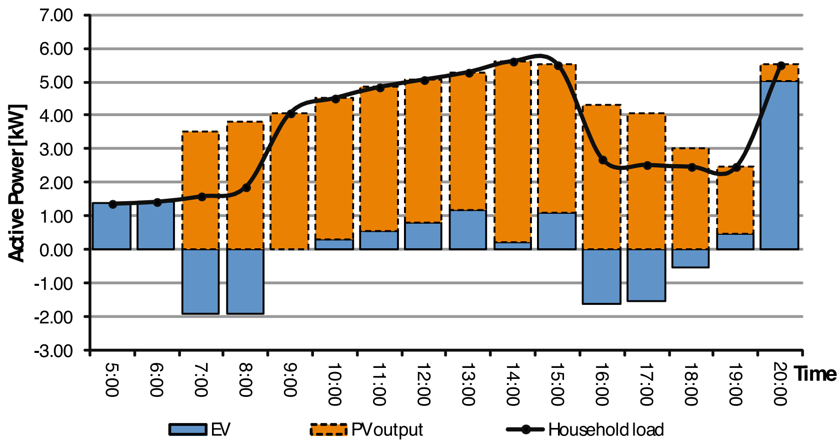


Figure 4.12 Demand profile flattening scenario with V2G and photovoltaic generation. Source: V2M project.

4.4 Conclusions

As can be seen throughout this chapter, the electric vehicle is positioning itself as a real alternative to many problems which currently exist in cities. The introduction of the electric vehicle will imply a revolution in many areas due to its many implications, and currently it is a road to no return.

Despite the generated prospects, the electric vehicle is enjoying neither the expected nor desired implementation to date. The barriers slowing down its acceptance on the part of users are many. Fear that there will not be a charging point, and low autonomy, together with the elevated cost, are the main obstacles which the electric vehicle must overcome in order to position itself as a firm candidate to substitute the internal combustion engine.

In the near future, when these drawbacks have been overcome, extending the electric vehicle into all areas will allow the city to be enjoyed with much less pollution, together with a flattening of the electrical energy demand curve, and it will allow for a much more efficient use of renewable energies.

Projects which are being set up within the scope of the European Commission state that the electric vehicle will signify a revolution in cities and, thanks to standardization, it will be possible to fearlessly drive throughout the whole of Europe.

Therefore, we are facing a new revolution which will enable a substantial reduction in the dependence on energy from petroleum, and all that this entails.

5

Alternative Fuels

Index

5.1 Strategic framework for the development of alternative fuels

5.1.1 European strategy for alternative fuels

At the beginning of 2013, the EU defined a new promotional framework for the development of more sustainable mobility solutions, in particular for those which involve alternative fuels to the conventional fuel of choice: petroleum[1].

The challenge of minimizing dependence on petroleum for transport

In the transport strategy document for 2050, the EU sets out greenhouse gas emission reduction targets for transport of 60 % by 2050.

It addresses the achievement of this milestone in order to break the dependency on petroleum in transport and establish demanding targets for various modes of transport which cannot be brought about using conventional fuels, but depend to a large extent on the promotion of alternative fuels.

The majority of European initiatives were directed mainly at vehicles, and in relation to alternative fuels, their distribution was not sufficiently considered. The efforts to promote via incentives have been insufficient and uncoordinated.

The EC considers that alternative fuels could help to reduce air quality problems in Europe, polluted to a large extent by emissions which are the result of petrol or diesel combustion in motor vehicles.

Main barriers in the development of alternative fuels to petroleum

The development of alternative fuels is subject to three main obstacles which constitute a vicious circle, preventing the clear massive expansion of combustion technologies which are an alternative to petroleum:

[1] European transport policy white paper 2011.

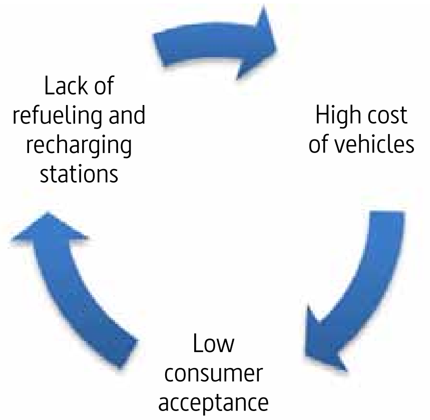


Figure 5.1 Vicious circle of alternative fuel technologies. Source: Institut Cerdà

Supply stations are not constructed because there are not a sufficient number of vehicles. The vehicles are not sold at a competitive price because there is not sufficient demand. Consumers do not purchase the vehicles because they are expensive and there are no supply stations.

Faced with this situation, the EC is proposing a package of obligatory targets so that the Member States facilitate the development of infrastructures for alternative fuels (electricity, hydrogen and natural gas), together with common standards for the whole of the EU regarding the necessary equipment and installations. Specifically, for natural gas (compressed, CNG or liquid, LNG):

- For 2020, the European Commission plans to develop a network of GNC filling points which are accessible to the public, meet common standards, and are located at a maximum distance of 150 km.
- In relation to LNG, the European Commission plans to install LNG filling stations at every 400 km on the main trans-European road network from now to 2020.
- For maritime transport, the Commission plans to install LNG filling stations at the 139 maritime ports and waterways on the main trans-European network between 2020 and 2050.

5.1 Strategic framework for the development of alternative fuels

5.1.2 Plans to improve air quality

In accordance with the Directive 2008/50/CE dated 21 May, if certain limiting values for air quality are surpassed, the competent bodies must draw up plans of action in order to improve and restore the air quality of the air.

In Catalonia, the Territory and Sustainability Department is the body responsible for evaluating the air quality.

Since the limiting values for nitrogen dioxide (NO2) and particles with a diameter below 10 microns (PM10) came into force as the result of European directives, the limiting values for air quality laid down for the two cited pollutants have been surpassed in 40 municipalities in Catalonia (see image of affected areas).

Figure 5.2 Area affected by the action plan for improving air quality. Source: Institut Cerdà.

In recent years, this situation has forced the Government of Catalonia to develop action plans to improve air quality in this territorial area. Currently, the action plan to improve air quality 2011-2015 is in force.

Action plan to improve air quality 2011–2015 [1]

The aim of this plan is to reach air quality levels for particles with a diameter below 10 microns (PM10) and nitrogen dioxide (NO2) which meet the levels stipulated in European legislation.

In order to lower the levels of local atmospheric pollution, environmental action is envisaged which will have an impact on the emitting focuses in the affected zones which, as a general rule and throughout the world, coincide with economically dynamic urban agglomerations. In the case of Catalonia, this is centred on the province of Barcelona.

Among the measures put forward, there are some which are directed towards positive discrimination in order to promote the development of alternative fuel technologies for vehicles:

- Measure 3. Promotion of the electric vehicle.
- Measure 4. The electric motorcycle, a benchmark in Catalonia.
- Measure 5. Promotion of the establishment of service stations with cleaner fuels and electricity charging points.
- Measure 9. The “greening” of fleets of heavy vehicles and goods vehicles.
- Measure 10. Green purchasing.
- Measure 11. Distinguishing transport fleets.
- Measure 12. Reduction in toll costs for clean vehicles.

5.2 An overview of alternative fuels

When speaking of alternative fuels to petroleum, the current option of reference is natural gas. There are other options, such as LPG, hydrogen or biofuels. This chapter deals with natural gas in depth.

The following gives a brief overview of the various options for alternative fuels to petrol and diesel.

5.2.1 LPG (liquefied petroleum gases)

A by-product of refined petroleum, stored under pressure and used as a liquid fuel. It is basically a mixture of propane, butane and other gases. It is usually used as a fuel in certain types of vehicles with a combustion engine, mainly in public transport (taxis, buses, etc.). There are experiences of its use both in diesel and petrol engines, although best results have been obtained with the latter technology. Under normal conditions, LPG is found in a gaseous state, but it is supplied in a liquid state in order to reduce the size of the tanks in vehicles using it.

5.2.2 Biofuels

The term biofuel basically covers biodiesel and bioethanol.

- **Biodiesel**: a liquid fuel obtained from vegetable oils (rapeseed, soya, sunflower) subjected to an esterification process using sodium hydroxide and methanol. Biodiesel can be used mixed with diesel or in an almost pure state; it represents an energy of 85 to 95 % that of diesel.

- **Bioethanol** (alcohol): ethanol of biological origin (sugar cane or sugar beet alcohol) which is used as a biofuel mixed with petrol at a specific percentage. A litre of ethanol contains approximately 65 % of the energy of a litre of petrol. [2]

These fuels can be produced form a wide range of raw biomass materials. Technically liquid biofuels can be used for propulsion in all modes of transport using current vehicle technologies, in various mix ratios based on the type of biofuel.

Although, by definition, biofuels would be a completely renewable and inexhaustible source of energy, the consumption of water necessary for the crops, together with the distillation, fermentation, and the energy consumed in the transport of raw materials and their processing offset much of their attraction.

5.2.3 Hydrogen

Hydrogen is the most abundant element in nature. The importance of hydrogen as an energy vector has been gaining ground thanks to technological developments associated with fuel cells (to convert hydrogen gas to electricity and heat) and competitive methods for gas storage.

The combination of hydrogen and oxygen is a combustion which frees energy in a similar way to that of coal or petroleum, with the advantage that the only residue is water in the combustion process.

However, with respect to the generation of hydrogen itself, the challenge is to be found in the use of electricity from renewable energy sources in order to electrolyse water. From these origins, hydrogen could be considered a form of clean energy which does not emit greenhouse gases and is capable of generating highly distributed energy with high efficiency and versatility.

The current level of technological development clearly conditions the economic viability of hydrogen as a real alternative in the short term. It is currently very costly.

5.2.4 Natural gas

Natural gas is a fossil energy obtained from nature in the same state in which it is consumed, being a mixture of gases, predominantly hydrocarbons, in particular methane with a proportion of above 70 %.

5.2 An overview of alternative fuels

Its use is becoming more and more common throughout the world, not only at an industrial, domestic or commercial level, but also as a fuel to propel all types of vehicle.

The main advantages of natural gas are: low NOx emissions, practically zero emissions of sulphur compounds and particles, and 25 % fewer CO2 emissions compared with liquid fuels.

In the area of transport, natural gas can be found in gas or liquid form:

- Compressed natural gas (CNG): CNG is natural gas compressed under high pressure (between 200 and 250 bar, depending on the regulations in each country) which is used as an alternative fuel.

  The reason for its compression is so that the vehicle using it has an autonomy comparable to those using conventional fuels. For this reason, it is necessary to have special tanks incorporated in order to withstand the high storage pressure.

- Liquefied natural gas (LNG): LNG is transported as a liquid at atmospheric pressure at -162 °C in special cryogenic tanks which maintain the low temperature. Liquefaction reduces the volume of transported gas 600 times and allows the storage of more energy per unit volume, thus increasing autonomy.

5.3 Natural gas in transport and mobility

The application of natural gas in the transport sector and the area of mobility is extended mainly to road transport, although it has begun to have an impact in the maritime sector during the last decade.

In fact, the European strategy of promoting alternative fuels establishes, for these transport systems, the basis for the development of natural gas filling in Europe, and is attempting to stimulate road and maritime mobility with this fuel.

The following provides an overview of the degree of penetration of natural gas in these segments of European mobility[2].

5.3.1 Road transport

Up to 1995, the vehicle market for natural gas was focussed almost exclusively on Italy. Since that year, the number of vehicles and countries have been growing and diversifying progressively.

Currently, Europe has over 1.7 million vehicles running on natural gas and some 4,000 filling stations for this type of fuel.

Italy continues to lead the process of introducing natural gas as a fuel for vehicle fleets. It has some 746,000 vehicles and 903 filling stations.

In terms of vehicle numbers, it is followed by Ukraine and Armenia, with almost 400,000 and 250,000 vehicles respectively.

In Spain, there are currently 3,700 vehicles propelled by natural gas, which places Spain behind Austria, Holland, Belarus and the Czech Republic, which respectively have: 7,000, 5,200, 4,600, and almost 4,000 natural gas vehicles.

In the past year (from 2011 to 2012), the figure increased by 14 % in Spain. The majority are trucks designed for refuse collection and street cleaning, together with buses. The distribution of the fleet is 17 % commercial vehicles, 46 % buses, and 36 % trucks, with the rest being other vehicles.

In relation to the number of fuel filling stations, Italy is only surpassed by Germany, with 904 stations, followed by Armenia and Ukraine, with over 300 stations each, and Austria and Sweden, which have some 200 stations.

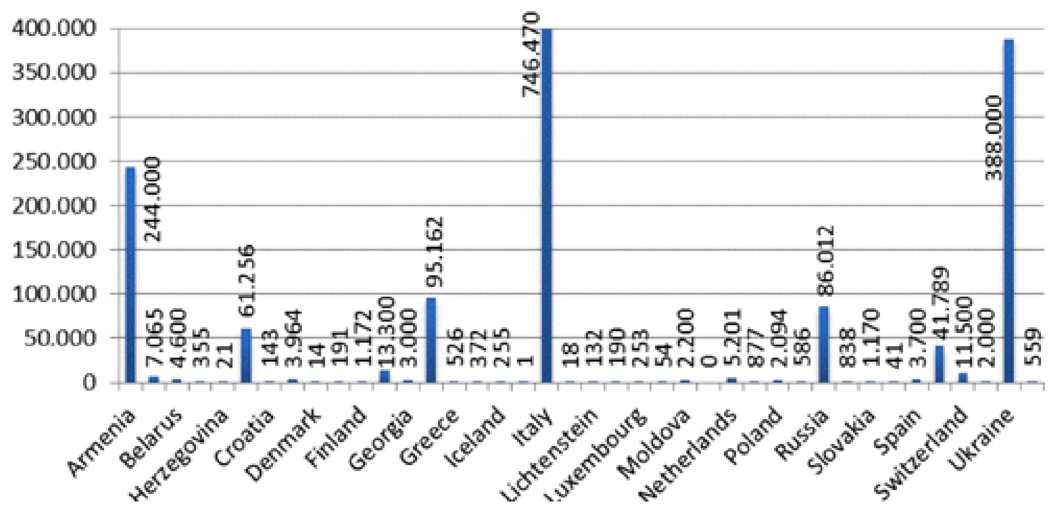


Figure 5.3 Number of natural gas vehicles by country in Europe. 2012 Source: house production from NGVA Europe data.

