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MADRID: A GLOBAL EXAMPLE OF THE DEVELOPMENT OF SAFE AND EFFICIENT UNDERGROUND URBAN ROAD AND RAIL INFRASTRUCTURES

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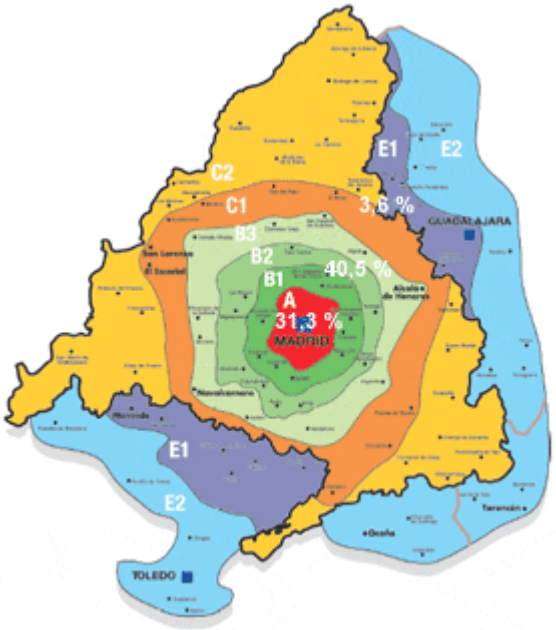
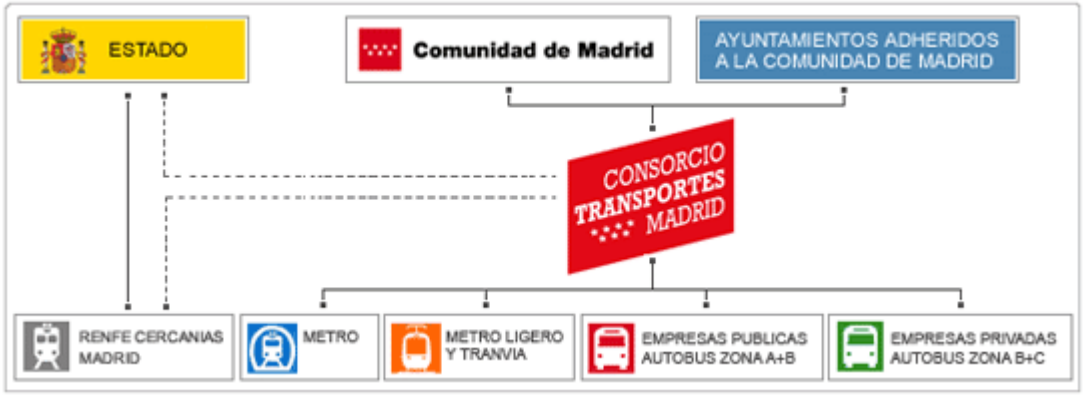
SUMMARY

1. Introduction – Transport system in Madrid



- The public transport system in Madrid is integrated in terms of management and ticketing with a coordinating, planning and funding body in which all the public authorities involved in public transport in the Region of Madrid are represented.
- This body is the Regional Transport Consortium of Madrid
- The public transport system comprises two complementary rail networks (Metro/light rail and commuter trains) and two complementary bus networks (urban and suburban) with both networks being fully integrated.



- The number of passengers using these services has grown from 951,000,000 in 1986 to 1,630,600,000 in 2007, which is a good indication of the investment and coordination effort made in recent years.

1. Introduction – Transport system in Madrid

- The total number of journeys by car, bus, Metro or commuter train in the metropolitan area is over 10 million per working day, with 50% of these made by public transport.
- This figure rises to 64% in the city of Madrid.
- The operators of the public transport network are:
  - ✓ Metro and light rail of Madrid: 319 km and 700 million passengers per year
  - ✓ Commuter trains network of Madrid: over 200 million passengers per year and 370 kilometres of track
  - ✓ EMT: the urban bus public transport network with 208 routes and over 450 million passengers per year
  - ✓ Suburban bus public transport network, with 459 routes and 1,924 coaches
- Since 1995 both the City Council and the Regional Government of Madrid have made significant efforts to improve the transport system in Madrid. Key projects:
  - Implementing measures to increase the pedestrian use of urban areas: construction of transport interchanges, public transport development, pay and display parking, etc.
  - Metro extension: 220 km built (most underground) in the last 12 years
  - A major urban renewal project of the M-30, the inner ring motorway, in which large sections have been redirected underground, with 99 km of road built, almost 70 km underground

