MADRID CALLE 30:
AN URBAN TRANSFORMATION PROJECT
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ABSTRACT
The M-30, major ring road of the city of Madrid, was designed during the sixties in the past century as a main part of the road network of the city.

However, during the last few years a transformation project has been planned to redesign different areas of the city considering, as starting point, the conditioning of the M-30 ring road. The challenge to be tackled included the construction of more than 40 kilometres of urban road tunnels in addition to different actuations on other peripheral roads.

As a result of this project, with the opening of the whole tunnels network in June 2007, the improvement in mobility all along the ring road has been complemented with a significant environmental improvement related, not only to the reduction of traffic congestion levels, but the consequent recovery of surface space.

Keywords: city tunnels, project, safety facilities

1. BACKGROUND (INFORMATION)

The M-30, major ring road of the city of Madrid, was designed during the sixties in the past century as a main part of the road network of the city.

Different design criteria were applied during its construction phases during the sixties and seventies, when Madrid was immersed in a remarkable economical growth, with a strong increase in population, an important development of the metropolitan area and a constant increment of the motor pool.

These differences in its planning and construction turned the M-30 a collector highway with very heterogeneous average speed depending on the considered section, and affected by different malfunctions caused by:

- The different capacity of each section, with important variation in the number of lanes.
- The highly heterogeneous characteristics of the road, due to diversity in the number of lanes as well as the different traffic conditions among sections: free flow, traffic-light regulated, etc.
- The notable complexity of its junctions.
- The high number of lanes dedicated to lateral movements of vehicles, mostly of short length.
- The excessive number of entrance and exit ramps.

As a consequence, a strong reduction of mobility levels was being suffered in the M-30 ring road, causing an elevated number of accidents due to rear-end collisions (related with the aforementioned heterogeneous speed) and lateral collisions between vehicles (associated with the existence of entrance and exit ramps without acceleration and receiving lanes and the resulting change movements of vehicles).

In addition, the environmental impact was significant due to the important barrier effect, which was due to its surface layout.
2. URBAN RECONDITIONING VS M-30 ENHANCEMENT

In order to promote the M-30 retrofitting project, a mixed company (joint government-private company) has been established. This company, named 'Madrid Calle 30' and mainly owned by Madrid City Hall (80 % of its capital), is devoted to develop the M-30 restructuring project.

Under the responsibility of Madrid Calle 30 is, not only the performance of the most important works of renewal, updating and improvement but also the operation and maintenance of the ring road.

The whole project, which represents a milestone with no precedents in the field of urban restructuring projects, has been accomplished in less than 30 months, with the consecution of the following three main lines:

2.1. Improvement of junctions and general layout

Under this subsection, three different types of lines can be considered:

a.1) Improvement of junctions: simplification of vehicle movements in junctions which connect radial highways with East-West general routes with the use of new direct branches, both underground or raised.

Furthermore, one of the detected problems was the inexistence of connection roads necessary to allow certain movements with remarkable traffic demand, which were redesigned.

a.2) Capacity increase of certain sections: construction of an additional (fourth) lane in 'Avenida de la Ilustración' section and redesigning of its surrounding and approaching roads.

Figure 1: Scheme of the M-30 restructuring project

The whole project, which represents a milestone with no precedents in the field of urban restructuring projects, has been accomplished in less than 30 months, with the consecution of the following three main lines:
a.3) Restructuring of the layout of the East sector of the M-30: extensive works have been done in order to allow vehicles to move between the inner core of the M-30 and its adjacent secondary roads by means of specially designed lanes. The objective was to eliminate direct links, without transition lanes, between the inner core and the approaching roads, which were closely related to collisions and traffic jams.

2.2. Coverage of the West sector and its access from the A-5

This project covers the construction of tunnels for the complete transformation of the West area of the city. The objective was not only the improvement of the traffic flow, but minimizing of environmental impacts (acoustic, visual and pollutant emission) derived from the high traffic levels on surface.

In addition to the benefits of the coverage works that where accomplished in the 6 kilometres of the former M-30 close to the river and 1.5 kilometres of Avenida de Portugal, the increase in the number of lanes or the enhancement of the safety levels have been complemented by the suppression of the physical barrier that the M-30 constituted between the centre of the city and the surrounding green parks as that one denominated Casa de Campo and the future conditioning works of the river surroundings.