[2] For the purposes of the statistics collated in this section, Europe consists of the following countries: Armenia, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Moldova, Montenegro, the Netherlands, Norway, Poland, Portugal, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, the United Kingdom.

5.3 Natural gas in transport and mobility

To date, there are 74 natural gas service stations in Spain. Among them, 23 % are public and the rest are private. Among the public stations, there are nine which supply both liquefied and compressed natural gas[3].

The European Union's new policies will promote natural gas for vehicles via the development of a filling infrastructure. During the five-year period from 2008 to 2012, Europe enjoyed growth of 35 %, from 3,000 to 4,000 natural gas filling stations.

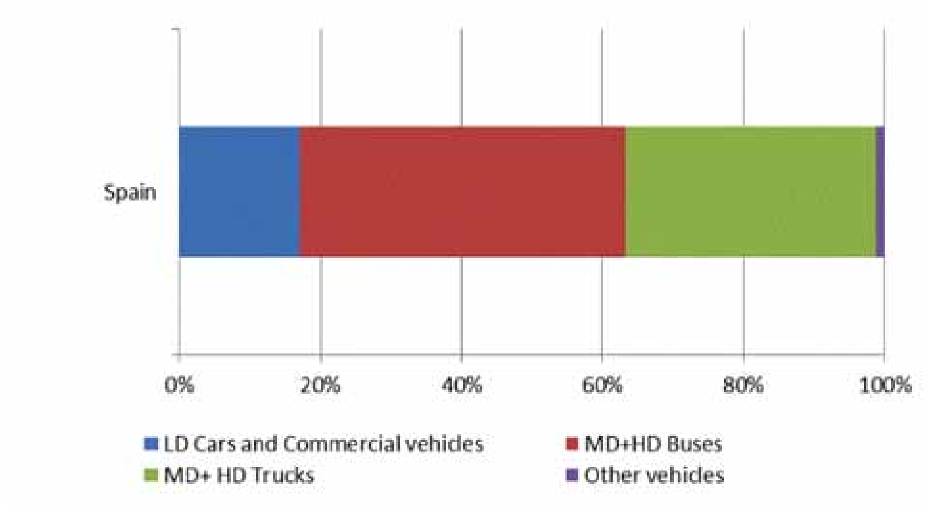


Figure 5.4 Distribution of the vehicle fleet for natural gas vehicles in Spain. 2012
Source: house production from NGVA Europe data.

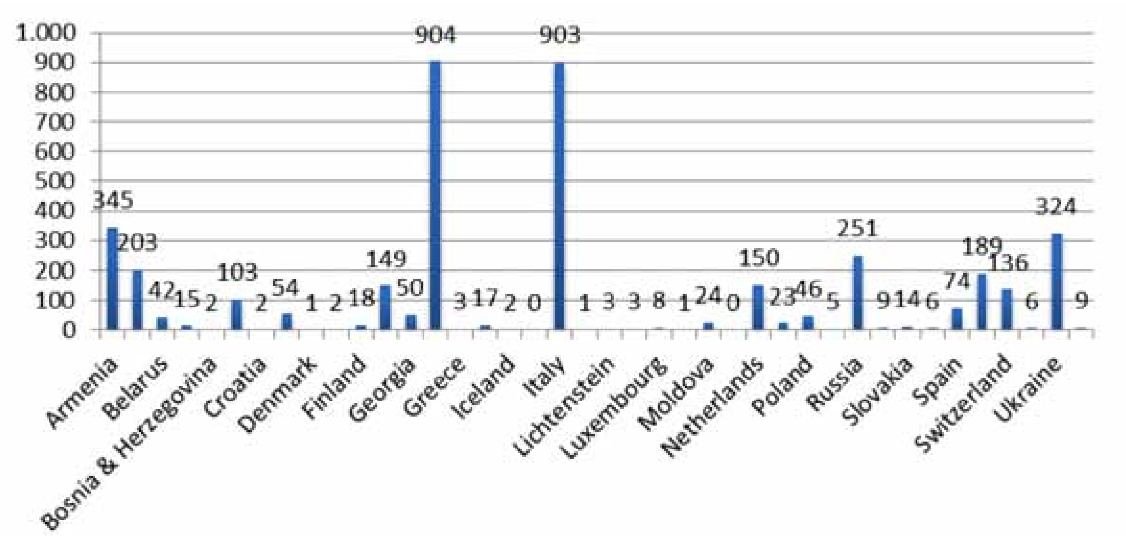


Figure 5.5 Number of natural gas filling stations by country in Europe. 2012
Source: house production from NGVA Europe data.

[2] NGVA Europe

5.3 Natural gas in transport and mobility

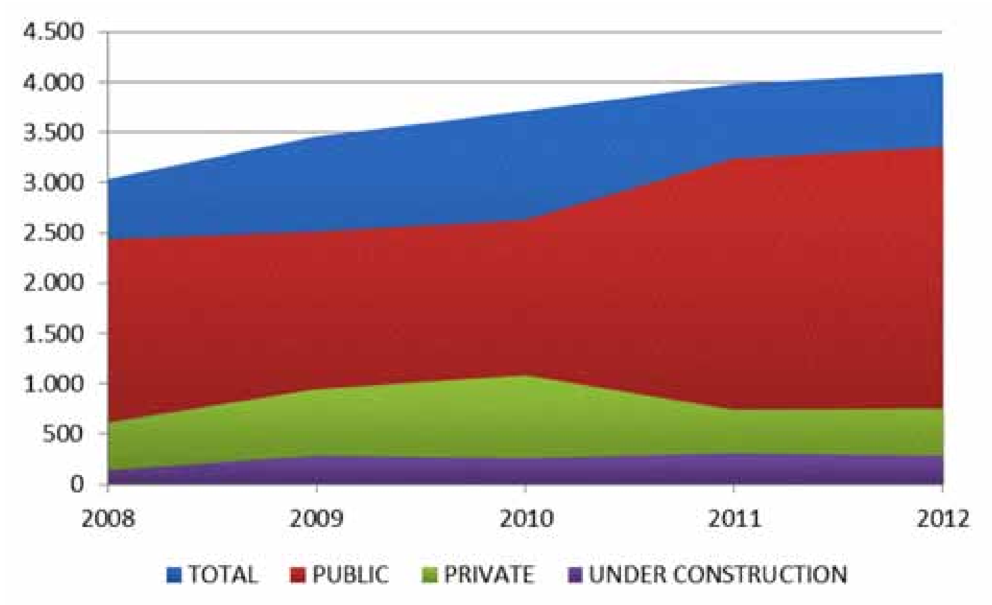


Figure 5.6 Evolution of the number of filling stations in Europe.
Source: house production from NGVA Europe data.

Since 2008, the natural gas vehicle fleet in Europe has grown by 64 %. The number has increased from a little over a million vehicles to over one million seven hundred thousand today.

The new European Union strategy to promote alternative fuels opens the way for a significant increase in gas technology in the area of road mobility in the next few years.

However, it must be borne in mind that the development of the European market does not follow any rules and has always been influenced by the incentives offered by each country and the influence of unpredictable factors.

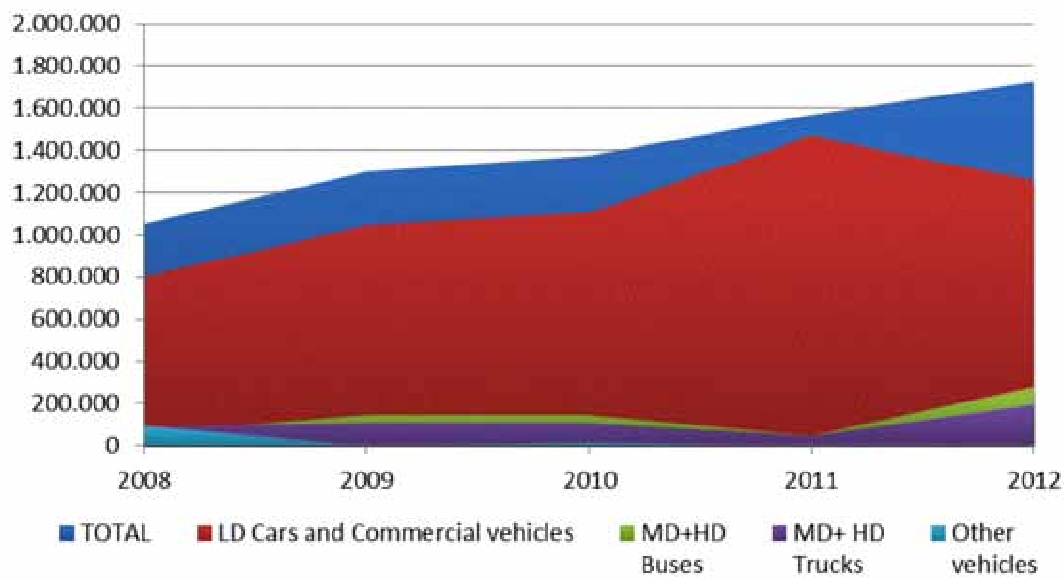


Figure 5.7 Evolution in the number of natural gas vehicles in Europe
Source: house production from NGVA Europe data.

5.3 Natural gas in transport and mobility

5.3.2 Maritime/waterway transport

In recent years, in specific maritime-port environments, the IMO (International Martitime Organization) has defined zones denominated ECA (Emission Controlled Areas), marine zones where the adoption of special obligatory procedures is required in order to prevent sea pollution.

In virtue of the international MARPOL convention for the prevention of sea pollution caused by shipping, the IMO has established a higher level of protection for these special areas than in other areas of the sea. In these areas, greater control is established regarding generated emissions, particularly for sulphur oxides (SOx), nitrogen oxides (NOx) and particles.

- In 2006 in Europe the SECA (Special emissions controlled area) came into force in the Baltic Sea, focussed on sulphur emissions. In 2007, the North Sea was also declared a SECA zone.

- In 2012, the North American ECA zone came into force, where emissions of NOx, SOx and particles are controlled. From 2014, the ECA zone for the US Caribbean Sea will come into force, which will also control NOx, SOx and particles.

The IMO foresees that measures will be taken to minimize the impact of maritime traffic activity in these special areas. Chiefly:

- Through the use of low sulphur fuels.

- Through the installation of control systems for atmospheric pollution (scrubber systems) on ships.

- Through the substitution of conventional fuels with other less polluting fuels such as natural gas.

Currently, there are around forty LNG ships in Europe. From 2015, the classifying organization DNV foresees a considerable increase in orders for LNG-propelled ships; around 500 for 2015 and several thousand for 2020. For the immediate future, substantial growth is foreseen for ships propelled by this type of fuel.

Special areas (ECA)	Date of coming into force	In effect from
Baltic Sea (SOx)	19 May 2005	19 May 2006
North Sea (SOx)	22 November 2006	22 November 2007
North American Sea (SOx, NOx and PM)	1 August 2011	1 August 2012
United States Caribbean Sea (SOx, NOx and PM)	1 January 2013	1 January 2014

Table 5.1 Annex VI MARPOL: Special areas for the prevention of atmospheric pollution caused by shipping (Emission Controlled Areas). Source: IMO.

5.3 Natural gas in transport and mobility

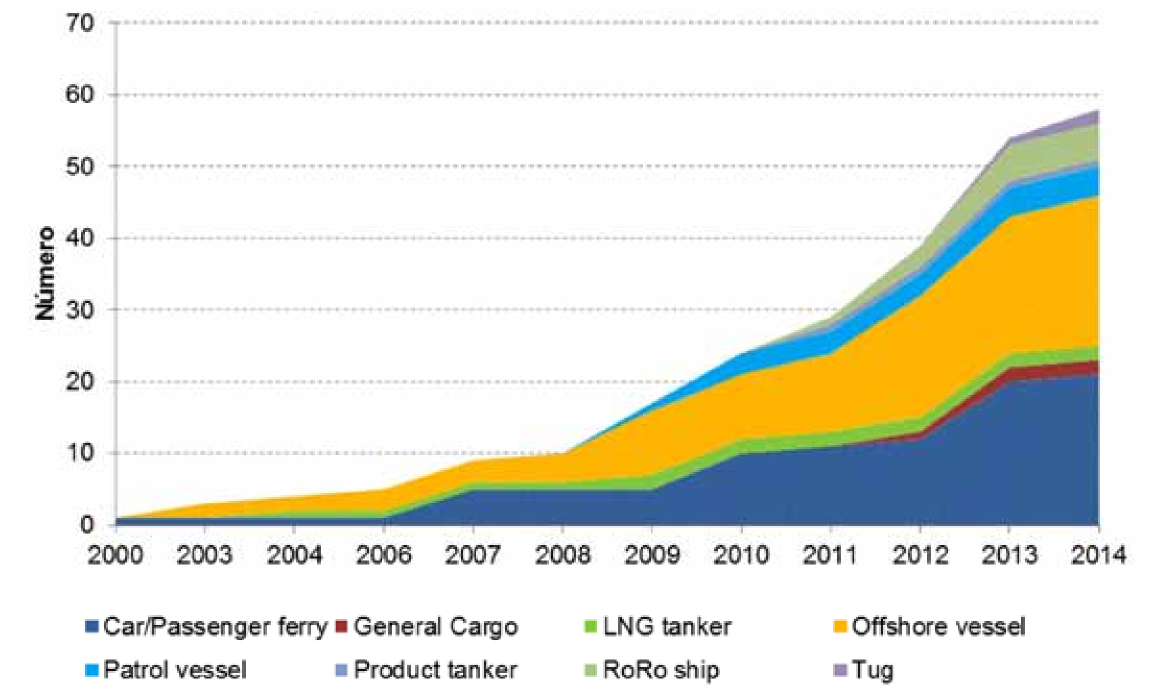


Figure 5.8 Evolution in the number of ships propelled by natural gas.
Source: house production from the Danish Environmental Protection Agency.

5.4 Technological solutions for engines using natural gas

On a technological level, there are principally four major engine solutions for natural gas:

- S1. Dedicated engines
- S2. Bifuel engines
- S3. Dual fuel low pressure injection engines
- S4. Dual fuel high pressure injection engines

The first corresponds to **dedicated** alternative internal combustion engines with spark ignition (S1 on the table), that is to say they only work with natural gas. A spark causes the ignition and detonation of the natural gas.

Figure 5.9 Diagram of a bifuel vehicle.
Source: Institut Cerdà.