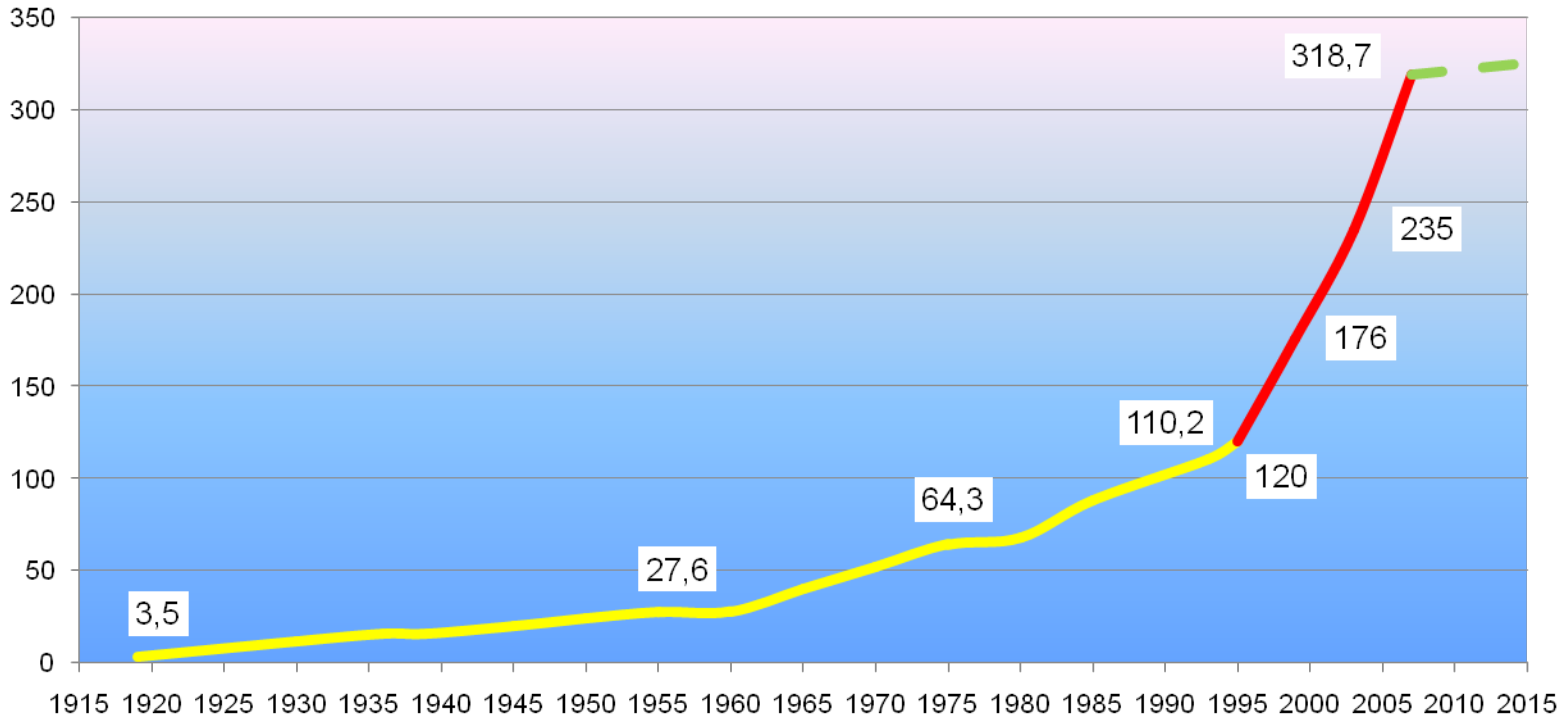
METRO EXTENSION PROJECT

1. Extension of the Metro network: 1995 - 2007
2. Metrosur as an example of intercity integration
3. Relevant data

2. Metro extension project

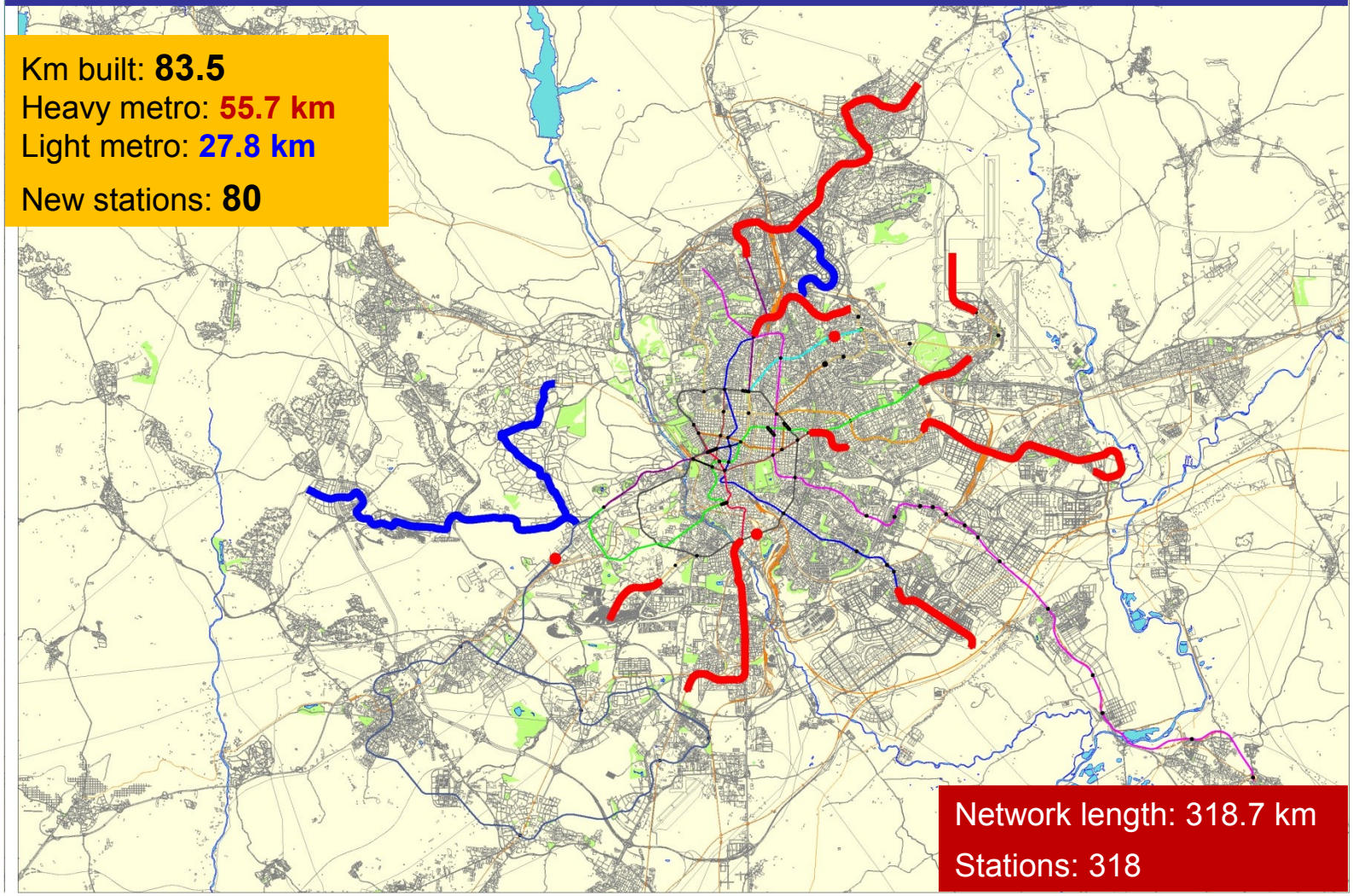
EXTENSION OF THE METRO NETWORK

From 1919 to 1995
From 1995 to 2007
From 2007 to ……



2. Metro extension project

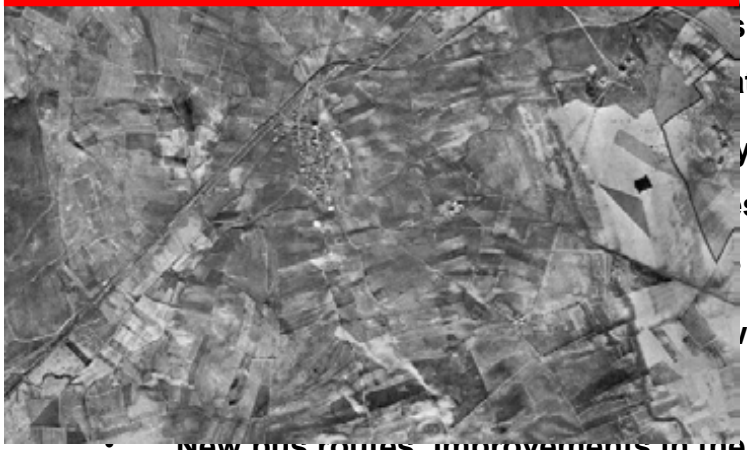
