

The Building of Present Day Madrid

BUILDING OF PRESENT DAY MADRID

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Miguel Aguiló




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Building is a fundamental mover for the advancement of society. In other words, building means contributing to the well-being of our fellow citizens and this noble enterprise is the work of the companies that today make up the ACS Group, some of which are over 140 years old.

The previous books in this collection on infrastructures showed a singular view of the subject, without losing our sector's traditional focus, i.e. grouping each volume by the type of works studied. With a more humanist than technical gaze, each book described what humans, with their capacity for innovation and creativity, have built to join, improve and progress throughout history.

Having completed this stage, the subject area of the collection has been reorientated to the very essence of the activity, by analysing the impact of what has been built on the places humans mainly inhabit: where they are born and die, where they work and rest, where they move and amuse themselves. In short, in the cities where they live.

Madrid is the city chosen for this new book, which assesses the contribution of architecture and engineering to its physical, economic and cultural transformation over recent decades. It is interesting to note through the evolution of its built landscape how an anodyne European capital of the mid-20th century has become, in a relatively short space of time, a dynamic, cosmopolitan metropolis. How it has become a city full of life, exciting and plural, open to everyone.

I am convinced that this book will give you a closer view of my city, to which I feel profoundly bound and which I am proud of having been able to aid in its recent development.

Florentino Pérez

Chairman of the ACS Group

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1 | Introduction

After a series of nine books dedicated to different types of civil works – dams, ports, roads, electricity, bridges, outstanding buildings, footbridges, the high speed railway and roofs, plus the last volume summarising the legacy of Spain's recent construction experience – it seems appropriate to reorientate the collection. The subject will not change, but the way of presenting it will. Architectural and engineering works constitute all that built and will continue to be its main theme.

As of now, the subject of the collection is arranged by cities and the city of Madrid was selected for this year, 2013. As in the previous books, we believe that this one will be more interesting when presented in the voice of the real leading players, before works arranged by type and time of city construction.

Beyond legislation, regulations and plans, cities are the fruit of sustained efforts by many professionals who have dedicated their work to their transformation and operation. As such, access will continue to be given to those who have played a significant role in building present-day Madrid. This attempts to avoid routine assignment of what was built to the governor's or works owner's impulses. These figures are only mentioned in a few cases, such as King Carlos III, who was a real developer and creator of a large portion of monumental Madrid, and a few recent mayors, who have brought about a new way of understanding Madrid and the city's substantive mobility.

To order the material, the structure of a recent book by the author on building activity has been followed [19]. Its content is sufficiently theoretical and general as to take in the different built realities capable of configuring cities belonging to other scopes and cultures.

Building is an essential urge for human beings, representing a primordial embodiment of our way of being in the world. So it has changed and will continue to do so as our world advances. Over a timeless base of needs, urges and utopias, what has been built is embodied in a variety of forms: it appears humble or arrogant, mean or generous, timid or daring, depending on the site's cultural accent and the time in which it is produced.

As an essential human action, building plays a fundamental role, going way beyond mere physical practicality, connecting with the deepest roots of man's existence. Direct products of the will to extend are the path as a mark of the repeated use of the same routes and the bridge as stable surmounting of an obstacle. Similarly, the will to build up leads to the tower for observation and defence, and the roof and wall as protection against the sun, rain, wind and earth.

To adjust his rhythm to that of the world, man regulates water with dams, conducts it with canals, cleans it in treatment plants and stores it in tanks. He channels it for irrigation and passes it through turbines to get power. He uses rivers and roads, together with ports and the sea for mobility and to transport goods. He delimits and occupies certain areas, divides them into plots and connects them with streets and squares and, with this, he develops the city and arranges his surroundings for coexistence [19:10].

The products which emerge from this will cannot be summarised or understood from the point of view of mere utility, nor is it enough just to appreciate their beauty. As products of construction are an essential part of life, they transcend their function and emerge as images in their process of development: they occur in space but are equally bound to time. Building is specifically involved in the process of development, and not just due to the extended lifetime of its products, the time its processes take and the evolution of its techniques. The defining demands of the functions of what is built also change, often being more lasting and surviving alone. And everything built is in or conditioned by the city, as the place where all the results of this essential action come together, meet and condense [19:17].

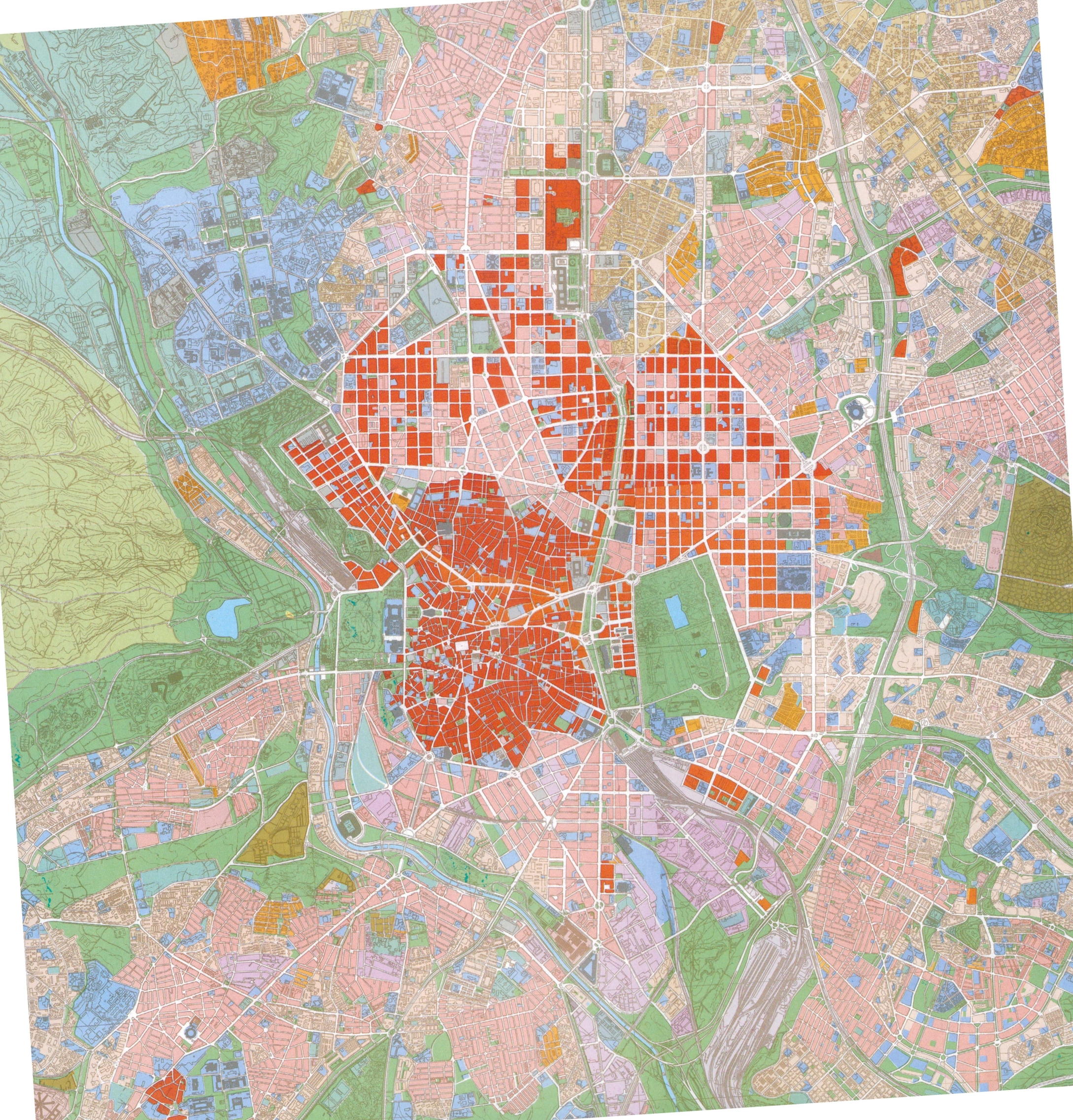
But every city is unique and needs a particular way of approaching its hidden aspects. In the case of Madrid, the main obstacle is the very proximity to the city itself and the authors or leading players in the latest changes. This proximity is, in turn, the reason for its choice as the first city to be the subject of this new focus for the collection.

On the other hand, a great deal has already been written about Madrid, and probably about any big city. The extensive bibliography, not in this case about the city in general, but rather related to its construction, is completely unencompassable, although no less necessary for this [111], [180], [133]. That made it essential to reduce or, to say the least, customise the approach to selecting the subjects and works on which the discourse is to be focused. It also, inevitably, makes it essential to cite the most appropriate bibliographic references to move forward with the necessarily schematic content of the text.

All this means the book is divided into nine chapters. After this introduction, Chapter 2 is on the Memory of what has been built, as a sketch of the process of developing the pre-existing urban assets encountered by recent constructors as the essential framework for their actions. The next four chapters cover the aforementioned essential actions to achieve mobility with roads and streets, rise up with structures, span with bridges and control flows of water and resources. Chapter 7 is entitled *Using and Enjoying the City* and deals with the synthesis and representation of the aforementioned and what is "not built-up" as an inseparable part of the city's construction. The eighth chapter contains ACS's implementations and the ninth the bibliographic references used and the indices.

In this book, the collaborations requested of the leading lights in current construction of the city called for explicit compositions, as these deal with reflections on their own or highly related actions, often over a long period of time, during recent years and not with specific works as in the previous books. Again this presents the difficulty of proximity to the subject, but it provides a very clear image of how you make a city, which only they can offer.

As in previous books, I would like to thank the Civil Engineers Antonio Sarabia and Guillermo Vázquez for their usual collaboration and the Forestry Engineer Santiago González Alonso for his help in reviewing the texts, as well as the Architects Patricia Hernández Lamas and Andrés Loiseau and the Civil Engineers Jorge Bernabeu, María José Ramiro and Óscar Castro for their assistance in obtaining, choosing and preparing the illustrations.



2 | Memory, Recent Plans and Works

Spain's New Image

The change which has occurred in Spain since 1975 has been a profound change, a radical transformation, a historical rupture. Seat of government, home of the country's big banks, of the stock market, the main means of communication (press, radio and television stations) and of numerous domestic and foreign companies, Madrid, the state capital, the country's main financial and commercial centre, projected the image of the new democratic Spain.

Juan Pablo Fusi concludes his 2012 essay, *Minimal History of Spain* [101] with Madrid, and its recent changes appear as a summary of the country's current image. He immediately supports this metonymy with a concise and systematic list of those changes:

Madrid's urban rebirth since 1975 has been formidable: new museums (Reina Sofía, Thyssen-Bornemisza), new university faculties and schools, libraries, auditoriums, hotels, large shopping centres, numerous underpasses, new metro lines, parks, large ring roads, new railway stations and air terminals, expansions and new neighbourhoods, spectacular buildings (Picasso tower, Europa tower, Puerta de Europa I and II, Barajas Terminal T4, the Caja Madrid, Cristal, Sacyr and Espacio skyscrapers). With ten towns with over one hundred thousand inhabitants (Móstoles, Alcalá de Henares, Fuenlabrada, Leganés, Alcorcón, Getafe, Torrejón, Alcobendas, Pozuelo and Rivas-Vaciamadrid), the Region of Madrid had the highest per capita income in Spain in 2007 [101:267].

Madrid, compendium and leadership

In turn, the economist José Luis García Delgado saw in the Madrid of 2006 *the best expression of a Spain more open to the world, after completing a long process of secular modernisation*. He supported this with macroeconomic data; *Madrid supplies 18% of GDP and its income exceeds the Spanish mean by 35%* and endorsed it *with an unbroken series of projects and implementations which give new relief and dimensions to its characteristic features* [102:33].

Its traditional central position in the radial road, rail and air route structure *is secured with an expanded airport with a continental scale logistics centre. At the same time, its powerful institutional cultural and scientific network adds to the concentration of large financial and industrial companies to assure an open space, a polarising focal point that drives productive activity on the national map*.

In contrast to the process of introversion and absorption of some other autonomous regions, *Madrid has stressed its extroverted, cosmopolitan nature*. It has also stressed *the integration of the central city and the peripheral areas and towns* in a bound of nearly 50 km in radius marking an urban continuum, *far from the disintegration of the first settlements*. Above all, *it continues to stand out due to its vitality… It has started to increase its population after years of decreases and has reduced the trend to ageing in its demographic structure* [102:35].

Construction and image of the city

The consideration of all this as *urban rebirth* leads to two key ideas; it was not like that before and it does not involve isolated implementations. Madrid has seen significant ups and downs as a city and they need to be pointed out to approach its current condition[1]. To do this you need to start from its territorial consideration, as no city can be understood as an abstract projection of its city centre, much less Madrid.

A few no less important nuances are also pointed out. The role of the new constructions clearly plays a leading part. The historian did not choose the undoubted political, social or economic changes to shape this new image, but rather the changes in *what was built*. The economist too mentions the important role of built networks alongside the institutional ones as support for leadership. In addition to spectacular buildings, on which everyone's gaze always falls, both authors also mention the main Public Works, which have an undoubted effect on the city's operation and image.

The role of communications routes and transport is appropriately highlighted among the implementations, as, in fact, they represent one of the outstanding features of the city and its renewal. All of this is necessarily related

[1] The attention Fusi pays to the cities and in particular to Madrid in his concise essay, combined with the intention to avoid converting this text into a history of the city, led to the decision to choose it as a basic source of the few general historical references in this book.

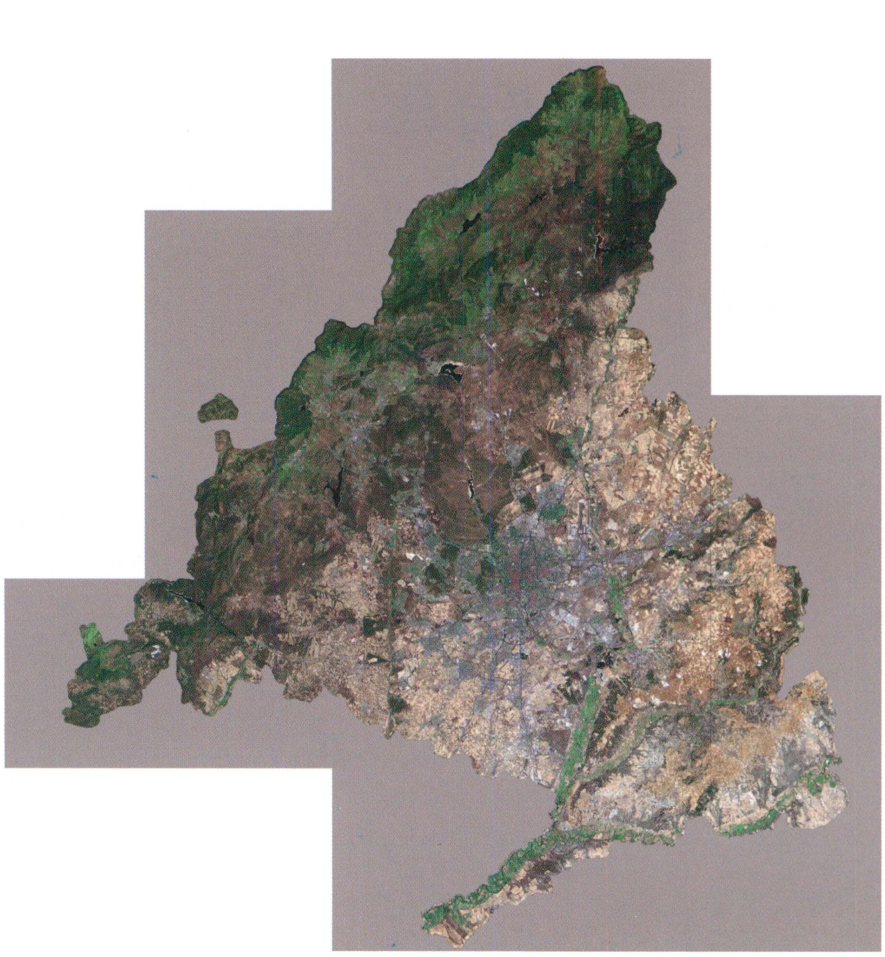
to the new neighbourhoods and significant towns and cities around it, which are also mentioned as essential participants in the capital. There can be no better compendium to begin this essay.

Madrid's territorial base

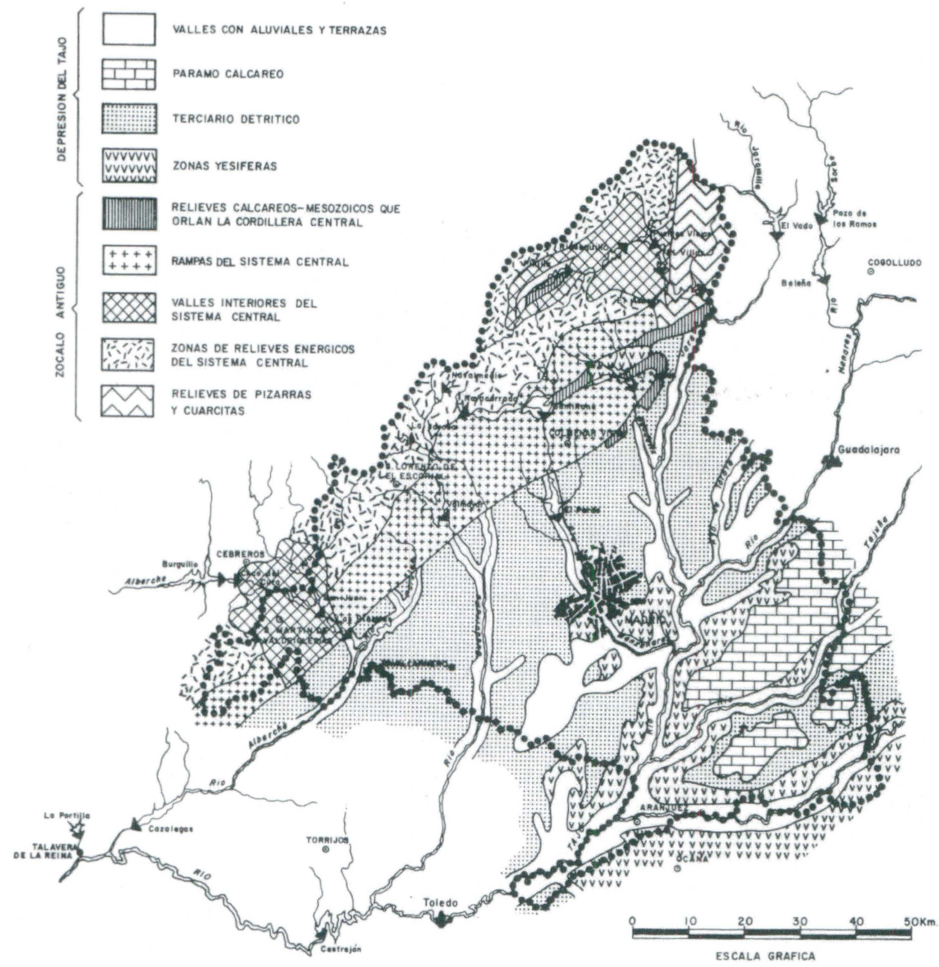
The abundance of what has been built in Madrid makes the task of understanding the city's territorial base more difficult, but it would not help much to turn to an analytical description of the morphology of the terrain, the rivers, the vegetation and so on as if what was built did not exist. As a city, Madrid is an indissoluble combination of pre-existing assets, constructions, people and behaviours and separating them is of little use. It is more promising to analyse how Madrid continues to be laid down and established, in close relationship with terrain that was never virgin.

Fernando de Terán signals an important initial idea: Madrid decisively conditions its immediate space and gobbles it up as it grows spatially. However, *this is not a ravenous organism making something valuable disappear*. This organism takes in and invigorates what is empty, at the same time as adding value to what has a chance of life. The city gives meaning to the territorial spaces surrounding it. The extension of the city does not destroy, rather *creates and gives life to spaces or areas that were empty before*. It also takes in existing villages as new neighbourhoods, giving them access to the centre's benefits and privileges [224:342].

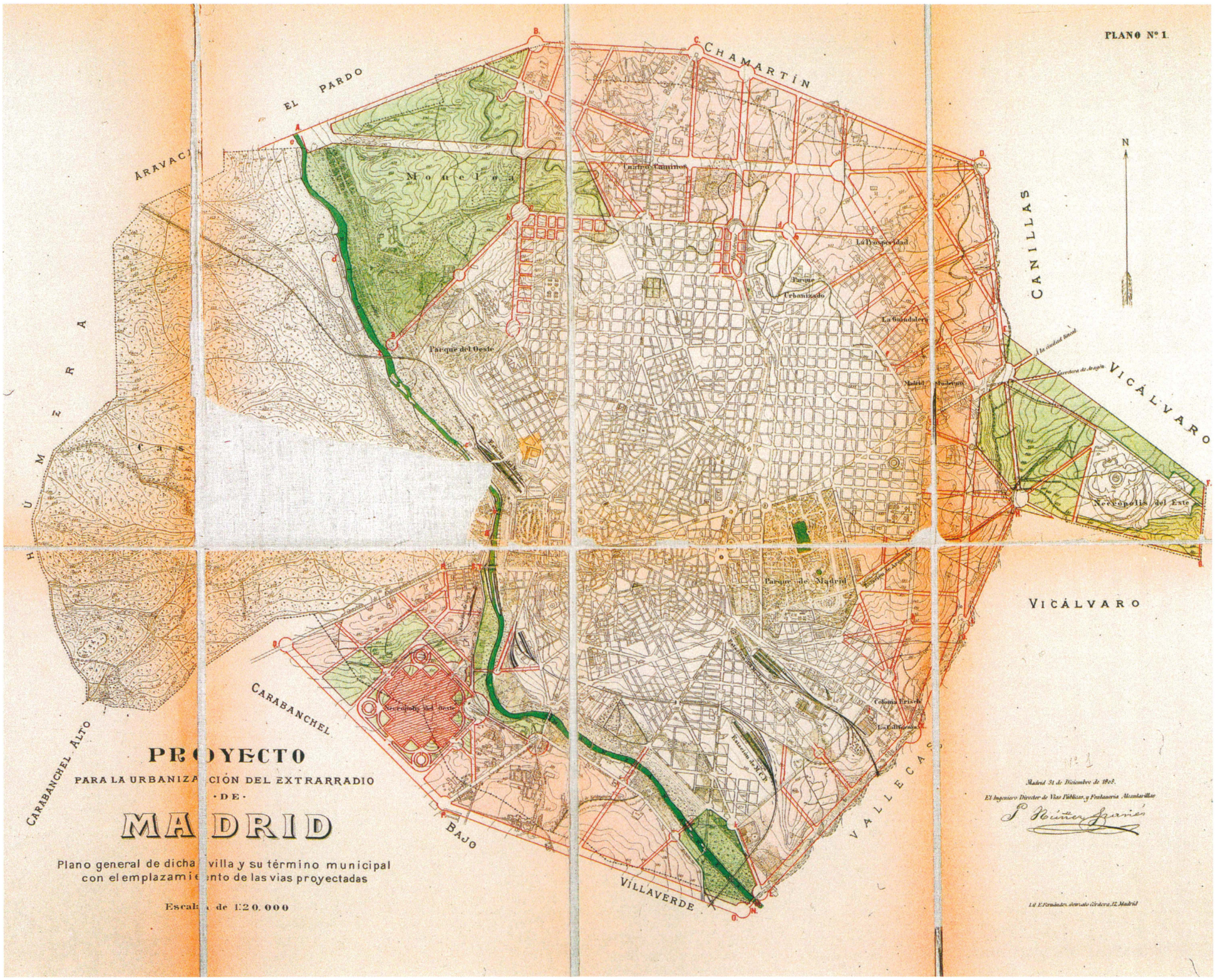
The geographer José Estébanez concentrates this task in time and extends it in space: *Madrid is an urbanising city which modifies the province's rural space in incredibly short periods of time, probing ever deeper into the rural spaces of bordering provinces* [86:524].



Orthophoto of Madrid

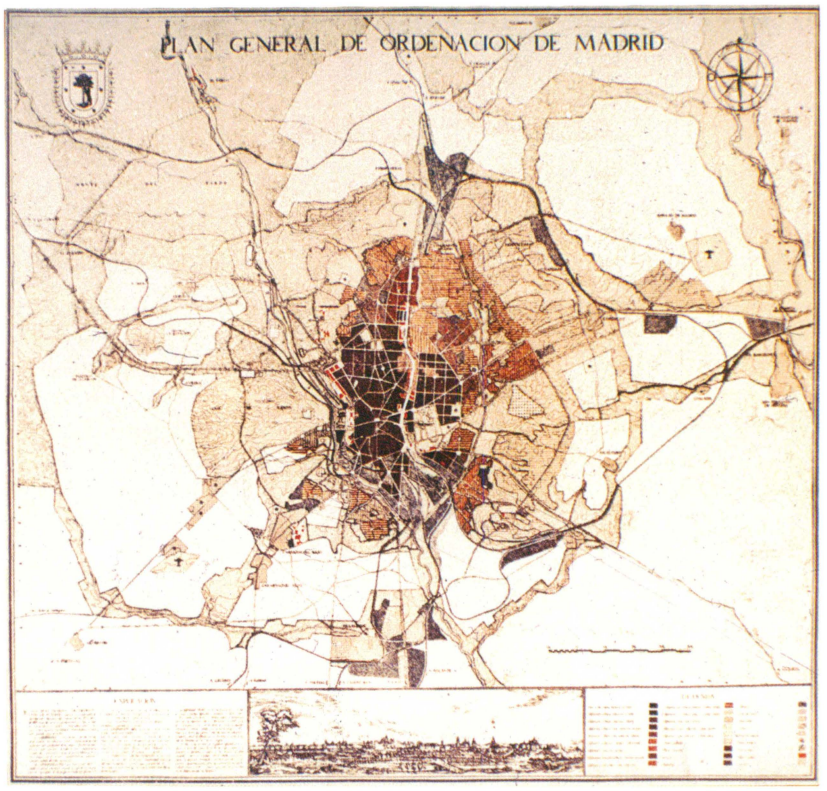


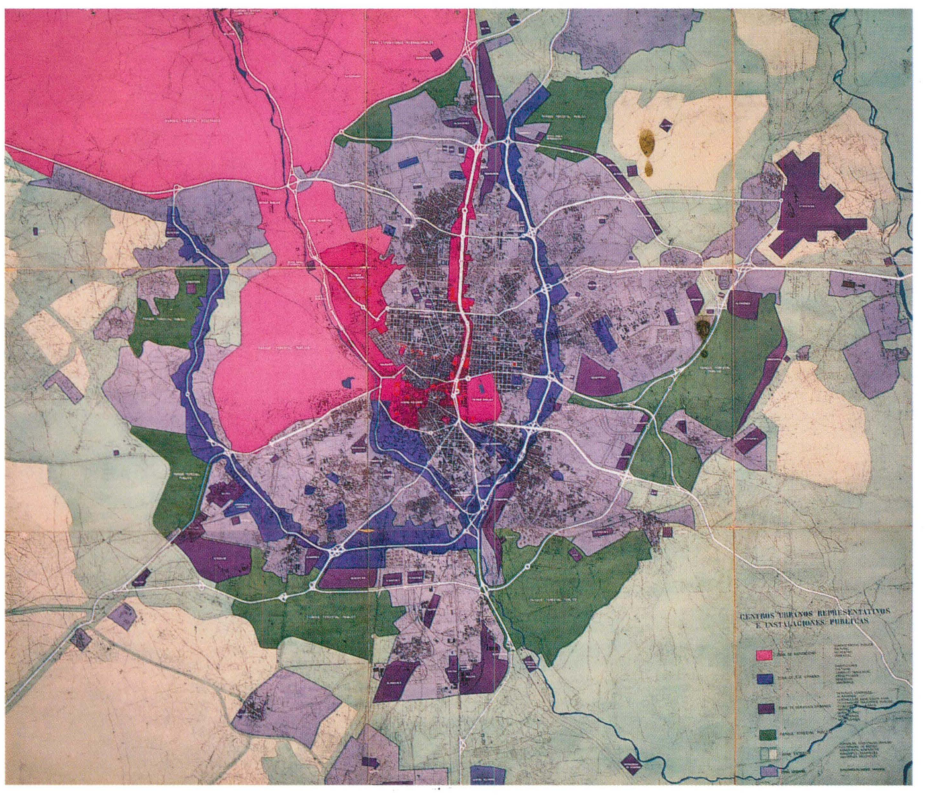
Geomorphology of Madrid



Urban development project for Madrid's outlying area by P. Nuñez Granés, 1910

The town planner José María Ezquiaga, however, indicates three large steps or jumps of organisation and scale in *the modern transformation of Madrid Metropolis*. First, the formation of the metropolitan area in the 1960's and 70's, when the city's traditional continuous, compact limits were exceeded. Then the *polynuclear region city*, on surmounting the simple relationship of the other metropolitan centres. Finally, *the post-metropolitan territory, initiating fractal transformation of a territory shaped around great axes of metropolitan development* [89:37].







Above left, Madrid General Urban Development Plan, 1946

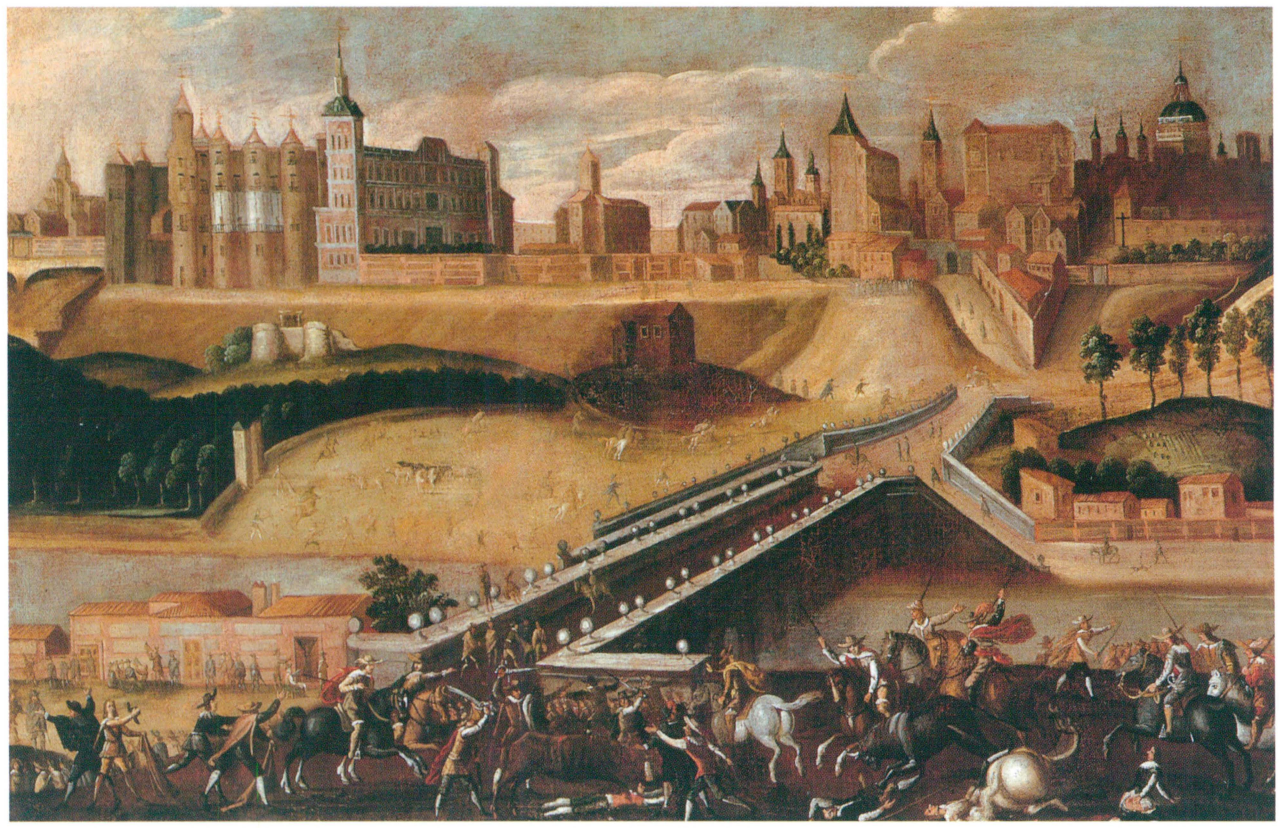
Above, Madrid General Urban Development Plan, 1963, representative urban centres and public facilities

Madrid metropolitan region, 2004.
Source: Local Government Ministry of the Environment and Territorial Development

Pre-existing assets, La Cornisa

Before continuing with the story of the transformations and their hypothetical division into periods[2], it is appropriate to remember the substrate on which the changes act. The city's most noteworthy existing asset is the rim above the river. The city walls were supported on the "scarp" as a natural defensive element. The construction of the Alcázar fortress there led to the consideration of the rim, or Cornisa, as one of the most significant elements in the raising of the city and for a long time it was the source of its most characteristic representations [186], [54].