Secondly, the **bifuel engines**[4] (S2 on the table) can work with petrol or natural gas. These are alternative internal combustion engines with spark ignition, where only the corresponding switching is necessary to go from one operating mode to the other (from petrol to natural gas, and vice versa).

For road mobility, **conversion kits**[5] have been developed for cars which allow the engines to be adapted in order to use natural gas as a fuel. For this transformation, it is necessary to go to a specialist garage which will install specific equipment for storage and supply, which basically consists of a gas tank (gas fed in from an additional filling nozzle located on the vehicle bodywork), gas injection devices, a new pipe system and an electronic control unit.

In third and fourth place correspond to dual fuel engine solutions based on alternative compression-ignition internal combustion engines. In contrast to the two previous cases, in which only a single type of fuel is being consumed at a particular moment, their main characteristic is that combustion takes place using a mixture containing diesel and natural gas.

Among dual fuel engines, we can distinguish between low pressure injection (S3 on table 5.2) and high pressure injection (S4 on table 5.2) solutions. In the low pressure case, a mixture of natural gas, air and diesel is injected at some 400 to 500 kPa (4 to 5 bar) during the admission phase. In the high pressure case, natural gas and diesel are injected at a pressure of over 200 bar during the compression phase.

The role of diesel in both solutions is to facilitate the ignition of the mix, as the pressure necessary to cause its detonation is reached. The main advantage of the dual fuel solution lies in the fact that it can work using diesel alone and permits variations in the fuel proportions in accordance with the engine revolution rate it is operating under. This factor provides more security to users because it is less dependent on natural gas, and, if necessary, can work using diesel alone.

The natural gas can be stored in the vehicles in gas or liquid form. The preference for one mode over another depends on the energy consumption requirements for each transport segment.

For mobility segments with medium or high autonomy, the storage system for the technological solution used in the vehicle is liquefied natural gas (LNG), as in a liquid form it has an energy density which is higher than in gaseous form (CNG), thus transporting more energy per unit volume. In this way, it is possible to increase autonomy using tanks with smaller dimensions.

[4] The bifuel technology is also a type of hybrid technology.
[5] There is also a conversion kit for the alternative fuel LPG. In this case it also includes a vaporizer (a heat exchanger to convert liquid to gas). They are usually fitted in the spare wheel void, which avoids taking up boot space.

5.4 Technological solutions for engines using natural gas

Engines	**Ignition type**	**Injection pressure**	**Scope of mobility application**	**Storage system for natural gas on vehicle**
S1. Dedicated engines: operate exclusively with natural gas	Alternative positive-ignition engines	Gas supplied at low pressure (4 to 5 bar)	Road / maritime	CNG/LNG
S2. Bifuel or hibrid engines: designed to operate with two fuels alternately	Alternative positive-ignition engines	Gas supplied at low pressure (4 to 5 bar)	Road	CNG
Dual fuel engines: they use diesel as a pilot sub-stance for ignition	Alternative compression-ignition engines	S3. Low pressure: the natural gas and diesel mix takes place during the admission phase at low pressure (4 to 5 bar).	Road / maritime	LNG
		S4. High pressure: the natural gas and diesel mix takes place during the compression phase at high pressure (> 200 bar).	Road / maritime	LNG

Table 5.2 Table summarizing natural gas engine technologies. Source: House production.

For this reason, long distance road transport and maritime transport use LNG as the storage system for gas in vehicles. In these cases, the technological engine solution which is most widespread is that of dual fuel.

In contrast, for cars, taxis, urban buses or refuse co-llection vehicles, the storage system is usually CNG. In these cases, the engine technology is usually de-dicated gas or bifuel.

5.4 Technological solutions for engines using natural gas

Energy diversification in the Barcelona IMT

Since 2006, the IMT (Metropolitan Taxi Institute), via its Mobility and Sustainability Department, has promoted various measures to reduce energy consumption in the sector: efficient driving courses for professionals, rationalization of vehicle mobility (promoting the use of ranks and fleet management systems) and the introduction of new technologies and fuels in order to enhance energy diversification.

In particular with respect to the latter, the IMT has managed to reduce the number of diesel vehicles in favour of those propelled by natural gas, liquefied petroleum gases and hybrids (electric/petrol). By mid-2012, the number of compressed natural gas taxis was over thirty.

This strategy has been carried out with the collaboration of various agencies such as the Catalan Biodiesel Association, Repsol Butane, GasNatural and the manufacturing companies. The allowances and grants provided by the Administration, and also by some manufacturers, have promoted this sustainable fleet renewal.

	2007		2008		2009		2010		2011		2012	
Dièsel	10.298	99,3%	9.963	95,8%	9.729	93,5%	9.393	90,1%	8.832	84,6%	8.704	83,0%
GLP	70	0,7%	331	3,2%	514	4,9%	578	5,5%	602	5,8%	614	5,9%
Gas natural	0	0,0%	14	0,1%	16	0,2%	28	0,3%	33	0,3%	33	0,3%
Híbrid	3	0,0%	93	0,9%	141	1,4%	421	4,0%	967	9,3%	1.141	10,9%
Total	10.371	100,0%	10.401	100,0%	10.400	100,0%	10.420	100,0%	10.434	100,0%	10.492	100,0%

In recent years, bifuel and dual fuel solutions are proliferating because they are alternative technologies which can be applied to engines which already exist through the corresponding conversions.

"GLUTRA", the first liquefied natural gas ship in the world

Norway is a huge producer of natural gas and it has been promoting this type of fuel as an alternative for transport during the last decade.

Since 2000, the first ship using LNG in the world is in Norway. It is called GLUTRA and is a ferry for vehicles and passengers.

It is fitted with four 675 kW LNG engines located in four separate engine rooms. These engines are 100 % dedicated LNG. Each engine is coupled to 720 kVA generators which supply electrical energy via frequency converters for 1000 kW asynchronous motors coupled to the propellers.

The Statoil Tjeldbergodden natural gas production plant produces 10,000 tons of LNG per year and supplies the LNG for this ferry. The LNG is loaded using liquefied natural gas cistern trucks which supply the fuel to the ship tanks located below deck.

The ferry transport operator and service provider is the Norwegian company MøreogRomsdal-Fylkesbåtar (MRF).

5.5 Natural gas loading infrastructures

The following gives an overview of the main fuel supply systems, fundamentally the filling stations for the various mobility segments: by road and maritime.

5.5.1. Road transport

The filling stations for vehicles using natural gas are the equivalent of traditional petrol stations where vehicles using other fuels such as petrol or diesel are filled. It is possible to differentiate between stations for CNG and for LNG (or those offering both gas products).

CNG stations

The CNG filling stations have as their objective the compression of the gas to approximately 200 bar, storage in tanks in some cases, and its subsequent supply.

The filling stations can be designed in two different ways, time filling and fast filling:

- Time filling or "in the car park": in this case the gas is compressed while being injected into the vehicle's tank, in such a way that end storage tanks are not normally required.

- Fast filling or "en route": this other type of filling uses compressors of higher power which can act directly on the vehicle or on storage tanks made up of a set of bottles which are then discharged into the vehicles connected for filling. In this case, the filling time constitutes a period of time of no longer than 10 minutes. It is also known as "en route" filling because it is better suited to the use of a conventional service station where vehicles are filled "en route".

Normally, the time filling system is used for buses and small fleets, taking advantage of the time the vehicle is parked overnight. For this reason, this method is usually called "in the car park" filling. This filling system minimizes investment in equipment, heating of the gas within the vehicle tank is at a minimum, and the system requires little attention on the part of the personnel to carry out the filling.

Furthermore, a compression station considered as time filling because it supplies a fleet of vehicles during one night could also have sufficient capacity to be semi-rigid in its filling because it can supply some light vehicles during the day, in such a way that it can improve the return on investment.

In the last ten years, the design of CNG filling points has evolved significantly and very compact modular solutions which minimize the use of floor surface area have been developed. In this way, innovation promotes the deployment of a network of fast or "en route" filling points so that cars adapted to this type of alternative fuel can be filled.

LNG stations

The deployment of filling points in Europe was described in previous sections. There were 74 in Spain, nine of which also supply LNG.

Figure 5.11 EMT time "in the car park" filling station in Madrid. Source: EMT Madrid.

5.5 Natural gas loading infrastructures

Figure 5.12 Fast/"en route" filling station, A Coruña City Hall. Source: A Coruña City Hall.

The main differentiating aspect of LNG stations, with respect to those only supplying CNG, is that the gas is stored in liquid form in a storage tank at approximately -162 °C and 4 bar of pressure. These storage tanks are thermally insulated and can supply directly to trucks which operate using LNG. In cases where the filling station is also set up to supply CNG, the system incorporates a cryogenic pump which compresses the LNG up to pressures of 300 bar, and it is gasified via ambient evaporators until it reaches the ambient temperature and is then stored in high pressure bottles. These bottles are connected to the dispensers which supply the CNG vehicles.

5.5.2 Maritime transport

The natural gas filling structure for ships is much less developed than for road transport, and it is intended that the new European Union strategy on alternative fuels will change this situation. The majority of ports, including those which are ports of entry to the country for gas, do not have their infrastructures adapted to carry out this function, although progress is being made.

Thus, in maritime transport, where the type of natural gas fuel used is liquefied (LNG), the solution to the provision of natural gas could be filling from a ship, that is to say via a type of mobile service station using provision through cistern trucks or the development of filling points.

The infrastructures for ships to fill with LNG are at a very early phase in their development; only Sweden has an LNG provision installation for maritime shipping. The Commission plans to install stations to supply LNG at the 139 maritime and waterway ports on the main trans-European network, to appear between 2020 and 2025. This does not mean significant gas terminals, but fixed or mobile supply stations. It includes all significant EU ports.

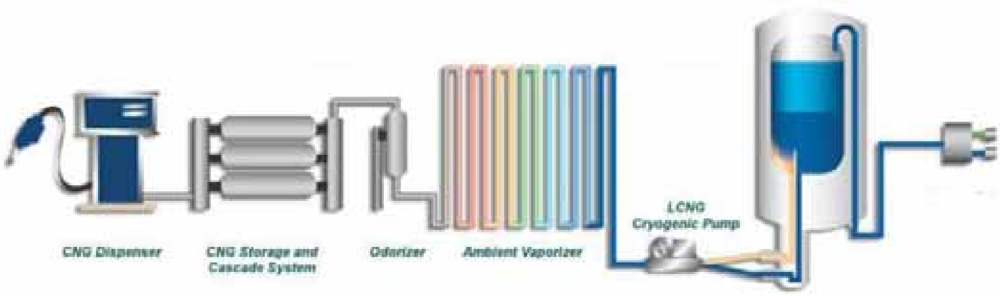


Figure 5.13 Diagram of a LNG/CNG filling point. Source: HAM.

5.6 Advantages and drawbacks of the use of natural gas as a fuel

Advantages	Drawbacks
Natural gas is a more economical fuel than petrol or diesel.	Natural gas, while generating fewer CO2 emissions than diesel, emits higher levels of methane. Taking into account the entire fuel cycle for both, the overall emissions of greenhouse gases are very similar.
Natural gas is a short and medium-term alternative, as shown in the backing given by the European Commission for its development.	The filling infrastructure is less widespread than the traditional one. Spain currently has 74 filling stations for this type of fuel.
Ecologically speaking, it is one of the “cleanest” fuels.	The price of natural gas carries a special tax.
Natural gas causes levels of emissions which are below those given in the Euro 6 standard, which comes into force in 2015.	The location of storage tanks for natural gas requires vehicle structural reinforcements, and for this reason the vehicle weight is increased.
Significant reductions are obtained in NOx, CO, and especially in particle emissions.	Currently, those vehicles with the technology for alternative fuels have a purchase price which is higher than the conventional alternatives.
It is compatible with diesel technology, especially with dual fuel engine technologies based on liquefied natural gas (LNG).	The necessary compression or liquefaction of natural gas increases the exploitation costs.
Natural gas engines display a lower level of vibration, and are quieter than conventional vehicles.	Filling with this fuel is slower.
As an alternative fuel, it reduces the dependence on traditional fuels: petrol and diesel. There are large reserves of natural gas.	The autonomy of a vehicle using natural gas is lower than one which works using diesel. However, the bifuel or dual fuel technological alternatives can equal or surpass this.

5.6 Advantages and drawbacks of the use of natural gas as a fuel

Advantages	Drawbacks
Vehicles using this fuel can take advantage of measures applied in low emission zones.	
Natural gas has a lower extraction cost, its regular supply is assured, and its price is stable.	
CNG is a gaseous fuel which is lighter than air so that, in the event of an escape, it rises without dangerous build-ups, as happens with liquids.	
Compressed natural gas has an ignition temperature which is higher than conventional fuels, which reduces the danger of accidental spontaneous inflammation.	

5.7 Conclusions

The European Union has devised a strategy for promoting alternative fuels, thus consolidating a development framework for the introduction of other fuels which are not petrol or diesel. Among them, natural gas is one of the leading options.

In Catalonia, the Action Plan for improving air quality 2011-2015 covers actions based on the diversification of the vehicle fleet and the introduction of alternative fuels in order to minimize gas emissions within a field of action affecting Barcelona and 39 municipalities in its immediate surroundings.

Thanks to technological development and innovation, it has been possible to create engine solutions which can work using natural gas stored in gas or liquid form, adapted to the needs of various mobility segments. Due to the fact that natural gas in liquid form allows the storage of a larger amount of energy per unit volume, liquefied natural gas (LNG) is extending into those mobility segments which have a more massive fuel consumption and greater autonomy requirements with respect to filling: long distance road transport and the maritime sector. Furthermore, compressed natural gas (CNG) is proliferating among mobility segments with a more limited field of action.

In this way, CNG is widespread in cars (currently a million vehicles in Europe) and certain captive fleets, especially in urban public services, such as buses or refuse collection vehicles. In these cases, the engine technological solutions tend to be dedicated or bifuel engines. For 2020, the European Commission plans to develop a network of GNC filling points which are accessible to the public, meet common standards, and are located at a maximum distance of 150 km.

LNG is starting to make headway in long distance road transport. To this end, the European Commission plans to install LNG filling stations at every 400 km on the main trans-European road network from now to 2020.

Similarly, there is growing interest in LNG as an alternative to the current fuels in the maritime sector. The main players (shipowners, shipbuilders, regulators, infrastructure owners, etc.) are evaluating the benefits and risks of LNG use as a shipping fuel, via the conversion of engines or their substitution for new ones, and they are mainly applying duel fuel engine technology solutions.