2003 – 2007 EXPANSION



2. Metro extension project

METROSUR – CONCEPT AND PLANNING

ALCORCÓN - 1956



ALCORCÓN - 1975

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New bus routes. Improvements in the suburban bus network

ALCORCÓN - 1991

ALCORCÓN - 2006

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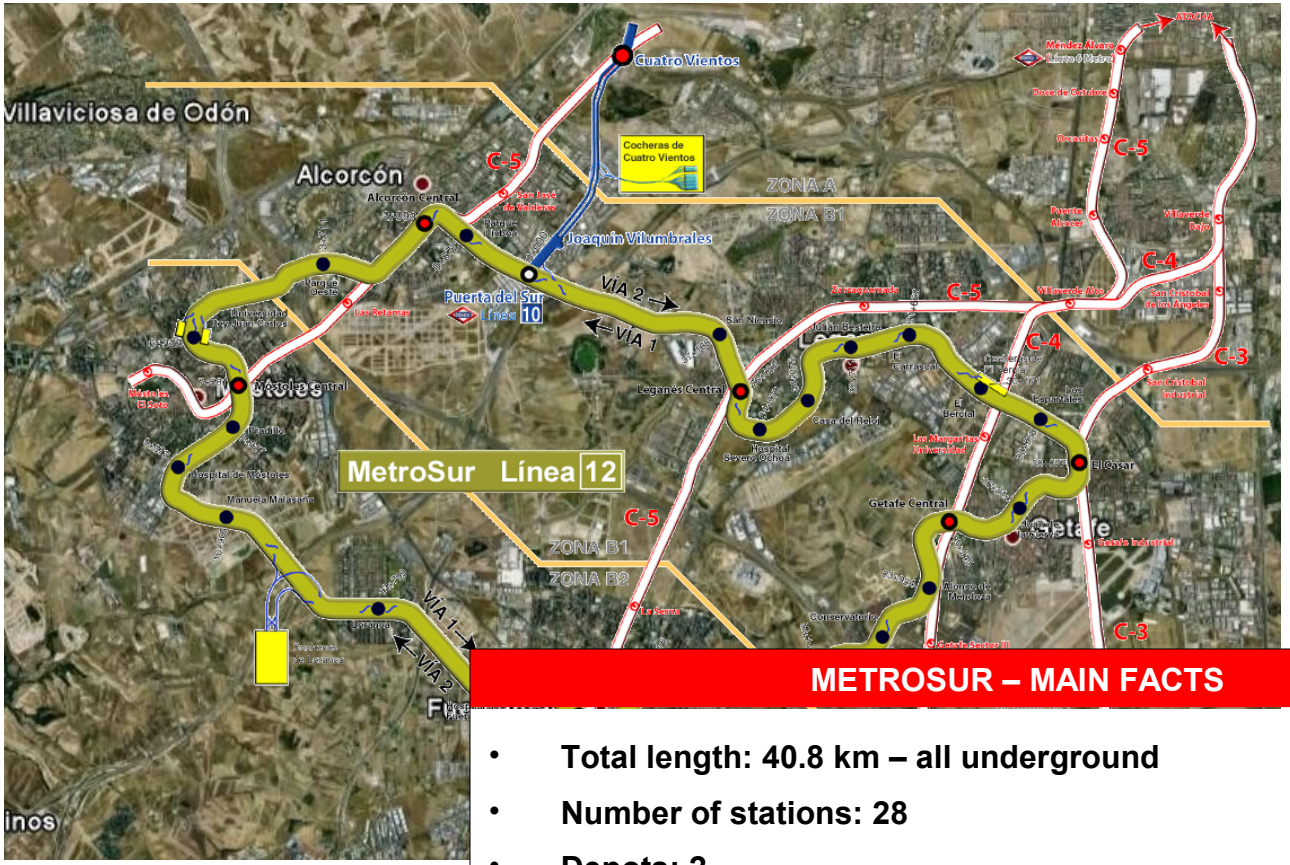
2. Metro extension project