Madrid's old Alcázar fortress occupied a strategic position on the scarp formed by erosion on the left bank of the river Manzanares. After it burned down on Christmas Eve 1734, Juan Bautista Sachetti laid out the new building to fit in with the scarp following the axis defined by the old palace and the adjoining fortifications. The new palace occupies a larger area, with a more representative than defensive role and it defines a public space with the features of an edge, a level area glimpsed from the plain of the Manzanares.



View of Madrid from the Segovia Bridge, 17th century



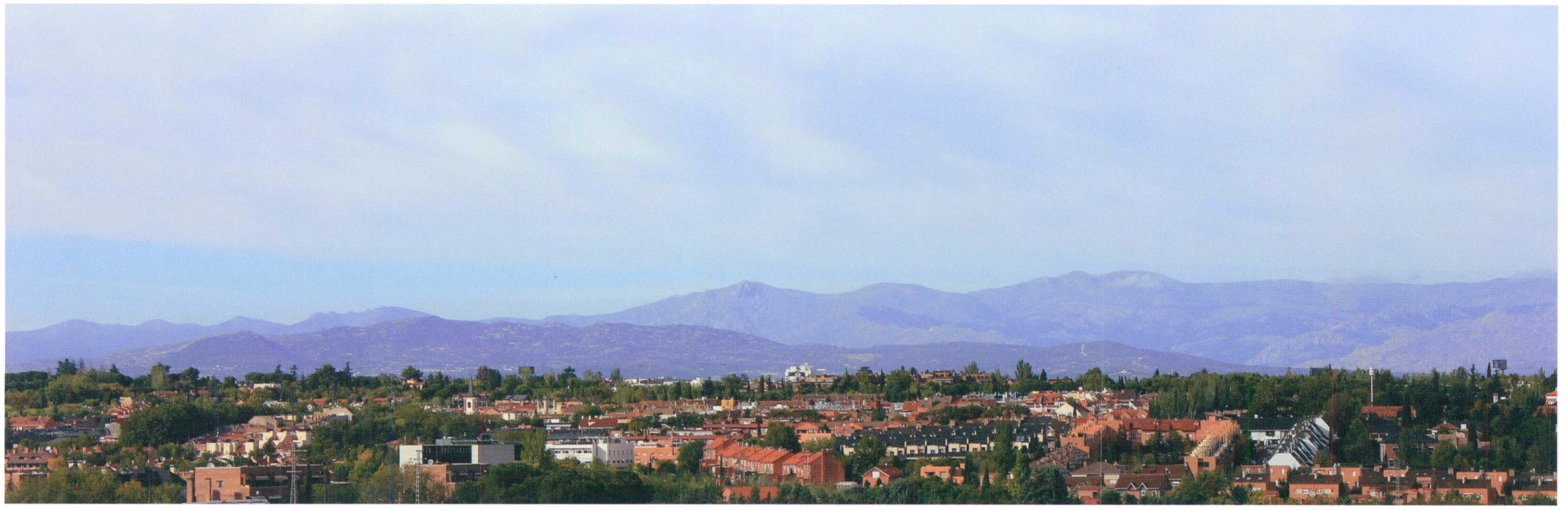
View of Madrid, A. Wyngaerde, 16th century

[2] The socio-cultural reading of history indicates some demographic and town planning "leaps" determined by political decisions associated with centrality which are considered less relevant in the "construction of Madrid" as tackled in this book. Tomás Rodríguez Villasante, for example, points to three times of great impetus for the city: King Felipe II, from the Restoration until the time of the dictator Primo de Rivera and the industrial revolution of the 1950's [207:648]. These are undoubtedly important times, but the footprint left as heritage in the city is considered less relevant.

That position favours views to the west and towards the Sierra de Guadarrama mountains. This is a view which, according to Juan Miguel Hernández León, forms a reference for distant nature for the city of Madrid. That constant is extended by the old Paseo de San Vicente and the rim of the current park, the Parque del Oeste. The steepness of the top part of the rim earns the palace the title of "despeñadero", or promontory, and its position at the edge of the city is a powerful determining factor for subsequent layouts [129:219].

Urban irradiation

The subsequent extension of the wings of what is now the square named Patio de Armas and the later prolongation towards the basilica of San Francisco el Grande, planned by Silvestre Pérez, reinforces the North – South axis. An axis was planned perpendicular to this, running from the eastern façade to the Puerta de Alcalá gate, which would end in the Plaza de Oriente square and the Teatro de la Opera. However, those first steps already mean it is necessary to introduce Madrid's nature as centre and capital to understand its motivations and importance.





Top, Current view of the Sierra de Guadarrama

Bottom, Current view of the Royal Palace

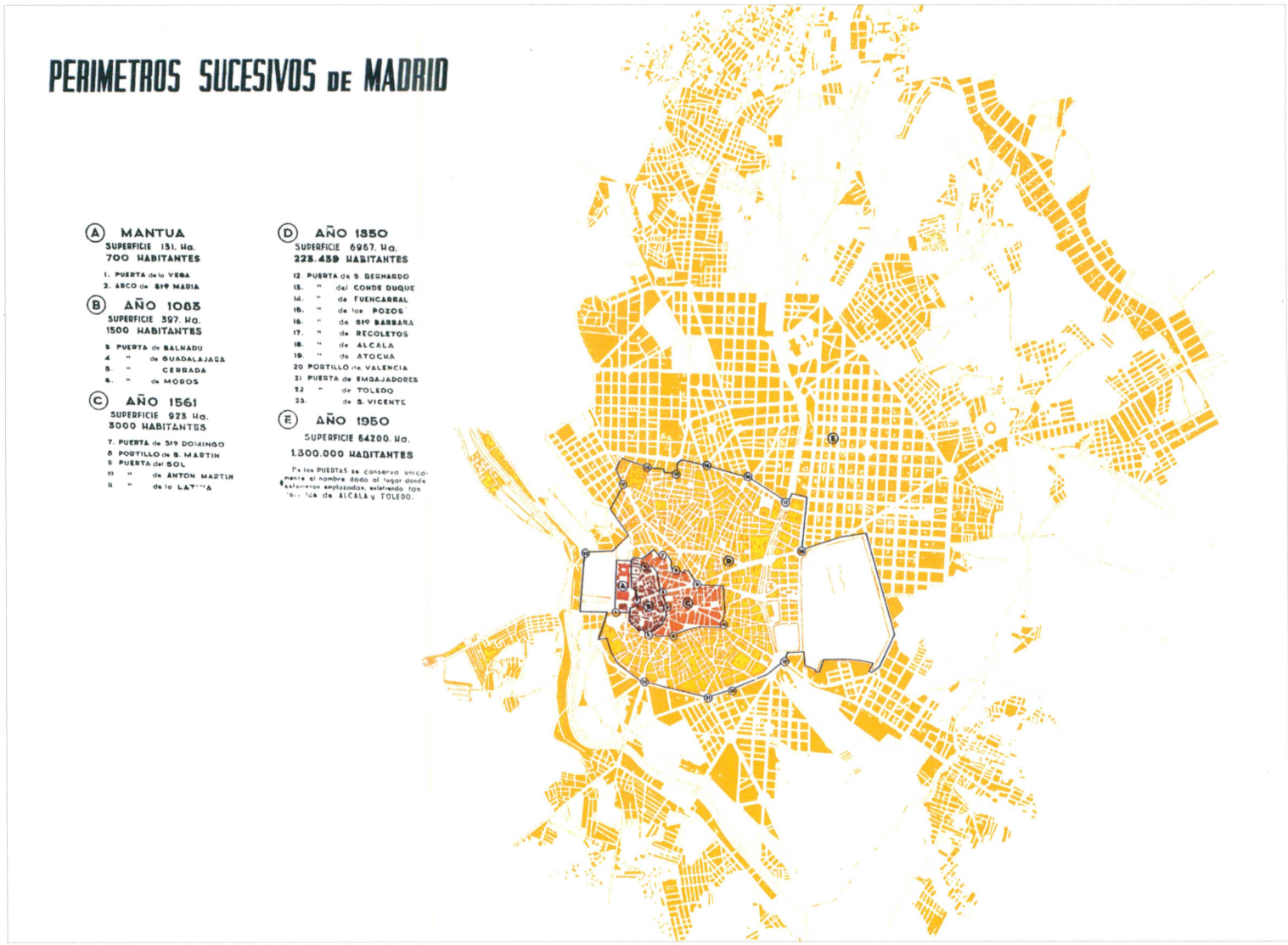
Capital and Centre

Indissolubly linked to Madrid's status as capital is its markedly central nature. It is the geographical, political, financial and, more recently cultural and service centre of the country and the region. The ports on the peninsula benefit more or less and have better chances of development depending on the closeness of their position and the quality of their accesses to the capital [8:78]. The city itself has a centre which has not been particularly active or dynamic for some time, but it continues to benefit from that status.

All cities are characterised by a significant number of inhabitants with a certain level of concentration. To calculate these two figures, though, you need to specify the spatial area to which they refer and this leads directly to the impossible matter of fixing or setting limits to the city.

Fixing the limits

It is well known that the action of delimiting, marking an area to fence it off from the rest, is essentially linked to the creation of the city. Mankind transcends what already exists by erecting a fence, a horizon that enables him to filter, reject and order artificially what comes to meet him. It is also well known that, from olden times, its walls become an element that defines the city. In the code of law of King Alfonso X, the Wise, the Partidas or parts, a city is any place enclosed within walls, and for many centuries no city could be conceived of without its respective walls[3]. Even when there was no fence, urban districts were known as enclosures in Spain, and districts outside the perimeter were known as outlying [6:211].



Successive perimeters of Madrid, 1950

[3] Part 7, title 32, law 6.

The fact is, though, that citizens know a part of their city and relate to it more strongly than to any other place, without knowing its limits. You do not even need to have been born or be living there for it to form part of your existential space. It is something you carry with you with pride and is born from associations between your memories and intentions and the place where they occur, the place where you lived or live.

Being and belonging

In Madrid, that feeling is especially significant and has particular characteristics. It is less bound to having been born in the city or living there than in other places. Mayor Tierno Galván used to say that the verb which best defines the city is *"to be"*, indicating situation: *In Madrid you are there and on top of that you are*. And he hammered it home with: *We residents of Madrid are here and consequently we are* [227:20].

This bond holds to something rather poorly defined, defying attempts to isolate it. It always has some very clear references, though: a degree of population concentration, a hierarchical setting, a centre of reference, some limits, even if they are imprecise, and a culture opposing the rural. A rather common option for defining population and concentration is to refer them to the municipal area, although administrative urban limits are irrelevant to explaining the city's true influence.

The old designation of metropolitan area, previously used to refer to the real population of users of the central city, has rather fallen into disuse. The concept of the Urban Area is used more these days, not so much to define limits, but rather as a reference to other municipalities of a certain significance located around it, the heartbeats of which are linked to it. This "significance" is applied including a series of towns and cities of a certain population within each municipal limit. The closeness and bond defining neighbourliness as compared to mere adjacency can be estimated from the means of public transport connecting them. This also leads to the idea of a hierarchical setting merely by looking at the number of towns and cities linked to the main or largest city in terms of population.

Concentrated population

In addition to the difficulty in fixing the limits, these numbers are always relative and need external references for the figures to take on some meaning. Given its status as a capital, one necessary reference is biggest cities in the country and another, if required, could be other capitals in the world or in related countries.

With respect to other Spanish cities, Madrid's population is practically twice that of the second largest, Barcelona, and around four times that of the next two, Valencia and Seville. However, the number of municipalities in Madrid's Urban Area is one third of Barcelona's, although the relative weight of the latter in its area is around one third, compared to one half in the case of Madrid.

Spain's largest cities in 2010

		Population in 2010	% Incr. 2010/2011	UA municipalities	Area, km²	Relative weight in UA, %			Density inhab./km²	
						Population	Area	Employment	City	UA
1	Madrid	2,957,059	10.7	52	606	54.3	21.0	65.1	4,880	,002
2	Barcelona	1,505,326	7.6	165	98	32.3	3.0	47.3	15,360	,002
3	Valencia	746,612	8.4	45	135	51.9	21.4	59.1	5,530	2,304
4	Seville	702,521	0.2	24	141	54.7	9.2	67.6	4,982	,898
5	Zaragoza	610,976	10.5	15	969	90.7	43.9	88.6	631	,338
6	Malaga	534,207	6.4	8	395	60.3	48.3	73.6	1,352	1,095
7	Murcia	367,189	20.2	10	886	68.8	72.0	76.4	414	,393
8	Palma	346,720	16.7	8	209	74.2	22.8	81.2	1,659	,655
9	Las Palmas	364,777	5.1	4	101	71.0	38.7	80.5	3,612	2,289
10	Bilbao	353,943	-0.2	35	41	38.8	8.2	46.3	8,633	1,877
	Mean value		12			59.7	28.9	72	109,101	,985

Source: Spanish Ministry of Development, 2010 [177: 235] and author's own preparation.

Dividing the population by this relative weight gives an approximate idea of the total population of the Area: 5.45 million in Madrid's Urban Area, compared to 4.66 million in Barcelona. The same calculation with areas gives a total figure for Madrid's Urban Area of 2,886 hectares and 3,266 hectares for Barcelona. Dividing the population by the total area gives densities of 1,887 inhabitants/hectare for the Madrid area and 1,427 for Barcelona. This calculation is repeated for the ten cities in the last column, placing Valencia in first position and Las Palmas second as the most densely populated Urban Areas.

In any case, density is definitely a misleading parameter, as it deals with mean values, which can result from combining very dense areas with neighbouring large empty spaces. Even within the city itself, the densities of each neighbourhood can be very different, showing the same phenomenon.

European cities

In relation to other European cities, Madrid is in third place[4], after London and Berlin, with Barcelona in eleventh and no other Spanish city in the top twenty. The difference to the second, Berlin, is smaller than to the fourth, Rome, which in turn is similar to the fifth, Paris. A quick simplification of the figures would show London as Europe's most highly populated city, with a population around twice that of each of the next three; Berlin, Madrid and Rome.

Most populous cities in the European Union in 2010

Position	City	Country	Population	Position	City	Country	Population
1	London	United Kingdom	7,556,900	11	Barcelona	Spain	1,621,537
2	Berlin	Germany	3,439,100	12	Munich	Germany	1,378,176
3	Madrid	Spain	3,255,944	13	Milan	Italy	1,307,495
4	Rome	Italy	2,743,796	14	Prague	Czech Republic	1,285,995
5	Paris	France	2,257,981	15	Sofia	Bulgaria	1,240,000
6	Hamburg	Germany	1,802,041	16	Birmingham	United Kingdom	1,016,800
7	Vienna	Austria	1,757,353	17	Cologne	Germany	995,420
8	Budapest	Hungary	1,741,041	18	Naples	Italy	963,661
9	Warsaw	Poland	1,710,055	19	Turin	Italy	909,205
10	Bucharest	Romania	1,677,985	20	Marseilles	France	852,395

Source: European Union

If you look at Urban Areas, Madrid remains in third place with a population around half that of London – which continues in first place – but second place is now held by the Paris Area. Barcelona, in turn, is now in sixth position, very close to the two above it; Milan and Essen-Ruhr.

Capital status, Court and city

Madrid shares its status as capital with Europe's ten most populous cities, among which is Hamburg, which has the pride of calling itself a city-state. However, neither that status nor its pejorative use from provinces or in relationships between Autonomous Regions and the State capital are things which especially concern Madrid's residents. When Madrid is said to have decided or done something, neither the city nor its citizens take it personally.

At the start of the 18th century, there were some attempts to distinguish between the Court and the city which had no significant impact on its subsequent evolution. For Teodoro Ardemans, this meant separating

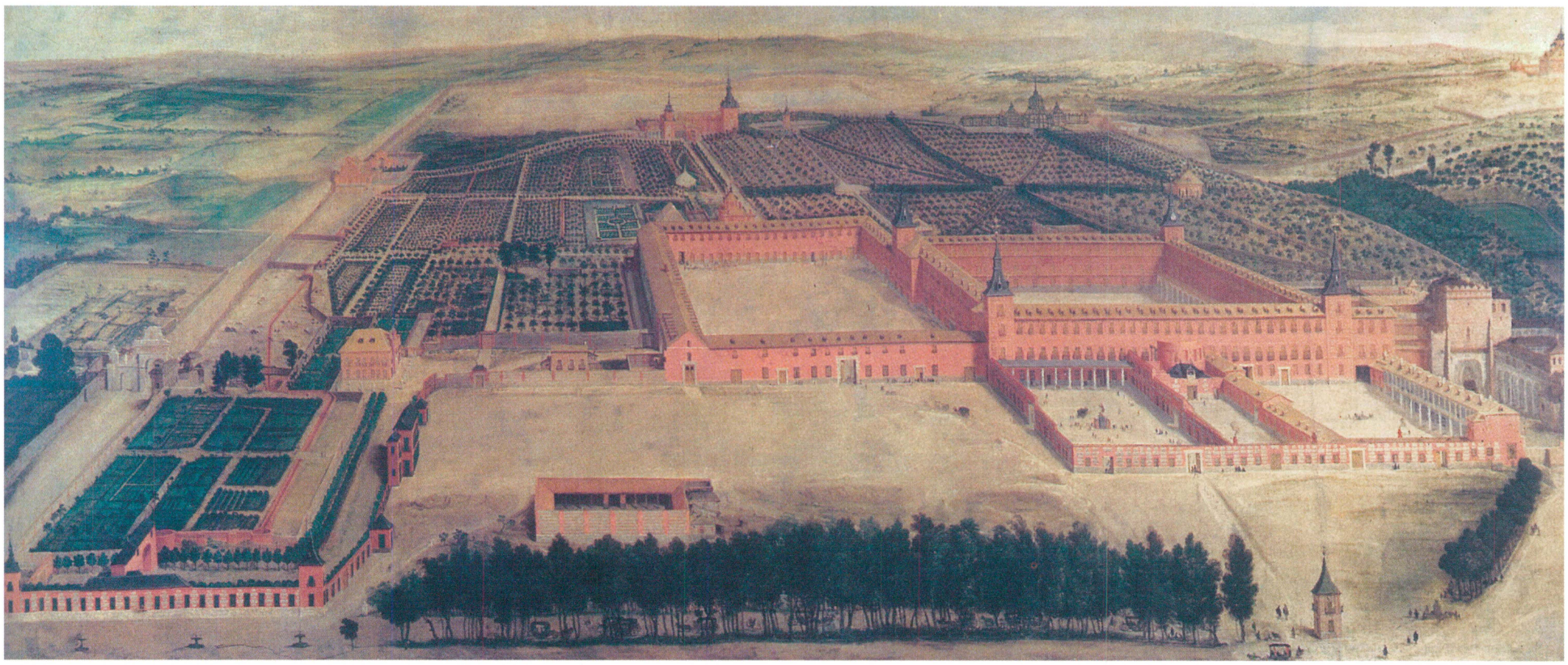
[4] Only relative terms are used here, given the differences in the populations indicated in this with those in the previous table.

Urban Areas in the European Union in 2010

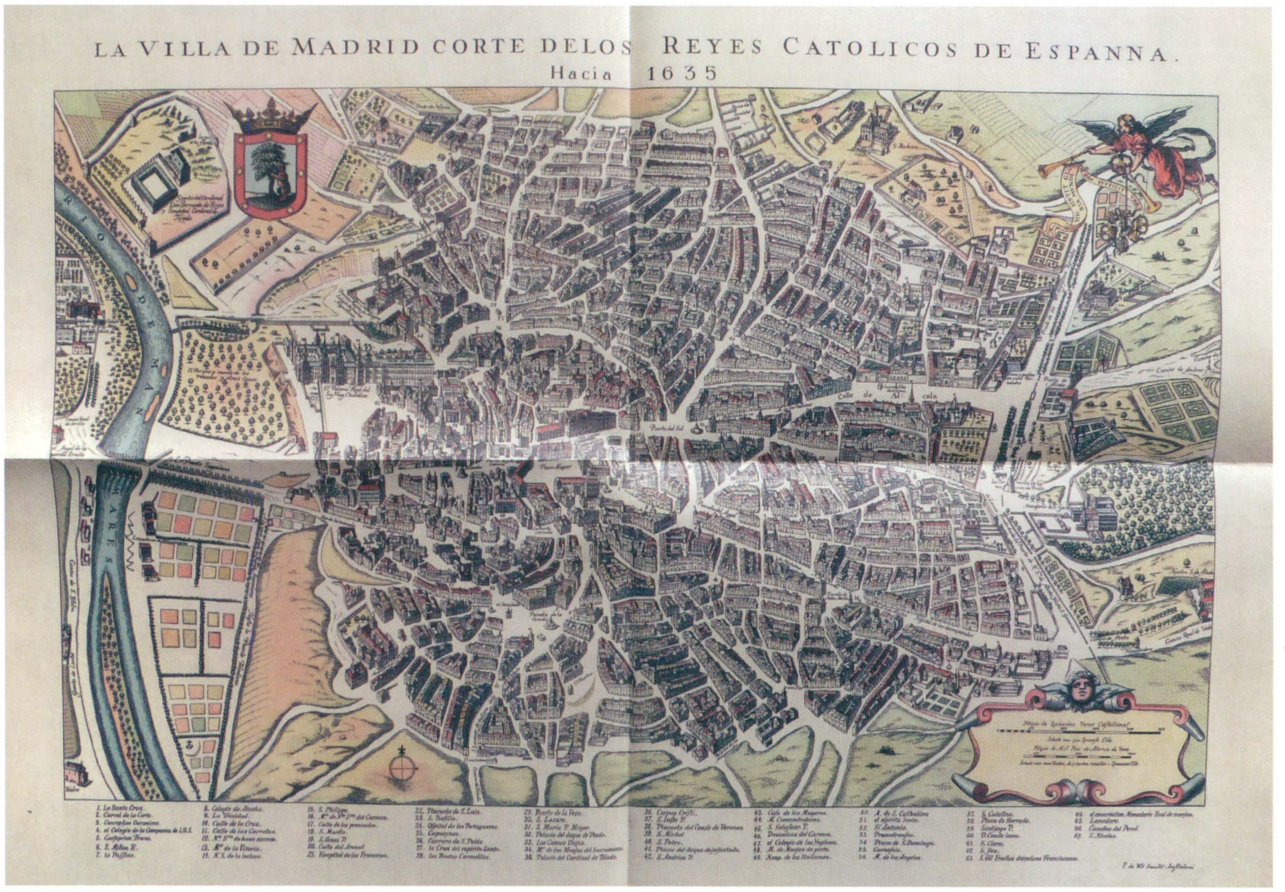
Position	Area	Country	Population	Position	Area	Country	Population
1	London	United Kingdom	12,500,000	11	Rotterdam-The Hague	Netherlands	2,900,000
2	Paris	France	10,500,000	12	Hamburg	Germany	2,625,000
3	Madrid	Spain	6,500,000	13	Manchester	United Kingdom	2,625,000
4	Essen-Ruhr	Germany	4,650,000	14	Birmingham	United Kingdom	2,625,000
5	Milan	Italy	4,575,000	15	Budapest	Hungary	2,525,000
6	Barcelona	Spain	4,500,000	16	Lisbon	Portugal	2,525,000
7	Berlin	Germany	4,325,000	17	Katowice	Poland	2,450,000
8	Naples	Italy	4,150,000	18	Warsaw	Poland	2,225,000
9	Athens	Greece	3,775,000	19	Bucharest	Romania	2,075,000
10	Rome	Italy	3,300,000	20	Munich	Germany	2,025,000

Source: European Union

from the Court what needed to be considered by Madrid's back cities, and making a certain separation in the city, including prices and land areas in these, depending on their class [30: 253]. This intention to clarify the prices of plots, though, did not take hold outside of the realm of property. Rather more generalised was the opposite posture of understanding the city as the embodiment of the Court, which took root above all in the provinces.



The Palacio del Buen Retiro, 1636-1637, Jusepe Leonardo



The City of Madrid, Court of the Catholic Kings of Spain, F. de Witt, around 1635

Madrid from El Retiro, F. J. Parcerisa



MADRID.
(desde el Retiro.)

Ballast or treasure

As the mayor Tierno Galván used to say, *We frequently fall into the error of identifying Madrid with the history of the State, and nothing is further from the truth* [227:20]. Additionally, Tierno continued, that condition does not affect Madrid's residents: *It does not appear necessary to add to the various notes defining the plurality of Madrid's image that of a capital city status which the city's inhabitants scarcely take into account and which they interpret, when they remember it, as a secondary consequence of its special historical vigour* [227:22].

Another, converted and amusing, inhabitant of Madrid, Juan García Hortelano, used to maintain that it *did not know what a city was and held town planning in scant regard*. However, he assumed, on the contrary, that *its status of being the capital* was important. According to him, it held an exceptional treasure that augmented its status as the capital: *To avoid going abroad when this big village gets on top of me, Madrid holds an inexhaustible reserve. While I can go through one of its doors I will be able, just a few metres from the Plaza de Cibeles square, to enter all realms, go from Madrid to heaven and hells just by pushing through a turnstile. Because Madrid is the Museo del Prado and whoever has the opportunity to live in Madrid, in addition to* their *city, has the chance, as long as they are somewhat cosmopolitan, of living in the capital of the universal world* [103:121].

Historical reasons for capital status

On the other hand, the historical reasons for the choice of Madrid for moving the Court in 1561 appear rather accommodating or more motivated by a degree of dissatisfaction with Toledo: Madrid's sandy soils were more suited to strolling and hunting than Toledo's clay; the existence of the Alcázar, which was already used by the monarchs on occasions; its reputation for healthy air, from the mountains; cooler summers than in Toledo; the abundance of firewood; Toledo's discomforts; and above all or perhaps because of it, the Queen consort, Élisabeth de Valois' scarce affection for Toledo [127:57].

In addition to possible strategic reasons of its more central nature, linked to the crossing of the two diagonal Roman roads near Madrid, the reasons of provision also appear sound. When other European capitals are located alongside the sea or next to a river, this guarantees general provision for the city. In spite of the limited flow of the river Manzanares and the lack of flour mills along its course, however, there was a good supply of flour in Madrid. This came from water mills on the streams on both slopes of the Sierra de Guadarrama and the tributaries of the river Tajo and the human- or livestock-powered mills in the city's bakeries themselves, with cereals from the soils of Madrid, Guadalajara, La Sagra and Arévalo. There were no serious supply problems in Madrid and the emergency *granaries* were only used a few times [127:60].



View from the river with part of Madrid and the Royal Palace, F. Brambilla

Supposed abundance of water

Also mentioned frequently are the water supply advantages, using underground and semi-underground ducts well known as "viajes de agua" – based on the Arabic *qanats* – as one of the most powerful reasons for selecting Madrid. Water was said to be guaranteed through the use of mines with Arab technology to lead underground water flows towards the springs. The matter has been studied exhaustively [232], [31], [83], [125], [144], [147], [195], [196], [142], but it is easy to show that the theme of this abundant bibliography is, paradoxically, Madrid's constant need for water.

The historical interest in this water technology is unquestionable and the progress made with it in supplying Madrid with water was significant. However, the ducts existing in Madrid to supply a population of around 20,000 before 1561 were few and they had already given problems. Lack of water and health problems continued to the point where one of the reasons given by the Duke of Lerma to King Felipe III to take the capital away from Madrid was that *Valladolid was a city with useful rivers* and *with copious springs* [195:22].

Chronic scarcity

From the time the capital returned to Madrid in 1606, scarcity was tackled for many years by building new ducts to bring in ever more distant underground water. Indeed, the majority of the most important and best known ducts were build from the 17th century. It would be anachronistic then to offer the water ducts as evidence supporting the argument in favour of Madrid as the place to establish the capital. Their important role came later, but the population increase driven by the presence of the Court was great and water supply was always provided with delays.

In his *New Manual of Madrid* of 1854, Mesonero Romanos spoke of the urgent need to transform into abundance the *age-old dearth of such an important element*. He expanded on this in 1861: *the great natural want of Madrid for its future development as a populous city and the Court of such an important monarchy was a large river, which while supplying the needs of a growing population, would also serve to fertilise and beautify its municipal area and countryside*.

In the absence of a river, the chronicler continues, *it turned to the means of acquiring drinking water through filtration into mines extending some distance and collecting water running off the neighbouring mountains*.