The entry into force of the ECA (Emission Control Areas) in specific maritime-port areas, which establish greater control over the emissions from maritime traffic, is becoming a factor which favours the deployment of LNG. In Europe, the majority of LNG initiatives for ships have been deployed in the ECA in the Baltic Sea and the North Sea.

The development of infrastructures for filling ships with LNG is at a very early stage. The Commission plans to install LNG filling stations at 139 maritime and waterway ports on the main trans-European network between 2020 and 2050.

6

Urban Goods Distribution (UGD)

Index

6.1 Introduction

In recent years, strong growth in demand for transport (both for persons and goods) has been channelled towards the road, which makes up approximately 80 % of the total transport consumption in Spain. For that reason, and given that the transport of goods has become a key factor in the development of a country, the aim of this chapter is to describe ways of optimizing urban goods transport, although it is essential to continue promoting alternatives to road transport (such as maritime or railway).

Product delivery and collection vehicles have a large impact on cities: they cause congestion on streets and access roads, they take up space during loading and unloading, and they pollute cities with emissions and their fuel consumption.

In order to manage their circulation, it is also necessary that municipal administrations apply various measures which allow urban goods traffic to form a part of urban mobility plans and the general policy of each city.

Thus what is presented in this chapter is an analysis of the operation and management of urban transport fleets in order to achieve an increase in efficiency and productivity, while at the same time reducing costs and journeys, minimizing consumption and emissions, reducing traffic congestion, etc. In short, offering ideas and compiling actions on how to address the problems of urban goods transport which must be faced by today's cities.

6.2 Externalities and problems associated with urban goods transport

The following shows the main reasons why it is important to manage urban goods transport fleets.

- High noise, emissions and energy consumption. In 2010, the impact of the transport fleets (urban and interurban) in Europe was: 428.37 Mt CO2 emissions with an energy consumption of 139.16 Mtoe. [1] Although the percentage of vehicles/kilometre for trucks does not make up more than 10 % of European road traffic, they may easily cause half of the nitrogen dioxide emissions, around a third of the particulate matter in suspension, and over 20 % of the emissions of greenhouse gases.[1]

- Degradation of infrastructures, which were initially designed for less dense or lighter traffic.

- On a European level, urban goods transport constitutes between 20 and 30 % of the occupation of road space; and between 10 and 20 % of urban traffic. [1] In Barcelona, 16 % of daily city journeys are made for goods distribution.[2]

- Urban centres endure a large volume of goods transport (high levels of congestion and a reduction in the circulation speed).

- A high demand for mobility, recently increased by the demand for home delivery promoted by the sale of goods over the internet.

- Accidents associated with these vehicles and the feeling of danger perceived by pedestrians and other drivers.[3]

- Insufficient infrastructures for loading and unloading. Interference with other modes of transport (pedestrians, public transport and the private vehicle).

- Disuse of the infrastructure dedicated to loading and unloading. In Spain, it is only 20 % used (in spaces-hours) [3] due to the distribution timetable and illegally parked vehicles.

- Expansive growth of cities: greater product distribution/delivery distances.

- The continuous development of cities creates new projects (shopping centres, industrial units, construction sites, etc.) for which large movements of products in and out are foreseen.

- An increase in logistics costs.

- High average age of the fleets.

- Urban distribution is made up of numerous supply chains and many economic sectors, in such a way that decisions taken by the Administration, by traders or by transport agents often present conflicts of interest.

- The proliferation of various regulations and requirements among cities with similar characteristics causes disruption among operators, distributors, etc.

As a consequence of all that, the **distribution companies**:

- Increase the number of personnel necessary (often for one journey it is necessary to use two workers, one to deliver and one to drive.

- Use a greater number of vehicles (of various sizes based on the action to be carried out) or make inadequate and inefficient use of them (too large or too small).

- Make more journeys.

- Increase their costs.

- Increase their consumption.

[1] IDAE
[2] CIVITAS Project
[3] Estudi Llotja

6.2 Externalities and problems associated with urban goods transport

- Have a greater level of stress when organizing and planning goods delivery activities.

On the other hand, for **shops and establishments**:

- Possible loss of customer sales or contracts.

- Uncertainty regarding delivery and collection of products.

- Poor image (entrances obstructed by delivery vehicles and a reduction in parking capacity for customers due to the loading and unloading zones).

- A large number of small and medium companies have difficulties in offering integrated logistics solutions.

6.3 Actions to improve the transport of goods

In this section, some actions will be covered which should allow for the optimization and improvement in urban goods delivery, taking into account that it is essential that there is compatibility among the various agents implicated.

6.3.1 Design, signage and control

This means streamlining the process of loading and unloading (L/U) for delivery vehicles.

On the one hand, the proposal is to design simple, obstacle-free routes in order to facilitate the last part of their circulation and promote use of the L/U zones (wide, accessible, protected pavements, indications of suitable routes and obstacles which should be avoided, such as low bridges, tight curves, narrow streets, pedestrian areas, etc.).

In order to be able to guarantee compliance with regulations, it is also important that the user of the public highway is provided with sufficient information (in a clear, visible and comprehensible form).

This point must also include suitable planning (design and location) of the zones destined for loading and unloading; there is a direct relationship between a high level of illegal occupancy of L/U spaces (up to 75 % of the time in Madrid) and the location of these spaces; they are often not located where requested by the transport companies or receiving establishments, and are thus underused. [4] Therefore, parameters such as the following must be taken into account:

- Number of delivery vehicles which access or leave the zone.
- Number of operations with L/U parking.
- Average stay with L/U parking.
- Rotation index (No. parking / space).
- Percentage of space occupation.
- Violation index for private/trade vehicles.
- Etc.

Advantages: greater knowledge on the part of companies and carriers of the zones which are suitable for correct circulation and parking.

The gathering of statistics is also promoted, which will help towards a better design of public spaces and, at the same time, will provide useful data for carriers.

Drawbacks: to prevent the illegal parking of vehicles in the L/U zones, it is necessary to increase surveillance, and this implies an increase in costs on the part of the city hall.

6.3.2 Dynamic management of L/U spaces

One measure that is now being piloted and is already operational in some cities is that of the dynamic management of the loading and unloading spaces, which has already been mentioned in chapter 2. This is the programming of loading and unloading through the prior reservation of spaces in such a way that carriers and distributors can ensure parking at the destination point for a specific period of time.

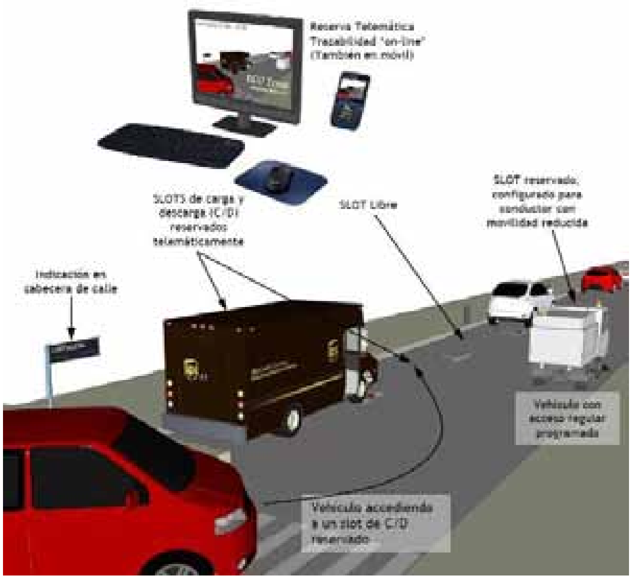
Companies would be able to reserve a time interval in order to carry out their operations based on availability and cost, which would avoid confluence with public transport, school transport, private vehicles, other delivery vehicles, etc.

Advantages: increases the rational use of L/U spaces, ensures exclusivity of use for trade and industrial vehicles –and at the same time reduces illegal parking–, guarantees a high rotation of vehicles –because it limits the maximum parking duration– and takes advantage of the infrastructure during the entire day.

6.3 Actions to improve the transport of goods

Furthermore, congestion is reduced (and pollution), the L/U operation times are improved, costs are reduced and the reliability of the delivery of goods is increased, which ensures the customer is offered a better service.

Drawbacks: development (definition and management) of the reservation procedure, installation of the technology and equipment to allow reservation in real-time, difficulties in complying with the reservation timetable caused by delays in delivery or operations, and the need for surveillance so that the time interval for the space is respected.



6.3.3 Adaptation and renewal of L/U vehicles

The age of the urban goods delivery vehicle fleets is often high and in many cases this causes high emission and consumption levels, together with a delay to L/U operations.

With the objective of streamlining the process of goods distribution in cities, it is necessary that delivery vehicles have elements which facilitate these operations (mechanical or hydraulic elements, elevating platforms, independent systems, etc.).

Furthermore, through vehicles which are low in pollution and noise, it is possible to define other configurations, such as night distribution or distribution centres (see sections 6.3.6 and 6.3.8) which help urban goods transport to be more sustainable and efficient.

Currently, the electric motor is also starting to be introduced in goods distribution vehicles. Given that all urban distribution vehicles spend nearly all their time inside the city, they have a large impact on air quality. For this reason, it is crucial to act on these vehicles in order to make them electric or hybrid. [4]

Advantages: the main beneficiaries of this measure are the carriers themselves, who obtain a reduction in costs, ease of operation, etc. together with the citizens themselves with the low acoustic impact of the new technology used, less pollution and, in short, a better quality of life.

Drawbacks: against this, the carriers must invest in this new equipment. However, the Administration, via policies of aid and incentives, can facilitate the progressive implementation of these technological improvements.

6.3.4 Management technologies. Navigation and communication

- The introduction of intelligent transport systems (ITS) and fleet management systems using Internet or other systems, constitutes an important tool in the management of urban goods transport. Using them would allow: Planning and optimization of routes (or real-time modifications).

- Detection of which vehicles perform best based on the type of work.

- Detection and prevention of break-downs.

[4] Catalonia road safety observatory

6.3 Actions to improve the transport of goods

- Introduction of efficient driving criteria. Recording and control of the drivers' driving style.
- Geolocation of vehicles. Location in real time of the product and a record of its status.
- Reporting to the customer in real time regarding the status of the product and its location.
- Issuing of reports for activities and production.
- Efficient assignation of work orders, which would ensure the delivery of the product, compliance with the timetable, an increase in productivity, and a reduction in costs.
- Immediate attention to incidents.
- Location and reservation of L/U parking spaces (section 6.3.2).
- Advantages: in addition to all those points mentioned, it would imply a reduction in the number of journeys, and therefore a reduction in pollution and congestion.
- Drawbacks: although the technology is already developed, it is not widespread in Spain. In addition, it supposes significant investment on the part of the carriers.

6.3.5 Multi-use lanes

The implementation of a multi-use lane consists of changing the use of a conventional circulation lane so that it allows trade operations during the periods of least demand. These lanes can be designated for use by the general traffic, or by public transport as a reserved lane, during the rush hour, and as parking at night in order to absorb residential demand.

These lanes must be used on roads with intense traffic and a high level of trade activity which also have insufficient space for L/U.

Together with their implementation, an information system must be installed to indicate the use of the lane during each period of time during the day. In order to manage them correctly, this information should be on information panels or luminous panels at the beginning and end of these lanes.

Advantages: a reduction in congestion (and pollution), an improvement in operation times for L/U, and a reduction in costs.

They also allow greater fluidity and speed of public transport if there was not a bus lane previously.

Drawbacks: the main drawback of this measure is that the space is not available for delivery vehicles during the periods of greatest demand (normally between 08.00 and 10.00), and thus in order to be more effective it should be accompanied by timetable changes on the part of goods distributors.

At the same time, if the lane is set up for public transport, it must be ensured that this measure does not prejudice these services.

Figure 6.2 Signage on the multi-use lanes in Barcelona [5]

In 1998, the first multi-use lane was implemented in the city of Barcelona within the framework of the European MIRACLES project. Currently, Barcelona has six multi-use lanes on Trafalgar, Balmes and Muntaner street, paseo Fabra i Puig, Travessera de Gràcia and Príncep d'Astúries avenue. These multi-use lanes use the L/U regulations and parking in conjunction with variable signage to communicate the various functions of the lane according to the timetable.

6.3 Actions to improve the transport of goods

The multi-use lane has been implemented in many European cities, for example in Cologne (Germany), where in August 2004 a multi-use lane was implemented on the ring-road which runs around the centre of the city.

6.3.6 Night delivery

Nocturnal logistics is proposed as a possible solution to urban distribution which avoids interference with private traffic and public transport during the morning.

According to a study carried out by AECOC (Spanish Trade Codification Association) [6], the standardization of this measure throughout Spain would signify a reduction of 45 % in the presence of vehicles loading and unloading in the city, and a drop of 40.7 % in the occupancy of the public highways.

As an example, in 2003 and in the city of Barcelona the Mercadona chain of supermarkets was the first company to put into practice AECOC recommendations for urban goods transport.

Advantages: a reduction in congestion (and pollution), an improvement in operation times for L/U, and a reduction in costs.

Drawbacks: to guarantee the success of this measure, great precision and coordination between the various players in the process is necessary, together with investment on the part of companies in order to adapt and prepare the handling vehicles and equipment which will be used in order to respect the noise restrictions set out by the city halls.

At the same time, it implies a relationship of trust between carriers and receptors in order to allow delivery during periods of less security. For this reason, this measure is better suited to those companies that deliver their own products.

6.3.7 Urban distribution centres

The centre or distribution platform for urban goods consists of a logistics installation located close to the zone it serves, whether it is the historic centre or other zone with a high commercial density, used as a focal point and where a trans-shipment takes place (where there is a change in the mode of transport for the goods).

This centralizes the entire transport of goods on a simple access point for vans and trucks and, in order to optimize journeys and the efficiency of the whole

Figure 6.3 Mercadona. nocturnal distribution. Source: [5]

City: Barcelona
Street: Valencia
Origin: Pilot trials in 2003, in conjunction with Barcelona city hall. Procedure currently active.
Description: Nocturnal unloading using vehicle adapted to noise limitation regulations.
Electric elevator and fork-lift.

6.3 Actions to improve the transport of goods

transport process, a single company manages all goods which are delivered, taking into consideration the destination and the urgency.