METROSUR – DESCRIPTION



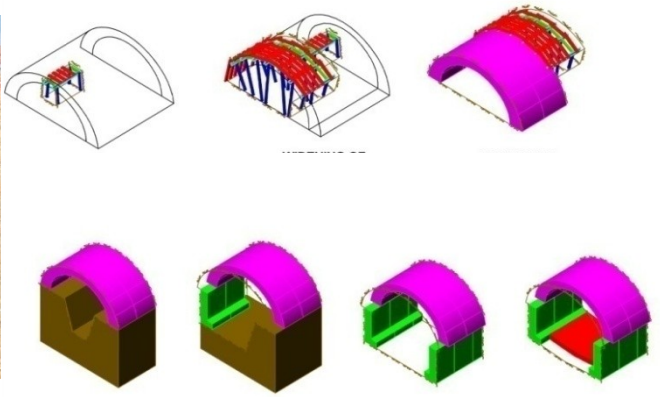
METROSUR – MAIN FACTS

- Total length: 40.8 km – all underground
- Number of stations: 28
- Depots: 2
- Links to the commuter trains network: 4 lines, in 6 stations
- Link to Madrid metro system by the extension of line 10 (8 km)

2. Metro extension project

METROSUR – CONSTRUCTION

- **Construction methods:**



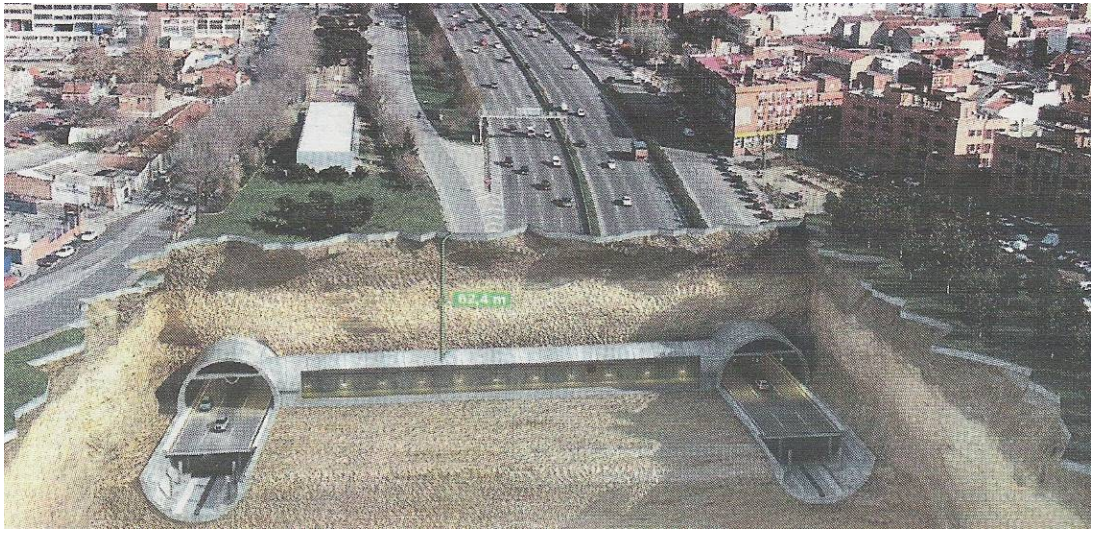
TBM: 27 km | **Cut and cover: 13 km** | **Madrid traditional method: 0.5 km**

- **Stations – cut and cover:**

2. Metro extension project

METROSUR – RELEVANT DATA

- **Program:**
  - **Planning and design: Final design contracts awarded in December 1999**
  - **Works begun in 29th of July, 2000**
  - **First trial runs in December 2002. Works completed in 29 months**
  - **Open to public in April 2003. Opening date constrained by the purchase of the rolling stock**
- **Final costs:**
  - **Civil works plus M&E equipment: 45.5 M €/km**
  - **Total cost, including rolling stock: 52.7 M €/km**
- **Demand:**
  - **After just one year the demand was 50% higher compared to the initial estimates**
  - **Demand increased by 5 - 10% each year. 60 Millions passangers (2007)**



THE M-30 GOES UNDERGROUND

1. Analysis of the problems associated with the M-30
2. Goals and constraints
3. Description of the solutions
4. Design criteria: Safety over costs and time
5. Construction
6. Relevant data

3. The M-30 goes underground

ANALYSIS OF THE PROBLEMS ASSOCIATED WITH THE M-30

- M-30: Planning 1929 and 1941. Construction 1970 – 74. Completion (northern section) in the early 90s
- Alignment determined by the Manzanares river and a large urban park
- Sections with very different configuration and capacity. Northern section with traffic lights
- Complex interchanges. 600 accidents per year (2002)

3. The M-30 goes underground

GOALS AND CONSTRAINTS

GOALS

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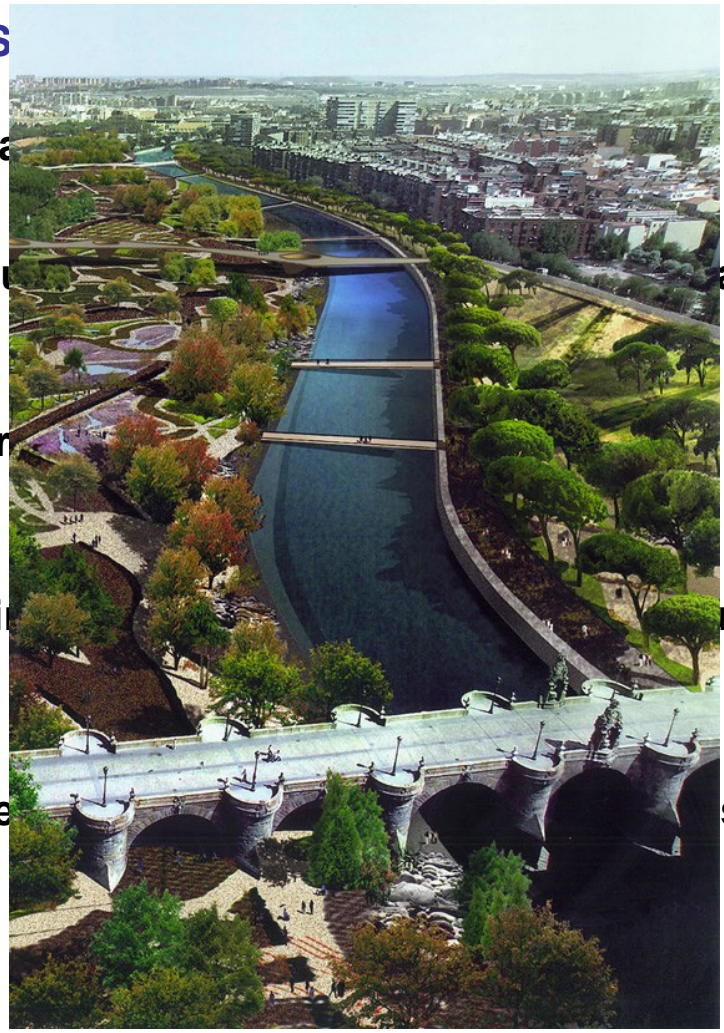