View of Madrid between west and south, F. Brambilla

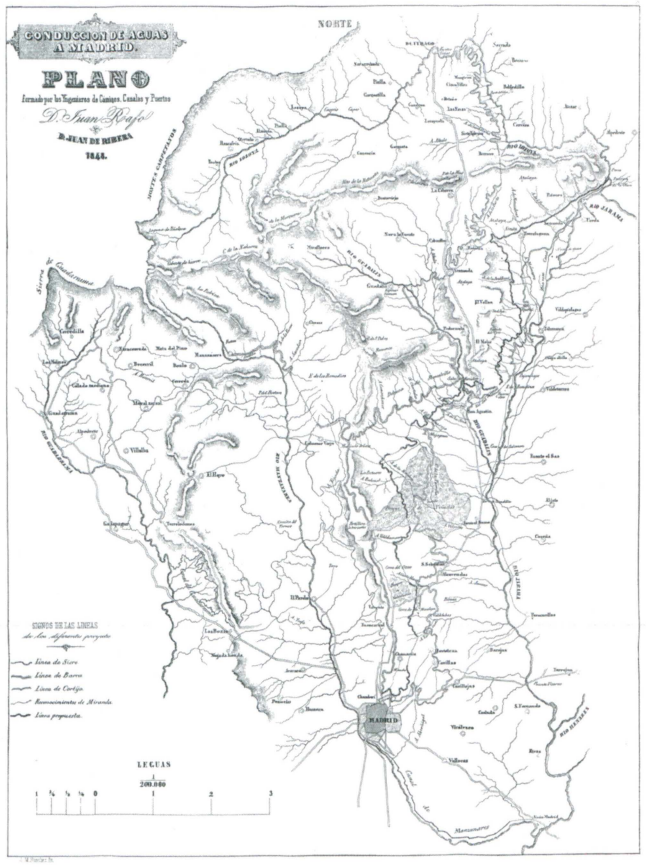


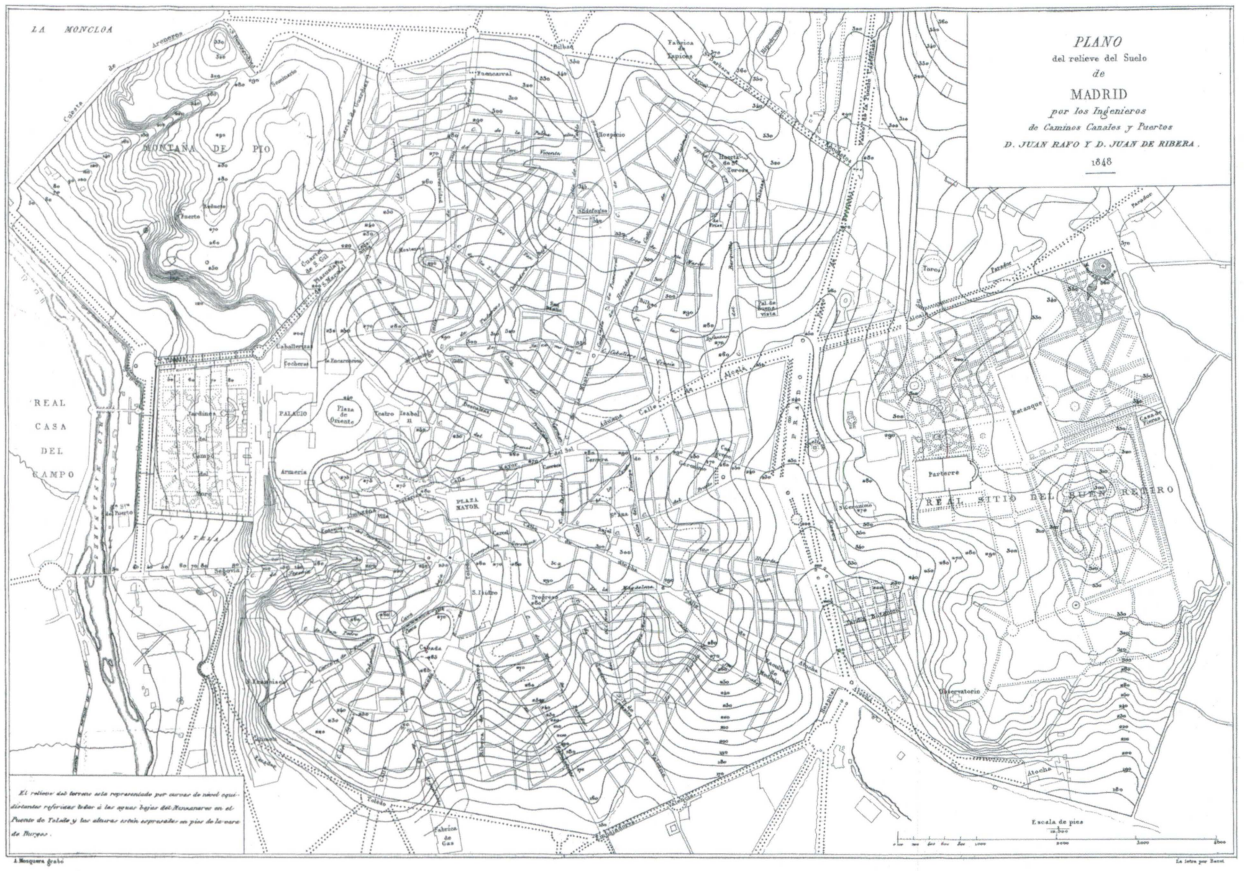
Current skyline of Madrid from the Casa de Campo: La Cornisa

These ducts ... They were sufficient, but not abundantly so, to provide for the basic necessities of the population... Until this century when it became necessary to tackle and execute the enormous works for the Lozoya Canal, which will change the material conditions in Madrid within a few years [164:XXX] .

Water for Madrid

In the light of Fernández de los Ríos' condemnation of that *scarcity that bore down day after day*, Antonio Bonet relates the projects executed without success: one by the colonel in the corps of engineers Sucre and Béjar in 1765; one by the architect Juan de Villanueva in 1786; one by the mathematician Mariano Vallejo in 1819; one by the engineer José Coquerel in 1822; and one by Francisco Javier Barra in 1829. *There was so much confusion that one began to think that Madrid would never be able to quench its age-old thirst,* Bonet concluded [47:31].





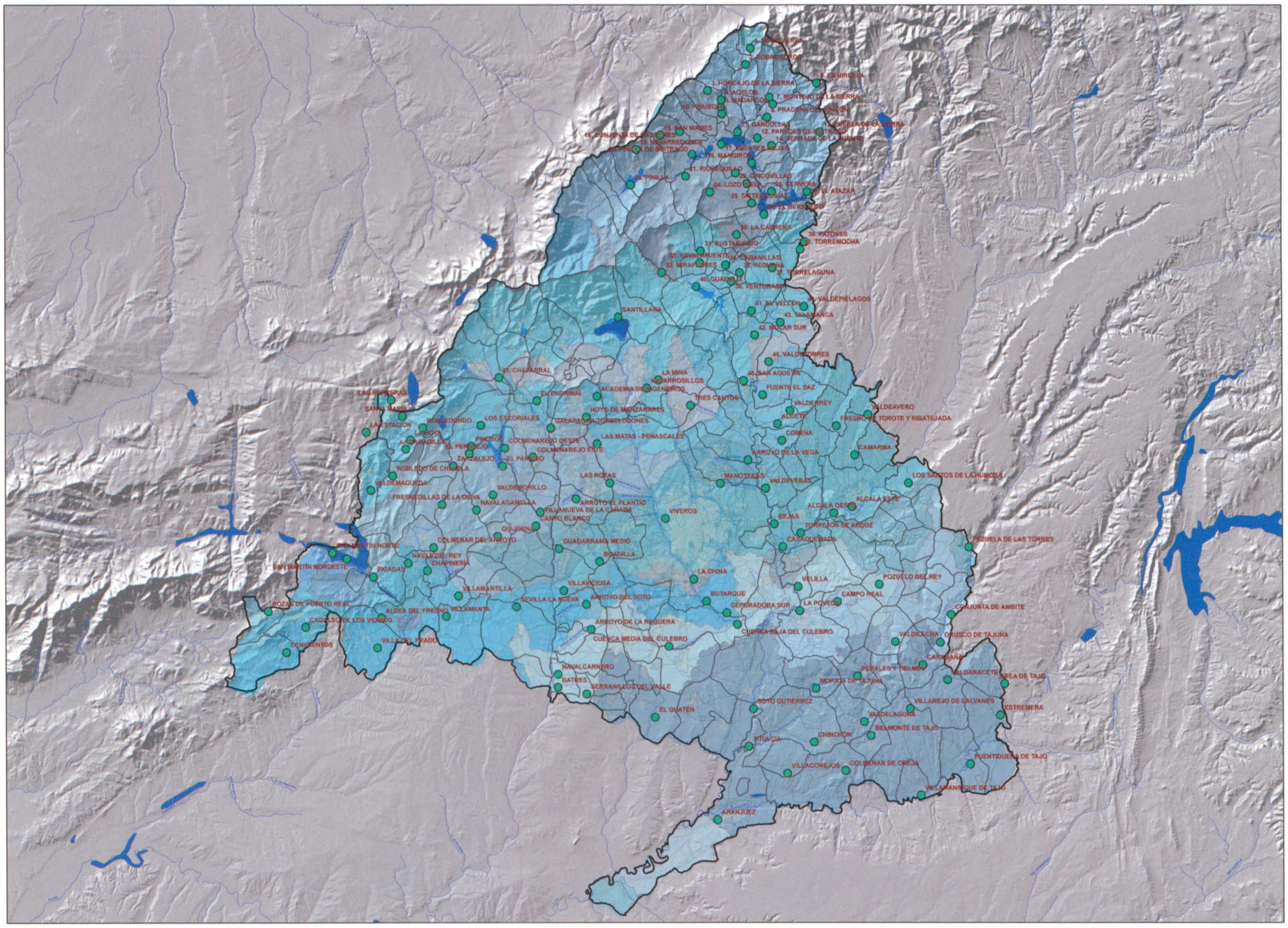
Left, piping water to Madrid, Juan Rafo and Juan de Ribera, 1848

Right, relief plan of Madrid, Juan Rafo and Juan de Ribera, 1848



Inauguration of the bringing of water
from the river Lozoya to Madrid,
E. Lucas Velázquez, 1858

Water supply and waste water
treatment: WWTP and river basins
[María José Ramiro Nuño]



In reality, Madrid only gave a solution to its water supply at the end of the 19th century, some years after the Isabel II Canal came into service. Like other large European and American cities, it solved its supply problems with *running* water, as the Romans would have done. The use of underground water or hydraulic machines to lift water from the rivers, in the Arab style, was not sufficient for the widespread urban expansion of the second half of the 19th century.

Legacy of capital status

What does seem clear is that its status as capital, not now of the country, but a whole immense empire, did not leave a particularly memorable built legacy. As Arturo Soria y Puig said in 1993, *In the Madrid of today, leaving aside the collection of royal paintings which ended up centuries later in the Museo del Prado and excepting the Royal Palace, which is also late with respect to Spain's time of splendour, is there anything to show for what was capital of such a noteworthy empire?*

The Madrid of the Spanish Habsburgs, he continues, *cannot compare with Imperial Rome, or with the Paris of the Napoleons, or with London, Berlin or Moscow. Its status as the capital of an empire passed then with neither sorrow nor glory. This is not, though, because no one in Spain knew how to make a new city: around the same time Spaniards founded hundreds in America and, furthermore, in general they did it well* [221:9].

The reason is clear, Soria continues: *The opportunities a Court brings with it were not exploited. Instead of constructing the buildings they needed from new and with dignity, they resorted to an old medieval formula: the tax on private houses, as it had been compulsory to house officials and servants of the Court when they were in transit. To avoid this charge, which affected the main floors of good houses in Madrid, its residents erected what were known as "spite houses", that is cheap and rather miserable houses.*

Continuing with his argument, he states that Madrid missed two other great opportunities; the timid, provincial mid-19th century expansion and the Metro and Suburban rail connection with the towns in the metropolitan area. Consequently, Soria wrote in 1993 [5], *Madrid, considered as a group of constructions, has neither been a wonder nor, what is worse, is it easy to put right from a material point of view* [221:1].

The enlightened drive

After King Carlos V's roaming, King Felipe II's attachment to Madrid only left its mark on the Escorial and the rest of the dynasty did not come to leave a decisive mark on the city. The imperial splendour was stamped upon the successive monarchs and their intentions for dominating Europe, with little protection for the city, which was practically considered as a circumstantial base.

The change in dynasty brought other territorial concerns and enabled fresh attention to be paid to the city in the medium term. The inspirer of this modernisation drive was King Carlos III, "Madrid's best mayor". After his reign, *The whole capital "appeared" to have been built by Carlos III* [226:42]. Carlos III had been the King of Naples, where he also acted as an enlightened monarch. He was a patient, cold, hard working governor who knew how to make use of advice from highly competent ministers, such as the Counts of Aranda and Floridablanca.

Buildings, streets, services

The buildings erected during the enlightenment housed institutions with instructional or social aims. The astronomical observatory, the Academy and the museum were accompanied by the foundling hospital and the post office. In Madrid alone, thirty two schools and the first modern bullring were built, the latter opened in 1749, beyond the Puerta de Alcalá gate.

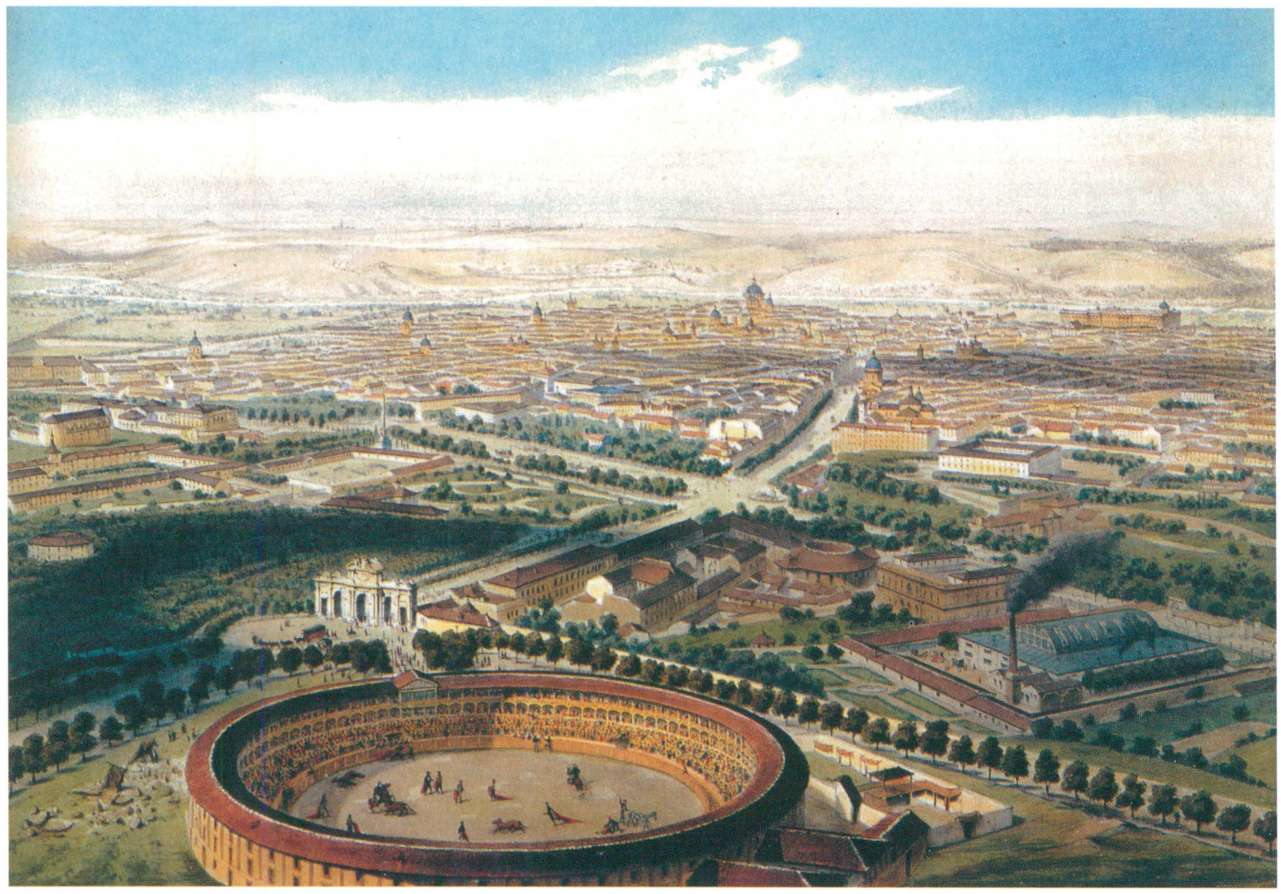
Sewerage and lighting were also introduced to streets around the 1760's. Street numbering began and their paving started, along with cleaning and systematic collection of refuse, which was previously thrown out onto the streets at night. New walls were built, of adobe again, of greater length and with new gates opened. The Prado gardens, which Madrid's residents had used as a promenade since the 16th century, were remodelled as the Salón del Prado, according to a design by the architect Villanueva and the painter José de Hermosilla, giving this a shape that was to remind one of Rome's Piazza Navona, like a hippodrome [226:43].

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[5] It may be open to discussion whether the buildings constructed in the expansion have improved or not since 1993, but, in spite of the difficulties, the metro and suburban railways have been spectacularly updated, putting an end to this deficiency.



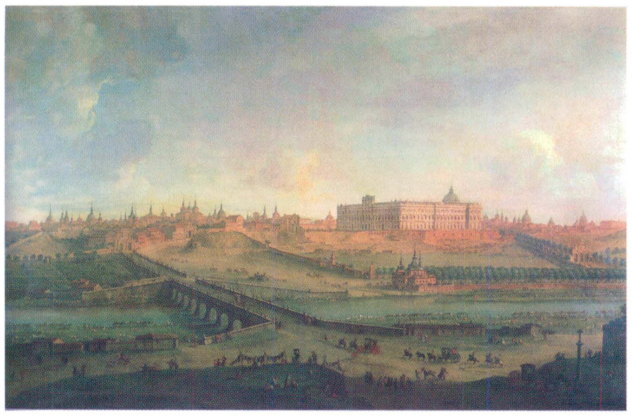
View of the Real Casa de Correos at the Puerta del Sol, 1902, José Gómez de Navia and Manuel Alegre



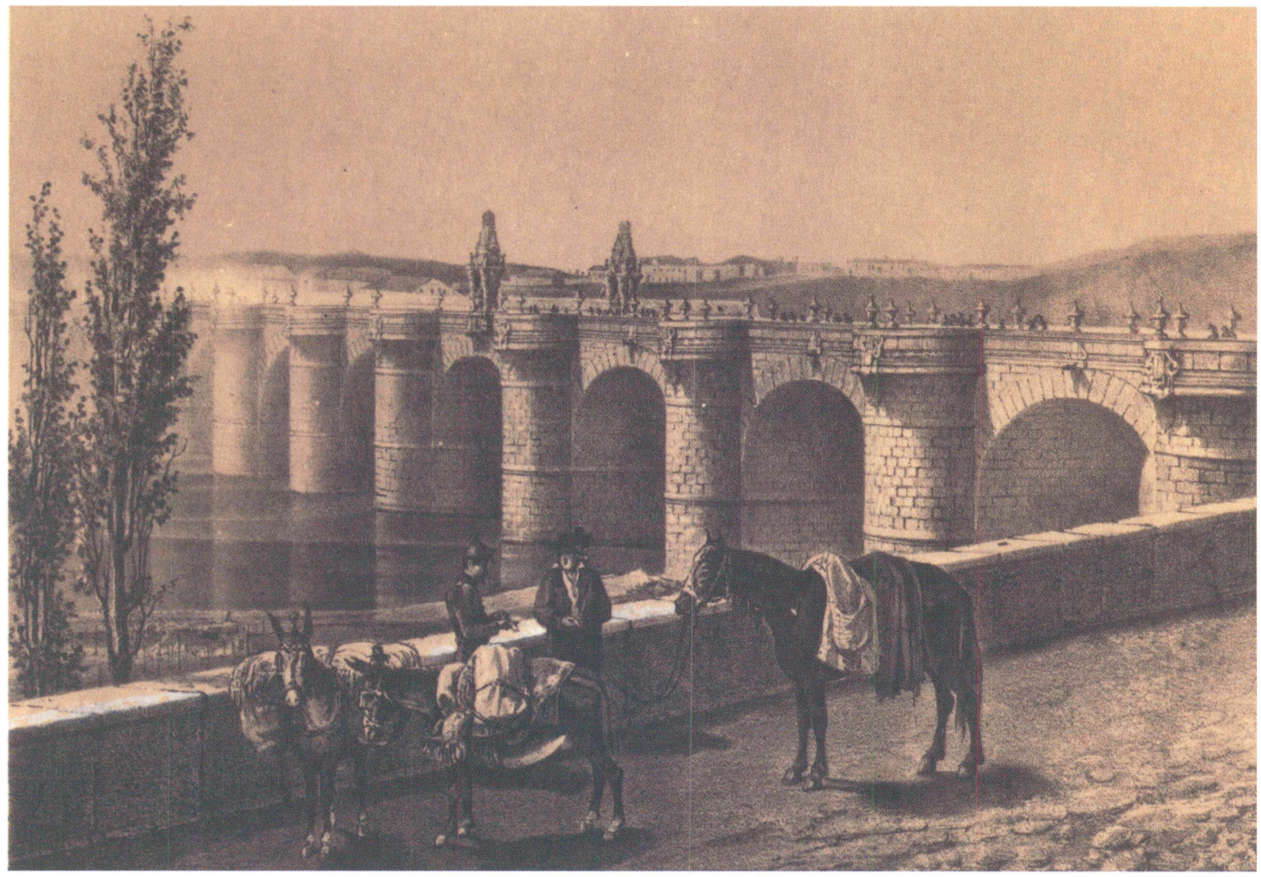
Bird's eye view of Madrid (around the bullring), around 1855, Alfred Guesdon

Throughout the 18th, the country appeared to have recovered its pulse, as the embellishment of Madrid showed. The list of works mentioned by the historian Juan Pablo Fusi in his concise article constitutes practically "all of Madrid" that current visitors seek[6]: *Royal Palace, works by Juvara, Sachetti and Sabatini, Pedro de Ribera's Cuartel del Conde Duque, Royal Hospice, Toledo bridge, Palacio de Goyeneche then the Academia de San Fernando, the churches of Salesas Reales, San Marcos and San Francisco, Sabatani's Puerta de Alcalá gate, Juan de Villanueva's Astronomical Observatory and Natural History Museum, Post Office building at the Puerta del Sol gate, Salón del Prado and Botanic Garden, also by Villanueva, the fountains at Cibeles and Cuatro Estaciones, transfer of the cemeteries, the start of the sewer system, channelling of the river Manzanares* [101:148].

Projection of Madrid







Spain's official projection was no longer the rocky bulk of the Escorial, but the fountains and gardens of the Royal Palaces of La Granja and Aranjuez and the colossal Royal Palace of Madrid, an enormous granite block on a dressed plinth, with pilasters and columns set into the façade and a grand upper balustrade and splendid interiors, with frescoes by Giaquinto, Mengs and Tiépolo, as well as exquisite furnishings and decoration [101:159].

View of Madrid from Segovia Bridge, 1750

View of the new road of Madrid, Domingo Aguirre, 1780

Puente de Toledo, F. J. Parcerisa

[6] The Hospicio de San Fernando was also included and is now the Municipal Museum. The Post Office building at the Puerta del Sol is now the seat of the Comunidad de Madrid. The Cuartel del Conde Duque housed the Royal Guard and is now a cultural centre. The Academia de Bellas Artes is housed in the Palacio Goyeneche, built by Churriguera and the Customs building, designed by Sabatini, later became the Treasury, on the Calle de Alcalá.

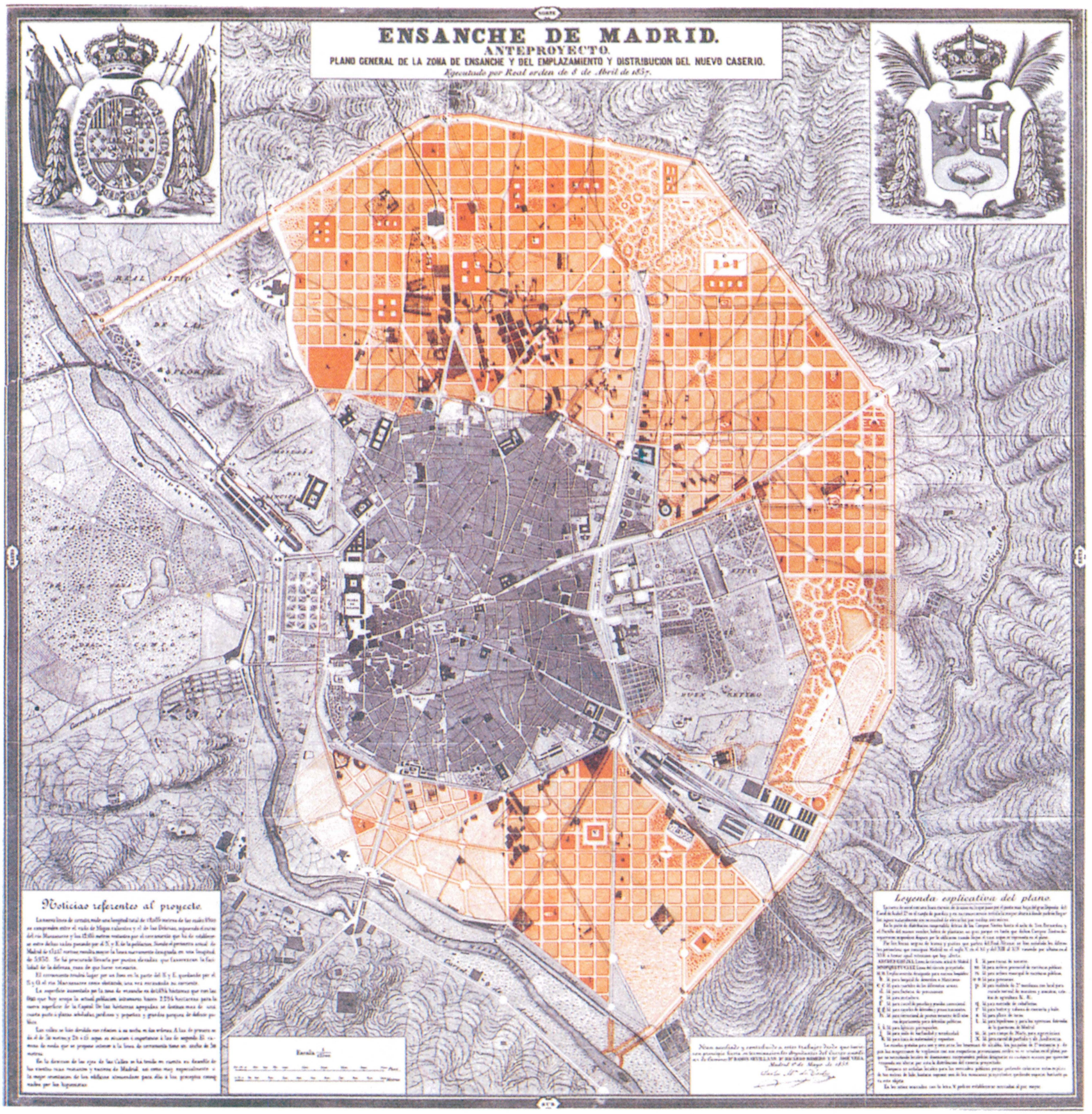
Economic boom

However, the urban fabric did not grow substantially. In spite of Bourbon innovations and overthrows of the Napoleons, in 1830 it continued to be essentially the city of the last Spanish Hapsburgs, enclosed behind its wall and its gates. After decades of shortages and wars, though, between 1840 and 1870, clear enrichment of the country occurred. It was *founded on the sale of Church lands started by Mendizábal in 1836 and expanded to communal assets in 1855, and driven by railway building starting in 1848 and colonial businesses in Cuba, the Philippines and Puerto Rico* [101:197].

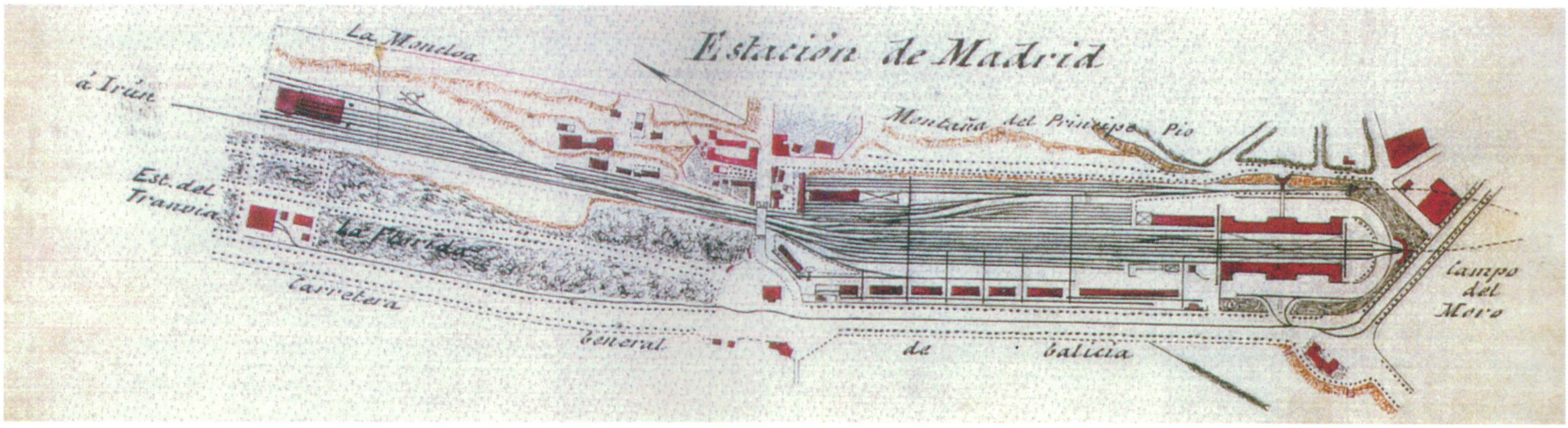
The city itself became a subject of public concern, a matter for improvement proposals and actions. The emerging middle class became the leading players in social and material change, attaining higher levels of power and influence. They managed to strongly condition the nature and orientation of the transformation, with immediate repercussions for their formal and spatial aspects. Madrid's middle class property activity started to function, with support from property sale processes, and the extension of the compressed city was set out, on the other side of the wall, not as a random occupation of space, but as a well planned and organised operation.

Bird's eye view of Madrid (Royal Palace and surroundings), around 1855, Alfred Guesdon





Madrid's enlargement ,1857: Castro Plan



Layout of Príncipe Pío station, project of 1877 (prior to the definitive 1879), C.G.E.



La Estación del Norte, Benjamín Palencia, 1918



A document was approved in 1860 which, according to Fernando de Terán, started to determine, conclusively and for many decades, the occupation of the area outside King Felipe IV's city walls, forming a broad arc around the city to the east of the river. This used a grid system, adjacent to the traditional concentric radial city. The radial roads and some other pre-existing features, such as the Retiro Park and Castellana water course were more or less inserted into this system. The incipient presence of the railway was also accommodated in the wharf at Atocha and the railway branch to Aranjuez, as well as the line leaving to the north, parallel to the Paseo de la Florida from Príncipe Pío, which still had no station, and the quarters which had grown outside the wall were also included [224:194].

Plans and routes for the new economy

In Spain, again according to Fusi, *between 1855 and 1874 around 6,000 km of railway lines were built thanks to foreign capital, which also drove the first Spanish mining boom... Numerous banks were founded between 1856 and 1866: speculative business on the Stock Exchange and investments in state debt mobilised substantial capital[...] Madrid developed considerably after 1840. Sixteen provincial capitals doubled their populations between 1850 and 1880: the growth of the cities and the works that called for (expansions, water supplies, sewer systems, housing, large markets, slaughterhouses, gas tanks and coal yards, railway stations[...]) stimulated local economies* [101:197].