This goods delivery concept includes various aspects dealt with in this book: dynamic management of loading and unloading spaces (section 6.3.2), the managed mobility zones explained in chapter 2, and urban distribution centres. This concept is known as consolidated goods delivery, which is nothing more than the optimization of the whole system in order to improve the elimination of inefficiencies.

This form of delivery is based on a system of access supply management within a managed mobility zone, as explained in chapter 2. This concept allows access to the managed mobility zones within a specific timetable and for a specified vehicle type. In this way, any private user would contract an external company to be responsible for the delivery of their goods. This company will consolidate various deliveries within the limiting zone from the urban distribution centre, delivering the goods within the foreseen timetable, minimizing the route through the zone, and thereby favouring the traffic in general.

Within this zone, there would be restricted access for the delivery of goods for other delivery companies; they would only be able to deliver via the consolidated delivery company. In this way reservations for timeslots for loading, unloading and goods transport would have to be made and thus there would be no simultaneous confluence of these operations between each other or with other programmable situations (school transport routes, daily deliveries, etc.), this system supposes the possibility of carrying out deliveries while avoiding rush hours and significantly reducing traffic.

This delivery method would enable the optimization of route distances in order to minimize delivery vehicle traffic, with the consequent reduction in pollutants. It would also be possible to carry out the transport operations during periods of reduced flow as with the detection systems it would be possible to produce statistics related to times of the day and the density of traffic in circulation.

This system would be possible via a simple web tool on which companies choose the timeslot based on availability and the cost of the available slots.

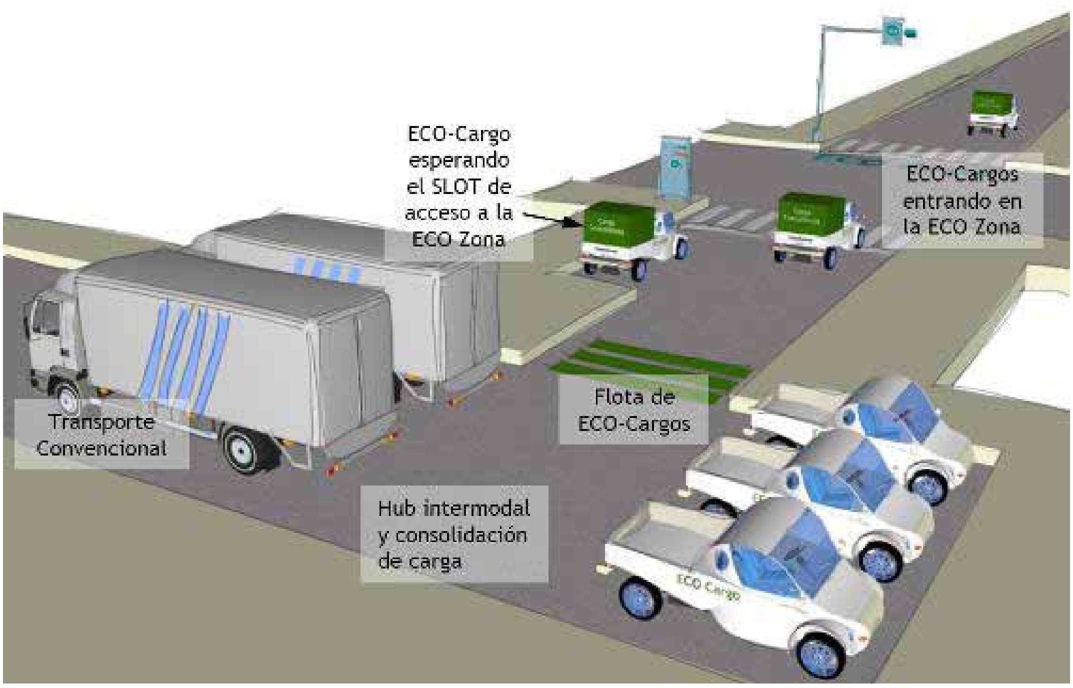


Figure 6.4 Outline of consolidated goods delivery from a distribution centre. Source: GTD/Siemens.

6.3 Actions to improve the transport of goods

6.3.7.1 Requirements

- Location: the radius of action for these distribution centres must be limited so that they are truly effective. In order to provide a good service to the whole city, it is necessary to locate several of these platforms in such a way that they cover all areas with significant commercial activity.
    - Peripheral platforms: large tonnage vehicles can arrive at these centres and unload goods so that other smaller vehicles can access the delivery zone.
    - Underground platforms: located at strategic points which allow access to the basic circulation network.
- Due to the competition in this sector, initial financing and management on the part of the Administration is required, although the objective must be that loading consolidation centres become self-financing (suppliers, receptors, etc.). It must also play a role in increasing awareness within the population and making the measure attractive to ensure its success. One alternative to this system is to offer the distribution centre as a concession in such a way that the administration does not have to finance the project.
- It is important to establish strong coordination between the various interested parties, especially with traders and local goods delivery companies. If there is not prior cooperation and trust, it is very difficult to introduce significant changes, such as the make-up of the integrated urban goods distribution centre.
- This measure is convenient for very dynamic zones which enjoy a continuous and high volume movement of goods which present significant problems of accessibility and transport, and in those where other measures which imply less investment and management would not work, such as those described in this chapter.

6.3.7.2 Complementary measures to promote positive effects.

There are various support measures which could improve the effectiveness and often also the acceptance of goods distribution and logistics:

- The distribution centre could provide complementary services such as the storage of products, packing and unpacking of goods, price setting for products, maintenance services and vehicle repair, etc. in short, services providing added value.
- The introduction of clean vehicles for goods distribution in well-defined specific zones.
- They offer incentives for carriers which use these centres, for example reserved loading and unloading zones, access to Bus-HOV lanes, wider delivery timetable, etc.
- Inform the general public and customers about current problems and foreseen initiatives, solutions, costs and the expected benefits.
- Limiting specific zones and establishing access restrictions (an unpopular measure for the general public, but highly recommended).[5]

6.3.7.3 Super-islands and urban distribution centres

A “super-island” is a set of housing blocks limited by a perimeter access road for passing vehicles (main roads) which has the following characteristics:

- The inner roads are restricted to passing traffic.
- Timetable regulation for the L/U operations for non-resident vehicles.

[5] Madrid City Hall

6.3 Actions to improve the transport of goods

- Guaranteed access for residents, public transport, bicycles and emergency services.
- Peripheral car park network.
- Redevelopment of public spaces for new street uses.

The super-island is made up of a set of basic roads in a polygonal configuration, the interior of which includes a group of islands. Within the super-island, pedestrians and cyclists regain their priority of passage and waiting time. The remaining mobility players, except for passing vehicles –residents' vehicles, goods distribution, services or emergency services–, can access as normal. The circulation of passing vehicles is channelled through a basic network of perimeter circulation through which the collective surface transport also circulates.

The implementation of super-islands in specific city zones can help, among other things, to improve urban goods distribution as there is more free space for the loading and unloading of goods, and there is also less traffic in those areas.

Reorganization of loading and unloading and parking

The reorganization of spaces and timetables for urban logistics activities is much simpler on top of a super-island system, as there is now more public space which was formerly dedicated to the private vehicle and it is possible to control access times through the use of retractable bollards. The construction of small logistics centres serves to progressively reduce the daily surface loading and unloading operations. Thanks to the construction of underground car parks accessible from the basic circulation network, the surface parking of vehicles is gradually being replaced.

Super-islands present a new scenario when facing goods delivery, and offer new lines of investigation for the optimization of these operations.

Advantages: they allow extensive use of the urban surface by citizens instead of for passing vehicles. Due to the fact that there is more space to locate distribution points, this reorganization of the space facilitates the delivery of goods.

They eliminate problems caused by the inadequate parking of vehicles, both distribution and private, making the task of delivery more fluid.

The redevelopment of streets which are not main thoroughfares, normally within the super-islands.

Drawbacks: there is a sudden huge reduction in the surface dedicated to the private vehicle, which forces the population to carry out a certain redistribution of modes of transport. This can lead to conflicts and rejection on the part of drivers who habitually used the roads which have undergone a change of use.

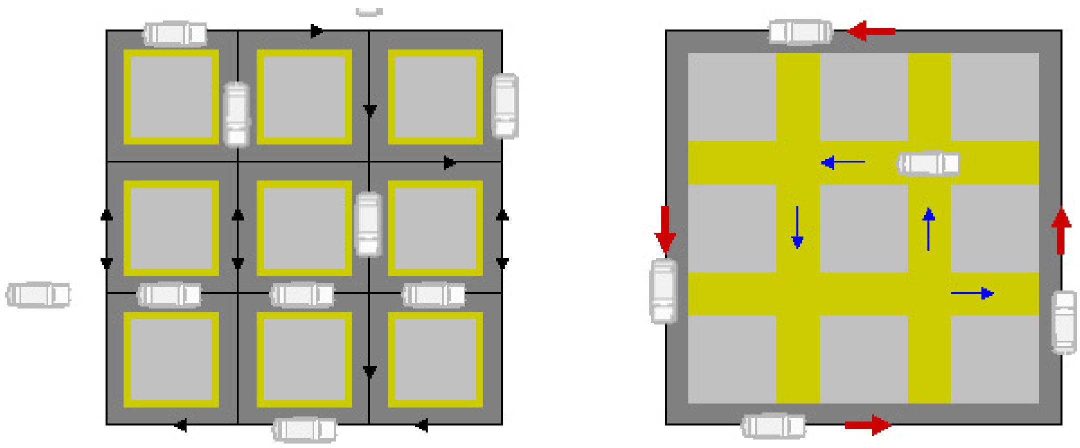


Figure 6.5. Diagram of the super-island model. Source: BCNecologia.

6.3 Actions to improve the transport of goods

It also requires the execution of numerous modifications to the road infrastructure in order to make it suitable, and this can be bothersome for the neighbourhood.

Uncertainty regarding the acceptance on the part of the citizens of the measures implemented and possible rejection by those residents on streets where there is traffic circulation due to a foreseeable increase in vehicles and the noise they bring.

The implementation costs of a super-island would mainly consist of resurfacing the streets, new signage, lighting and green areas.

Example of the Gracia neighbourhood

One example of a super-island already in place is that in the Gracia neighbourhood in Barcelona. Although on a small scale, it is a clear example of a super-island in the middle of a city. This cell is the result of grouping various islands from within the complex urban area of Gracia and diverting the traffic flow towards the exterior streets. It is approximately 400 m long, and has been designed with the aim of improving urban functionality and quality of public space.

The Gracia super-island has led to an increase in the number of journeys on foot (> 10 %) and by bicycle (> 15 %), together with a significant increase in commercial and service activity. [9]

This example of application has had very different repercussions to those it would have had if it had been done in L'Eixample in Barcelona because the traffic volumes are much more reduced than in the first case. Cases of cities which have implemented super-islands extensively have not been found, but cities such as Vitoria or Barcelona itself (in the L'Eixample neighbourhood) have put forward the possibility of doing so in the future and are now planning the operations. [8] and [9]

Figure 6.6 Current aspect of a street corner; and with the space recovered for pedestrian use. Source: BCNecologia.

Figure 6.7 Detailed image of the Gracia super-island. Source: BCNecologia, Gracia district mobility plan.

Figure 6.8 View of a redeveloped street in Gracia. Source: Barcelona city hall.

6.3 Actions to improve the transport of goods

6.3.8 Advantages and drawbacks

Advantages	Drawbacks
For the distribution companies:	
An increase in productivity because they can optimize itineraries, journeys and loading and unloading processes.	Costs associated with the acquisition and installation of signage and information panels, and alternative routes.
A reduction in costs because delivery efficiency is increased.	Additional costs related to communications and logistics equipment.
A saving of time associated with the reduction in congestion.	The need for joint implication and participation of all parties (goods suppliers, carriers and customers).
Greater reliability when delivering or collecting the product.	The carriers usually are opposed to this through fear of losing direct contact with their customers.
Needing fewer personnel could lead to a reduced price for the service.	Given the high level of competition in the sector, in order to establish distribution centres it is necessary that the public administrations provide initial finance and assistance.
Greater use and conservation of the vehicles.	The distribution centres cause a time lapse between the arrival at the platform and the final delivery to the establishment or business. For example, this fact could lower the quality of fresh produce.
Benefits associated with the use of clean vehicles (discounts, circulation tax, reservation of special spaces, etc.)	Consolidated goods delivery will only be successful if it is applied in zones with defined limits and access restrictions are established.

6.3 Actions to improve the transport of goods

Advantages	Drawbacks
Less stress, both in the organization and planning of the activity and the journey itself.	
A reduction in the journeys/km.	
A greater control over the goods.	
For the recipients:	
The increase in reliability of delivery could imply a reduction in product stock.	
A possible image improvement with the perception of fewer annoyances on the part of the residents.	
A possible improvement in the perceived social image if the trader contracts fleets of clean vehicles to collect and deliver goods.	
Traders can be more accessible if the measures are linked to access restrictions.	
For the general public:	
A reduction in congestion because there is a reduction in the number of goods transport vehicles in the urban centre.	
An improvement in city accessibility.	

6.3 Actions to improve the transport of goods

Advantages	Drawbacks
A reduction in pollution (emissions, consumption and noise) and accidents.	
A reduction in vibrations which are damaging to buildings because the number of trucks in circulation is reduced.	
An improvement in quality of life.	
A reduction in sanctions due to illegal parking.	

6.3.8.1 Experiences in the field of urban goods distribution centres

During the last two decades in Europe, various projects have been carried out in order to create urban goods distribution centres. Numerous projects of this type have been abandoned, as in the case of France, where many of the projects were dropped, although it remains the country which has most opted for the creation of these platforms. [11] Despite this, the cases of Monaco or La Rochelle are pioneers in this type of centre, together with the cities of Siena, Nuremberg, Bristol and Genoa, which have also installed them with greater or lesser profitability. [12]

La Rochelle

La Rochelle (a city with 83,000 inhabitants and a metropolitan area of 140,000) was one of the first cities to create an urban distribution centre in France, with 700 m^2 of dedicated surface area. In 2001, it began its activities with a 40 % investment from the EC (ELCIDIS[6] project) and the rest shared between the city hall, the National Energy and Environment Agency (ADEME), the Regional Council, and the Chamber of Commerce. It is currently still operational. From the centre the intention is to manage three mobility services based on fleets of electric vehicles: public transport by minibus, a carsharing service, and the distribution of goods itself.