3. The M-30 goes underground

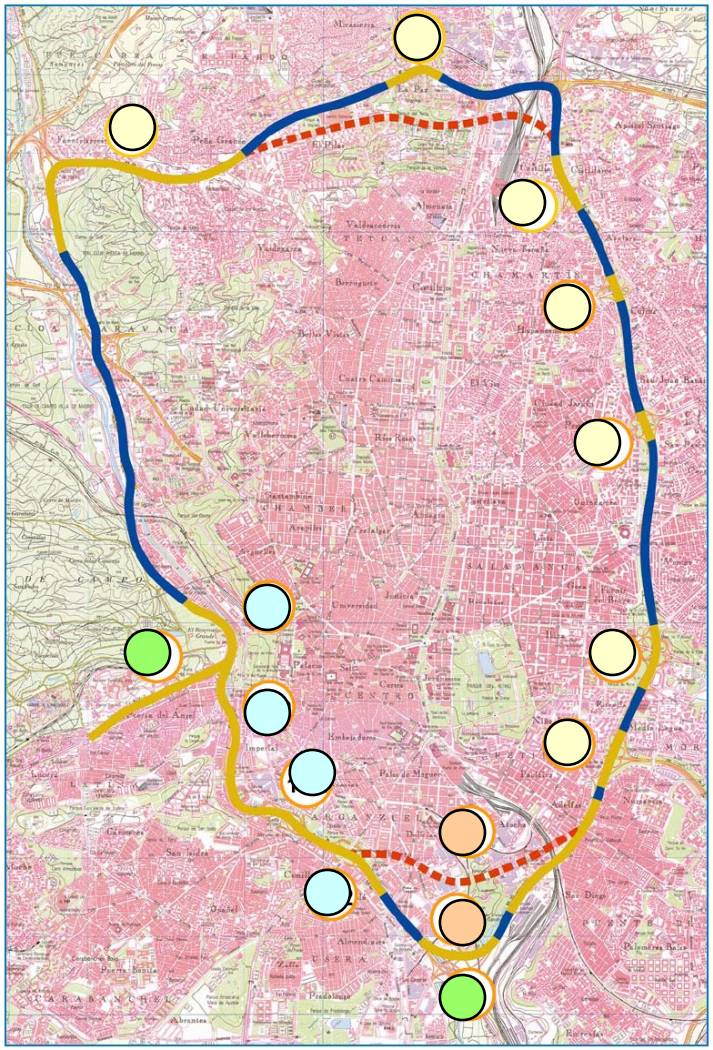
GOALS AND CONSTRAINTS

CONSTRAINTS

- **Program:**
  - **Tender and construction had to be concluded during the Mayor's term in office: 4 years. However, safety during construction was always a priority.**
- **Final costs:**
  - **With an initial budget of almost 3,000 M€ (phase 1), intensive cost control is required.**
- **Minimizing interference with normal urban activity**
  - **The M-30, before the works, carried over 260,000 vehicles daily. Challenge: build one of the largest projects in the world, quickly, safely while allowing surface traffic.**

3. The M-30 goes underground

DESCRIPTION OF THE SOLUTIONS



- Improvements on interchanges and other upgrades
- Southern By-Pass. New twin tube. Almost 4 km in length. 15.2 m in diameter
- New tunnels: direct links downtown
- Replacement of the existing surface motorway with a new underground motorway

M-30 RING ROAD – MAIN DATA

- More than 70 km of tunnels, including slip roads
- Total initial budget of almost 3,000 M€
- Financed by a PPP (Public Private Partnership)
- 80% of the PPP owned by the city council

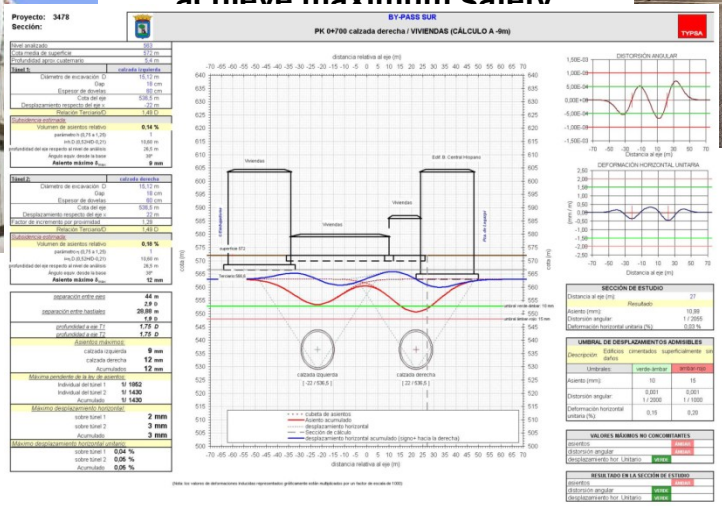
3. The M-30 goes underground

DESIGN CRITERIA: SAFETY OVER COSTS AND TIME

- **Top priority: Safety. Safety of the workers during construction, not to affect the buildings on the surface during the works, and safety of the users once completed**