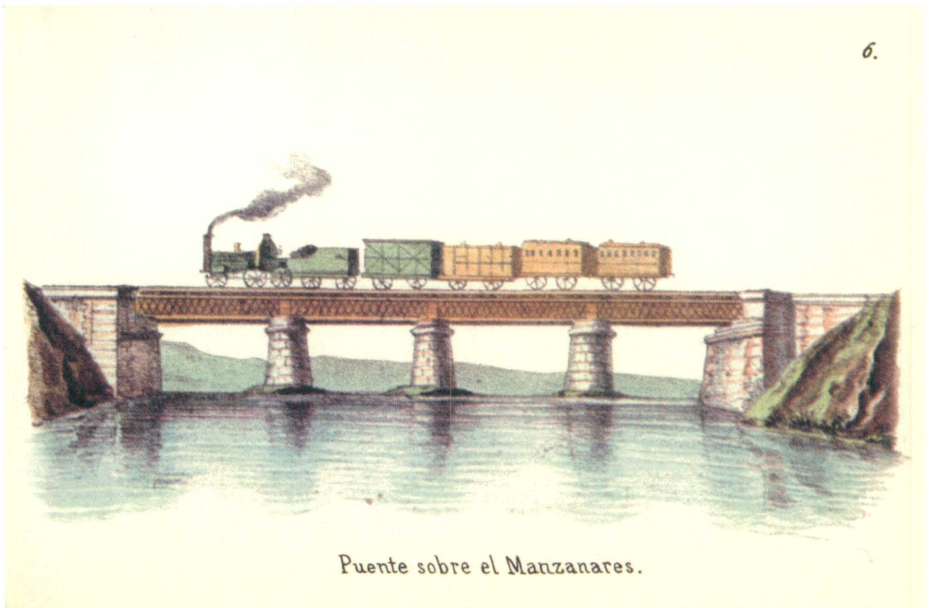
The changes took place very slowly, though, and agriculture was still backward and traditional, with large estates. Urban development processes were slow. Until well into the 1880's, the banking sector was fragile, with frequent crises, and industry depended on foreign excess capital and technology.

Islands of modernity

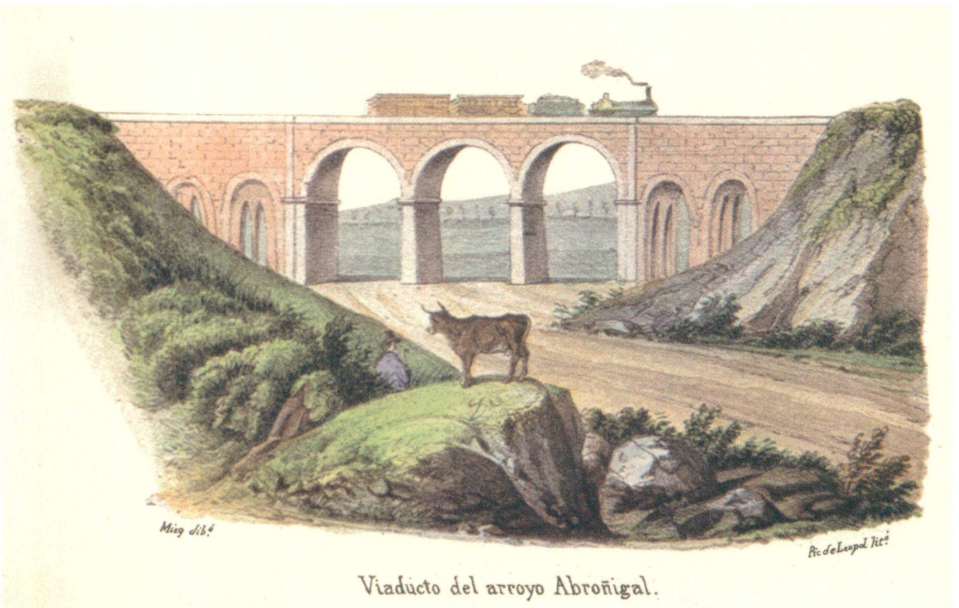
Coexisting in that Spain, in fact, were a poor, traditional, stagnant, subsistence economy – the picturesque Spain of romantic imagination – and a modern, urban, capitalist economy. *That modern Spain had in its cities, Madrid and Barcelona above all, real "islands of modernity", while rural Spain languished behind, with a lack of ideological direction, weighed down by custom, local powers and the church* [101:199].



Current Príncipe Pío intermodal station



Wooden railway bridge on the Madrid - Aranjuez line over the river Manzanares [165:6]



Railway viaduct on the Madrid - Aranjuez line over the Abroñigal brook [165:1]

Two decisive events in the 19th century

For Mesonero Romanos, the 19th century had two important events for Madrid: *The whistle of the locomotive Madrid heard for the first time on 9 February 1850 and the immense cry of joy that greeted the arrival of water from Lozoya at the city walls on 24 June 1858 were the two classical decisive events for 19th century Madrid* [164:62].

This was, then, clearly and emphatically this first great action in the process to build the city; not the streets or squares, but the bases that enabled Madrid to evolve to become a great city. The railway and the Isabel II Canal made today's great Madrid and those first constructions – with alterations and extensions – continue to have been used continuously from that time.

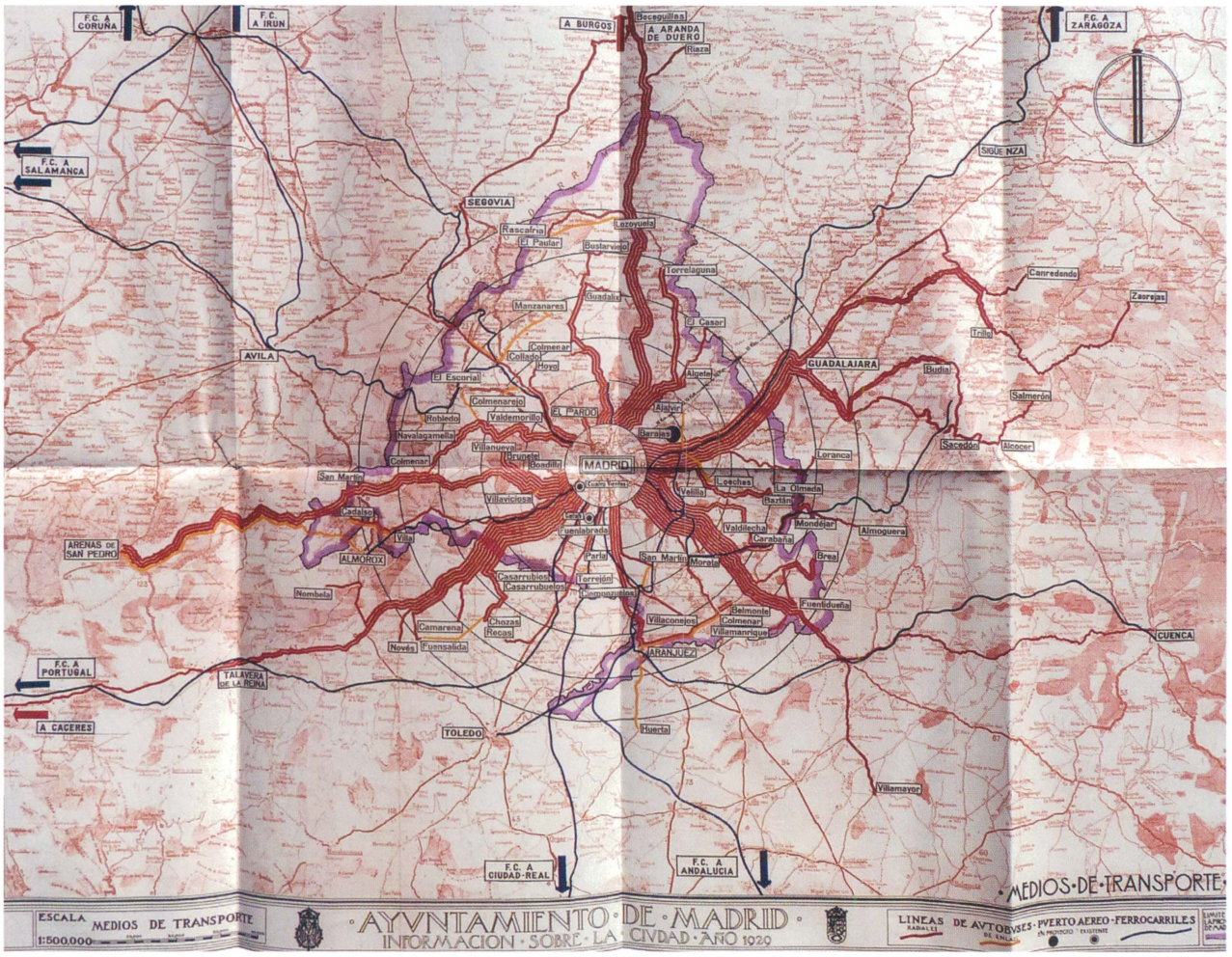
Railway in the city

From its first steps, the railway chose Madrid and Atocha as key pieces in the whole system. As José Almazán pointed out in 1857, the idea of a central station as *to bind, connect and relate the whole system of lines and stations on the peninsula*, comes from olden times and appears to be linked to the concept of the railway network itself. [26:7].

The choice of Madrid contributed to emphasising the city's centrality, while the selection of Atocha made the city swing towards the east and south. The altitude conditions of the lines pointed to Atocha as the most suitable place, although it did bring a series of problems to the city that could not be tackled until the 1930's (see page 47).

Basis and ideas for planning

Urban planning was limited to accompanying the city's growth. According to Fernando de Terán, bases and antecedents for the real construction of the city's spatial organisation were progressively laid down throughout the 20th century. Ideas related to the basic infrastructure framework played a fundamental role in this. Knowledge of it enables you to understand *the tension experienced historically between the constant demands of urgent needs, on the one hand, and faithfulness to prefigured optima, on the other, which are driven by the former*. The 1929 Competition, the 1931 Expansion Plan, the 1939 Regional Plan, the 1946 and 1963 General Plans and the 1964-67 Arterial Network are milestones in the history of constructing the city model.

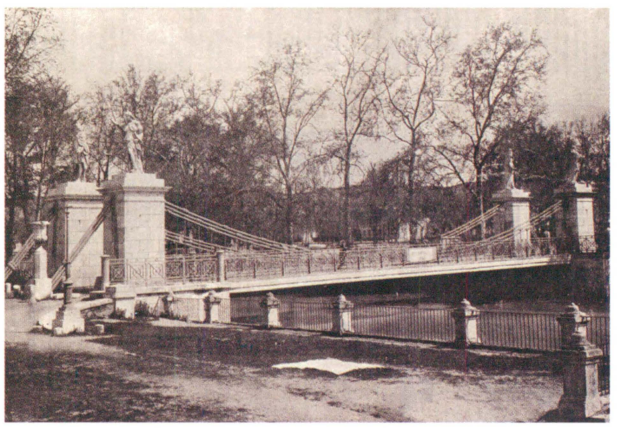


Means of transport, Madrid City Council, Information on the city, 1929

MILESTONES IN MADRID'S URBAN PLANNING

- Felipe II's Ordinances of 1590
- Municipal Ordinances of 1892
- Municipal Ordinances of 1972
- Castro's Madrid Enlargement Plan 1859
- Núñez Granés Plan of 1909
- The Ciudad Lineal
- International Urban-Planning Contest of 1929
- Zuazo Plan of 1929
- General Extension Plan of 1931
- Madrid Regional Plan of 1933
- General Layout Plan of 1939
- General Layout Plan of 1946
- General Plan of 1963
- Arterial Network of 1964-67
- General Plan of 1985
- Basis of the Territorial Strategy Plan of 1996
- General Plan of 1997

Source: Comunidad de Madrid [82].



Aranjuez suspension bridge [ROP 1897, 523]

It led onto the Madrid-Andalusia Road and was located between the Parterre Garden and Calle Reina, where an old floating bridge was previously in use. The deck had a single span measuring 33 m, suspended from groups of three chains on each side which were supported on stone pilasters. The pilasters were crowned with statues and the railing was manufactured in wrought iron. Although it required several repairs it remained in service until 1935[1].

[1] It was replaced by a bowstring bridge. *Revista de Obras Públicas*, 1897, 44, volume I (1129): 523.

These milestones[7] are continuous, *make up a sequence, follow one another, inherit elements from each other, which they take on and rework, and they progressively define a model to be adopted by the real construction process*. Construction in reality adopts it and destroys it in parts, because in the second half of the century, things were very different to that imagined. Reality sets, at a new level, then, other demands for peremptory attention, which distort the use of what was anticipated.

[7] The Comunidad de Madrid has collected all the Urban Development Plans for Madrid in [82].



The Gran Vía, current view

Construction power

The construction of the radial road network had no clear effect on population distribution. No significant variations are recorded in the population's spatial location in the settlements closest to these main roads, in contrary to what had been happening before. However, the drive and direction of modern Madrid has followed models closer to construction than to planning. This was not so much due to insufficient planning as to the inability of municipal and state government to control the city's explosive growth for a society in a process of change [224:345].

Madrid, which had started the 20th century with half a million inhabitants, was radically transformed. *The expansion of elegant neighbourhoods and the construction of luxurious buildings, the opening of modern hotels (the Ritz and the Palace, both in 1910-1914), the layout of the Gran Vía (1910-1931) changed its physiognomy: Madrid was, above all, a commercial and banking city. In those times, almost all Spanish cities*[8] *incorporated,*

[8] Between 1900 and 1930, the country's population rose from 18.6 to 23.3 million inhabitants. Urban population in settlements of over 10,000 inhabitants increased from 32% to 42%. Barcelona passed one million inhabitants and Madrid approached that number.

to a greater or lesser extent, many of the services and advances of modern life, such as electricity, gas, electric trams or cars, like the ones produced in Barcelona from 1904. Madrid, for example, had its Metro from 1919 [101:204].

New society of the 1930's

In 1930, over half the population worked in the industrial or service sectors and only one third lived in settlements of less than 5,000 inhabitants. The aristocracy had even lost its formal presence. Social power had shifted – within the upper classes – to industrial and financial circles. Ways of life adapted to the likes and aspirations of an increasingly urban middle class in the industrial and service sectors. New professionals emerged in State bureaucracy and in industry, companies and banking. The middle class expanded significantly (to around four million Spaniards in 1930) and the active industrial population increased [101:210].

Around 1933, an ambitious Plan for River Catchment Confederations (Lorenzo Pardo) and Public Works was drawn up, marking out the future of water and mobility in Spain. Communications and the electrification of the country were boosted appreciably. A first Spanish public sector was created and significant economic and labour reforms were made. Among the many facets embarked upon, probably the most significant for Madrid was the railway links project and the new attention to mobility included in it.

Attention to the railways in the 1930's

The improvements to *railway links* concentrated the lines from the west, south and south-east at Atocha and those from the north, north-east and north-west at the future Chamartín station. The two stations were to be linked by means of a railway tunnel which would run under the entire length of the Paseo de la Castellana. The plan contained other measures not related to railways, such as the widening and improvement of the various entrances to the city and the setting up of an effective suburban service, bringing all Madrid's residents closer to the mountains, expanding its action to the cities of Toledo, Guadalajara, Segovia and Ávila. All the above would have a bearing on the city's urban planning, improving mobility in terms of destinations and journey times.

The plan encouraged growth of the city towards the north – *its natural space* – leaving the already congested centre behind, with guarantees of land for housing at affordable prices and new Metro lines to facilitate communications still further. The intention was also to move the centre of Madrid to the north, with the construction of the Nuevos Ministerios and Charmartín station itself.

The ignominy of the laughter tube

As a whole, the Plan had greater scope than indicated by its name of "railway links" which ended up *damaging the project*, in the words of Indalecio Prieto, *because the objectives go so much deeper than linking two railway networks*. The part was taken as the whole, focusing on the so-called "tubo de la risa", or laughter tube, named after a popular fairground ride of the time. The name came not so much from popular invention as a discredit to the radical party sown by their political rivals, who considered them to be invading municipal autonomy.

In reality, all of Madrid related to the axis of the Paseo de la Castellana results from the railway link project: *The current urban morphology of Madrid cannot be understood well without first knowing of the projects Prieto tackled with both excitement and firmness at the end of 1932* [106:71].

Poor sites for railway stations

In his first radio address of 8 November 1932, Prieto revealed his surprise at the absurdity of the northern station being located at the foot of Príncipe Pío hill: *Because in a city like Madrid, which is extending naturally to the north, it is hard to understand the great railway stations having been sited at the lowest points in the city.*

For Prieto it was an economic nonsense, given the higher cost of transporting goods uphill, which was reflected in high commodity prices. Housing prices were also high in Madrid, not due to *the landlords' rapacity... but rather to the artificial and unjustifiable price of land in a city with all imaginable suburban developments* [201], [106:206].





Recoletos station, current view

Effects on the city setting

The concentration of lines at the future Chamartín station enabled Príncipe Pío station to be dispensed with, but required that the lines from the north be diverted with a new track from Las Matas station to Fuencarral. This line would cross the top of the El Pardo neighbourhood, meaning that the number of compulsory purchases would be very few because the lands belonged to what was Royal Heritage and is now Heritage of the Republic. That was no problem in Prieto's eyes because the Law of 22 March 1932 that transferred the lands laid down that *The woodland of El Pardo will be used as a park by establishing, reforming or expanding the communication routes that lead to greater enjoyment of it by the public* [106:208][9]. They came to think the opposite over time: that it would be better for the park itself if El Pardo were protected rather than open to the public.

At another conference in 1934, Prieto revealed attacks on his link project by the Compañía del Norte due to the supposed detriment caused to it related to the Madrid - Burgos rail line terminating at Chamartín on a new line instead of at Príncipe Pío over its lines. *The Madrid - Burgos railway, which has already been built to the Valle de Lozoya, lacks only around 68 km from Gargantilla to Madrid... and when it is finished, it will almost write off the Burgos line through here, because all the traffic from the north will use the direct route, travelling 100 km less... That will let them reduce it by three hours and so go from Madrid to Bilbao, really comfortably, without forcing the speed, in six hours* [106:336].

Links and extension of the Paseo de la Castellana

After an ineffective Railway Links Commission, which lasted a few months, the Gabinete de Accesos y Extrarradio, or approaches and outlying areas office, was created in 1932 to definitively resolve the links problem. The leading lights in various actions taking place at the same time came together in this: on the one hand, the proposal for expanding Madrid to the north by the architect Secundino Zuazo and the German developer Jansen, later known as the Zuazo-Jansen Plan, which planned the connecting tunnel under the Paseo de la Castellana; and on the other the project to extend the Castellana by the Council to Zuazo in 1931.

[9] The conviction imposed over time is that, for its sustainability, it is better to protect El Pardo than to open it as a park for Madrid's residents.

Indalecio Prieto named Zuazo as vice president of the Office and work started on the two projects, plus the Nuevos Ministerios which would be built on the lands of the old horse racecourse. The Office requested Zuazo to draw up a new project to extend the Paseo de la Castellana and he did this with the collaboration of Eduardo Torroja with great urgency. The extension was opened to the public in 1933 and the tunnel works for the links started in May the same year, but ground to a halt in 1935.

At that time, the tunnel excavation was almost complete and the largest work was finished for the Recoletos halt and the Nuevos Ministerios station, by Torroja with the architects Carlos Arniches and Martín Domínguez, under the Nuevos Ministerios market The station is composed of two parallel bays with spans of 20 m, intersected in the transverse direction by two others of 12 m, forming groin vaults [3:106].

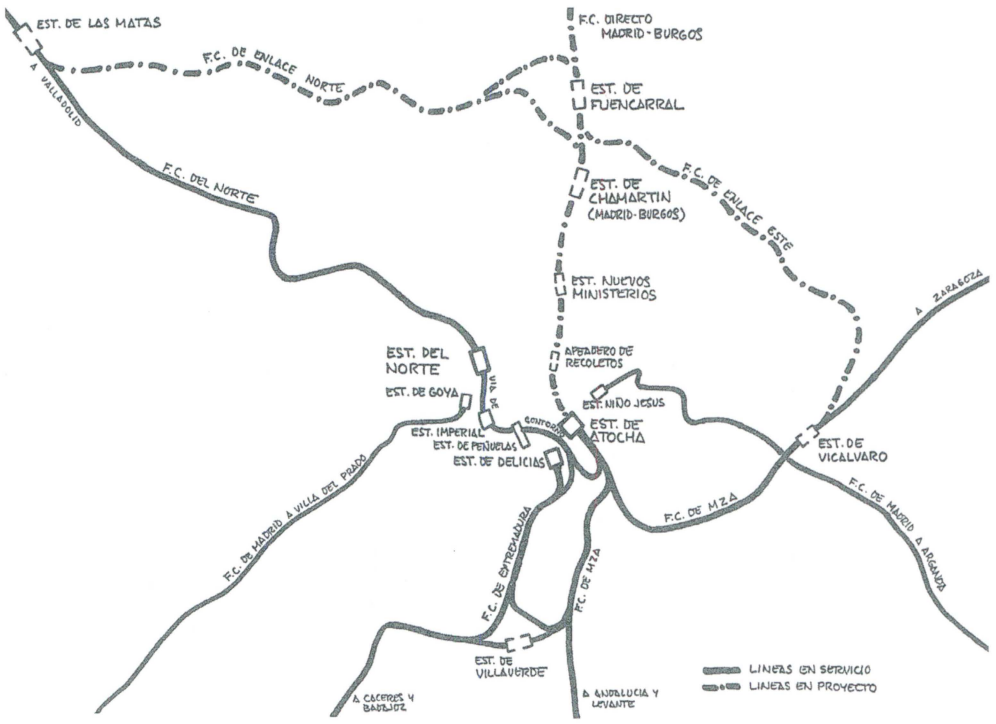
As George Orwell said though, in Spain *history stopped in 1936* [101:227].

Pause

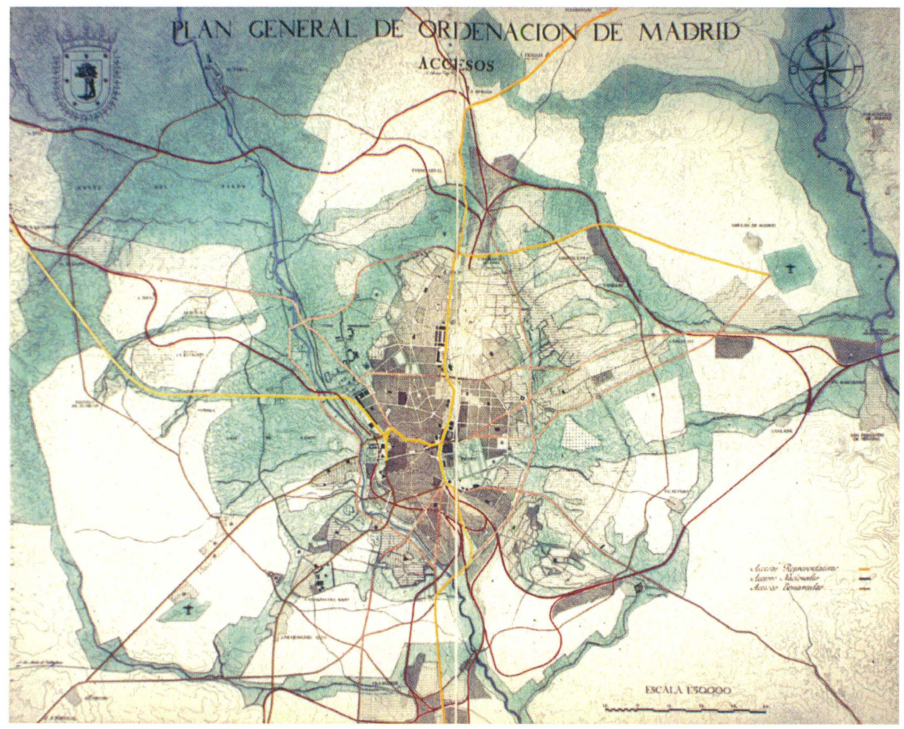
Madrid took twenty years to start moving again. According to Fernando de Terán, *a considerable new part of the city emerged, because the impotent Government tolerated this form of producing the urban space (or even collaborated in it), faced with a problem overwhelming it. And accepting the facts as they were, a process of legalisation and provision of minimal infrastructures took place, consolidating the occupation of unplanned places and an undesirable form of organisation and coherence between the parts* [224:336].

The post-war city

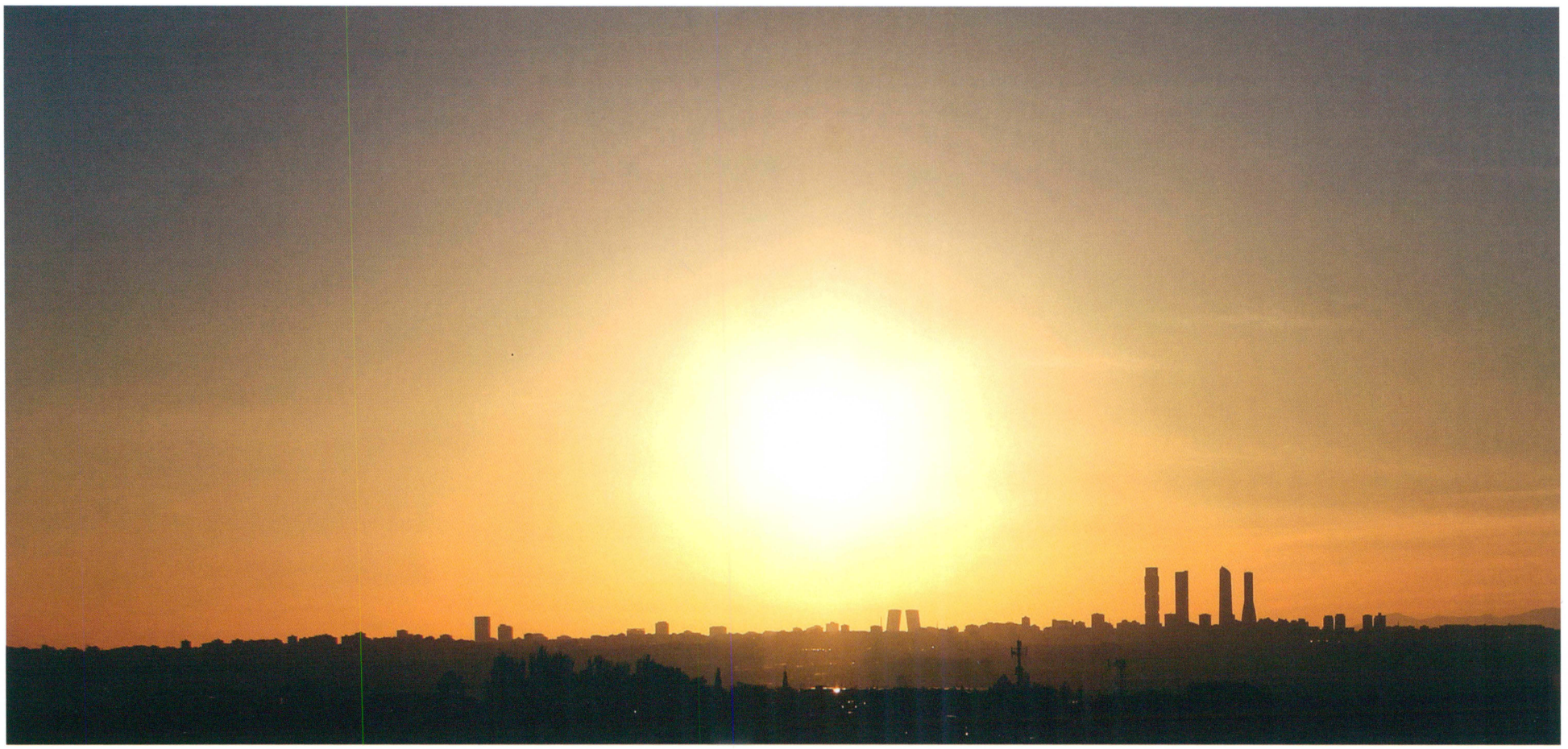
In the developmentalist 1960's, support for the setting up of industry in Madrid produced new jobs, triggering significant immigration and increasing population concentration. The city tried to absorb this the best it could, as Terán said, *it needed to improvise quick responses to urgent demands, one step behind the changes, which soon became insufficient. It was a phase of hectic transformation and infrastructure reorganisation, making it possible for the whole to continue functioning, overcoming the worst times for congestion and shortages* [224:337].



Railway Links Plan [3:106]



Madrid General Urban Development Plan, accesses, 1946



Current skyline of Madrid in which the Castellana towes stand out

Chamartín Railway Station

Construction of the provisional Chamartín station started in 1966 and the link tunnel was completed in November 1967. The two works were opened in 1968, together with the Madrid-Burgos railway line. Delicias station was closed in that same year and Atocha absorbed the traffic from Extremadura, with trains from Catalunya then going to Chamartín.

The definitive project for Chamartín station was approved in 1972. This was commissioned from the architects José Antonio Corrales, Ramón Vázquez Molezún and Rafael Olquiaga. The works then started, built by Dragados y Huarte, coming into service in 1976. The station had a long distance area and a suburban services area, a covered car park, a hotel, restaurants, shops and a thermal power plant [3:110].

An urban country

In those years of development, from 1960 to 1975, the country became industrialised and urban, Fusi said. Four million people left rural areas, almost half of them to go to Europe, and tourist numbers increased from six to thirty million. Production of cars and household appliances grew spectacularly. Three in every four wage earners now worked in industry and services and only one in four in agriculture.

In 1975, three-quarters of the population lived in towns and cities with populations of over ten thousand. Per capita income increased eight-fold to 2,400 dollars over those years. Among the aspects set off against this were the stagnation of agriculture, considerable regional imbalances, in spite of the creation of regional development hubs... urban planning horrors in tourist areas and the large cities, ecological disasters, overcrowding of industrial population in quarters lacking services (Madrid, Barcelona, Bilbao...) [101:235].

The car at centre stage

In the aforementioned 1960's, mobility was monopolised by cars, with public transport basically meaning buses, driven by the powerful presence of Madrid's public transport company, the Empresa Municipal de Trans-



Chamartín station

portes (EMT). For many years, buses and cars produced traffic jams and aggravated the urban pollution problem generated by coal-fired heating. In 1967 alone, growth in the fleet of cars was 60% compared to the year before.

The 1963 General Plan and the 1964--67 Arterial Network renovation were the planning instruments put into effect to tackle these problems. Both had a decisive influence on the subsequent shaping of the city's layout. They coincided with the implementation of the 1967 REDIA, or asphalted route network, Plan, a five-year plan for the whole country specified and complemented in the Madrid area by the Arterial Network.