In 2002, it was working with six Berlingo vans (five electric, plus a refrigerated diesel), an electric truck (FAAM Jolly 1200) and three electric scooters; four people were dedicated to the management of the platform and it was receiving a grant of 54,000 Euros (Patier, 2005). The normal operative carried out

[6] Inter-American Development Bank. Urban distribution of goods, urban strategies. Juan Pablo Antún, 2010

6.3 Actions to improve the transport of goods

Figure 6.9 Source: Communauté d'Agglomération de La Rochelle.

some 400 daily package deliveries for a dozen carrier customers (of some 50 that enter the city). The customers were charged around three Euros per package and a municipal contribution of 0.24 Euros per packet and 3.88 Euros per pallet was received, which means that 26 % of the managed volume is subsidised. In order to promote its use, access to the city for trucks of over 3.5 t is only authorized between 06.00 and 07.30, meaning a significant reduction in the previously existing margin, which limited access for trucks of over 7.5 t until 11.00.

Microplatform, shopping area and pedestrian streets in the city of La Rochelle

Within a long list of measures, the city of La Rochelle is attempting to take advantage of its participation in the CIVITAS-SUCCESS project (started in 2005) to improve various aspects of urban distribution and the access control system.

Genoa

Genoa, with 650,000 inhabitants covering an area of around 240 km^2, was the first Italian city to create a low emissions zone for pollutants in the city centre. The micro-platform experience was organized with finance from the Italian Environment Ministry, and coordinated by Genoa city hall, in order to reduce emission levels generated by the delivery of goods. It became operational in March 2003, following five public tenders designating the lease of space for the micro-platform, the development of IT control and management applications, the purchase of equipment, the purchase of ecological vehicles (eight electric and two CNG) and the selection of the company charged with managing and carrying out the deliveries.

It has twelve employees in order to carry out the operations of the distribution micro-platform. During the first four months, the service was available for a

6.3 Actions to improve the transport of goods

third of the historic centre (2 km² in total), and subsequently it was extended to the whole zone. During this initial phase, an average of 144 packages a day were handled. After the summer, and after extending the service, this figure rose to an average of 490 packages per day (from September to November), with a daily weight which, in October, surpassed eight tons. In order to improve the service, during the first year the vehicles were equipped with a GPS tracking system.

There are no clear estimates of the CO2 savings, nor sufficient published data regarding all costs; this makes it difficult to evaluate profitability (in the case of Genoa) or the total subsidies received (in the case of La Rochelle). A series of references based on various French studies, with a set of data from various cities, leads us to conclude that the urban platform has to find its role within a modular, evolving scheme of solutions in which railway connections and self-collection and bicycle courier services could improve its profitability.

6.4 Basic elements for the success of the measures

Throughout this White Book for Efficient Mobility, the importance of complementing all the measures proposed with parallel actions has been pointed out. The following are thus some essential elements for success in the management of urban goods.

- Contact, communication and cooperation on the part of all those involved (carriers, distributors, traders and the administration).

- Political commitment to the implementation of measures with reference to urban goods distribution, as it is possible that new traffic regulations are required.

- Awareness within the population. Residents within the zone where the application of these types of measures is desired are also a relevant public, given that they can exert social pressure on various traders and carriers so that these types of strategies are applied.

- It introduces a distinguishing factor for those companies participating in these initiatives.

- The carrying out of publicity campaigns regarding the need for the measures, their operation, the expected costs and benefits, etc.

6.5 Conclusions

The distribution of goods in the city is vital for its successful function and the development of its activities. It represents a local economic motor as it is a strategic process for the economic, social and cultural growth of the city. Without a flexible distribution system, there is a reduction in competitiveness and the relevance of the city, compromising its smooth functioning and also its growth. In addition, efficient management of UGD allows the associated externalities to be minimized: consumption of fuel, use of space, congestion, etc.

When trying to implement measures to make this process more efficient, it must always be taken into account that these activities are developed within an urban environment where other uses which will also continue to grow and demand their space in the city coexist. For this reason, the proposals must guarantee economic vitality without detriment to the quality of life of citizens.

The actions which are carried out must implicate all players who intervene throughout the process, and this is not always simple due to multiple factors which conjoin in the same space and often present a conflict of interest. Goods traders are the true customers of urban distribution and they wish to maximize the surface area dedicated to this activity.

In this chapter, various measures have been put forward which allow this distribution to be carried out more efficiently, but it is evident that there is no single solution which can resolve all the problems which this delivery generates. Each city presents its peculiarities, and for that reason different measures will surely be necessary to deal with similar problems according to the city. What is certain is that within the area of urban distribution, there is margin for the optimization of inefficiencies, and that these are detrimental to all users of the public highway.

Local administrations have a very important role to play in this aspect, and their collaboration will be key to the management, planning and promotion of services and the operations, defending a coherent mobility policy.

In conclusion, the field of development for urban logistics is wide both in scientific aspects and in application, organization and the law, and there is still a long way to go.

7

Incorporation of New Technologies on the Public Roadway

Index

7.1 Introduction

Currently, policies for reducing pollution in cities are based on reducing the circulating traffic, which is the main polluting agent in urban surroundings. However, this is not the only action possible; there are other alternatives which could help to reduce the noxious effects of pollution.

With the help of materials used in urban surroundings, it is possible to correct to a certain degree many of the negative effects deriving from mobility which are produced every day in large cities, such as pollution, noise, etc. The type of paving, the presence of gardens and green zones, and the type of vegetation can have a significant effect on the climate and the distribution of pollutants. For this reason, investment in innovation for these elements is very important, as it could offer products which can be quickly implemented and act as a short-term solution. However, it should be pointed out that the solution to environmental pollution cannot be addressed only by trying to eliminate it from the environment, but mainly by reducing total emissions. The measures proposed here serve to attenuate some of the externalities produced due to mobility, and above all those relating to the private vehicle and the urban bus.

These measures are beyond the scope of this book as they are not measures promoting efficient mobility. Despite this, the measures which allow the collateral effects produced by mobility to be alleviated are just as important for a city that wishes to have efficient mobility in a clean, pleasant space.

7.2 Photocatalytic paving

7.2.1 Atmospheric pollution

Atmospheric pollution, a constant reality in modern cities, is due to the presence of substances in the atmosphere in quantities which imply a risk to the health of humans and other living beings. The main mechanisms for atmospheric pollution are those industrial processes which involve combustion, both in industry and in motor cars and residential heating, which generate carbon dioxide and monoxide (CO_2, CO), nitrogen oxides (NOx) and sulphur, among other contaminants. In large urban agglomerations, the high level of motorization and the presence of industries have led to unacceptable levels of particles and polluting substances in the air in many cities throughout the world. In the case of large Spanish cities such as Barcelona or Madrid, some indicators surpass the levels stated in European standards regarding pollution, having a very negative effect on the health of the population.

There are two main types of pollutants in the atmosphere: primary and secondary pollutants. Primary pollutants are those which are emitted directly into the atmosphere, such as sulphur dioxide, SO_2, which affects vegetation and causes irritation to the lungs; lead, Pb; carbon monoxide, CO; nitrogen oxides, NOx; hydrocarbons, HC; and particulate matter, PM; as the most significant pollutants. On the other hand, secondary pollutants are those which form in the atmosphere via atmospheric chemical processes which act on the primary pollutants or non-polluting substances. The main products obtained are sulphuric acid, which is formed through the oxidation of SO_2; nitrogen dioxide, NO_2, which is formed when the primary pollutant NO is oxidized, and ozone, O_3, which is formed from oxygen.

Pollutants	Sources
Sulphur oxide	Combustion of carbon, petroleum and foundries
Suspended particulate matter	Products of combustion (fuels, biomass)
Nitrogen oxides	Combustion of fuel and gas
Carbon monoxide	Incomplete combustion of petrol and gas
Ozone	Chemical reaction
Lead	Combustion of petrol and coal
Organic substances	Petrochemical solvents, vaporization

Table 1.1 Main sources of atmospheric pollution

7.2 Photocatalytic paving

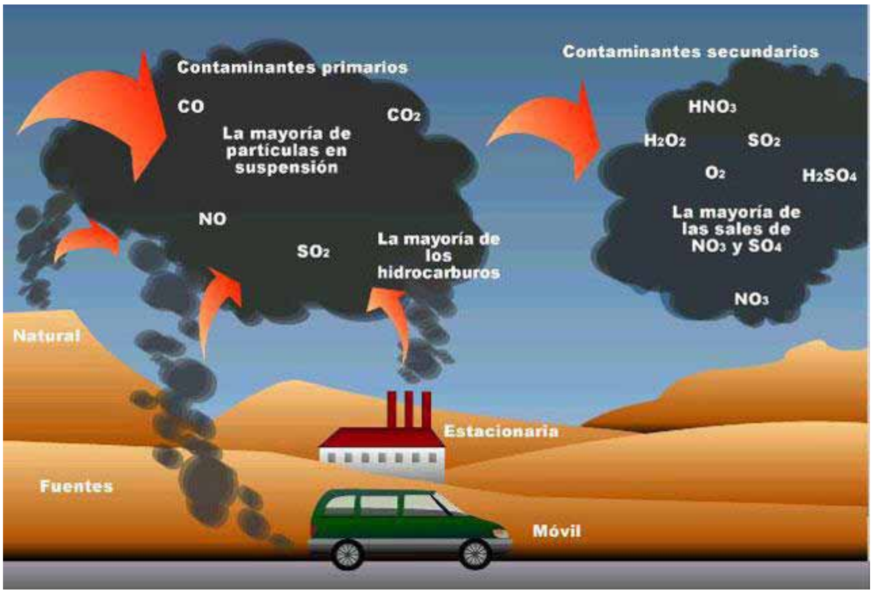


Figure 7.1 Image of the process between primary and secondary pollutants. Source: [1]

Climatic characteristics, meteorological situations and complex terrain all impact on the dispersion, transport and diffusion of pollutants. In cities, these levels depend to a certain extent on the density of the city and its climate (less wind, higher temperature, etc.). The consequences of poor air quality depend on the pollutant and its concentration, the exposure time, fluctuations and the sensitivity of the receptors.

From a general point of view, the main effects on a global scale are:

- An increase in the emission of gases which favour the greenhouse effect.
- A reduction in stratospheric ozone due to the emission of chlorofluorocarbons.
- Eutrophication and acidification of water, the soil and ecosystems. Damage to forests and crops (O3), the transport of pollutants over large distances and the subsequent precipitation as acid rain or dry deposits.

Furthermore, as has been known for many years, emissions from traffic, industry or heating have effects on a local scale:

- Regarding people's health: irritations, respiratory difficulties, cardiovascular problems, asthma, poisoning, an increase in respiratory problems, etc. (fine particles, ozone, etc.).
- Regarding ecosytems and vegetation: less growth (interference with photosynthesis and CO_2 exchange), wounds, weakening and higher susceptibility to pathogens (ozone).
- Regarding materials: corrosion of stone, oxidation of organic materials such as rubber and paint, etc. (acidifying compounds and ozone).

7.2.2 Photocatalysis

Photocatalysis is a natural phenomenon which has many similar aspects to photosynthesis, in which a substance denominated the "photocatalyst" activates a strong oxidation process via the action of natural or artificial light which causes the transformation of noxious organic and inorganic substances into completely innocuous compounds. See figure 7.2. That is to say, photocatalysis accelerates the oxidation processes which exist in nature. It favours faster decomposition of pollutants and prevents their accumulation. Decomposition of up to 30

7.2 Photocatalytic paving

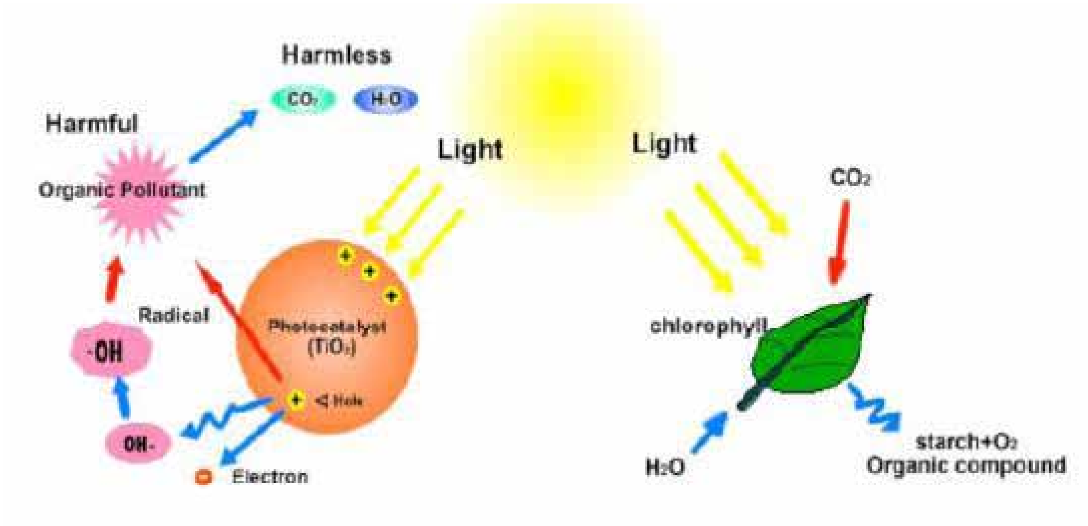


Figure 7.2 Diagram showing the principle of photocatalysis. Source: Cartif foundation.

times faster than that which would occur naturally can be obtained.

The substances obtained are common inorganic salts (such as nitrates and sulphates originating from NOx and SOx) which can subsequently be washed away by the rain or remain in the soil in a biodegraded state.

Through photocatalysis, it is possible to eliminate the greater part of those pollutants present in urban zones: PM10, NOx, SOx, volatile organic compounds, CO, and others.

7.2.3 Photocatalytic paving

To apply the principle of photocatalysis in cities, photocatalytic paving has been created which incorporates the photocatalyst substance (TiO_2) on the surface in order to generate the chemical reaction. TiO_2 is the most used semiconductor in photocatalysis due to the fact that it is chemically and biologically inert, non-toxic, stable to photochemical and chemical corrosion, and is abundant and economical. Thanks to adherence technology on the paving, the TiO_2 remains intact throughout its useful lifetime without disappearing.

The mechanism by which pollutants are eliminated using photocatalytic paving is shown in figures 7.3 and 7.4.