TBMs as the safest construction method

Comprehensive geotechnical studies to achieve maximum safety



Complete safety measures

3. The M-30 goes underground

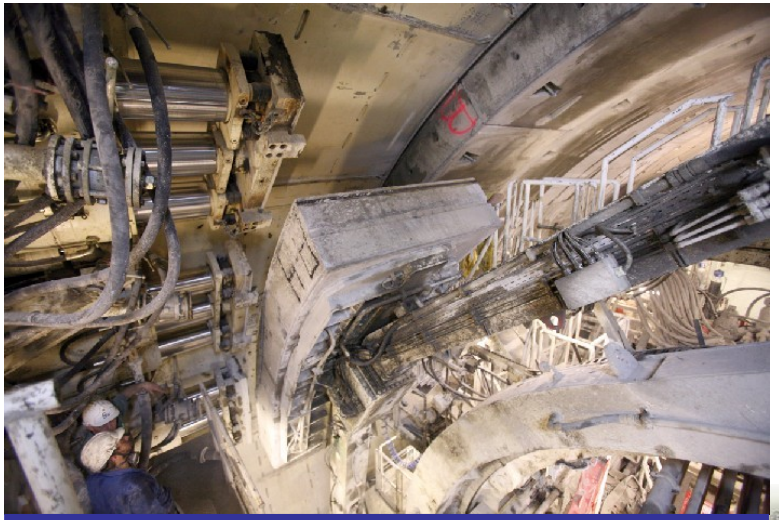
M-30 – CONSTRUCTION

TBM LAUNCHING SHAFT – SOUTHERN BY-PASS

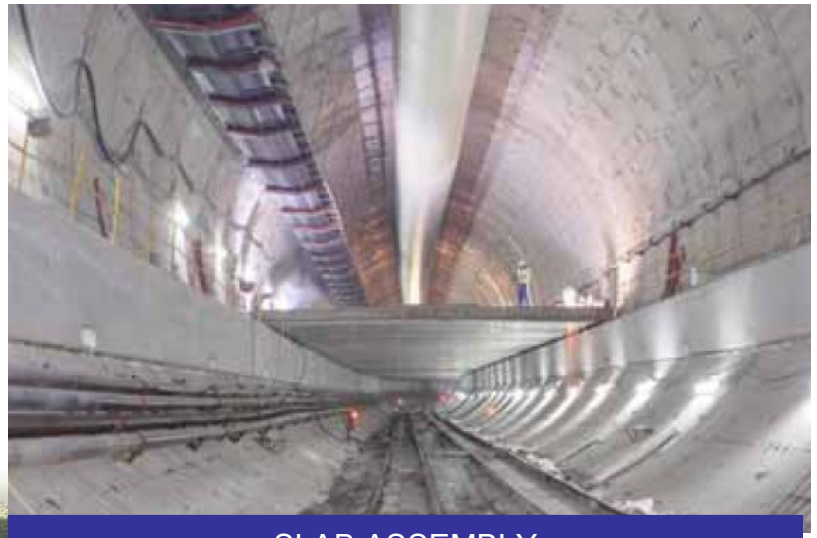
SHAFT – SOUTHERN BY-PASS

3. The M-30 goes underground

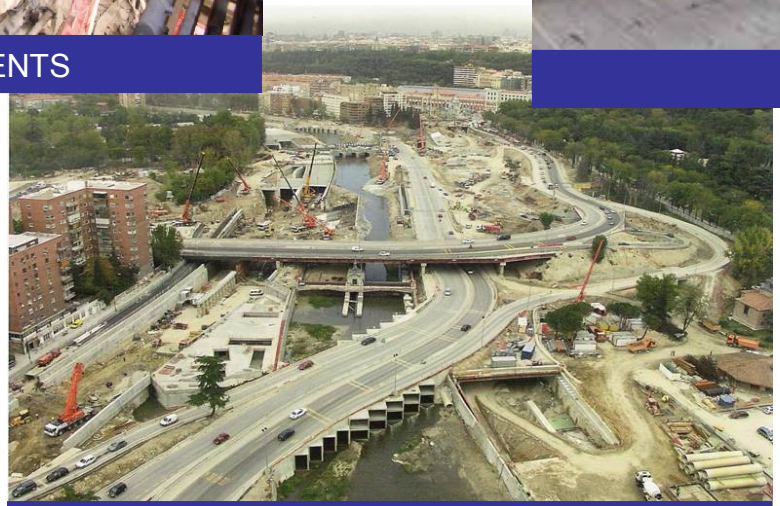
M-30 – CONSTRUCTION



PLACING OF SEGMENTS



SLAB ASSEMBLY



TEMPORARY DETOURS – RIVERBANK

3. The M-30 goes underground

M-30 – RELEVANT DATA

- **Program:**
  - **Construction began the 24th of September, 2004**
  - **Sections opened to public from late 2006. Last section opened was the southern By-Pass, the 8th of May, 2007**
- **Final costs:**
  - **Final costs of 3,700 M€**
- **Goals achieved :**
  - **Recovery of the Manzanares riverbank. New area available for the future M-RIO park, with more than 1,000,000 m^2**
  - **Reduction of CO_2 emissions by more than 35,000 t/year**
  - **Saving more than 700 million hours in travel time over the next 30 years**
  - **Reduction of accidents on the M-30**
  - **The result: The world's longest urban tunnel. Section A-5 to A-3 is more than 12 km long**

KEY FACTORS AND LESSONS LEARNT

1. Previously established design criteria
2. Construction methods established by the management team
3. Monitoring and control in real time
4. World Bank Report: Implementation of Rapid Transit (2000)

4. Key factors and lessons learnt

PREVIOUSLY ESTABLISHED DESIGN CRITERIA

- Projects of this kind are usually located in heavily studied urban areas. Geotechnical conditions are well known, contrary to non urban projects

- The management team, helped by specialized engineering firms, should establish criteria for:
  - Geotechnical parameters and design criteria
  - Functional design
  - Architectural solutions