To achieve all these goals safe tunnels have been constructed, equipped with the latest technology which has allow an incremented in the number of available lanes to four, five or even six and buried direct branches at different depth have also been designed.

It is also remarkable that restoring works on historical bridges of Madrid have been accomplished.

Furthermore, taking advantage of the fact that the traffic will flow underground, filtration systems for particulates have been installed which allow to eliminate (with a performance above 90 % –even for particle sizes up to 0.5 microns) almost all the pollutant particles exhaled by the more than 200000 vehicles that will daily use these infrastructures. This means a notable improvement in the environmental pollution parameters, not only in the river area but also in the whole city.

2.3. Design of underground alternative routes

And last but not least, new tunnel connection have been constructed: the link between Embajadores street and the M-40 (the outer ring road of the city of Madrid) and the By Pass South tunnel. Both tunnels have allowed to reduce the traffic intensity in more than 30% in the road junction with the largest traffic intensity of Spain –more than 250000 vehicles per day.

3. CONSTRUCTIVE TECHNIQUES APPLIED

For the construction of the more than 50 km of tunnels that forms the new M-30 –both main and branch tunnels-, a wide variety of techniques have been used, ranging from classical methods for shallow tunnels (sections between sheet pile walls), traditional techniques for deep tunnels (Madrid method) or sophisticated high performance methods for deep tunnels (earth pressure balance tunnel boring machines).

Some figures that give an idea of the magnitude of the project are the following: more than 1.2 millions of square metres of sheet pile walls, 0.5 millions of linear metres of piles, 1.2 millions of square metres of carriageways, 3 millions of cubic metres of structural concrete, 0.5 millions of tonnes of steel for structures and 12 millions of cubic metres of soil dug during the works.
In those sections in which an improvement of its functionality and capacity was required the cut-and-cover technique has been used. The East sector junctions, the whole West sector and the access through 'Avenida de Portugal' are examples of the use of the cut-and-cover method.

Since it was a requirement to maintain, upgrade and, in most cases, increment the number of available connections with the surface roads, the depth of this infrastructure could not be excessive. This all conditions make the cut-and-cover method particularly suitable in this context.

For the construction of the medium-size new underground alternative routes, as the tunnel connection between 'Embajadores' street and the M-40, classical mine digging methods have been used. The 'Madrid method' is a clear example of these classical digging techniques.

In the case of the long size new underground alternative routes, as the south by-pass of the M-30, minimum construction time and maximum safety conditions –both for workers and for surface equipment- were requirements to be fulfilled.

For that reason the two world largest earth pressure balance tunnel boring machines were specifically designed, with a digging diameter of 15.16 metres. Tunnel boring machines (TBM's) are particularly suitable for long and depth tunnels which have to be dug in a short term period.

The average month performance reached by the TBM's in the south by-pass were 15 and 18 metres advances per day, reaching maxima of 750 and 930 metres per month. This allowed to dig both tunnels ~3.6 km length each- in a record time of 6.5 and 7.5 months respectively.

### Technical characteristics:

<table>
<thead>
<tr>
<th>Drilling diameter:</th>
<th>15.20 metres</th>
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<tbody>
<tr>
<td>Maximum thrust:</td>
<td>315880 kN (usually 10-20 %)</td>
</tr>
<tr>
<td>Maximum relief torque:</td>
<td>125 MN·m (usually 30-40 %)</td>
</tr>
<tr>
<td>Maximum penetration speed:</td>
<td>65 mm/min</td>
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<tr>
<td>Power on cutting wheels:</td>
<td>14000 kW</td>
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<tr>
<td>Number of hydraulic engines:</td>
<td>50 in outer wheel, 10 in inner wheel</td>
</tr>
<tr>
<td>Number of hydraulic pulling jacks:</td>
<td>57 (in 19 groups)</td>
</tr>
<tr>
<td>Foam equipment capacity:</td>
<td>417 m³/h</td>
</tr>
</tbody>
</table>
Technical characteristics:

- Digging diameter: 15.20 metres
- Maximum thrust: 317.000 kN (usually 10-20 %)
- Maximum relief torque: 86 MN·m (usually 30-40 %)
- Maximum penetration speed: 65 mm/min
- Power on cutting wheels: 10024 kW
- Number of electrical geared motors: 28 units of 350 kW
- Central shaker: 5 metres diameter, 5 engines of 45 kW each
- Number of hydraulic pulling jacks: 57 (7 groups of 7 units and 1 group of 8 units)

4. CONVENTIONAL AND SPECIAL SAFETY EQUIPMENT

With the aim of ensuring the safest conditions in the operation of the new tunnels of the M-30, a pyramidal control system has been implemented. This control system comprises four levels, ranging from field level to main Control Centres level.