- The pollutant is absorbed into the surface of the tile or cement.
- The absorbed pollutant is oxidized in two stages into an inert compound such as NO^2.
- The inert compound is eliminated from the surface of the tile through the effects of the rain.

In all cases the effectiveness of photocatalytic cement materials has been demonstrated, and they have been shown to be of real eco-sustainable value. Laboratory trials have shown that three minutes of radiation can be sufficient to obtain a reduction in polluting agents of up to 75%; large-scale experimental testing has confirmed values of reduction which can be even higher.[1]

It has been shown that the maximum nitrate values obtained are found to be within the legal limits: for 1 m^2 of paving, the values are 15 mg/L (for surface water) and 1.6 m/L (for subterranean water) in one year.

[1] TX Active, Italcementi

7.2 Photocatalytic paving

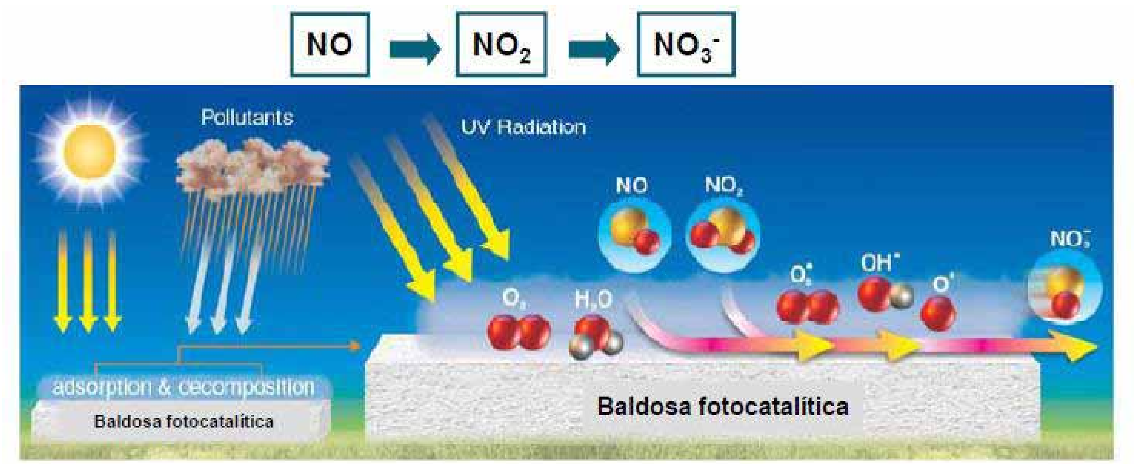


Figure 7.3 Diagram of the process followed by pollutants during their transformation. Source: [2]

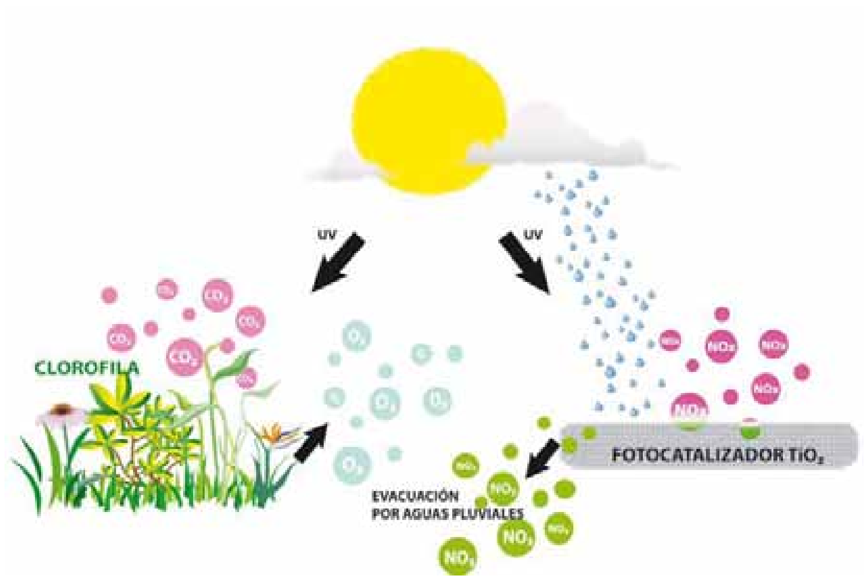


Figure 7.4 Analogy between photocatalysis and photosynthesis. Source: [3]

Through materials which incorporate this technology (cements, paints applied to building facades, etc.), a very significant reduction in the levels of pollutants in cities is achieved. Many cities have already implemented this measure and installed paving in zones with high pollution levels.

The most common technique which is used to implement photocatalytic paving in an existing street involves percolation of a photocatalytic cement slurry over an open bituminous mixture. As previously mentioned, this technique is mainly used on streets which already exist because, in zones where there is new construction, it is possible to mix this cement with the bituminous mixture and apply it at the same time, or tiles can be selected for street paving, or even paints for the urban walls.

In order to evaluate the behaviour of this type of depolluting paving, in the first place it is necessary to carry out exhaustive quality control at the point of origin, and subsequently, during the laying and exploitation phases, carry out checks on the photocatalytic efficiency in order to verify its long-term behaviour in terms of durability. The absence of Spanish regulations is creating the need to define an

7.2 Photocatalytic paving

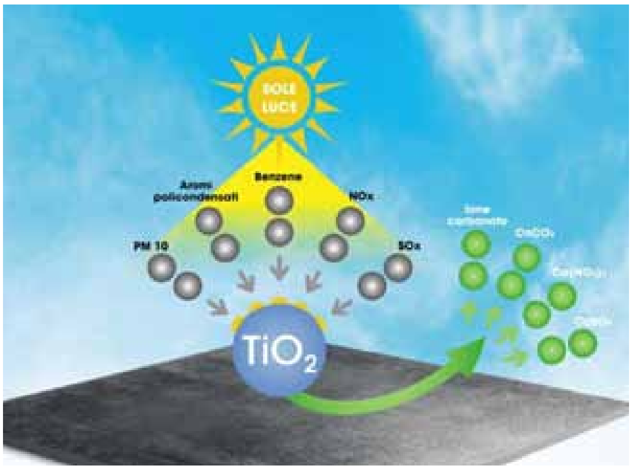


Figure 7.5 Compounds which are oxidized via the photocatalytic reaction. Source: [4]

agreed action protocol which includes the development of laboratory and on-site trials.

Photocatalytic paving can appear in the following ways:

Cement slurry

The cement slurry is incorporated into a bituminous mixture which has a 20 to 25 % pore volume. With the aim of filling the pores in the bituminous mixture, the slurry made up from titanium dioxide, cement, water and a mineral and fibre load is percolated (figure 7.6).

Through the photocatalytic processes, the presence of titanium dioxide in the paving leads to a reduction in the concentrations of NOx, and it also contributes to an increase in the durability of the wearing course as it creates high mechanical capacity and good resistance to attack from chemical products (lubricants and fuel, among others) and the ageing of the binding agent. In addition, given that the resulting surface is light grey, this type of treatment allows a reduction in the effects of the sun's rays with respect to a conventional agglomerate layer, as instead of absorbing them the rays are reflected to a large degree. This makes the use of this type of technology in paving very advantageous, both in terms of the reduction of air pollutants and in the reduction of overheating phenomena in urban centres.

On the other hand, it is possible that the use of this technology causes a certain degree of loss to the surface texture of the paving due to the flow of the slurry. This situation will have to be checked by carrying out on-site testing.

Finally, it must be pointed out that this technique is applicable to wearing courses on road surfaces, urban streets, tunnels, car parks, airports, ports, bicycle lanes, etc.

Figure 7.6 Image of the photocatalytic cement slurry. Source: [5]

Photocatalytic spraying

Whereas it was necessary to apply the slurry over bituminous paving with a high percentage of pores in the previous case, a specific type of spraying is not necessary in the case of photocatalytic spraying. It is therefore not necessary to modify the paving, with the associated reduction in costs.

This technology is highly versatile as it allows the application of a photocatalytic product directly to existing paving or any other surface. The treatment consists of an inorganic base to which TiO is added, and it is then sprayed over the desired surfaces (figure 7.7).

7.2 Photocatalytic paving

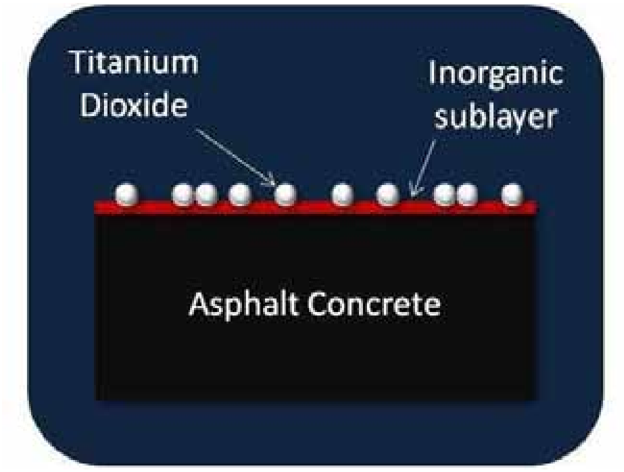


Figure 7.7 Application of spraying and the paving resulting from this application. Source: [6]

The durability of the sprays on the paving is not comparable to that obtained through the percolation technique, but its effects must not be undervalued. The adhesive and wear properties on paving provide good results. Despite this, the photocatalytic efficiency is not as high as with the cement slurry.

In recent applications in areas with high traffic densities in Europe[2], it has been shown that these products can be successfully used in urban areas such as, for example, car parks, tunnels, ports, airports, bicycle lanes and urban streets.

Photocatalytic tiles

Photocatalytic tiles incorporate within them the same titanium dioxide, which is mixed directly with the cement during manufacture. In the majority of cases, the photocatalytic cement is located only on the upper side of the tile given that the interior body of the piece is not in contact with the exterior air and cannot carry out the photocatalytic function (figure 7.8).

These tiles can be used for both city paving and bicycle lanes or in squares and pedestrian paved areas. As is shown in the examples in the following point, they can be of many shapes and colours, as the only difference to the manufacture of conventional tiles is the addition of the photocatalytic substance.

The drawback presented by this type of paving resides in the fact that it can only be applied in cases where new paving is being constructed or remodelling of the existing paving is taking place. In other situations where renewal is not necessary, it could be very costly, and for that reason action to the bituminous paving is recommended.

Figure 7.8 Photocatalytic reaction in a tile. Source: [6]

[2] Depolluting paving via aerosols.
Gianni Rovito Scandiffio (EPTISA)

7.2 Photocatalytic paving

7.2.4 Examples of application

Some examples of application are that of the city of Erfurt (Germany), figures 7.10 and 7.11; that of Milan airport, figure 7.12; or that of Icod de los Vinos, in Tenerife, figure 7.13.

Figure 7.9 Trial stretch for tiles in Erfurt, Turingia (Germany). Source: [6]

Figure 7.10 Detailed image of bituminous paving after the application of a photocatalytic cement slurry. Source: [5]

Figure 7.11 Image of the application of photocatalytic spraying in a tunnel in Milan airport. Source: [5]

Figure 7.12 Tiles located on the side of a bicycle lane between La Mancha and La centinela, Icod de los Vinos, Tenerife. Source: [7]

7.2 Photocatalytic paving

Advantages	Drawbacks
They reduce levels of NOx in the city air.	They require a certain investment depending on which paving is changed.
They can be installed easily and various systems can be selected.	On cloudy days the reaction does not take place in an efficient way.
They constitute a way to reduce environmental pollution without reducing the number of vehicles in the urban environment.	Pollution of surface water which picks up the compounds which are left on the photocayalytic surface.
They constitute a measure which is easy to implement in the case of using photocatalytic spraying.	The application work could cause temporary cuts to the public roadway.
If the paving is cleaned with water at certain intervals, its effect is not diminished with the passage of time.	

7.2.5 Conclusions

- Photocatalysis is an emerging process backed by over 40 years of research and thousands of scientific publications. It is considered to be the most appropriate treatment for the elimination of air pollutants.
- The widespread use of tiles for paving over land in cities together with the compatibility of use in conjunction with cement and the photocatalyst is a very relevant aspect in the reduction of gaseous pollutants.
- The use of titanium dioxide does not produce parallel environmental damage.
- Although it depends on the source consulted, it is possible to reach NOx elimination levels of 70 %. Despite this, the performance is very high.
- The photocatalyst does not undergo an irreversible deactivation, but only becomes saturated with the passage of time. This does not present a problem as it regains its catalytic action through washing with water, either due to the rain or through street cleaning.

7.3 Noise-reducing paving

7.3.1 Noise pollution

Noise pollution is one variable which indicates the quality of life in a city. The excessive noise on roads with intense traffic, which is above all produced by private vehicles, but also by buses, can be noxious for health. Barcelona, as in other European cities with similar characteristics, has appreciable noise levels as a consequence of the type of urban fabric with a high demographic density and the extensive use of private transport. As previously mentioned, environmental noise produced by traffic, in addition to being bothersome, is one of the causes of sleep disorders, and can cause fatigue, stress, and other alterations which disturb the health of the population.

In Mediterranean cities where the streets are usually narrow with significant traffic flow, these problems are accentuated with respect to other types of city where densities are much lower. The main noise emitters in cities are private vehicles, as can be appreciated from figure 7.14. This data depends, above all, on the proportion of noise due to light vehicles, motorcycles, etc. in addition to the mobile fleet of vehicles in the city, which may vary greatly from city to city.

Noise pollution produces some very noxious effects in people, and it can cause those subjected to high noise levels to suffer from the following psychological effects:

- Fatigue
- Stress (due to an increase in hormones associated with stress, such as adrenaline), depression and anxiety
- Irritability and aggression
- Hysteria and neurosis
- Social isolation
- Loss of sexual desire or sexual inhibition

One of the proposals to try and reduce this noise pollution to a certain extent is to use a type of asphalt agglomeration which reduces the noise generated by the vehicles which are circulating over it.