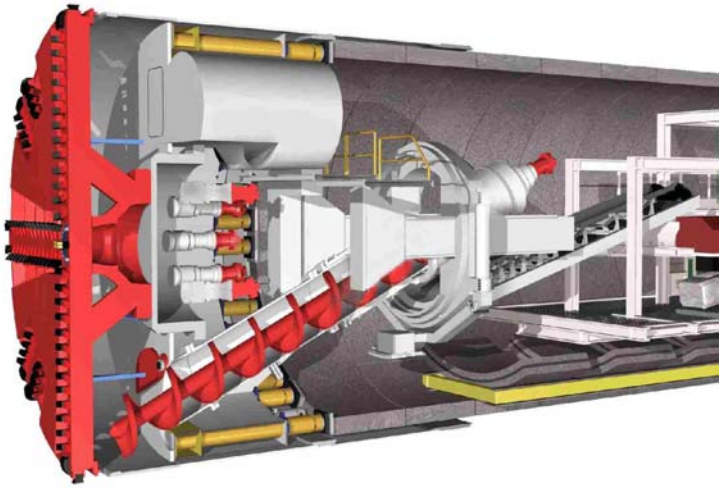
- Establishing clear criteria prior to the drafting of design projects has the following advantages:
  - Quick decisions. No misunderstandings
  - Solutions are homogeneous
  - Construction supervision and solving any incident that may arise during construction becomes a much simpler task
  - A more functional and clear design saves money

- In order to succeed, the criteria is to be developed by a highly experienced multidisciplinary team. Hiring an experienced consulting firm improves the design and saves money both during construction and operation

4. Key factors and lessons learnt

CONSTRUCTION METHODS ESTABLISHED BY THE MANAGEMENT TEAM

MAIN TUNNELS – USE OF TBM (EPBs)



The use of TBM assures maximum efficiency, safety and speed

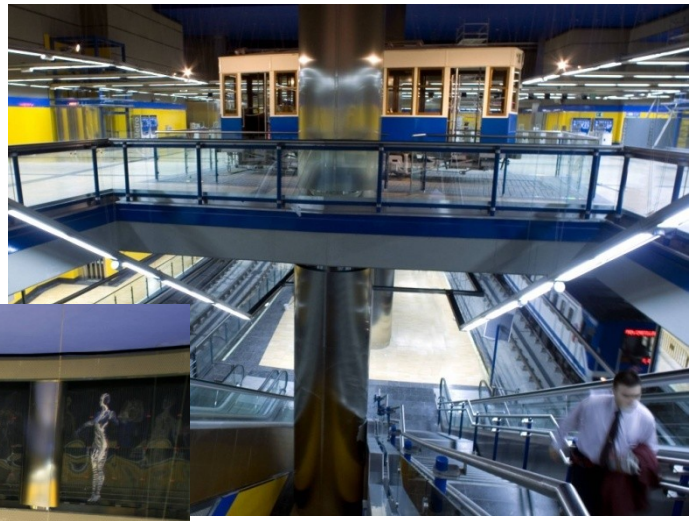
TBMs used in Metro de Madrid and M-30 have achieved extraordinary performances with up to 400 – 500 m / month

4. Key factors and lessons learnt

CONSTRUCTION METHODS ESTABLISHED BY THE MANAGEMENT TEAM

METRO STATIONS AND SHAFTS – CUT AND COVER

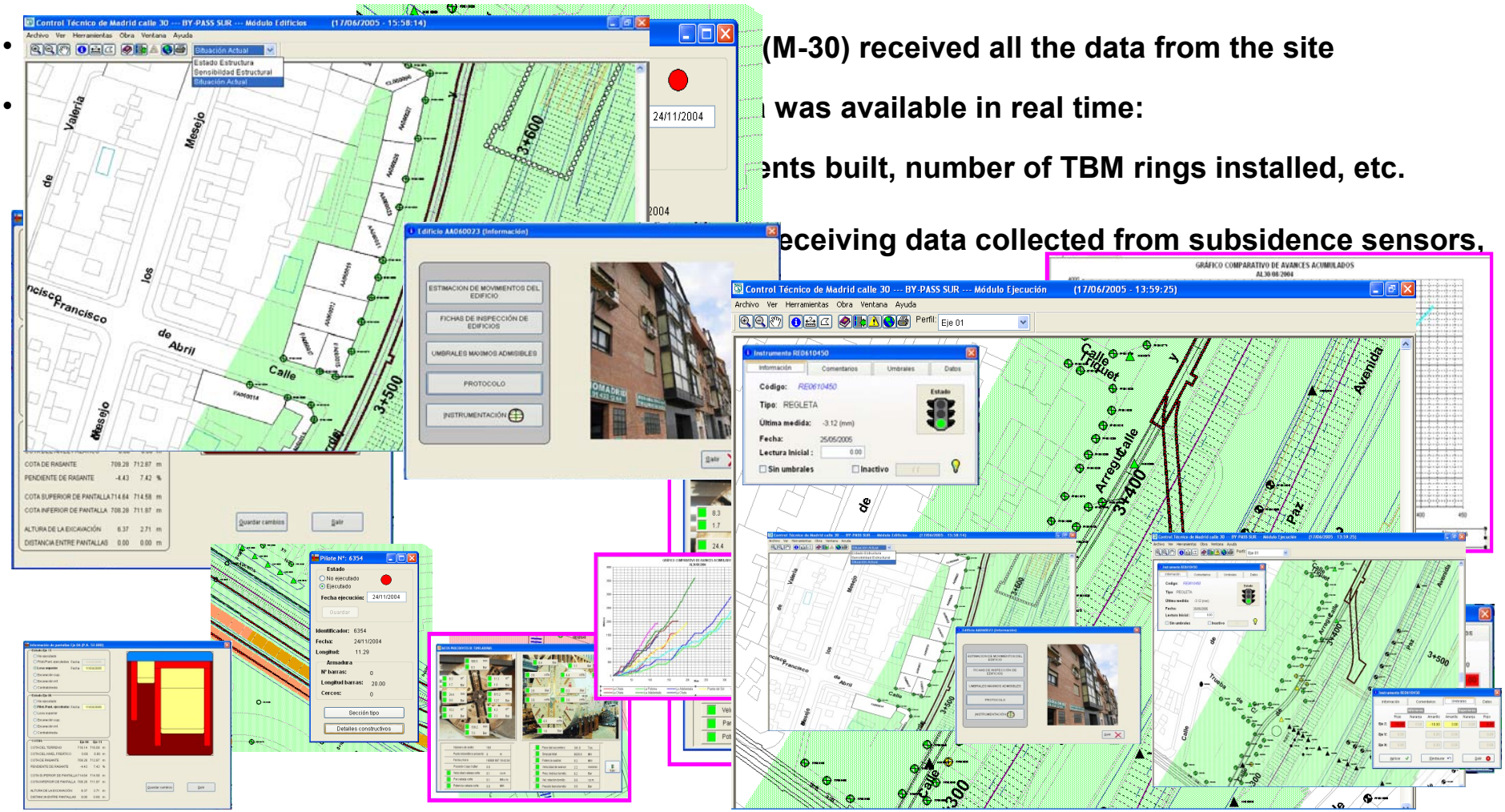
Stations built using diaphragm walls: inexpensive and safe, but also wide, bright and attractive for the user