Effects of the roads plan

Spain's Ministry of Public Works, under Silva Muñoz at the time, decisively tackled the renewal of certain communication routes which had been poorly maintained since the modernisation of the Republic. The REDIA Plan was used to undertake modernisation of 5,000 km of main roads, essentially the six radial roads running out of Madrid. This confirmed the network's centralist definition, not so much due to the logical commitment to giving precedence to the old radial routes as to ignoring many of their historically consolidated "branches" which enabled the network to reach marginal areas through which they did not run.

The REDIA Plan improved the surfaces of the radial roads by making general use of bituminous bound surfacing, but, above all, it standardised the transverse section with 7 m of carriageway and two hard shoulders of 2.5 m, giving a total width of 12 m. Extra lanes were also added on climbs, to do away with jams caused on inclines and at mountain passes. It was an enormous effort for which the only precedent was the "Special Road Surfaces Circuit" of the late 1920's, which had inferior features and was limited to the north-west of the peninsula. Some

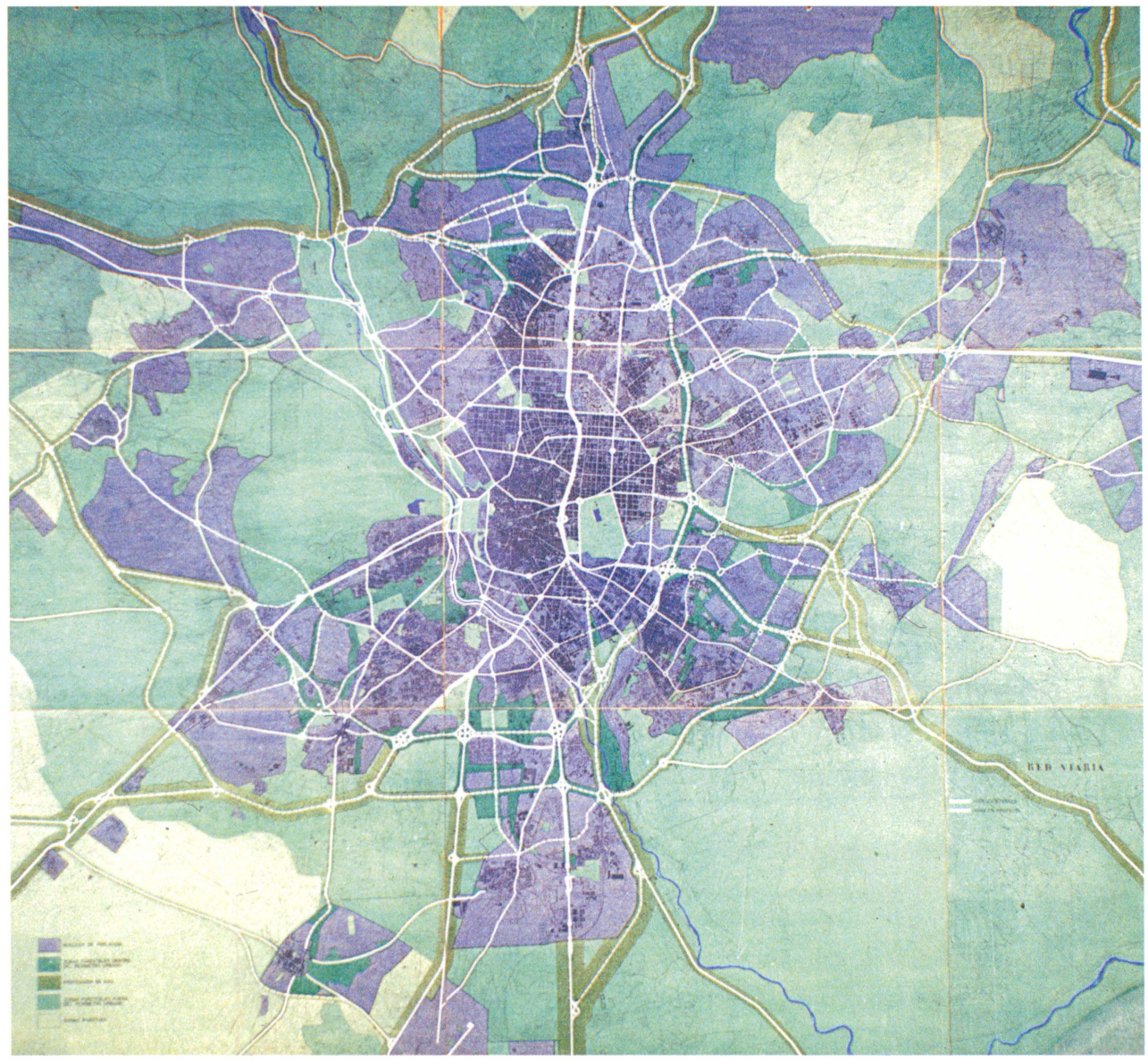
of the most dangerous bends were also straightened, although not all of them. With this, drivers frequently went out onto the road, seduced by the comfort and smoothness of its surface, but without the safety of the cambers demanded by the speed it induced.

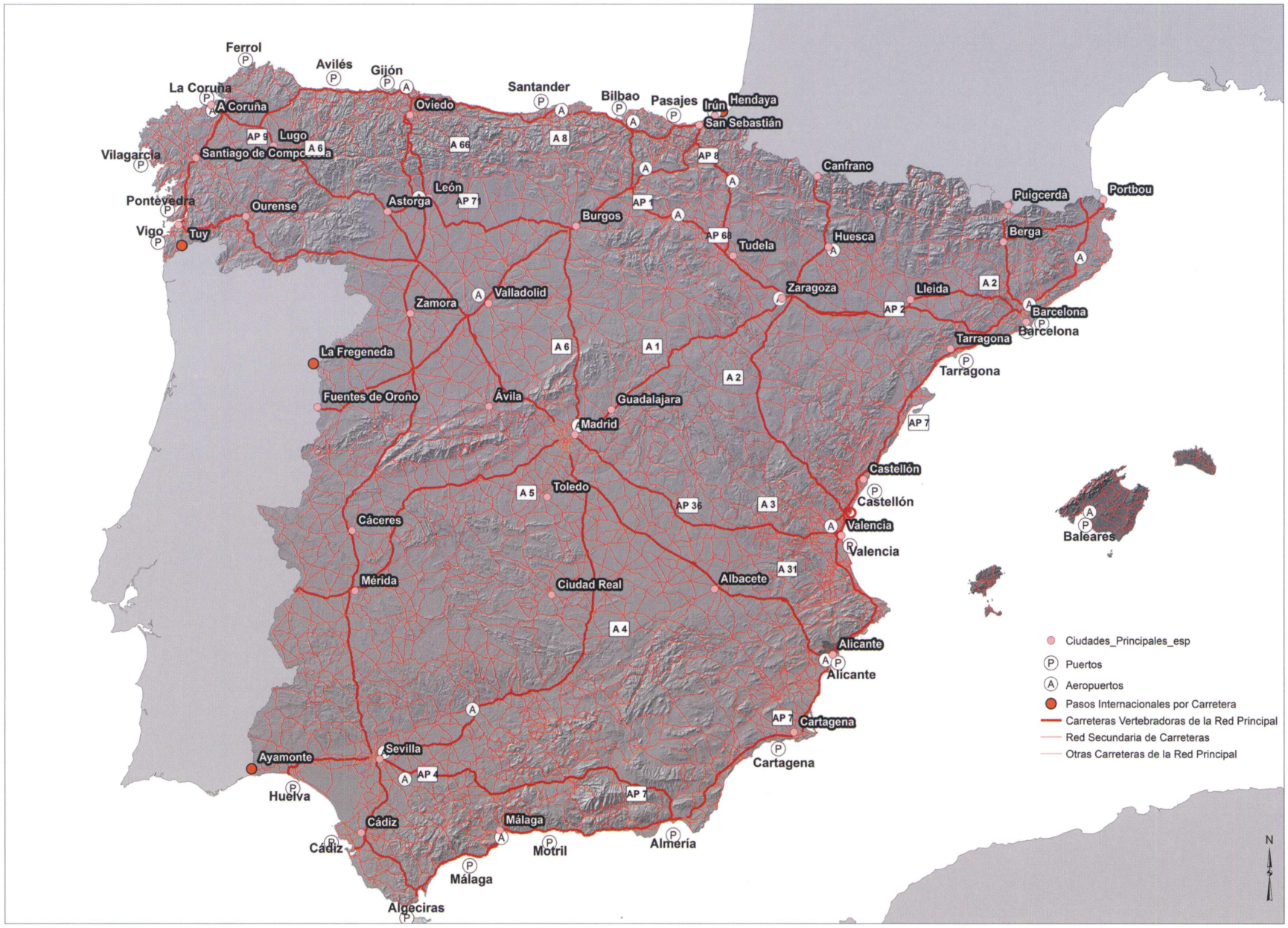
Entries to Madrid

The new improvements received special care in entries to Madrid, under the Arterial Network Plan. The La Coruña motorway was widened again, increasing it to three lanes in each direction from the two of the 1950's. The Puerta de Hierro entry was rationalised again and the important Villalba junction was reorganised, where the NVI road split towards Navacerrada and Puerto de los Leones, with an additional branch running to Cerceda and Manzanares. The intention of all this was to tackle the weekend traffic jams due to the proliferation of second homes in the Sierra de Madrid.

However, the arterial reform was more ambitious. It distinguished between entries, access roads and ring roads, in principle oriented towards the main Spanish cities. This involved widening and improving existing roads, as well as building other new ones, to guarantee fluid urban traffic flow to the general road network. Included too were the so-called "ejes de núcleo", or settlement axes, the purpose of which was more clearly oriented towards town planning, but with less impact on the network and, consequently, less investment support.

General Plan of 1963, Road network





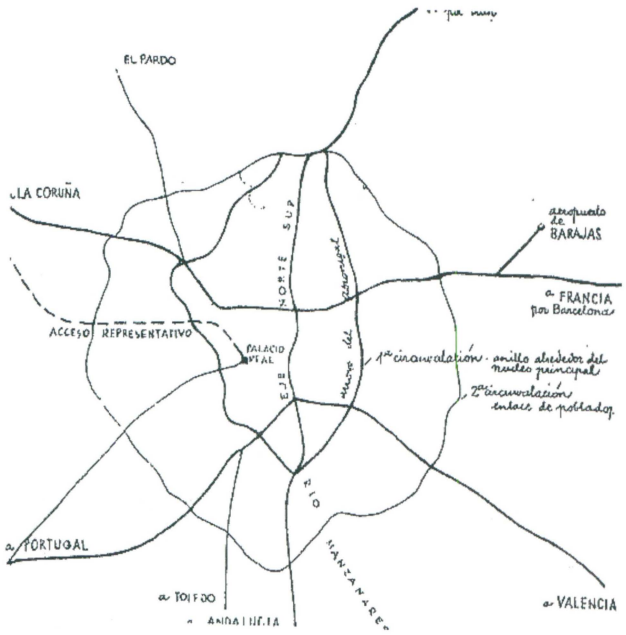
Layout of the road network
[María José Ramiro Nuño]

In any case, Madrid clearly benefited from its central nature in resource allocation for major public works construction. Even when public investment in civil works grows less than economic activity, though, Madrid always holds on to the minimum ratio. The strong demand for public works driven by great concentration in terms of space and economic activity bears out this latter position [18:29].

Ring roads

In Madrid, the design rationalised the existing Ring Roads and established the so-called third ring, named M-30. The first, very indistinct, was basically made up of the roads encircling the Madrid of the Hapsburgs. The second around King Carlos II's rings, known as the boulevards, the central pavements of which were removed to give priority to cars, to connect Moncloa, San Bernardo, Bilbao, Alonso Martínez and Colón, was completed in a less precise form by the Paseo de la Castellana and Calle Atocha or another a bit further south.

There had been a further, rather more complete, ring called Las Rondas, which ran from Moncloa to Cuatro Caminos, continued along the streets named Raimundo Fernández Villaverde, Joaquín Costa and Francisco Silvela, to the Manuel Becerra roundabout and proceeded along Calle Doctor Esquerdo and Paseo de María Cristina, reaching Atocha to then continue along the streets named Ronda de Atocha, Ronda de Valencia and Ronda



Entries to Madrid and ring roads, P. Puig, 1950

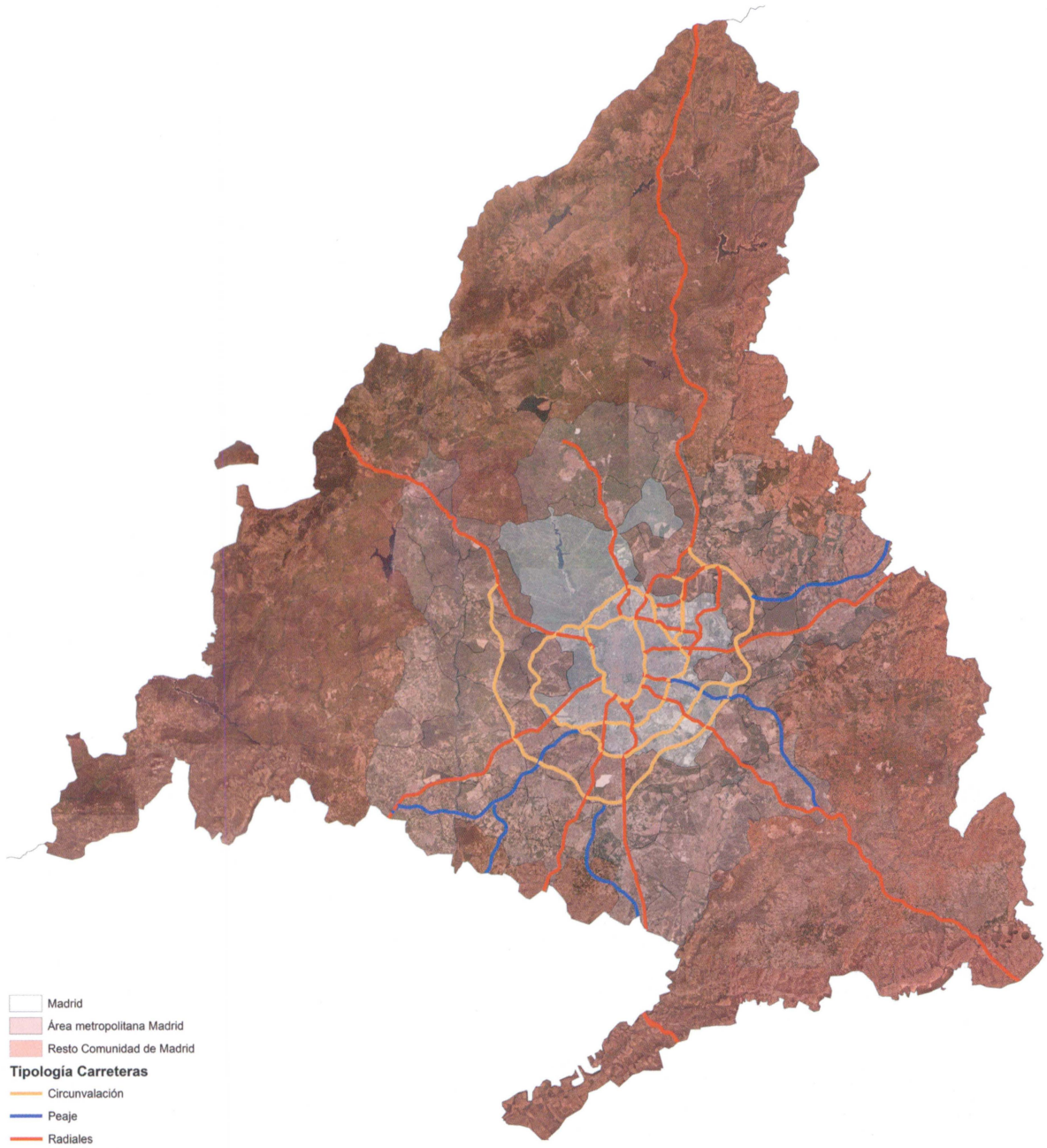


Diagram of ring and radial roads
[María José Ramiro Nuño]

de Toledo, until it connected with the Calle Bailén and continued along the streets named Ferraz and Rosales to return to Moncloa.

The rationalisation of this ring – which was never called the M-20 – kept its urban nature and traffic lights, but was treated as a fast road. Spain's first urban overpasses were used to resolve the main junctions. The key points of Cuatro Caminos, the crossing of the Paseo de la Castellana, the Manuel Becerra roundabout, Atocha and the Plaza de España square used overpasses or underpasses. Designed by a new generation of engineers, they constitute the seed for all modern bridge technology development in Spain [14:414] (see page 107).

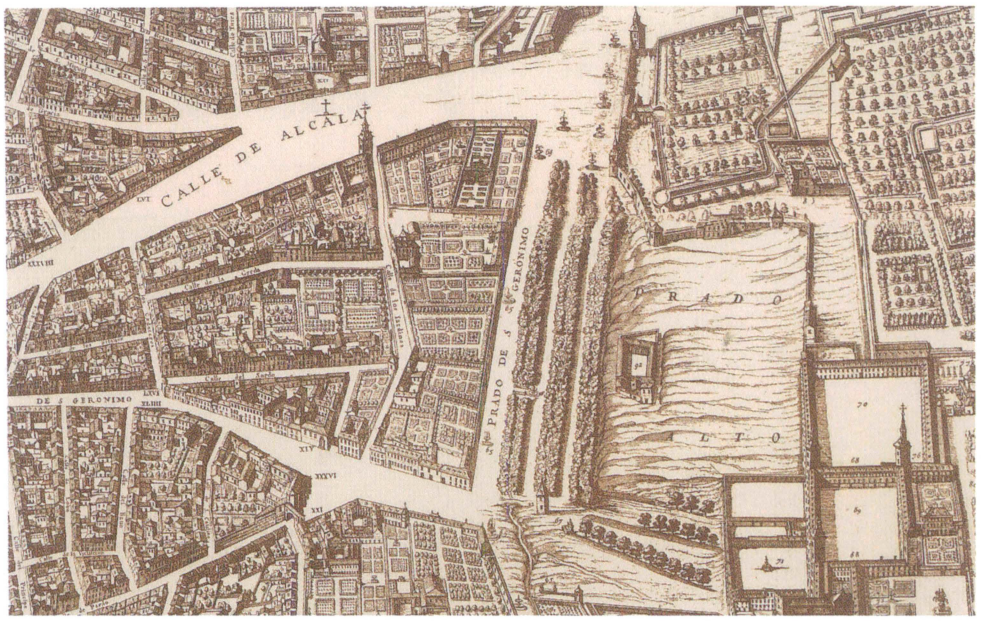
M-30 delimiting rings

Since 1929, with the Zuazo-Jansen Plan, presented to the International Contest for preparation of a Preliminary Plan for Madrid's Road Layout and Urban Development, the creation of another ring road around the city had been proposed. This was not officially recognised until the 1941 General Urban Development Plan (Bidagor Plan), which was approved in 1946. The Bidagor Plan was based on Pre Spanish Civil War studies and planned for the construction of two outer ring roads, the first of which was to be the M-30.

However, construction of the M-30 did not begin until 1970, in two differentiated stretches: the eastern stretch, or Avenida de la Paz, between the Irún and Cadiz roads (A-1 and A-4), following the bed of the Abroñigal brook, which had been channelled and ran under the motorway; and the western stretch, or Manzanares Motorway, between the Puente de los Franceses and the Cadiz road, which was built following the river Manzanares along the majority of its route. The two stretches met at the Southern junction and were not completed until 1974. In the case of the western stretch, this was after considerable local opposition as, in many cases, the new motorway ran a few metres from houses.

Planning of the urban area

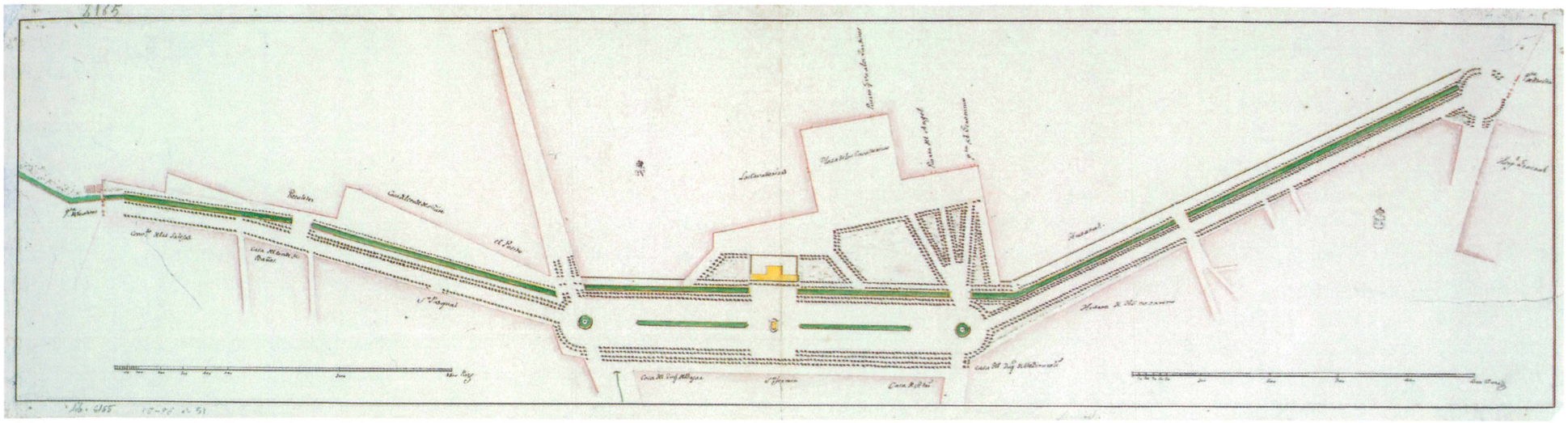
In those years of great growth for Madrid, Fernando González Bernáldez remembered[10], *the authorities and specialists showed little ecological sensitivity, as well as poor ethics as regards land use*. However, the Commission for Planning and Coordination of the Madrid Metropolitan Area (COPLACO) already existed in the Ministry of



Biginning of the configuration of the Paseo del Prado, Texeira drawing, 1656

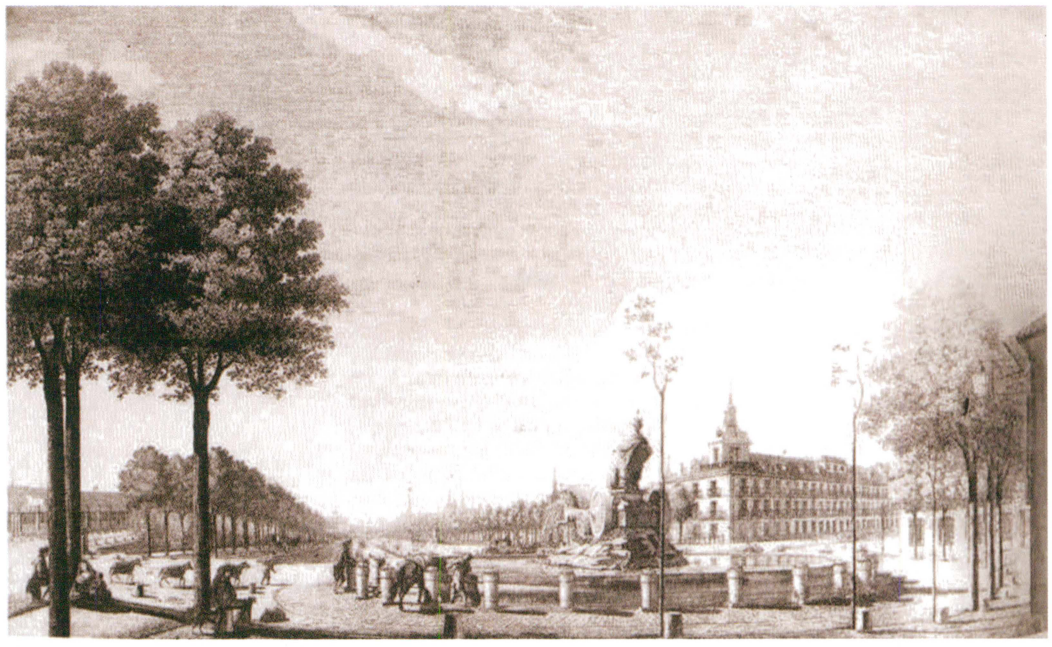


Paseo del Prado



Paseo del Prado design, 1774

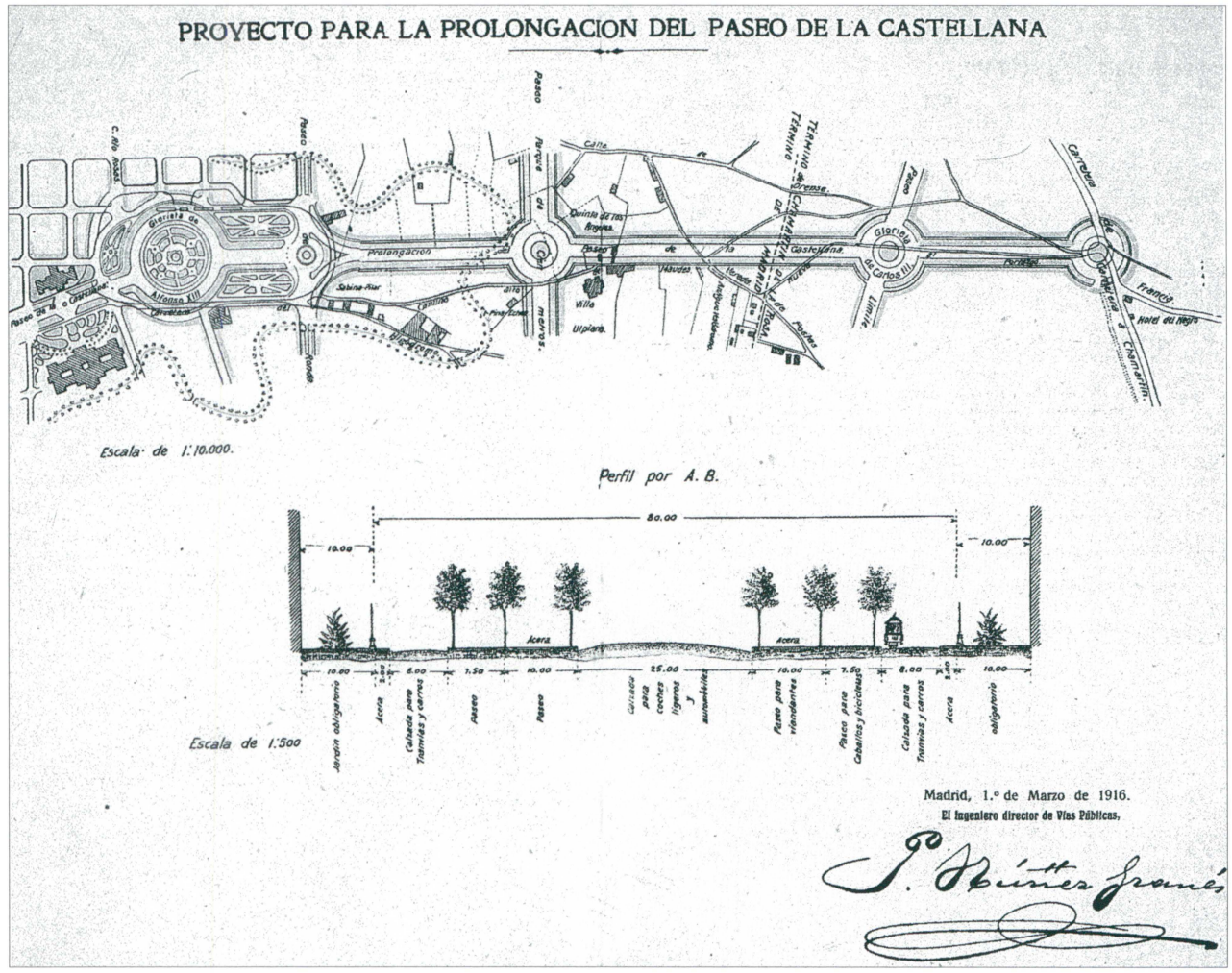
[10] The important article by Fernando González Bernáldez is entitled, *Forty years of ecological troubles* and forms part of [121].



View of the Cibeles Fountain and the Palacio de Buenavista, J. M. Avrial y Flores, 1836



Paseo del Prado



Project for the extension of the Paseo de la Castellana,
P. Núñez Granés, 1916



Redevelopment of Recoletos-Prado layout



Redevelopment of Recoletos-Prado, model



Current view of the Paseo del Prado

Current view of the Paseo de la Castellana



Current skyline of Madrid from the Casa de Campo: the Castellana towers



Milestones in the evolution of the Paseo de la Castellana

Some of the most important milestones in the birth and development of the Paseo de la Castellana throughout history are as follows:

■ In 1837, when Madrid's population was around 215,000 inhabitants, it was proposed to extend the Paseo de la Castellana to the Fuente del Cisne (now the junction between the Paseo de la Castellana and the street named Eduardo Dato) and then to the Fuente Castellana (now the Plaza de Emilio Castelar). The reason for this proposal was Madrid's needs for expansion, which could only take place to the north, as the wall built at the time of King Felipe IV (17th century) lay to the east. This development proposal would determine Madrid's urban future.

■ In 1860, when Madrid's population was around 260,000 inhabitants, the engineer Carlos María de Castro proposed the Madrid Expansion Plan, which was approved. This Plan prepared the layout for the new districts of Chamberí, Salamanca and Arganzuela and practically the totality of the development was executed in the following years. The Plan proposed an orthogonal grid around the city, except for the west, where the river lay.

■ In 1929, when Madrid's population was around 1,000,000 inhabitants, an international competition was called for preliminary plans for the road layout and urban development for the area lying between the limit of the Expansion and the city's municipal limit. Although the competition was declared void, the preliminary plan by the Secundino Zuazo, from Bilbao, and Hermann Jansen, from Germany, was selected in first place and was to form the base for the extension of the Paseo de la Castellana. Some of the most relevant parts of the Zuazo-Jansen Plan proposals were as follows: 1) it conceived of the extension as a structure established by the city's north-south axis, including the extension to the Paseo de la Castellana; 2) the importance of the great north-south axis called for the opening of the Paseo de la Castellana to the north, which required the demolition of the Royal Hippodrome, now occupied by Nuevos Ministerios; and 3) it proposed a railway line running along Prado-Recoletos-Paseo de la Castellana, with new stations at Fuencarral and at the meeting point of the Paseo de la Castellana with the street named Bravo Murillo, which is now Chamartín station.

■ After the Civil War, it was to be Bigador who took up the extension to the Paseo de la Castellana, based on the Zuazo-Jansen proposal. This proposal conceived of the Paseo de la Castellana as a space to represent what a capital of the empire should be, placing buildings symbolic of the Regime around it.

■ From the end of the 1950's, development started on the lands on either side of the road to France, to the north of Plaza de Castilla square. Studies began in the 1960's for the execution of a fast ring road, the M-30, work on which was to start early in the 1970's. The junction between this fast road and the Paseo de la Castellana to the north of the Plaza de Castilla required the construction of the Northern Junction, next to the Hospital de La Paz, which was opened in 1975.