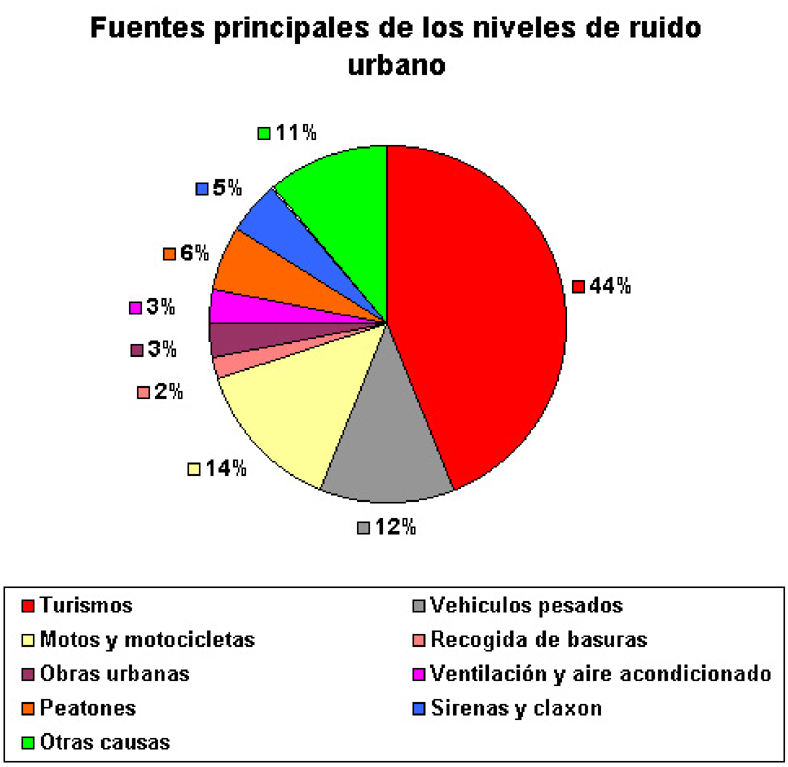


Figure 7.13 Main sources of urban noise levels. Source: [8]

7.3 Noise-reducing paving

7.3.2 Noise-reducing paving

Noise-reducing paving is an asphalt agglomeration (a mixture of aggregates, bitumen and mineral powder) which minimizes the two basic factors which cause noise from the circulating traffic: vibrations from the tyre when coming into contact with the asphalt, and the phenomenon of resonance from the air "pumped" by the tyre (compression/expansion). Firstly due to its surface characteristics, as its texture reduces vibrations. Secondly due to its structural characteristics, because as it is a porous paving the spaces reduce the resonance effect.

In addition, this new type of asphalt improves the surface performance of the paving, such as adherence. The new asphalt is a discontinuous asphalt mixture (without intermediate-sized aggregate) with structural pores (12 to 14 %) which is applied in 2 to 3 centimetre layers. From an experimental point of view, some actions have also been taken in Barcelona with crumb tyre rubber in order to promote recycling (paseo Bonanova) and with mineral aggregates originating from the demolition of old asphalt (side road surface "direction Llobregat" on the Ronda de General Mitre, between Alta de Gironella and Tres Torres).

The reduction in environmental noise is between 2 and 3 decibels, although this can reach 4 to 5 decibels in streets with a very high volume of traffic. In addition to the noise level, the noise-reducing paving also creates an improvement in noise quality because it is particularly effective in reducing medium and high frequencies, which are the most bothersome. It is also necessary to add that the use of this paving reduces both the exterior and the interior acoustic impact; that is to say, that perceived by drivers in their vehicles.

7.3.3 Examples of application of noise-reducing paving

Figure 7.14 Image of the paseo Paloma where noise-reducing paving has been implemented. Source: [9]

Figure 7.15 Image of calle Esteve Terrades in Barcelona after the incorporation of noise-reducing paving. Source: [10]

7.3 Noise-reducing paving

Advantages	Drawbacks
It reduces noise pollution levels in the city.	It requires renewal of the entire paving, with the consequent economic cost.
In its manufacture, old tyres can be recycled.	It reduces noise levels but the pollution is still present, not eliminated.
It allows short-term actions regarding noise levels in a specific street.	This type of paving is only possible for bituminous paving, not for concrete.

7.3.4 Conclusions

- The reduction in noise pollution improves the quality of urban spaces both for pedestrians using it and for residents, and also for the drivers themselves.
- The asphalt mixture can be formed using used tyre waste, which allows the recycling of a material which normally ends up in tips. This material substitutes a part of the aggregate in the bituminous mixture.
- It improves the acoustic sensation for vehicle drivers.
- The streets which show a greater noise reduction are those which display a more homogeneous emission level along the whole of the calculated stretch. [3]
- There are more improvements to the frequency aspects than in overall terms of noise pressure.

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Interviews with agents and relevant companies of the mobility sector

Backing better mobility

The Director General for Environmental Quality, Assumpta Farran, defined the current problems relating to mobility and pollution, and provided us with some key points and possible alternatives which could help to reduce the environmental impact.

Assumpta Farran highlighted four main difficulties: problems of mobility on the access routes into and within metropolitan areas where there are over 4.9 million motor journeys every day, which in turn generate pollution and congestion; the lack of planned strategies on the part of the EU in the short and medium term which help to identify and implement agreed solutions; urban planning which does not always consider the need to enjoy air free from atmospheric pollutants with good acoustic quality, and last but not least a society that isn't sufficiently aware of the problem and often reduces it to global problems associated with climate change and does not realize that there is local pollution which affects the health of the population.

The air quality improvement plan on the horizon for 2015, which has already been presented and is being executed to a large degree despite lacking final approval due to the need to adapt some measures to the specific requirements of the European Commission, will try to solve the negative points previously mentioned. What will these new proposals be? Some of them are mentioned below. For example, it is necessary to rationalize the use of private vehicles for the journey to work and increase the use of public transport which, if the journey times and parking are normally taken into account, could signify a time saving that is not usually considered, or even alter the citizen's feeling that the journey time on public transport is greater than the time taken by a private vehicle.

Assumpta Farran and her team are confident they can reduce the high volume of vehicles that enter the main Catalan cities daily by linking car parks at various locations connected to the main public transport stations. These infrastructures could achieve their main objective if they were accompanied by electronic signalling on the main road routes which show in real time the time it would take to arrive by public transport using the car park and the train in contrast to how long it will take if continuing to travel by private vehicle. With real and reliable signalling, as "10 minutes using the Local Rail Network" and "30 by car" has to be much clearer in terms of journey times, public transport can be more competitive than the private vehicle.

It must also be taken into account that vehicle occupancy for journeys to work, which is less than 1.2, is extremely low. That is to say that for every five vehicles, four of them only contain the driver and one contains a passenger. These journeys, in addition to being inefficient, are extremely expensive in terms of energy, the environment and journey times.

The linking car park mentioned could also be useful for high occupancy vehicles by taking advantage of rail travel. Private vehicles with only one occupant would have to park in nearby car parks, and from there the various travellers would have to form groups to continue with their journey. This would be a clear saving in terms of energy costs, pollution and time. However, despite a great public investment effort, the mechanisms which allow car sharing and greater collective profitability from this infrastructure have not been developed. For this reason it is important that companies from the technological and communications sector identify solutions in order to increase the volume of vehicles with greater occupancy.

According to Assumpta Farran, there are various innovations which should be taken into account, for example, the renewal of the vehicle fleet. Measures should be promoted which make it possible to identify vehicles which could be considered clean and with low NOx, PM10 and CO2 emissions, encouraging them via reductions in the metropolitan toll, subsidies for green and blue zone parking meters, longer loading and unloading times, a reduction in road tax, and help with commercial urban distribution vehicle renewal.

A good number of these measures are not having as much success as expected. This is due to the fact that the identification system for clean vehicles is usually complex. It is necessary to have Teletac to use the discounts, it is necessary to go through the manual toll booth to prove that the vehicle is carrying more than three people, etc; in short they are complex mechanisms, when what is required is easy and simple mobility. For this reason, it is essential that the technological world address and provide solutions which overcome these barriers so that the citizen may begin to use these mobility improvements without being subjected to complex identification procedures and waiting times.

Assumpta Farran also highlighted the importance of improvements to the bus network, both in terms of quality and speed, in order to reach the same quotas as trains and metros.

Barcelona Regional

Barcelona Regional is a public agency for strategic planning, urban planning and infrastructures, and develops large transformational projects for the city on a metropolitan scale. In these projects, the infrastructure, urban planning and environmental dimensions are inseparable, with this specific practice leaving a recognized transversality footprint.

Among the projects undertaken by Barcelona Regional, one involves characterizing vehicles which move around the city daily via licence plate recognition systems and calculating the actual emissions from vehicles using RSD (Remote Sensing Device) technology. This project has helped determine which actions are the most effective in reducing the emissions of local pollutants due to mobility. However, the historical intuition that the vehicle fleet in circulation is newer than the registered vehicle fleet has been put to the test using figures. This is an example of how technology can help with decision making and the drawing up of environmental improvement policies in the intelligent cities of the future. To this end, to make cities more intelligent, it is not only important to know which vehicles are moving within the city, how much they emit and how old they are, but also to know where they come from and the route taken, when they come, etc., and have the technology available to show the information in a simple way in order to manage it better in real time.

In the years to come, cities will be full of sensors which will help to improve traffic. What is more, they are doing it now: a simple sensor to detect free parking spaces and provide information (before entering the street) is helping to prevent unnecessary driving and indicating the correct direction. This represents a saving in time and cost to the user, in addition to a reduction in lane occupancy and city pollution. This exchange of information between the user and the city leads to an improvement for both parties.

There is still a long way to go, but you only have to look at advances made from the first "portable" telephones from 25 years ago to the complex personal pocket computers they have become. The dynamic signalling and signage which is beginning to be implemented will make way for a system of intelligent traffic control which will be self-regulating between vehicles, while we will go from the current Bus-HOV to lanes in which the application of new technologies to optimize space will prevent the huge-scale road works of today.

With respect to electric vehicles, although it is interesting technology which will reduce the demand for primary energy as it is more efficient than the combustion vehicle and improve the air quality in the city, it should be understood that we are talking about private vehicle mobility and, as such, it will not solve the problem of congestion. Barcelona Regional is backing diversified mobility where the main features must be non-motorized mobility (on foot and on bicycle) and collective transport, with private vehicle mobility only used as a last resort.

RACC

RACC presents a project that deals with six points it considers important: low emission zones, Park and Ride, the Bus-HOV lane, the electric vehicle and the RetBus.

Luis Puerto, Director Técnico RACC

RACC backs low emission zones because it believes that they are a good strategy for promoting the renewal of the vehicle fleet, and through this improving the air quality in cities, provided mobility and accessibility in the centre of the city are guaranteed along with competitive journey times. The Catalan corporation also favours other functions of the LEZ (car park management or dynamic alteration to some roads during specific times of the day), but warns that economic rationality and return on investment is essential.

With respect to the provision of large car parks near the Bus-HOV lanes so that users stop using private vehicles and take the bus, RACC is in favour but points out that other action must be taken to make sure that those who previously used public transport do not tend towards the private vehicle when they realize that the roads are less congested.

The most innovative project for mobility is the electric vehicle. RACC is taking part in various European projects for the implementation of electric vehicles in cities (pilot trials with electric motorbikes via a sharing model, among others). The objective of this research is to validate various aspects, such as battery life, the availability of the motorbikes, the incorporation of ICT and to inform users whether it is fully occupied or not when arriving at a charging point.

According to RACC, the RetBus has already been defined and studied and now only requires implementation. The company reinforces the idea of the need to use simulation models prior to definitively putting the project into practice.

The CENIT proposals

The director of CENIT (Transport Innovation Centre), Francesc Robusté, is proposing various measures to improve mobility; more public transport, the use of energies with a lower social cost such as electric vehicles, dynamic traffic management, and the promotion of I+D in mobility focused on the user.

It is necessary to promote I+D in mobility which is focused on the user and services via cooperation between universities, public administration and companies in order to define a "Catalan model" or "Barcelona model" which can be exported internationally. It is necessary to design services from a system viewpoint and manage them in a suitable way with the support of ICT. Its applications are increasingly sophisticated, and optimization of the system requires more training and better resources (time, data and money). Apart from companies developing ITS applications, there are few Catalan companies investing in I+D for mobility.

The increase in speed and frequency of buses within a new network of the few corridors that operate in a coordinated manner is the key to this means being competitive; various town halls have already carried out these re-engineering exercises: Lerida (new radial network implemented in May 2013) or Barcelona (new orthogonal network being implemented). The Catalan capital was a pioneer in signalling two decades ago, but has now dropped behind: it would be necessary to implement dynamic traffic management instead of fixed plans, and implement the latest discoveries regarding the basic macroscopic traffic diagrams for each neighbourhood, which would promote increased fluidity and density control for vehicles within a specific area of the city.

The 'Park and Ride' concept has been used internationally for decades, but it is a recent development in Barcelona and requires infrastructure and financing for investment and operation, aside from fare integration (if there is a charge for parking). The Park and Pool requires cultural changes (regular working timetables, punctuality, etc.) aside from infrastructure, connectivity and user assignation resources.

The Bus-HOV lanes are more useful for buses than increasing car occupancy (due to the cultural problems mentioned, as has been seen on the N-VI in Madrid), and they are advantageous providing the cost is reasonable and when the route provides specific advantages (it is not the case with the Bus-HOV lane on the C-58).

Among the projects with a promising future are the LEZ, low emission zones, the "last mile" urban goods distribution, or the electric vehicle, despite the fact that the majority of these measures will provide sector-based improvements rather than overall improvements.

Ecodriving on the Barcelona Tram System

TRAM is working on the implementation of an efficient driving project through which it estimates that a significant percentage of traction energy will be saved.

One of the most significant strategies in the development of technological projects for TRAM is energy efficiency, and it has been working on an efficient driving project for a few months. The aim of this project is to determine whether the slopes on the routes can be used to accelerate and brake, making best possible use of the difference in order to consume the least quantity of energy possible and train the drivers to drive in this way.

In order to reach these objectives, a system to monitor energy consumption was installed on trams which helped to understand how energy was being consumed and to identify the main areas for improvement. This monitoring system showed that the distribution of energy consumption between different drivers was significant (up to 20%), a fact that shows that the saving expected from this project is considerable.

The project is divided into four phases:

- Energy evaluation of the drivers: to understand how drivers are driving from an energy point of view by monitoring data, and set the starting point for assessing driving improvements that must be implemented.
- Theoretical inter-stop analysis: theoretical design of the most energy-efficient standard practice.
- Validation of instructions: to check that the theoretical study matches the real data.
- Training: production of the necessary documentation for training drivers, and personalized training with cabin accompaniment.

The phase which is currently in progress is the production of the theoretical design for standard practice, and it is expected that the training of drivers will be carried out from the second quarter of 2013.