1. Main control level: Control Centres
2. Communications level
3. Distributed control level
4. Local equipment level
4.1. **Main control level: Control Centres**

Equipment and human resources are coordinated from two major control rooms. The Main Control Room is the location where all the surveillance tasks for the M-30 tunnels are accomplished. Its functional design allows the latest technology in control systems with the needs of the daily operation.

To cover possible incidences that could damage or destroy the Main Control Room, there exists a Backup Control Centre from which traffic control, as well as the others functions of the Main Control Centre, would be assumed.

System architecture in both control centres is formed by the application servers, the data basis and the operation points, all connected by a redundant high capacity LAN network. The application servers comprises systems such communications network management, simulation, monitor, maintenance, Internet, vehicle number detection, radar system, PA system, video management system, SOS points and AID system.

4.2. **Communications level**

A powerful Gigabit Ethernet communications network has been set. Provided with redundant topology, it allows to connect the control centres with all equipment installed, as well as other emergency centres of Madrid (Fire Brigades, Police, medical assistance, DGT, Department of Urban Mobility, etc.).

Some characteristics of the communications infrastructure are: wire ring of 128 single-mode optic fibres along the whole M-30, two main access nodes located in both control centres, 36 nodes provided with Gigabit access located in the technical rooms of the tunnels and 302 Field Ethernet nodes (ERU's and UCDT's).

4.3. **Distribution control level**

Its functions are data acquisition and order transmission to the local servers from which directly depends tunnel equipment.
4.4. Local equipment level

- **Energy supply system**: with a medium voltage ring topology. It is capable to provide up to 56 MW by means of three main substations and several backup substations.

- **Ventilation and filtering systems**: with 165 high power axial fans, 270 extraction support fans, 470 jet fans, 30 stations for particle filtering and 4 stations for gases purification. Control ventilation is made by means of opacity, CO and NO₃ analyzers, placed every 300 metres, as well as by anemometers placed every 100 metres.

- **Fire protection system**: comprising a fire hydrant network (one fire hose every 30 metres in both sides of the tunnel) and wet and dry hydrants network in every emergency exits (every 200 metres at the most). Moreover, there is a water-mist system in every technical room and in the deepest sections of the tunnels. Fire detection is performed by linear detection wire; indirect measures such opacity analyzers and AID system are also considered.

- **Radio communications system**: formed by redundant and independent radiant wires for security and general services. For security services, TETRA system is provided for Fire Brigades, Local Police and medical assistances, and TETRAPOL for National Police and Guardia Civil. In terms of general services, mobile GSM telephony, eight FM channels and two channels for maintenance are supplied.

- **Emergency exits**: every 200 metres an emergency exit is accessible. All emergency exits are pressurized, automated, remote-controlled in its connection to the surface and permanently supervised.

- **Lightning system**: tunnels have been equipped with continuum lines of white light luminaries in both sides, in order to ensure homogeneity, comfort and safety conditions. It is possible to adjust light intensity from the Control Centre.

- **Traffic control system**: which includes variable-message panels, maximum height control (both mechanical and electronic systems), safe closing barriers, traffic lights, vehicle number detection system and radar system along the tunnels.

- **Closed TV circuit and Automatic Incident Detection system**: more than 600 cameras supervise tunnel conditions every 80 metres, as well as the emergency exits, technical rooms and emergency exits. A codifier-recording MPEG-4 system stores the images and then sends them to the Control Centre. Additionally, an Automatic Incident Detection system, with capacity for eight cameras, is available.

- **Emergency boxes**: SOS points are accessible every 75 metres. The communication protocol used is TCP/IP.

- **Loudspeaker system**: a loudspeaker system with TCP/IP protocol covers the whole tunnel network.

To ensure a correct operation of all systems, a comprehensive document (Operation Manual) have been written, in which all activities required for the proper operation of the tunnels –security, traffic control, maintenance, etc.

For every single task, a detailed list of the human and material means that should be available is collected. So on, the classification of possible events or incidents has been accomplished taking into account the severity classification, the procedures to manage the situation with the main objective of achieving the goals of safety and comfort for the users.