(Text by Luis Irastorza) (see "Project for extending the Paseo de la Castellana" on page 264)

Sector or regional plans

Public Works and, in 1972, this *was relatively progressive and stood out due to the presence of young, enthusiastic specialists interested in seeking rationality in planning a Madrid which was expanding precipitously*.

That aspiration *came into conflict with a series of vested interests and the designs of the pressure groups and in 1976, after a long period of tensions, COPLACO's most dangerous teams were broken up in an operation that put around one hundred professionals on the streets. However, the results of the ecological studies continued to influence COPLACO's activities and were converted into documents such as the Special Plan for Protection of the Physical Environment, the recommendations of which remain in force* [121:222].

COPLACO was part of the Ministry of Public Works and Urban Development and was the first attempt at regional planning, with a degree of independence from sector planning. Until right in the middle of the 1970's, public investment mainly followed a sector logic in the investing organisation or government. Priorities were allocated with supposedly technical criteria, without taking local requirements into account. The only way local councils had of asserting their interests was through direct political pressure on the relevant sector ministers or directors general.

With mayors and councillors elected democratically, the model changed and the difficulty then lay in how to set spending priorities between the requests received. One possible solution was to maintain absolute autonomy in political decisions and give complete freedom of action to a person or commission, with technical reports usually being requested, but without being bound by their contents.

Differences in facilities and immigration

In parallel, the growing importance of the regional dimension generated great attention to the making of inventories of the physical environment and of the buildings, works and services needed. Rationalisation in the allocation of resources was sought using medium-term criteria, accepting political corrections, though, to make the execution of the plans viable.

One of these inventories[11] identified needs for investment in Madrid's municipalities, including paving, distribution networks, sewerage, rubbish tips, buildings for the city council itself or social services etc. Pursuing its main objective of fairness, these infrastructure inventories revealed the enormous disparities between Madrid municipalities very short distances apart. They also showed great deficiencies in the most basic services in places very close to the capital. In 1982, only twenty kilometres from Madrid, there were a dozen small towns without water supplies and the majority had no sewer system or paving.

The differences in ways and conditions of life between the capital and small towns was substantial and their inhabitants moved to Madrid both in search of work and to improve the former. Later, when cooperation programmes and improved local budgets bore fruit, the trend reversed and many of Madrid's residents decided to enjoy the new advantages from the recent investments.

New regional view

One of the first works affected by this new regional view was the completion of the M-30, which was not finally achieved until the 1990's with a noteworthy modification. The route originally planned started from the La Paloma junction, continued along Avenida de Costa Rica and Avenida Alberto Alcocer and crossed Madrid's meadows. Later, it was moved further north, although some sections do not have motorway characteristics and it is a road with traffic lights (Avenida de la Ilustración).

The engineer Antonio Figueroa, who was in charge of Madrid's roads for many years, from the Ministry of Public Works, explains one of the major fiascos in its design: *The Ministry of Housing ordered that the Vicente Calderón Stadium needed to be moved excessively close to the river to leave space for buildings for officials' associations, invading the strip of land planned for the Channelling of the river Manzanares and infringing on the reserve set aside as the towpath imposed by the Water Act for all water courses. Faced with the threat of long delays due to a confrontation between two state organisations and the difficulty of demolishing the stadium, as the mayor wished, the decision was taken to pass under the stands* [98:25].

From encircling to bypassing

The third ring, named the M-30, which was a success and was unanimously accepted, was completely different in nature to the other rings. It was designed as a motorway built practically ex novo, with entry controls, divided directions of travel and under- and overpasses, although the budget limitations made it necessary to cut back on these aspirations.

It made up a true ring road, with sufficient separation from the second ring, which ran along the main water courses that shape the city, but it contravened the basic rules for a motorway at many points (see page 43).

Projects for new rings

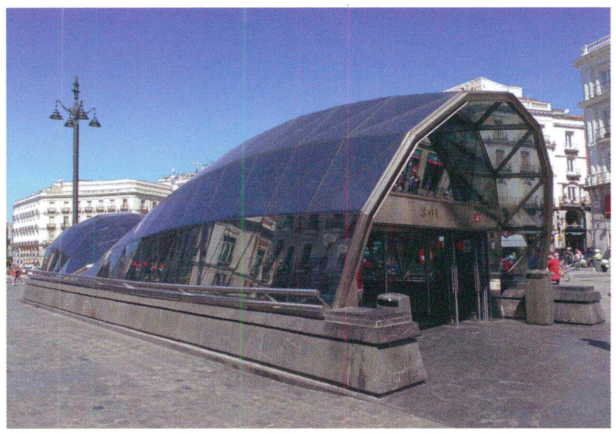
The next ring had another purpose, in principle. According to Figueroa, the objective of the next, initially known as the fourth ring, was the connection of the municipalities and quarters in the metropolitan ring, such as Alcobendas, San Sebastián de los Reyes, Fuencarral, Hortaleza, Canillas, Barajas, Coslada, Vicálvaro, Vallecas, Villaverde, Orcasitas, Carabanchel, Campamento, Húmera, Aravaca and El Plantío. This was now a complete route outside the city itself and was designed without support from the Ministry of Public Works' urban development plans [98:25].

However, the construction of the M-40 meant the definitive establishing of a polar structure for Madrid and its subsequent role in delimiting land uses and values. Some neighbourhoods managed to stand out

[11] Prepared jointly by Antonio Sarabia and the author in 1984.



Puerta del Sol, John Lewis



Puerta del Sol, new Suburban rail station



Puerta del Sol, current view



from the polar grid of circular segments and came to be known by name, but the location references are absolutely general.

In spite of the expansion of the Urban Area, the centre continues to be an essential reference in position or in journeys and concentrates many Metro and bus lines. The recent construction of an underground suburban railway station at Sol has emphasised its real function as a central interchange. There, not only do you go to or come from the centre, you also change between metro, suburban or bus lines, like at other exchanges in the city, perhaps with more options, even though there are no peripheral bus lines.

A well-defined centre

The radial scheme has also had a powerful impact on the recognition and valuation, including economically, of the areas delimited by the communication routes. The central core is defined by the M-30 motorway and the outside continues to be understood as "outlying areas", another clearly centralist name. The sectors defined by the radial roads concentrate specific uses: between the A1 and A2, homes of a certain level and the airport; between the A2 and A3, facilities, services and logistics; between the A3 and A4, more transport and homes; between the A4 and A5, popular housing; between the A5 and A6, the "Casa de Campo" park, sparse dwellings, education and commercial; and between the A6 and A1, the green reserve area with a few luxurious home and buildings.

Railway stations

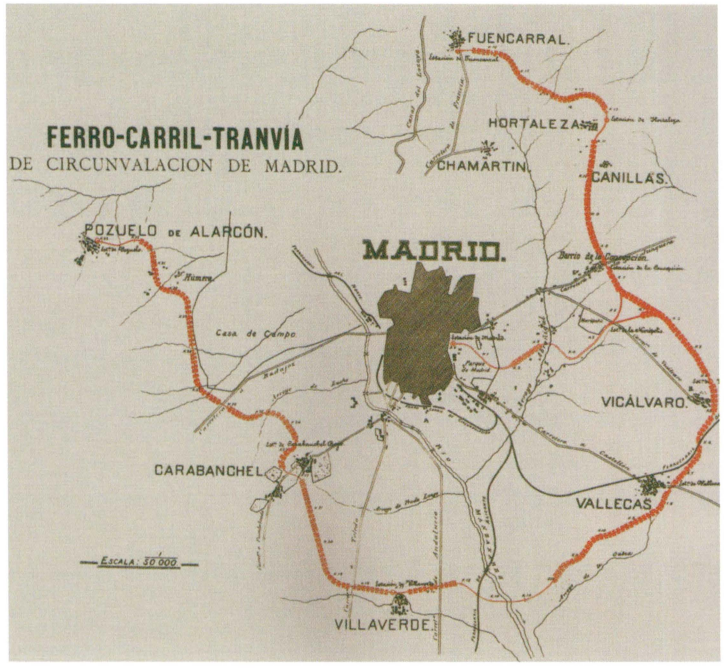
In principle, the presence of main roads has a great impact on spatial layout, but their appearance or proliferation does not usually generate population dynamics. Initially, according to Fernando de Terán, their emergence had little effect on demographic behaviour. However, railway lines could be seen to produce expansive dynamics in terms of their surroundings and they lead to significant modifications in the settlements where stations are located. What happened with the Madrid Metro network, which was used initially to promote new areas of housing, is very significant in this regard.

In the 19th century, the railways showed greater regional impact and a greater capacity to produce increased vitality around them than roads [224:346]. It would be difficult to determine whether the current occupation patterns were defined by communications routes, whether road or rail. Before the railways, traffic moved along the roads in horse-drawn carriages, at very low speeds and on poorly maintained road surfaces. The railway represented a real revolution, but, since years ago, well-managed peripheral buses have clearly shown their ability to provide quality public transport, at much lower costs than those of the railway.

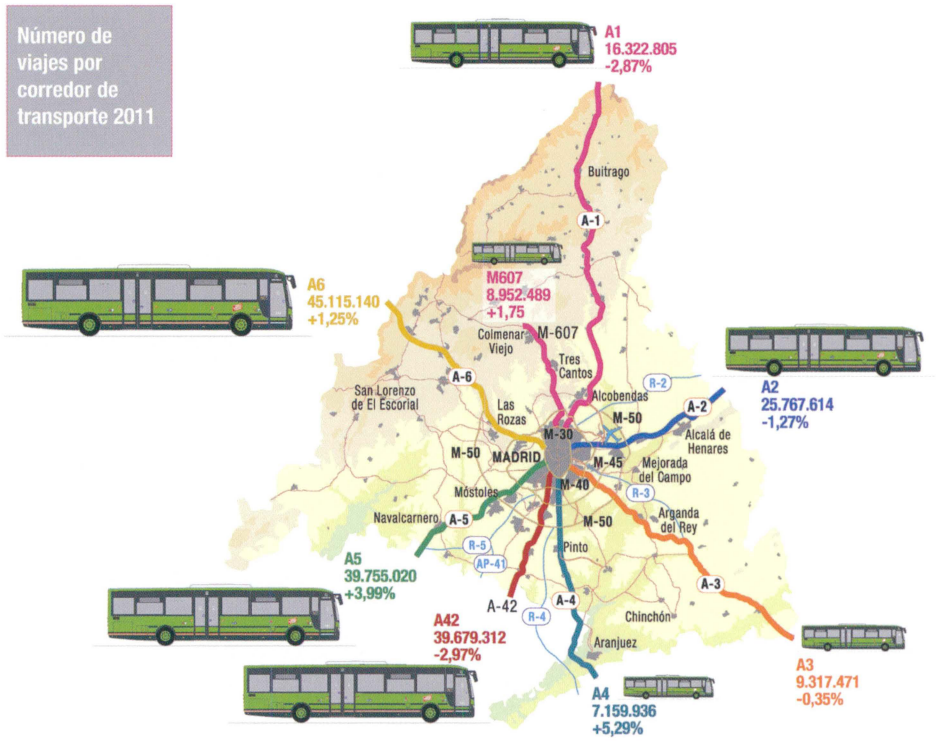
Intervention in the Metro by the State

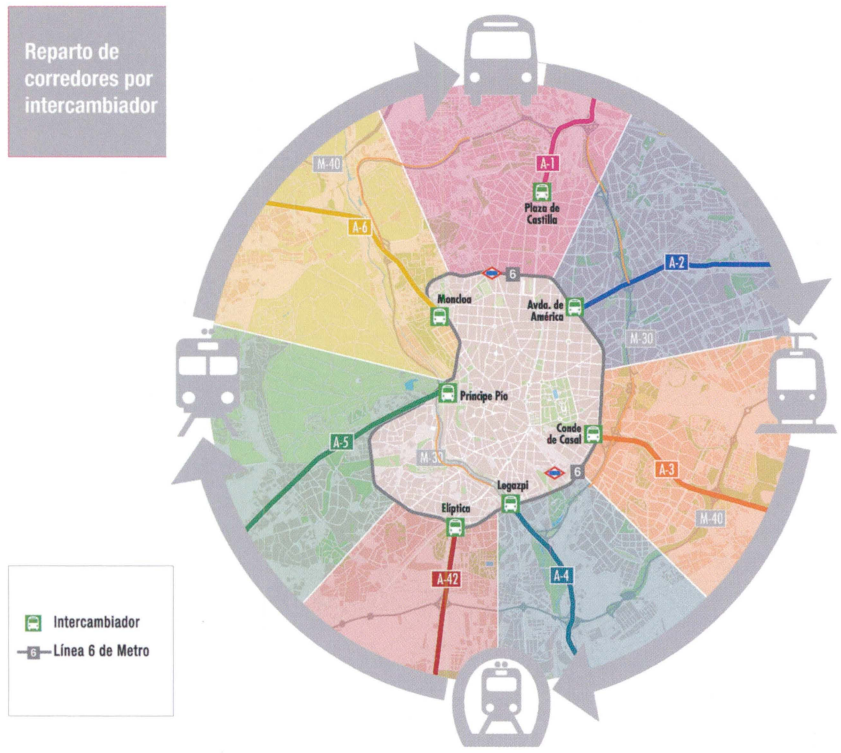
Inside the city, the tram was the initial option for public transport, firstly animal powered and later electric. This was later complemented by buses, both in the centre and out towards the new neighbourhoods. Madrid committed itself to an underground railway early. Since its creation in 1917, the Metro increased its network





Editorial presentation of Arturo Soria's project: "Railway-tram ring from Madrid to Canillas, Hortaleza, Fuencarral, Vicálvaro, Vallecas, Villaverde, Carabanchel and Pozuelo. Data and news referring to its construction and operation", Madrid, 1892. Drawing and illustration.





Interurban buses and interchanges.
Source: Community of Madrid Transport Consortium

and number of passengers continuously until 1969, when it reached 500 million passengers per year. Expansion was proposed in 1967, under the Ministry of Public Works, which was responsible for building the lines after 1955.

After 1969, the Metro lost the support of Madrid's residents, with occupation falling to 300 million passengers in 1985 and the operating account worsened. In 1978, the Ministry designated an intervention board, chaired by the Civil Engineer Juan Torres Piñón and the following year the company was nationalised, to then report to the City Council and the Madrid Provincial Office. Construction of lines then restarted, with 36 km being built in five years with financing from the Ministry of Transport (see page 30).

Public transport

In the mid-1980's, the problem of transport started to be considered globally and for efficient development. As José Manuel Vasallo stated, *Public transport is more efficient than private vehicles in terms of energy consumption, infrastructure occupation and pollution. Consequently, the promotion of public transport is positive from the environmental point of view.*

However, it is difficult or even impossible to finance through the users and needs subsidies which can only be justified due to this efficiency. *In any case*, Vasallo concludes, *it should not be forgotten that certain means of transport, especially the metro, are very costly and their subsidies have continued to grow, so a compromise solution needs to be found between reducing external income and the viability of financing them* [235:51].

Urban buses

In the 1960's, Madrid's public transport company (the EMT) started to take significant decisions on mobility. Created in 1947, based on what remained of the old 1933 Empresa Mixta de Transportes Urbanos, it had subsisted through the 1950's without many significant occurrences. It managed the tram network without adding extensions, but it installed the first trolley bus line in 1950. The trolley bus service was scrapped in 1966. Three years earlier it had stopped traffic of the old open trams, which let passengers get on and off at any time.



Príncipe Pío interchange

Red de Metro y Metro Ligero

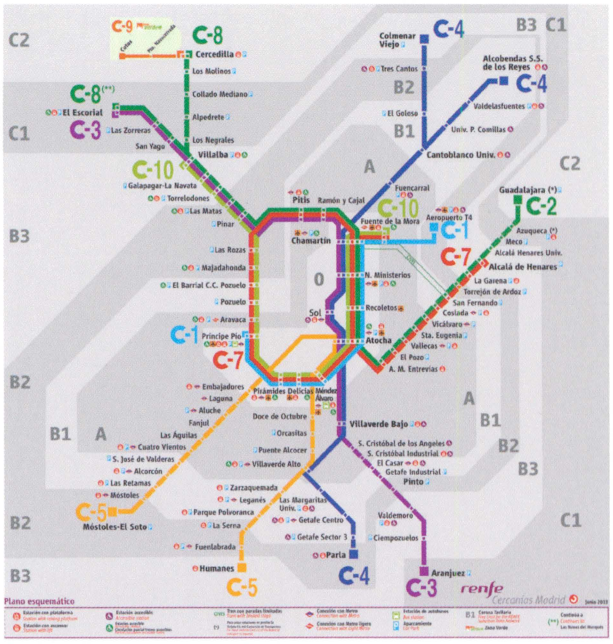
Metro · ML

2013

LONGITUD DE RED (km)	294
Nº DE LÍNEAS	13
Nº DE ESTACIONES	237
Nº DE VIAJEROS (millones)	595



Madrid Metro diagram 1919-2013.
Source: Community of Madrid Transport Consortium





Historic drawing of the Metro. Source: Madrid's Regional Transport Consortium



Metro of Madrid [MaríaJosé Ramiro Nuño]

The EMT's commitment to various types of buses was now definitive. In that same year of 1966, private companies started to run eight minibus lines, in principle suitable for routes with few passengers or for running along narrow streets. These lines only survived until 1990. The first articulated buses came into service on lines with large numbers of passengers and the city had its first bus lanes. The network was extended to the University City and the funfair and was completed in 1970 with the Cuatro Caminos - Embajadores circular line.

In the 1970's, the EMT gained in strength and reasserted the bus's supremacy over other means of public transport. On 1 June 1972, the last remaining tram lines, the 70 and 77 closed, with which the tram service disappeared for good. The Colón – Airport line and the night buses were created in 1974. The minibus services were taken over by the city in 1975 and these were progressively replaced by normal buses and the Express lines were created in 1976. The company also concerned itself with its image and replaced blue with red for the corporate colour of its fleet in 1973, like other large cities, although it has recently changed back to blue. Productivity improvements were also introduced to the fleet, with new vehicles without conductors and the sale of the first ten trip bus tickets in 1979.

Air transport

In countries without fast means of ground transport, the airport was a starting point in creating the first grid in a regional structure. In the most highly developed, however, the plane usually simply confirmed urban triumphs. In this task, the location of an airport is more important than its site. When the distance from the urban centre is around twenty minutes, success is much more likely. The natural site is less important in the end than the site created and interpreted by man, as the runways and area for aircraft can normally be conditioned at an acceptable cost within the investment.

Barajas Airport opened to traffic in 1930 and was Spain's first civil airport [229]. It had skeletal development over a long period, as air transport guidelines could not foresee the enormous development coming for aircraft and this development was interfered with many times using criteria which were not strictly aeronautical. The explosion of the Spanish Civil War destroyed the air navigation that had started to become established.

In 1958, a plan was approved which foresaw the significant development in air transport, compared with the deficient condition of our airports, which were incapable at the time of dealing with the traffic, much less that to come in the future. These considerations were valid, but they fell far short of reality as they did not take into account the effective growth in tourism [79:313].

Growth in passenger traffic

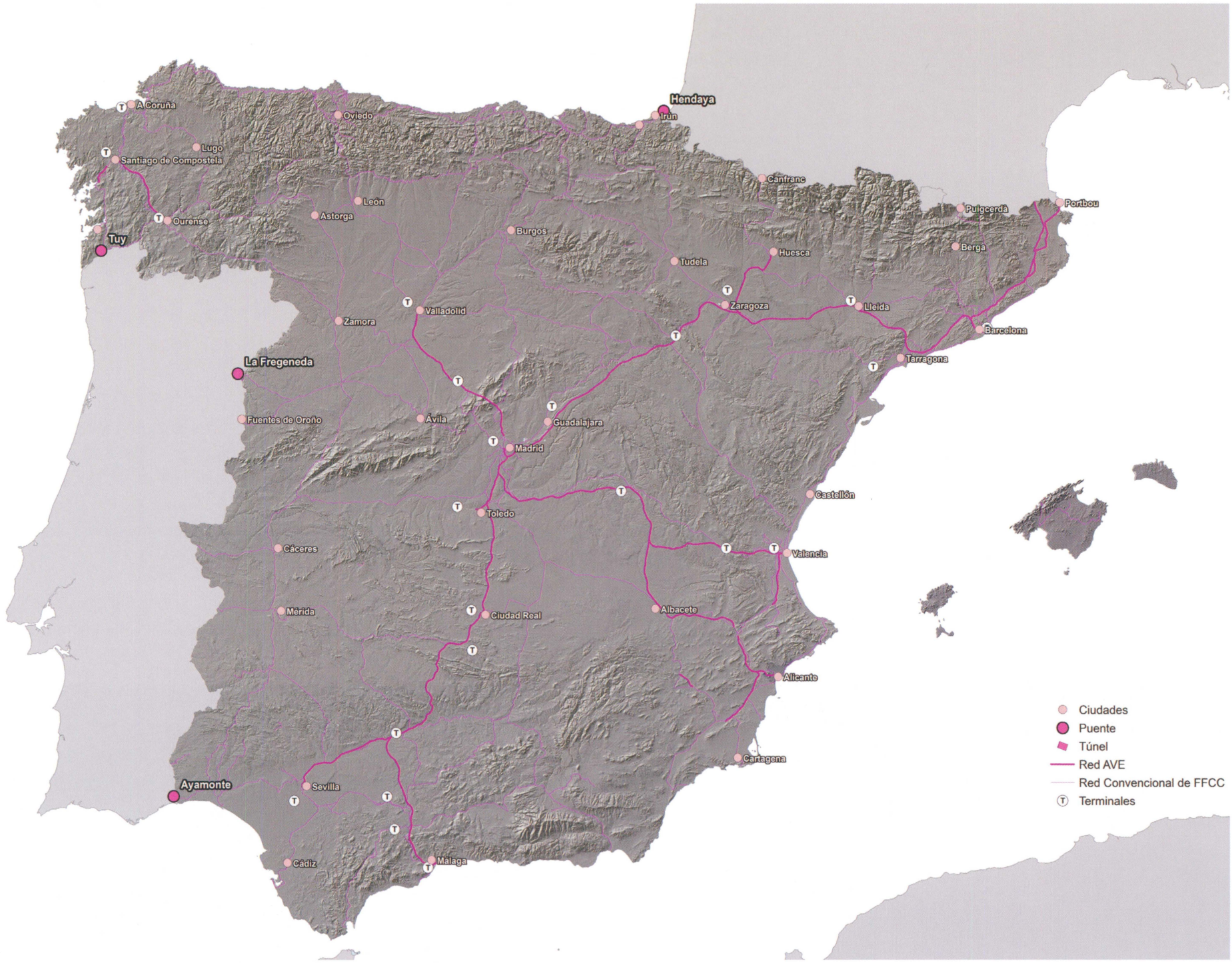
The increase in passenger traffic unexpectedly exceeded the forecasts made when the first plan was formulated and it became necessary to expand the terminal building. Barajas resolved international communications problems, but not domestic ones. It managed to bring the capital closer to the large settlements on the coast and the islands, but it did not develop traffic to the rest of the regions, instead concentrating on Madrid, Barcelona, Las Palmas, Malaga and Palma de Mallorca. Movement of passengers between these airports, making up Spain's Primary Air Communications Network, absorbed 80% of total passenger, goods and post traffic.

The characteristics of air traffic increases in Spain are startling. When worldwide passenger increases showed figures of 12%, Barajas' was 20% cumulative annually, with spikes of 21% in 1968 and 25% in1969. In aircraft, the figures were 8% and 12%, respectively [79: 317]. Indicated as probable causes were the poor condition of Spain's main roads, giving rise to unusually high domestic air traffic for a country of its size. In spite of this, nothing more than immediate investments were planned for many years.

Air traffic in Spain

	1941	1943	1945	1950	1955	1956	1960	1965	1970
Thousand pax	43	19	38	249	515	607	906	2,038	4,227
Thousand aircraft	3.5	-	2.9	13.6	23.5	-	31.0	49.1	82.0

Source: Dstis, 1973 [79:321].



Rail network drawing [María José Ramiro Nuño]

High-speed rail network

When the decision was taken to deal with the chronic problems of the railway network, the opportunity arose for a profound review of entire stretches of the network from a new philosophical viewpoint. This was no longer "repairing" or "relaying" a traditional black spot, but rather undertaking a qualitative leap in the service, in agreement with the features of railways in the other European countries. As such, the initial idea of installing double tracks in troubled stretches changed there and then to the adoption of high speed and the European track gauge.

Madrid is, undoubtedly, the great beneficiary of the new Spanish High-Speed Network, as all the lines have it as their origin. This rationality, call it centralist or whatever, represents a new way of tackling the problems of the railways, totally divorced from the initial concessional system. The first Madrid-Seville "AVE" high-speed rail line not only went faster, it was a different product to the traditional railway. It was designed focusing on user convenience and sold as a new experience inspired by aircraft. It needed to be treated independently from the remaining railway services which, instantly, ceased to exist. Consequently, the initial success of the Madrid-Seville high-speed train multiplied the demands from the other cities and autonomous regions in the whole country for a similar service and the AVE high-speed train became an aspiration no part of the country could relinquish. Inevitably, Madrid was its centre.

The AVE brings cities closer

For long distances, the plane continues to be the preferred means of travel, or the only one in the case of reaching islands or areas separated by the sea. For short distances, of less than 100 km, high-speed rail is a rigid, unsuitable means of transport and suburban rail gives a better service. For intermediate distances, though, the AVE has shown itself to be irreplaceable. Cities located at distances of one hour or a little over an hour away may be great beneficiaries of the high-speed train, because their alternative is not the plane, but the car. The train offers a comfortable journey of 60 or 70 minutes as a maximum, as against the alternative of three hours by road, which cannot compete except on price when the vehicle is used by three or more people [15:51].

For cities such as Ciudad Real, Valladolid or Cuenca, the AVE becomes almost a suburban service with respect to Madrid. Guadalajara and Segovia are too close, but they also lost their chance as their stations are located too far away. Zaragoza, Cordoba and Valencia are further away and, although they cannot be considered suburban, the AVE provides an unbeatable connection to Madrid. As a necessary step in channelling these new fast connections, Atocha has been remodelled on two occasions; first in 1992 to receive the Madrid-Seville AVE; and then in 2010 to expand its capacity for the Madrid-Valencia AVE.

Land structure and uses

All these improvements in communication routes and transport decisively influenced the city's *structure*. However, the effect of planning on determining uses should not be belittled. The level of urban land occupation by





Ave high-speed trains and line

built elements or buildings is usually used as a first approximation, although similar problems arise as with those noted before on concentration.

As before, the definition of what is built is affected by the way limits are located to measure the area occupied by the buildings, In areas of isolated dwellings, for example, it is possible to consider as built area only the footprint of the house or the whole plot. The same occurs with multi-storey buildings with common green areas. In general, the occupation or artificially occupied area is usually calculated, considering the part of it corresponding to the building separately.

Comparison with other cities

Again you need to compare with other cities to give levels of comparison that let you appreciate abstract figures better. This time the comparison is more focused on Spanish cities, given the dependence on local rules with respect to national legislation. Again, the most populous cities have been chosen to make comparisons between entities with a certain level of homogeneity.

The city with the highest percentage of artificial area is not Madrid, which is in third place with 55%, but Barcelona with 78.8%, followed by Seville with 61%. The green zones of El Pardo and the Casa de Campo probably lower Madrid's index, while Barcelona's green areas, which are a similar distance from the centre, belong to other municipal areas.

Growth of the artificial

The evolution of this artificial area is a signpost for the high level of construction over the last twenty years. The city with the highest percentage increase in artificial area is Murcia, with 99.3%, i.e. practically doubling in twenty years. Madrid is in fourth place with 45.3%, behind Zaragoza and Palma de Mallorca. Barcelona and Bilbao are in the last two places, with a process of municipal land occupation which has practically stopped.

As regards the percentage of building on these artificial lands, Madrid has 26.7% and lies in seventh place. This may be due to the large proportion of artificial area for facilities and roads. The city with the highest percentage of buildings with respect to artificial area is Barcelona, with 51.8%, followed by Valencia with 45.6% and Las Palmas with 41.2%.

Land occupation in 2010

		Corine Land Cover			Artificial areas (% of municipal area)	Building	
		Artificial occupation in 1987 (ha)	Artificial occupation in 2006 (ha)	Increase in artificial occupation 1987-2006 (%)		Total building divided by artificial (%)	Buildings between dividing walls %
1	Madrid	21,931	31,869	45.3	55.5	26.7	58.3
2	Barcelona	7,964	8,339	4.7	78.8	51.8	54.4
3	Valencia	4,061	5,176	27.5	40.3	45.6	64.9
4	Seville	6,341	7,446	17.4	61.1	20.0	49.2
5	Zaragoza	7,183	12,130	68.9	14.4	29.5	15.3
6	Malaga	5,615	6,839	21.8	21.6	24.2	30.0
7	Murcia	3,480	6,938	99.3	10.7	32.4	37.2
8	Palma	4,592	6,973	51.9	28.9	40.9	29.0
9	Palmas	2,643	3,626	37.2	41.4	41.2	32.9
10	Bilbao	1,522	1,528	0.4	46.7	25.8	44.5
Mean value		6.533	9.086	42	45	38	45

Source: Spanish Ministry of Development, 2010 [167:236].

Compactness

Finally, the percentage of these buildings located between dividing walls gives an idea of the "compactness" of what is built or its ordering in closed blocks, compared to the "dispersion" of isolated dwellings. Understood in this way, the most compact city is Valencia at 64.9%, followed by Madrid at 58.3% and Barcelona at 54.4%.

In principle, a high percentage of buildings between dividing walls implies a greater definition of streets, a more marked distinction between public transit spaces and private residence areas, although there can be other factors to explain the differences.

Details of occupation

This hypothesis on the comparative meaning of the above parameters is explained on detailed study of land occupation and artificial cover in Madrid, without comparing it to other cities. The green area, the sum of parks and urban green zones, plus forested areas and meadows, plus sheets of water, occupies 46.6%, rising to 52.2% if crops are added – over half the municipal land.

In turn, the percentage of urban land in total is 22.1% and that for communication routes and other elements of transport is 10.3%.

Other uses

The following table shows the absolute values for each of these classes of land occupation in greater detail. Some categories not mentioned before also appear, such as the 5,574.1 hectares of land not built up, or 16.6 %, and the 2,697.1 hectares under construction, a far from negligible 8% of municipal land. The sum of the last two figures represents practically a quarter of municipal land, a figure which any responsible plan should aim to reduce given the large number of vacant homes in the city.

Also noteworthy is the existence of 8.9% of land dedicated to extraction and dumps, which in other large cities varies between 1 and 4%. As the large solid waste dumps are mainly located outside the municipal area, these would be extraction zones, gravel pits or mines, such as the sepiolite pit in Barajas airport itself.