4. Key factors and lessons learnt

MONITORING AND CONTROL IN REAL TIME

- (M-30) received all the data from the site
- was available in real time:
- ents built, number of TBM rings installed, etc.
- eceiving data collected from subsidence sensors,



4. Key factors and lessons learnt

WORLD BANK REPORT – IMPLEMENTATION OF RAPID TRANSIT (2000)

REASONS TO EXPLAIN MADRID'S SUCCESS

A. General reasons

A1.- Full commitment at regional political level (President of Regional Authority, Minister of Public Works), ensuring project financing, on-time payments and full confidence from the contractor of getting a profit.

A2.- A small and highly experienced project management team (6 Civil Engineers) with full power both for technical and financial on-the-spot decisions.

A3.- Contract procurement based not on the cheapest bid, but on sound technical and experience reasons, with the construction method specified by the administration (i.e.: EPBM).

A4.- Fair prices allowing construction and supplier companies to have a normal profit in the projects.

A5.- Strong involvement and direct regular presence in the field, of top management officials.

B. Reasons for specific cost reductions in civil works

B1.- Use of twin track single tunnel, with extensive use of EPBMs.

B2.- Strong geotechnical supervision monitoring.

B3.- Standardised station design concept.

C. Other cost reductions: equipment, rolling stock, design, supervision and management

5. Conclusions

1.- Decisions made in 24 hours

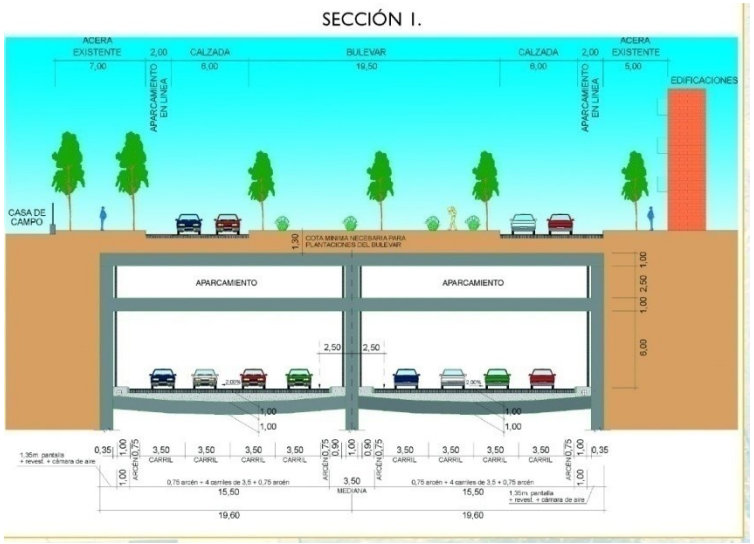
2.- Project management done directly by the City Council management team and supported by experienced engineering firms

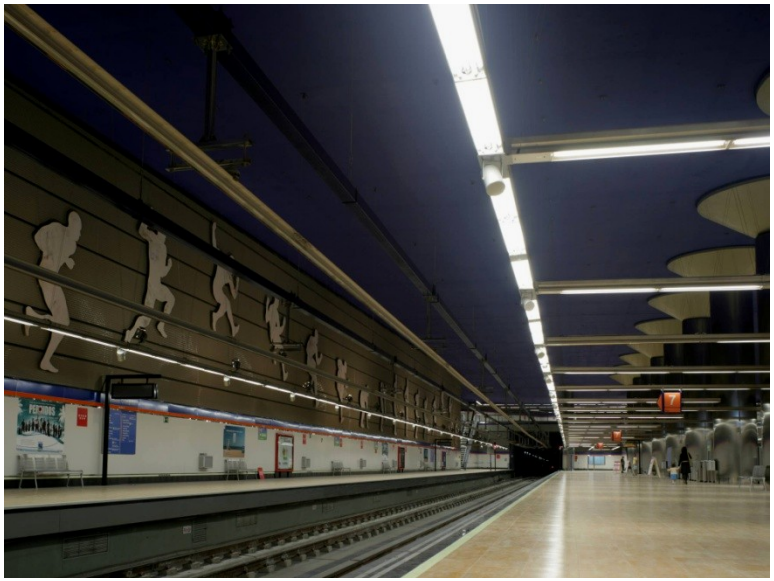
3.- Selection of construction methods

4.- Solving disputes before they arise. And when they do arise, solving them at a technical level

5.- Safety before cost and time

6.- The use of extremely powerful tunneling machines





THANK YOU FOR YOUR ATTENTION