Land occupation in Madrid

Urban. Centre	0.8
Urban. Expansion	20.9
Urban. Discontinuous	0.4
Other constructions	0.1
Artificial, not built	1.8
Agricultural residential	0.1
Family kitchen garden	0.0
Facilities	7.4
Parks and urban green zones	5.6
Tertiary	1.5
Industrial	3.4
Transport Infrastructure	10.3
Energy, water and other infrastructure	1.4
Agricultural and forestry operations	0.1
Mines and quarries	1.4
Crops	5.6
Forest and meadow areas	38.1
Inland water	0.9
Wet zones	0.0
Land with little or no vegetation	0.2
Total	172

Source: Spanish Ministry of Development, 2010 [177:66]

Detail of simple artificial cover

	Hectares	%
Building	8,956.0	26.7
Building between dividing walls	5,221.2	58.3
Semi-detached single family homes	365.4	4.1
Detached single family homes	675.3	7.5
Detached building	1,419.6	15.9
Industrial units	1,274.5	14.2
Other	0.0	0.0
Urban artificial wooded green zone	6,265.9	18.7
Artificial sheet of water	330.1	1.0
Roads, car parks, pedestrian area without vegetation	7,194.9	21.4
Land not built up	5,574.1	16.6
Other constructions	2,278.8	6.8
Extraction or dump zones	2,984.4	8.9
Simple artificial cover Total	33,584.1	100.0
Simple artificial cover in hectares and % of construction	2,697.1	8.0
% Artificial cover divided by municipal area		55.5

Source: Spanish Ministry of Development, 2010 [177:66]

Built Madrid

In the early 1990's, the result of so much construction was not particularly brilliant. As Arturo Soria said, *Considered as an artefact or a group of constructions, Madrid was never a wonder. Its location was good, as were its sky, its air and its water. But the constructions raised on its lands were not particularly striking if compared with those in other large European cities* [221:9]. Neither were the communication routes and public transport comparable in terms of functionality or monumental nature, except perhaps for the axis of the Paseo de la Castellana.

However, since the fall of the dictatorship, political agreements between social forces led to the city taking another course and becoming the new image of Spain Juan Pablo Fusi pointed to. A great deal has been built and built well in Madrid over the last 30 years [11], [12], [13], [14], [15]. The road structure and public transport are exemplary and could only be accused of excess. Excellent new institutional buildings have been constructed and all its valuable heritage, and even many examples of limited interest, have been restored. It may have also been to excess, considering the difficulties of maintaining it in times of crisis. Undoubtedly excessive are the housing development and residential construction in the urban area, resulting in a cheerless landscape of empty plots and dwellings.



Buildings in the AZCA complex

THE PERIOD OF INTERVENTION IN THE METRO

Juan Torres Piñón
Civil Engineer

The Madrid Metro, opened in October 1919, was initially executed and managed by the Compañía Metropolitana Alfonso XIII, a private company established in January 1917, in which King Alfonso XIII personally held a 10% stake.

Its evolution from that time adapted to citizens' needs for mobility, to the growth in Madrid's population and to the Country's economic situation, going through significant and highly traumatic upheavals between 1936 and 1940.

The Decree/Law on the Shared Regime for the Financing of the Compañía Metropolitana de Madrid was enacted in September 1955. This established that financing of the Metro would be the responsibility of the State on the one hand, which would execute the infrastructure for new lines, and the Compañía Metropolitana de Madrid on the other hand, would be responsible to commercial operation and the maintenance of the installations and services, as well as for purchasing and maintaining rolling stock.

Forecasting Madrid's population growth trends, the expansion of the metro network was proposed in 1967.

From the early 1970's, the Madrid Metro ran into serious economic difficulties. The Government controlled the fare structure and the wages of the Compañía's personnel and, given the imbalance between the two, negative economic results were produced which led the Metro to significant reduction in assets and reduction in maintenance of its installations. At the time the Metro had a network with a total length of 64.3 km.

Faced with this situation, the State decided to take control of the company by means of the Royal Decree/Law of 7 July 1978 and it placed it in the hands of the Ministry of Transport, transferring management to an Intervention Board.

The Company was nationalised on 9 November 1979 and became the property of Madrid City Council and Provincial Office. Nationalisation made it possible to gain access to resources to improve the infrastructure and take the urgently required safety measures.

Construction of the planned expansion was initiated and financing was fully covered by the Ministry of Transport, such that the Metro had a total length of 100 km in early June 1983.

When I took over the Chairmanship of the Intervention Board in early 1979, I became clear of the need for and correctness of the decision taken. At that time the Company's personnel felt a worrying expectation, because although they were clear that the Metro was a Public Service, they knew that it had not proved viable to maintain it as a private company due to the accumulated losses caused by the increases in operating and maintenance costs and the lower increase in direct income from users as ticket price increases had been limited, due to necessary considerations of a social and economic type, and also due to the significant fall in user numbers in recent years.

The State was also clear that Madrid needed an underground infrastructure that made it possible for it to maintain its metropolitan development as the capital and to retain the traditional attraction of its coexistence.

It should be emphasised that during its first sixty nine (69) years of the Company, 64 km of lines were built, i.e. less than one (1) km per year. In the five years that passed from 1978 to 1983, thirty six (36) km were built, i.e. more than seven (7) km per year, all planned, financed and built by the Ministry of Transport.

It was that push that led to the Madrid Metro of today having 284 km of network, making it the sixth biggest in the world and third in Europe by length. It is also fifth in the world by number of stations.

It is clear that the decision to nationalise the public service taken in 1978 made it possible for Madrid to have a public transport system, essentially based on the Metro, which has provided its citizens with a significant improvement in their mobility. Also significant was the change in mentality of the Company's management which meant and enabled its positive development over those recent years.

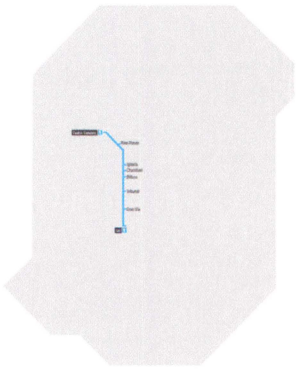
Advertising campaigns started in 1979 to attract travellers to the Metro. These have been maintained over long periods and have managed to bring in new users and to significantly increase passenger numbers. In 1977 the annual number of trips did not reach 390 million, but in 2007 the figure of 680 million trips annually was achieved

The signalling was later changed and updated to ease network circulation for users, subsequently bringing it up to date with successive expansions. The Metro stations also started to be provided with commercial services, enabling passengers to find shops and services, giving the underground setting greater attraction and life.

It was in these later years when renewal and innovation in rolling stock accelerated. In turn, automatic ticket sales increased. A variety of systems for paying for municipal and autonomous public transport were also implemented, making it possible to decrease the cost of this transport for the user, accounted for at constant currency rates.

In short, it does not appear disproportionate to assume that one of the most important aspects in the renewal and improvement of the city of Madrid as a metropolis has been the growth in road infrastructure and in its public transport.

(Text by Juan Torres Piñón, Chairman of the Intervention Board from 1979 to 1983).



1919 3,5



1925 13,5



1935 20,3



1945 25,6



1955 27,6



1965 42



1975 62



1985 99



1995 116



2003 226



2007 259



2013 294

THE 85 PLAN: A REFERENCE AGAIN

Eduardo Leira
Architect and Plan writer

The Madrid Plan of 1985 was a grand, not to say controversy-free, plan in which we introduced many innovations. The first of these was the setting up of a specific body to undertake it: the Plan Office. It was in humble offices in the old EMT depot, alongside, but not in, the Municipal Urban Planning Office itself.

We managed to set up a public company, belonging to the City Council, but with its own legal and economical personality. We negotiated the budget annually. We managed them almost like a private company. Now, 30 years later, it would come as no surprise. At the time it was a real milestone.

We responded to an exceptional enthusiasm, the product of the historical times we were lucky enough to be living through: the political transformation, the first flush of democracy. It is difficult to explain it without having lived through it. It is certainly unrepeatable.

There were around fifty of us over four years. Over 400 people worked on the Plan as external collaborators, including those who took part in the innovative "50 ideas" exercise. Something over €200 million was spent, which lay in the range of costs acknowledged as proper for a plan for a big city.

We undertook the plan in four years, which is still a record. On the way, we made, as we thought appropriate, a lot of noise. We also innovated in areas which later became lavish, but surely not with so much conviction and dedication. The plan, a collective work, needed to be known and disseminated so that people would participate in it, as was also intended. We managed that. We used several advertising campaigns to do this. The first, the Plan Preview, in 1981, was the pioneer and had the greatest scope.

It still moves me to hear Joaquin Sabina's song 'Pongamos que hablo de Madrid', or Let's talk about Madrid. We used it as the base for radio commercials, with Plan messages inserted. One day, Madrid awoke "papered" with over 400 hoardings saying 'We've Got a Plan' and those commercials. We announced a book, *Recovering Madrid*. That enabled us to get a reduced rate in TV advertising. Culture was subsidised at that time. We achieved what we think was a landmark in an institutional campaign, a commercial of the restoration of a painting of the Puerta de Alcalá, at the end of which was a phantasmagoric inverted image, both exciting and surrealist, in which the Puerta stood out against a blue sky with bright white clouds. The book announced, which was sold in kiosks, was a best seller for several weeks.

An Urban Development Plan, a city plan, represented something really new and unusual for an advertising agency. They needed to learn how to communicate it, like us and with us. All of us, in those fascinating times, were learning.

We rejected the first campaign proposal, with barrel organ and the same old Spanish traditions. That was not right. A second campaign was designed, the one with the *Puerta de Alcalá, which not by chance came to be a symbol of Madrid*. This was of a new Madrid, full of modernity which, together with its modernisation, we contributed to implementing and later to building, with the Plan. The symbol endures: it was the basis of the Madrid 2020 Olympic logo.

You need to remember that, led by the great Mayor Tierno, we were in the early years of the 1980's, at the time of the *Madrid scene*. This vague movement undoubtedly represented a self-assertion of Madrid, of a Madrid that wanted to throw off the burden of having been the centre of the Franco system. The slogan for the Plan, "Recovering Madrid", although it could court controversy, was a suitable slogan. It answered, as was stated, to *a new, growing feeling: we liked Madrid and wanted to improve it*.

Beyond its acknowledged media impact and its acceptance by its citizens, it was a *technically solid Plan*. The National Urban Planning Award was fully justified. The Plan represented a reference in the 1980's, at the time when, rightly, the great master Solá Morales titled it the one of *urbane urban development*.

Every corner of the city was dissected and systematised, differentiating the areas regulated conclusively and directly from the portions referred for further detailed planning. This represented a real technical innovation, even being recognised by its detractors. Today, 30 years on, all plans are made as if obvious. It was not so then.

Beyond its systematisation, though, *the Plan introduced many innovations,* some of which were immediately questioned due to their "danger" in the eyes of certain interests, and others were only acknowledged in fact with passing time.

In 1989, after the first four years of Plan 85 coming into force had passed, and still before any new urban developments, I wrote an article reflecting on its condition as a *Transformation Plan*. With this focus and this nature, it really was pioneering and ahead of its time. *The extension of the city', in short its physical growth, was in fact considered in a second term,* in spite of having been considered, until then, as an expression of the "city model" all plans contained. Perhaps for the first time, *the Ma-*

drid Plan openly tackled the enhancement of the existing city's value, faced with its relative neglect, in fact, as against the leading role always granted to its endless extension. This enhancement was achieved by means of its conservation and, where appropriate, its remodelling, introducing concepts such as the stitching and continuity of its fabric, which can be so in vogue today. This really was ahead of its time. So was the introduction of the land redivision that, overridden by the courts, does no more than give monetary value to the exchange economy, to which land compensations appear to be relegated exclusively. This type of land redivision in Urban Land will be necessary if the wish is to apply recent Law 8/2013, which finally needed to acknowledge the leading role the consolidated city warrants. It needed the severe crisis to come to acknowledge this, but better late than never.

The focus on the existing city, together with the intention, declared from the start as a pragmatic objective, for the Plan to be useful and applicable from the time it came into effect, was one of its successes that was never acknowledged. The second five-year period of the 1980's with Spain's entry to the European Union and its consequences saw the first explosion of financial overdemand for housing. Faced with this, Plan 85 was clearly functional: *it has unlocked, in terms of management, and therefore revitalising, enclaves in the city centre area* making it possible immediately to channel (without long planning and development processes beforehand) the investment drive that demand generates. Perhaps the clearest example is the extension of the Calle Príncipe de Vergara, (a strange portion of avenue in the centre of Madrid that had not been executed), where the new National Music Auditorium is located. As well as bringing an attractive enclave into play and revitalising it, in market terms, this area also shows what the Plan gave rise to in the very centre of the city: *the incorporation of new facilities,* both exceptional, at city level, such as the Auditorium, and of more limited scope, at district or local level.

In this sense, the Plan's success is not open to discussion, above all as regards the stated objective of *rebalancing the North/South of the city,* once the painstaking prior diagnosis carried out had shown the great accumulated differences between the two halves of Madrid, both inside the central core (inside the M-30) and outside it. That success was fully recognised later, on initiating works that continued over decades, with the support of the following Plan that, on this point, continued the trend started by Plan 85. Indeed, with the most restrained logical approach with which we could formulate proposals for Action, our *emphatic structural proposal on Manzanares river,* it was only in the South, and attempted to compensate for this.

The bastion of the Plan was its *transport policy. Plan 85 championed public transport without beating about the bush,* as a need for present day metropoli that could not adapt themselves to the car, in fully and highly motorised societies. They even branded us "antiquated" when we were clearly forerunners. With the insight and moderation of our realistic investment estimates (as against those who could not forecast high indebtedness) we were only able to include *13 kilometres of new Metro line* in the Plan. The same people who then accused us of being "outmoded" for insisting on the Metro, were years later those who proposed and executed dozens of kilometres when, happily for Madrid's residents, they discovered that, as well as keeping the tunnel boring machines busy, extending the Metro lines won votes.

Our commitment to *suburban trains,* within our metropolitan strategy, was a real success. It managed to show that, in contrary to what our technical colleagues in the state-owned railway operator, Renfe, told us (with great conviction and knowledge of the cause), it was possible to have profitable trains.

If there is a symbol and an icon to represent Plan 85, I think it would have to be *Atocha station,* the ultimate expression of a new concept: *transport interchanges*. We, at the Plan Office, introduced and minted both the concept and the term itself in Spanish. As well as its status as a great interchange, two elements reinforce the character which can be attributed to Atocha station. On the one hand, its status as the Gateway to the South, with the intended aim of pointing from the city towards the South, with all that meant for the transformation of the Arganzuela district, which was previously the city's machine room. On the other hand, Atocha was the first in a dynasty of elements which, due to their urban importance, from the time of their planning and as part of it, required special project attention. That is, it needed an Architectural Project and not just a functional solution. On calling a competition, from the Office we managed to make it a real Project that would last and constitute a benchmark, both in the city and outside.

Talking of the big projects in the city, such as the Atocha project, it is appropriate to bring up our confrontation with the Banco de España. Unintentionally, it was a precedent for many other later cases.

Without taking the City Council or the Plan Office – at that time piloting the application of the City of Madrid Conservation Plan – into account, the Banco de España called a competition for the expansion of its headquarters. It had bought the neighbouring building, previously the Banco Pastor, for this. This was a registered building that, according to that Plan, could not be knocked down. They failed to take this into account when they called the competition. On the contrary, without more ado they included in their specification that it would be demolished, as certainly had been occurring in earlier years with so many other magnificent buildings, of which no trace remains. Moneo won the competition, with an imitation reproduction of the Banco de España building to complete the block uniformly, as was built years later [41].

When we were finally notified, we opposed it. The Banco Pastor building could not be demolished. It was a very bad example and precedent. On top of that, in certain professionals spheres, they challenged us: how could Madrid reject "a Moneo"?

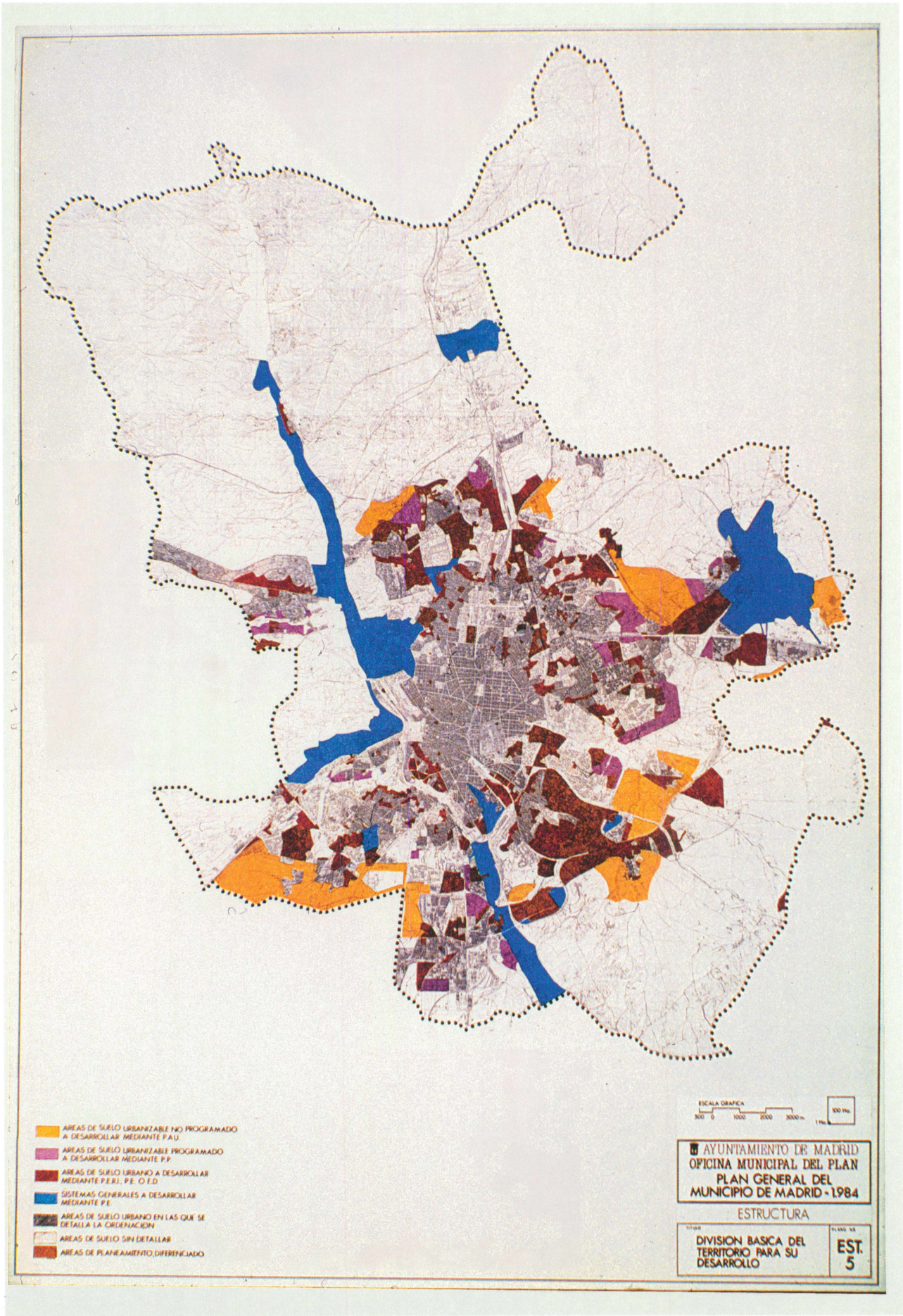
I called the Director General of the Banco de España to my modest office. He came mixing surprise and offence. I proposed to him that they call (and pay for) a new competition among the same leaders in Spanish architecture as called before, with new specifications. In the new competition, the Banco de España would set out its needs with no precondition involving the demand for demolishing the neighbouring building. It would be the great professionals called who, alerted to the registered status of the building, would decide whether (or not) they would be able to meet the Banco de España's demands in what had been the Banco Pastor building.

It was a strange interview. The financier could not believe it. He told me he liked Moneo's solution. I answered him by saying that if we were going to talk about urban aesthetics, we could go to the bar on the corner and, like two companion citizens, we could keep talking about buildings with each one giving their own opinion. There, in that office, I was the one with the responsibility for establishing which buildings were conserved and which not. He could only talk about the optimum conditions for saving the country's reserves and any other matter relating to the Banco de España's many important powers. With regards to the city, he lacked these powers.

We were convinced of our task. We took our way of exercising it very seriously. My proposal for a new competition was undoubtedly not well received and our resistance to the demolition of the Banco Pastor was unsuccessful. The City Council finally withdrew its status as a protected building.

The anecdote, which was no more than strange and perhaps is only explained by our political/governmental inexperience, nonetheless highlights a significant matter that started there. Later, after decades of economic euphoria, what we branded in that time, with real clarity, "very well made garbage" has proliferated. Moneo's proper proposal did no more than respond to an error in approach that, with the skill of the master, tended to be avoided.

How many political decisions were taken later, even more questionable than that example, which have been "covered" by the great (and sometimes not so great) project of the great architectural firm! That made criticism of the decision to tackle the project difficult, when it did not prevent it, which is what should really be questioned. *The list of the "well made items of garbage" could be very long.*



Going back to the Madrid Plan of 85, which we left at Atocha, also to be pointed out are its solutions in the *conception and design of urban roads,* which were equally pioneering and innovative.

We were criticised for not favouring the incessant expansion of fast roads for cars in the city, as had happened since the 1960's, in that losing battle between new supply and growing demand, both in general and as generated by the improvements themselves.

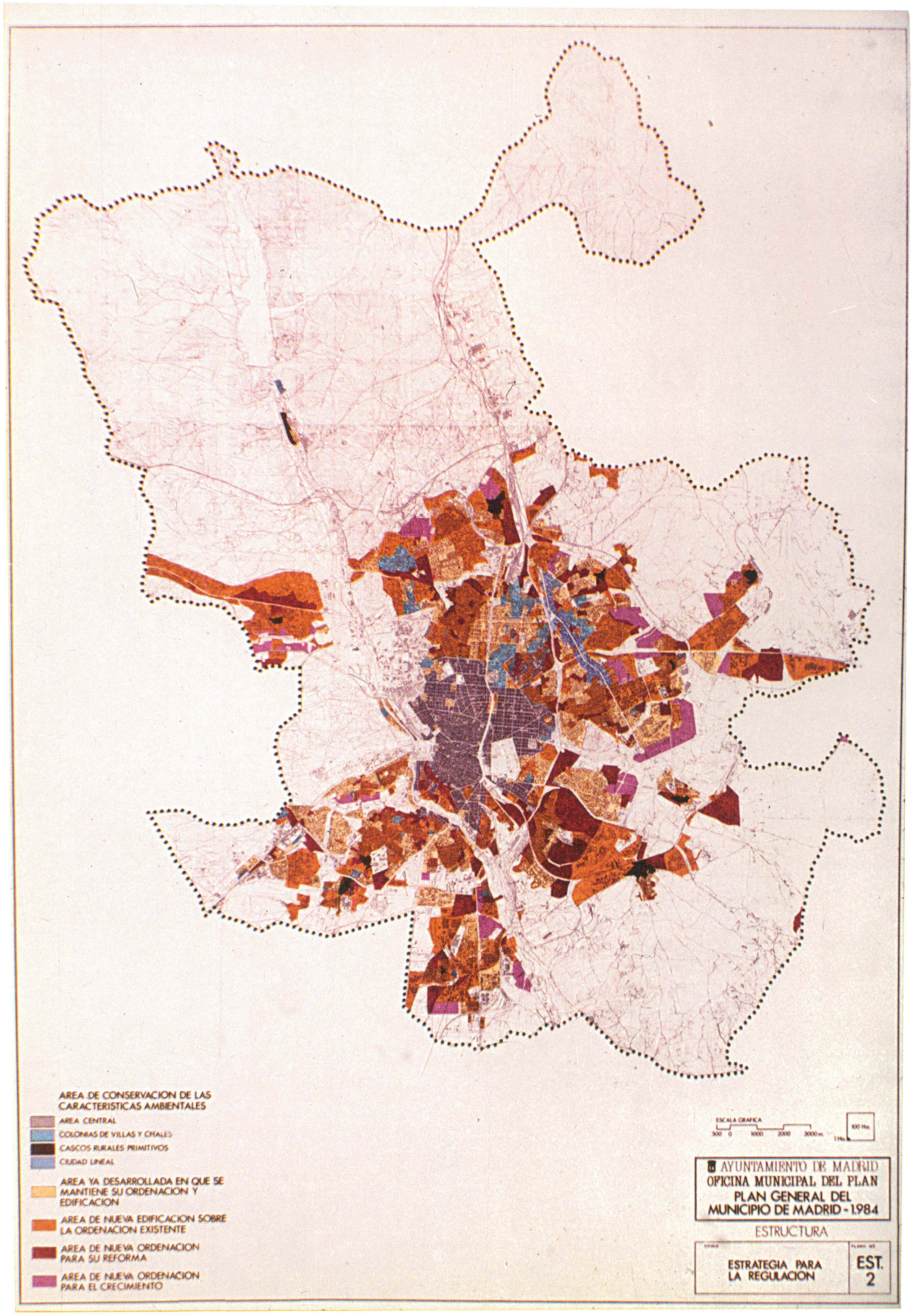
Far from a generic denial of large infrastructure works, which are absolutely necessary, we raised the so-called "Southern bypass" to the category of one of the Plan's great structural actions. However, this was not in the heart of the consolidated urban fabric.

Faced with this criticism, both highly topical and indeed very antiquated, *the 85 Plan was the first modern plan to start to introduce new formulas,* as against the incessant and always insufficient generic increase in "arterial" capacity. In Barcelona too, years before, they had come to propose a fast road to replace Las Ramblas parade. I do not think anyone today would dare to question the suitability of its rejection, nor of what was in my judgement the best "Olympic works": the Urban Rings of the city of '92. Years later, in Madrid, we completed our necessary, but mistakenly planned M-30 (to run round the city of Madrid and for through traffic), using the North-West grid, made up of three roads: Herrera Oria, Sinesio Delgado, with a tunnel, and the Avenida de la Ilustración, the paradigm of a high capacity urban road which showed that, over its whole route, it need not necessarily be a motorway all the time.

Even Los Angeles, California, "car metropolis", needed to invent public transport to try to stop people using their cars for everything, as San Francisco had done years before with its BART. There was then a *new message the Plan pledged to transmit*. It was even newer in Spain, with our much more recent and accelerated motorisation: *the car should not (and could not) be used in the city for all types of trips,* although we "all" had them, as we started to say back then.

The commitment to public transport, made by the Plan, was not, then, a consequence of our insufficient motorisation. Public transport should stop being considered as a solution for captive demand from those without cars. It needed to be set out as a means of attracting a more exacting demand too, from car owners, so that they stopped using them. That commitment was an alert, ahead of its time, of the urgent need in current metropoli, to see that the car could not be used for everything.

It does not belong here to set out what, ultimately, constituted the supposed basis for the early revision of the 85 Plan. That is: *the dimensioning of the Building Land,* of the extent of the city. This was immediately considered



1985 General Plan

"insufficient" due to the speculative pressures on those that remained outside the enclosed delimitation of that land class. In spite of everything, in quantitative terms, the 85 Plan established, comfortably, a significant area of building land, of nearly 3,500 hectares. Since its approval, almost 30 years ago, Madrid has not planned and occupied that total area of new land, even after the bubble years. This represented an average of over 100 hectares/year of new city; a really significant rate.

Today, hundreds if not thousands of hectares, of which only a small proportion are developed and the majority are only "dizzy" (from so many "passes" over the land), are there "hoarding" millions buried and extracted from the productive system, locked up and in the "arsenals" of the Bad Bank and the bad banks. Once again, and along the same lines, we could do with the optimism of the 85 Plan.

Going back to the title, as alluded to, the Plan of 85 continues to be a reference. It showed prudence and restraint, while being optimistic, which have been missing from later episodes of urban planning for Madrid. Its optimism appeared, 30 years earlier, to be related to what the National Government calls for from us now, in 2013 and reviling the "brick crisis", faced with economic recovery.

INFRASTRUCTURES AND THE CONSTRUCTION OF THE TERRITORY

Eduardo Mangada
Architect

Otto Wagner, on accepting the preparation of the Vienna Plan, "emphasises the importance of infrastructures as a key instrument organising extensive urban growth". At the time when this Plan was formulated, the word infrastructures referred almost exclusively to infrastructures linked to transport, whether roads or streets, railways or trams and, to a lesser extent, to drainage and water pipe networks. That is to say, those infrastructures with a footprint on the territory that require geometric definition and engineering to execute them.

We may qualify this understanding of infrastructures as reductionist now, because fitting into and needing to be understood as "infrastructures", as parts structuring an urban territory, are other elements such as a university, a large shopping centre, a big hospital, a sports complex or a cultural centre, not forgetting, in big metropoli, the airport, not just linked to air transport, but also a doughty container for increasingly complex activities, representing in itself a portion of the city.

In the development of the Madrid-region over recent decades, road transport infrastructures (circular or radial), the suburban railway and the Metro have been very important in the form and location of the new urban developments. This has been for good and ill, as although they have enriched the metropolitan area with a noteworthy increase in mobility and interconnection of the existing settlements, it has also led to, or at least justified, the perverse Urban Development Plans in the east; real adipose adherences poorly named expansions.

But let us not forget that the siting of the University Carlos III in Getafe and Leganés and the University King Juan Carlos in Alcorcón, Fuenlabrada and Móstoles has had a great influence on the physical and social revitalisation of these large metropolitan settlements. With the passing years, I can say that the location of the University Carlos III in Getafe and Leganés was more important in constructing the metropolitan area than the urban development plans with their proposals and regulations.

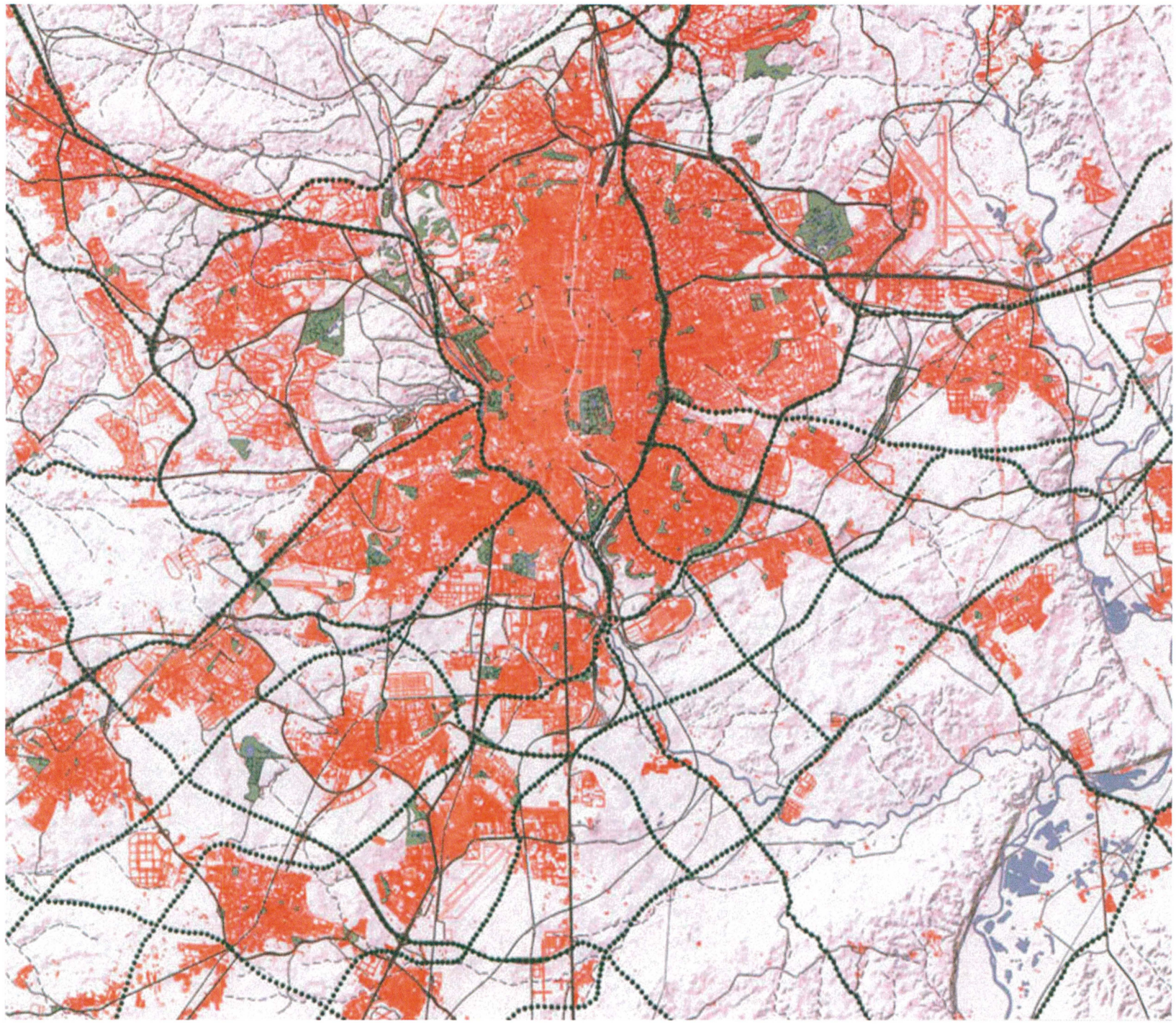
In any case, there can be no doubt that infrastructures, of whatever type, have an intimate relationship with, a direct influence on, land use and the location of activities in a broad metropolitan or regional area like Comunidad de Madrid. This relationship is more direct and assumed in the case of infrastructures linked to transport.

For this reason I have for many years defended the need to conceptually link plans that establish land use and transportation planning. Land uses and transport infrastructures with combined understanding and planning, feeding into itself, as well as the need for a single technical/political organisation responsible for planning it and controlling the form and timing of its execution. Unitary understanding and management to guarantee (which should guarantee) greater coherence in the new geography and better integration of the structures of existing or newly developed settlements, preventing the spatial and economic irrationality of empty infrastructures or new developments without the essential accessibility and interconnections.

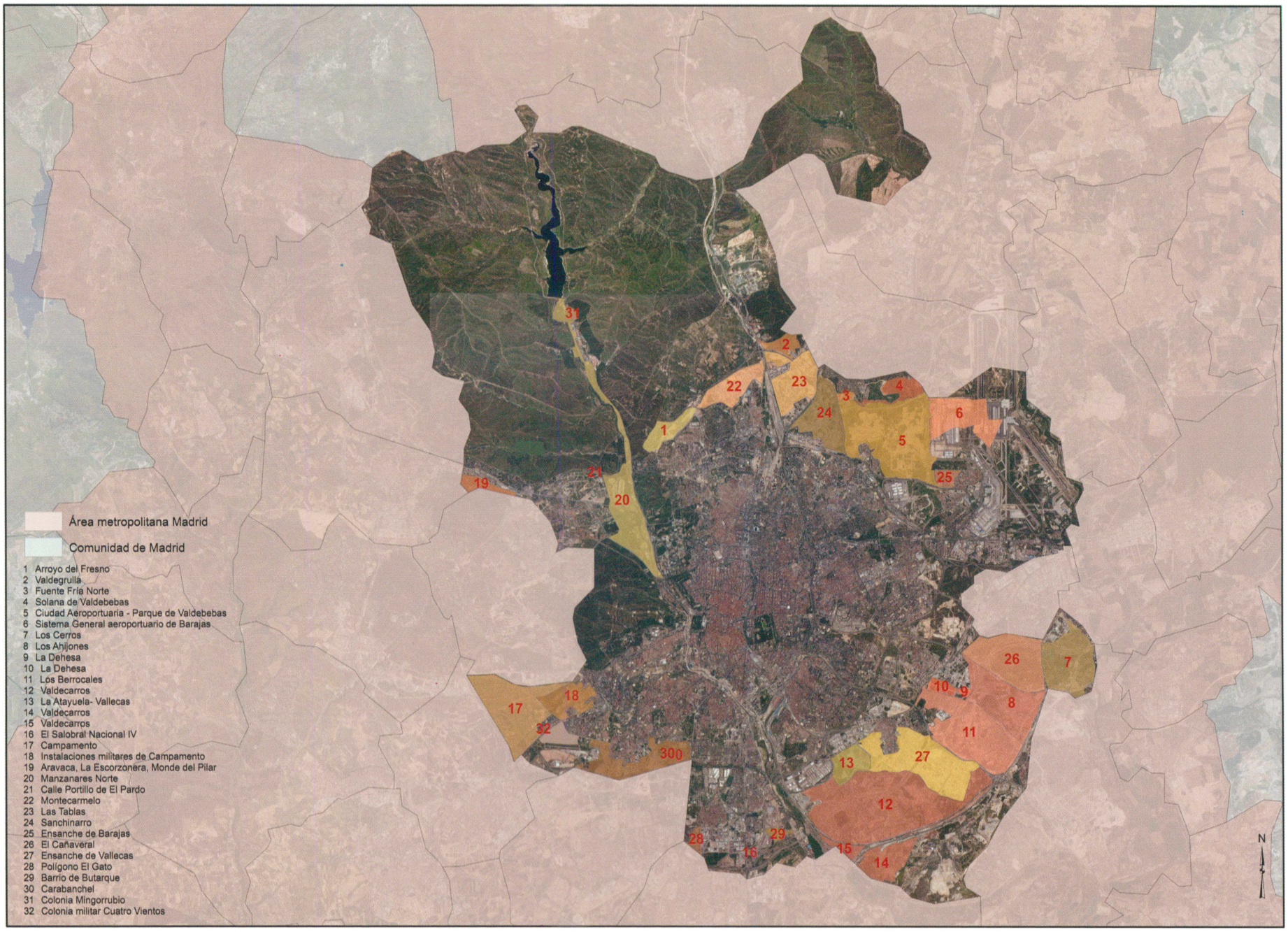
This is why in the second legislature (1987-91) the responsibilities for urban development, public works, housing (JVIMA) and transport management (Regional Consortium for Transport) lay in the Council for Territorial Policy, Public Works, Transport and Urban Planning, not due to the will to concentrate power in the Council, but rather for intellectual coherence and the desire for a more balanced and effective construction of regional territory.

Some specific actions, up to 1991, can be offered as examples of a policy linking land use and transport, making the theoretical discourse real. Located in Getafe, near the Suburban Station and near the junction between the A-42 and the alternative M-45 route, is the new University Carlos III campus and the Getafe North residential development. Something similar occurred in Leganés, likewise linking the railway and new vehicular routes to the new University Carlos III site and the new Leganés North expansion. At Alcalá, taking advantage of and based on the renovation of the railway and the construction of a new station, along with the alternative N-2 route, the new urban development of La Garena was proposed and developed, as a public promotion, including large shopping areas, tertiary activities and a significant number of dwellings.

More modest and localised is the siting of El Corte Inglés in Pozuelo de Alarcón, taking advantage of the regional accessibility provided by the junction between the N-6 and the M-40 and forcing construction of a railway station and a public car park to draw traffic to satisfy a double objective: decreasing pressure on El Corte Inglés at Princesa, in the heart of the capital, and spreading central services in the metropolitan region. These examples were more or less achieved, but they embody a political will and technical intervention in the linking of land use to the regional transport system. In other cases it has been a development proposal for new land that has called for and justified a new item of infrastructure, as happened in the case of the Eje del Culebro road, defined in the Strategy for the South as a chain of logistical, industrial and commercial activities, together with the regeneration and plantation of the course of the brook itself, which made it necessary to build the highway from the Andalusia road to Fuenlabrada, which would come to form part of the present M-50.



1996 Regional Plan, lines of the grid development for the territory



Urban residential developments, Madrid [María José Ramiro Nuño]

In recent decades (1980 a 2008) Madrid, as a central city, and the metropolitan-regional area have been enriched by the consolidation of a system of roads circling the capital which has moderated the radiocentric model, and radial and alternative routes which have improved connections to metropolitan municipalities and between them. At the same time, significant modernisation of the suburban railway took place, with new lines, new stations and new rolling stock.

Add to this increase, in quantity and quality, of roads and railways, the expansion and renewal of the Metro, including the MetroSur, capable of connecting five major urban settlements in the first metropolitan belt, with a total population of one million inhabitants. Furthermore, these new infrastructures sought immediate interconnection in large facilities that took the name of "interchanges", answering the need to integrate these infrastructures into a multi-mode system. Atocha, Plaza de Castilla, Avenida de América, Príncipe Pío and Moncloa are examples in the capital. Alcorcón Central and El Barrial are in Madrid's periphery.

Improvements have certainly been made to what existed, together with the construction of new road and rail infrastructures which have made the metropolis's operation more effective, although these have not always been sensitive to landscaping and environmental conditioning. An enrichment, in any case, with some serious sins, such as perhaps the radial toll roads, the Pozuelo-Boadilla light rail and the priority given to private cars, missing the chance to use the new roads as supports for collective public transport. To these sins I dare to add the underground section of the M-30, now camouflaged as Calle-30, which is considered by many (including Professor Peter Rowe, whom I hold in great esteem and for whom I have great respect) to be the queen of operations in the construction of new infrastructures in



Madrid-Río, general drawing [Garrido & Burgos]

Madrid and, judging by the electoral results, favourably received by its citizens.

It would take a long time to argue for this negative assessment, which is in the minority and unorthodox, but it basically focuses on four aspects. Firstly, the disproportionate consumption of economic resources, which has left a costly burden for Madrid's residents over many years. Secondly, the lack of a cost benefit analysis to assess the social utility of this grand intervention in comparison to other alternatives for interventions in the city, both in the impoverished centre and the peripheral districts. Thirdly, the substantive contradiction between an environmental rhetoric of pursuing energy efficiency and the construction and operation of a tunnel seven kilometres in length (dumping of wastes from the excavations, energy costs for constant lighting and ventilation, etc.). Finally, a slightly more sophisticated argument: the loss of perception of urban space for several kilometres, of the city as a reference space in which the citizens, on foot or in a car, can place themselves and identify themselves by finding visible urban landmarks that orient their route.

This is a great sin which sought pardon by creating a wonderful urban operation in the park known as Madrid-Río, which arrived to enrich the city by incorporating a marginal, impoverished area into urban life, for the citizens' pleasure. I just want to add a note to this comment. Among the structuring proposals in the 1985 Plan, a "Parque Lineal del Manzanares" was already put forward, domesticating, not burying, the M-30 and this found a graphic realisation in a sensitive drawing by Juan Navarro Baldeweg. In any case, the current Madrid-Río park merits an unreserved round of applause.

If the construction of new infrastructures is visible and successful, at least as important is the management of the various means of transport that run along them. Traffic engineering needs to be complemented by traffic management if you wish not just to increase the area of concrete and asphalt or the length of the steel rails, but to guarantee improved operation and greater social efficiency from these infrastructures. The creation of the Regional Consortium for Transport answered this desire and need. The attempt was made from this to rationalise and relate the various means of public transport and a fare policy was established to draw in more addicts to collective transport (buses, suburban trains and the Metro) by prioritising season tickets over single tickets and compensating distance from the regional centre with lower costs for users. Greater regional cohesion.

Perhaps I should refer to other large items of infrastructure developed in these recent decades, such as those related to the water cycle, both in the supply network and the treatment of waste water, which have enabled the Madrid-Region to enjoy drinking water of excellent quality, and the recovery of its rivers (measured) thanks to the great operation for comprehensive drainage executed during these three decades. The ducks and perch in the river Manzanares are a symbol. Comprehensive water management thanks to sole management by a great inherited and renewed public agency, the Canal de Isabel II. This management is practically self-financing and has even attempted landscape improvement operations on the banks of rivers and dams, allocating part of its business profits to this. Unfortunately, this magnificent institution is threatened by the shadow of an irresponsible privatisation that fits a neoliberal ideology and not technical, economic and social rationality.

The importance I have attached to infrastructure management, whether roads, railways or pipes and treatment works for water supply and waste water drainage, with the aim of improved efficiency, both functional and social, will become more relevant over the coming years, in which the scarcity of public resources due to the economic crisis threatening to go on will make new works difficult, not to say impossible, and rational exploitation of inherited infrastructures will be mandatory.

FINAL NOTE. While I was writing these lines I read an article by Joan Busquets in which he lamented the "loss of value in public spaces reduced in the Plan to a mere abstract condition without attributes; talking of roads and not the



3 | Moving Around with Roads and Streets

Road, street and city

Roads are public works par excellence as, in addition to being a civic product, they provide access to what is public and construct the city. This is the way you reach what is private, the way you go to get inside, but it is also outside, where you can interact with everyone else. The road incorporates action into the built-up world in the form of making movement possible and it claims the rhythm of time in the sense that it is lived as through it were a route.

Roads emerge from collective action: they serve to reinforce and maintain social order, to link the place at the centre to all the spaces that make up a community's territory. This territory comes, precisely, from the appearance of roads: on building them we construct the territory, making the city possible.

Distances and movement

The possibility of coexistence offered by what is built depends on delimiting spaces on the ground and opening roads which, for the first time, create distances and make relations possible. The classic image associated with cities is that of an enclosed space, defined by its centre and the limits that used to mark the inside and the outside; summary definitive place. In Egypt, the sign to represent a city is a cross inside a circle; that is, a crossroads in an enclosed place.

As an individual, man likes to set down roots, to remain in one place and not move from there: roads are a threat. As a citizen, he or she likes to go out and seek the place where the action and discourse are. The city, where man becomes a citizen and can be seen, starts just outside his or her door, where roads are for public life. And from this distinction between inside – outside, man starts to build ideas of distance and setting [19:35].

Space you can go into and from which you can leave, a space defined not only by what is inside, but rather by the relationship between the inside and the outside. The refuge city is a space that simultaneously permits mobility and receiving others. Overlaid on this view of the city as a place is the progressive consideration of flows. At the end of the 19th century, the growth in industrial urban population inverted values and its flows became progressively more significant than its places and landscapes [19:167]. And its mobility is a critical factor in understanding it.

Structure of mobility

As already stated, mobility in Madrid is structured around a polar layout, with a centre, radial and ring roads. The Puerta del Sol is *kilometre zero* for the radial roads and the naming system for Spain's whole road network is based on centrality. The radial roads are numbered from 1 to 6 in a clockwise direction and those which are not radial are referenced to the radial roads from which they emerge and the distance of this emergence from Madrid. The new toll access roads are also radial and have been named similarly, from R2 to R5. The successive rings are named M-30, M-40, M-50, incrementing by ten as you move away from the centre, and the roads between them receive intermediate numbers, such as M-45.

This configuration is tremendously effective for channelling movements for access to the central area and generating a perfect location reference. According to the Civil Engineer Pedro Puig, radial and ring roads act as distributors between the radial roads and enable drivers to choose the least busy access route to the centre, optimising the total capacity of the entrances. This favours travel for access or transit from outside of the urban area, consistent with the main objective of the arterial network: *to penetrate to the urban centre as quickly as possible from the interurban network or to cross the centre, running around it* [202:57].

New radial toll roads

The construction of a new fan of radial toll motorways to complete Madrid's accesses was one of the most painful episodes of contemporary road planning. Justified as relieving the existing A1 to A6 motorways at very high traffic peaks, concessions were granted for four new radial roads, R2 to R5, with a total of 170 km in built length, constructed from the late 1990's to the first few years of the following decade.

Their dimensioning was clearly shown to be excessive, as the traffic using them was lower than forecast, with deviations of between 25 and 50% in 2008, the year when traffic was heaviest. The traffic really drawn by the radial roads with respect to their alternatives was of the order of 14% in 2008, then falling practically to zero as from 2011 [181:46].

These access routes promote new homes in areas far from the centre, which, in turn, increase demand for mobility to the service or industrial areas where the work is. As the price of land is inversely proportional to the distance from the centre, the new residential areas can be of lower density, giving rise to dispersed urbanisation. This encourages greater car use and unsustainable ways of living, not simply due to the waste of land and the cost of urbanisation, but in terms of energy and the use of natural resources.

Car, traffic and sprawl

Forced dependence on the car gives rise to this dispersed building patterns and generates what is called sprawl; the growth of the city like an oil slick. Shopping and cultural centres proliferate near the residential centres: These are endowed with enormous car parks for easy access by car. These centres generate large numbers of journeys which, in turn, require access roads and junctions crossing at different levels, given the concentration of traffic generated. The city becomes a mesh of roads and junctions in this way, embracing the urban developments and binding them to consumption.

The widening, expansion and improvements to Madrid's classic access roads have been constant over the last two decades. Crossroads have been eliminated from the main roads, with junctions and overpasses multiplying with increasingly carefully designed implementations (see page 105). However, some of the entrances to Madrid itself have not been duly treated by the planning process, taking on their status without any reflection.

Consolidated radial access roads

The case of the N-VI, the emblematic La Coruña road now called the A6, is the clearest example. The traditional exit or entry of this road was always the Castile road, running along the right bank of the river Manzanares and entering the city over the Segovia bridge. At one stage, the decision was taken for it to pass through the middle of the University City and cross the river via a new bridge, built by Fernández Casado alongside the San Fernando bridge. This made sense as there was no ring road, but it was not corrected when the M-30 was built, which offered a great opportunity to do so. The options for entry from this road multiplied with the M-30, but the existing one was favoured and one of Madrid's most noble and emblematic areas was ruined.

Architecture critic Antón Capitel explains what happened: *Indeed, after the Civil War, both reconstructions and, above all, new constructions consolidated this first phase of the University City. The Museo de América, the Schools of Naval Engineering and Aeronautical Engineering, and new Halls of Residence were built during this phase, and this consolidation was symbolised with the construction of the Arco de Triunfo. The monument powerfully signalled the start of the University City, with a stretch of avenue from the square named Cardenal Cisneros, from which a second stretch of avenue to the site of the Auditorium Hall, which was never built.*

Entry through La Ciudad Universitaria

However, in the 1970's, the Ministry of Public Works ignored the university status of this stretch of road and converted it into the extension of the road towards the inner city *removing all other attributes and functions it might have had. The footpaths were greatly reduced, rows of trees were felled and a tunnel was built to avoid the need to pass through the square named Cardenal Cisneros and so to convert this university road into a stretch of highway* [59].



The M-30 has a decidedly fluvial nature, which may be forgotten or ignored by Madrid's citizens, but which is nonetheless real. Its route runs almost exclusively along the water courses that define the city's shape, which later came to be called "la almendra". The whole flank of west and south sides of the city are limited by the river Manzanares. Almost the whole of the eastern side is defined by the Abroñigal brook, which, as the first stretch of the river, runs in the north-south direction, following the province's characteristic slope. The north side has to span the gap between the two water courses. This is the least well defined and allows for various options.

This lack of definition led completion of the M-30 to be delayed by a few years and, with the onset of the post-Franco democratic period, it was the cause of an interesting controversy. Supporters of a traffic-centred solution called for a single closure, with no traffic light junctions and the nature of a motorway, similar to the rest of the road. But the 1986 General Plan opted for a more complex solution of an urban nature. Instead of completing it with a single unbroken motorway, it proposed three fast roads with traffic lights and squares, more fully integrated into the city: These roads were named Sinesio Delgado to the south, Cardenal Herrera Oria to the north

and the Avenida de la Ilustración between the two. This diluted the traffic and avoided completely cutting in two the neighbourhoods crossed.

Northern closure

Sinesio Delgado avenue has a winding course starting alongside Chamartín Station and, after crossing the Paseo de la Castellana, it runs down the north side of a water course from which it breaks away at Valdezarza, where it enters a tunnel to come out at Puerta de Hierro. The Avenida de la Ilustración breaks off from the M-607 road at Colmenar Viejo and runs south-east through "La Vaguada" to reach the river Manzanares at Fuentelarreina, on the opposite bank to the Zarzuela Hippodrome. The street named Cardenal Herrera Oria starts a little further north off the same Colmenar road and follows the same south-easterly direction. It runs along the old Playa road which, at its end, runs parallel to a stream to reach the river practically alongside the previous route.

Other than this northern branch, located over a road, the other two also run – although partially – along water courses. This reinforces the M-30's fluvial nature, traced practically entirely by the banks of rivers, streams and water courses. So, the so-called "almendra central", central core, is like a peninsula stretched out between the river Manzanares and the Abroñigal brook, and sloping generally towards the south. It has its central drainage along the axis of the Paseo de la Castellana and two north-south watersheds along the axes of the streets named Príncipe de Vergara – Menéndez Pelayo and Bravo Murillo – Fuencarral. The first of these is well defined and the second is more sinuous, with high points where sub-basins begin at plaza San Ildefonso, the Telefónica building and the El Ángel and La Cebada squares.

Avenida de la Ilustración

The Avenida de la Ilustración was designed as a Parkway by a team consisting of José Antonio Fernández Ordóñez, Jerónimo Junquera, Julio Martínez Calzón and Estanislao Pérez Pita. This was a large, landscaped urban road, with traffic lights and squares, of mixed use for cars and pedestrians, marked by a series of grand sculptures.



Northern completion of the M-30

The idea of the project was to reinforce the city's configuration in a poorly structured, scattered zone. The accentuation of the connections with the current grid will enable easy implementation on the ground, helping to revive lost human relationships which are characteristic of European cities.

This recovered a criterion similar to that implemented in Madrid by the enlightened Bourbons of the 18th century, as against functionalist criteria, with strict and impoverishing divisions between zones with a single use and networks for traffic designed solely for cars [126:88].

It was a solution with sufficient transverse permeability, radically different from what a real motorway is assumed to be like. Supporters of the strict solution harshly criticised the presence of the traffic lights, precise symbols of coexistence between vehicles and pedestrians.

Criticism from the beginning

Obscure voices, supporters of the design of the city as a matter of vehicle transit, then protested greatly. They were voices which had already very often become actions and, since then, were practically the only ones, wrote the architect Antón Capitel in his blog. *A rather sinister point of view, which converted almost all the actions in modern Madrid into serious mistakes in urban planning* [59:entry 11/1/2010].

In spite of the decision to subdivide the northern completion of the route into three roads contained in the plan, the Ministry of Public Works – then the owner of the works – gave the name M-30 to the central route occupied by the Avenida de la Ilustración. The first stone was laid in 1986, but the works were drawn out and the M-30 was not completed until 1992. Later, the road was transferred to Madrid City Council which, to avoid procedures with environmental impacts in its reforms in the first decade of the millennium, defended its nature as a street and went on to name it Calle 30.



Sculptural intervention in the Avenida de la Ilustración

M-30 costs and functionality

In spite of everything, the main problem with the rest of the M-30, i.e. the motorway itself, was precisely that it did not have the characteristics of a true motorway. Devised in years of budgetary shortage, it was finally built with some merging and simplified junctions which did not obey the safety demands for a motorway. There were exits to the left, such as at the street named Costa Rica heading to the East towards the North, highly forced merging at 90°, essential weaving with insufficient space, such as at the junction with the A2 or the northern junction, which were a source of constant jams.

This led to ambiguous situations for drivers and generated confusion in its use. Madrid's residents took a long time to learn how to travel on it, as there were movements or logical detours that had not been considered in the design. It was often necessary to get ready early for the exit or merging of accompanying roads to be able to make a turn or deviation.

Sense of the reforms in the first decade of the millennium

In fact, the road was subject to a large number of changes and significant alteration works undertaken between 2004-7 by the City Council, which changed several original junctions to prevent numerous local jams. Beyond the criticism of the Avenida de la Ilustración, what is clear is that the M-30 as a whole only operated fairly well from the time of the M-40 construction and improved decisively with this last alteration.

The decision to soften its nature as a motorway in its northern closure was highly criticised, but where the functionality of a motorway really failed was in the rest of the M-30. The savings achieved with the initial design led to a scarcely functional scheme, with permanent widespread jams which demanded an enormous budget for alterations to build tunnels and overpasses. Indeed, of its 99 km of total length, 56 km of tunnels were constructed in the reform to improve its functionality. That is, it was completely remade and probably cost a lot more than if it had been planned better from the start.

The alterations of the 2000's made sense, precisely as Manuel Melis explained in his description of the works (see Appendix A), due to the elimination of the hazard black spots on the whole route and not, as some claimed, due to the elimination of the traffic lights that would have ruined the best designed stretch of road and which were left exactly as they were in the end.

Scale of the alterations to the M-30

In the words of the person in charge and its main driver, Manuel Melis, *the so-called M-30 project really consisted of several projects of great importance to Madrid which, due to their enormous scale, had been avoided for years as intractable. This M-30 project is made up of 30 works to improve the traffic in Madrid and to clean up the river, executed between May 2003 and April 2007*. The works can be grouped as shown in the tables and the detailed description of them is included in Appendix A.

Assessment of what was built

In May 2007, at the zenith of the process of building Madrid, an excited mayor named Gallardón opened the final works stating: *Today, the new M- 30 is safer, flows more freely, is more integrated and sustainable than just three years ago, having been converted into a factor for cohesion, rebalancing and invigoration of our economy and our quality of life... an effective traffic distribution road has been created, which has already been made a reference for a city model* [234:5].

Peter Rowe, the Harvard urban design professor, stated in 2007 that the M-30 *is much more than a motorway*. As laudable aspects, he emphasised that the traffic will improve and *with this improvement will come more effective regulation of property developments and opportunities for creating public spaces*.

Flows and crossings

Regardless of the traffic, he believed the road would have beneficial effects on the city's air and water flows, though with certain cautions: *Air quality may not improve, although a reduction in emissions has been forecast between 2007 and 2037*. And in the river *the capacity of the city's general drainage systems has increased and spaces for open-air recreation and community facilities will multiply*.

As beneficial local effects, he said that *the connections between the two banks will improve. Importance will be restored to the rim, which was fundamental in the construction of the Alcázar.* On the river itself, he believed

A. New junctions in the Eastern arc of the M-30 (6/2003 to 9/2006)

	Project	€ M
1	Entry and connection of the Avenida de la Ilustración to the M-607 Colmenar Highway	37.8
2	Construction of the Los Dominicos bridge	6.5
3	Redevelopment of the A-1 service roads between the M-30 and M-40	36.1
4	Tunnel ramps connecting the Northern Bypass to the N-I. Preparation of future Bypass	10.4
5	Redevelopment M-30 junction (La Paloma Junction), Pío XII and Avenida de Burgos	61.3
6	Redevelopment of Calle Costa Rica, Plaza José María Soler and connection with the M-30	37.1
7	Redevelopment of the M-30 junction with the Avenida de América/A-2	27.6
8	Junction between the M-23 - Calle O'Donnell and the M-30	25.1
9	Extension of the tunnel from Calle O'Donnell to the Calle Alcalá	34.2
10	Junction of the M-30 with the N-III Valencia Highway	221.1
11	Connections between the Manoteras and Southern Junctions. M-30 trunk road in the eastern arc.	31.5
	Total	**528.7**

B. New Madrid East-West connections (10/2003 to 01/2008)

	Project	€ M
1	Cuatro Caminos tunnel. Elimination of the overpass at the roundabout	27.9
2	Connection of Calle Ventisquero de la Condesa with the M-40.	9.8
3	Construction of the Junction with the M-40 at the Sanchinarro urban development plan	10.1
4	New Pío XII tunnel under Chamartín station	56.5
5	Distributor ring under the four towers of the Real Madrid Sporting City	118.4
6	Junction of the Las Tablas urban development plan with the M-40	26.4
7	Avenida de la Ilustración - Ventisquero de la Condesa connection tunnel	73.7
8	Sor Ángela de la Cruz - Marqués de Viana tunnel. Tetuán and M-30 connection	84.4
9	Remodelling M-30 NW service road and widening to three lanes of the NW M-30	48.9
10	Connecting tunnels of Calle Embajadores with the M-40.	198.4
	Total	**654.5**

C. Tunnelling work for traffic in the western arc

	Project	€ M
1	Marqués de Monistrol-Segovia bridge	508.9
2	Segovia bridge-San Isidro bridge	318.8
3	San Isidro bridge- Praga bridge	341.3
4	Praga bridge-Southern Junction	347.6
5	Tunnelling works for the Avenida de Portugal between Paseo de Extremadura and the M-30	200.7
	Total	**1,717.3**

D. Duplication of the Southern Link: the enormous Southern Bypass tunnels

	Project	€ M
1	Southern bypass. N-III tunnel north - Santa María de la Cabeza. Left carriageway	331.4
2	Southern bypass. N-III tunnel south - Santa María de la Cabeza. Right carriageway	410.3
	Total	**741.7**

E. Other traffic improvement works

	Project	€ M
1	Connection of the Montecarmelo urban development plan to the Calle Costa Brava	1.9
2	Widening of the bus only lane between the Moncloa transport interchange and the Puerta Hierro junction	1.5
	Total	**3.4**

that *the removal of the strange crossing structures will offer a fair re-establishment to monuments such as the Toledo bridge and to enormously valuable river containment structures* [234:12-15], [208].

Building everything at once

At the same time, urban designer Rowe highlighted the advantages of building everything at once. He believed, firstly, that *if it is possible to build without loans, the cost will probably be lower* (sic) [234:15]. Then he viewed positively *the reduced delay in obtaining benefits*, although he did not say of what type.

Somewhat later, he pointed to some reasons more solidly based on the city's occurrences: *It promotes the possibility of facing up to opposition, which has recently emerged, from community groups lined up against aspects of the project. It is good to focus on local organisations, but not to the point of diluting project coherence*.

Emphasis and oversights in Calle M-30

In spite of everything, the distancing effect of questions of circulation shapes the summary of its assessment: *The success of the M-30 will depend on the remodelling being seen not just as a motorway, but rather as a pretext for urban remodelling and revitalisation of an important and rather forgotten part of Madrid* [234:15].

Neither the mayor nor the urban designer attach significance to acknowledging the role of engineers and builders in the exceedingly fast construction of a huge work with a minimal number of incidents. Although this tends to be forgotten, it must be stressed that few cities are capable of tackling a work of this scale in a record time.

Layout of the M-40 motorway

The construction of the M-40 was tackled in a radically different way to the M-30. It was a time of greater governmental stability and they did not want to repeat the mistakes made with the M-30. The action was carefully planned and design parameters were specified that were closer to what a heavily loaded motorway needed to be. The only planning incident occurred in the northern link on the edge of the El Pardo park. The City Council's unwillingness to pay for some compulsory purchases lead to a proposal that altered the park boundary and was bluntly rejected (see page 100).

The later motorways, the M45, M50, M10, etc., were proposals with less impact on the city itself, although they do represent significant improvements in resolving traffic problems or they have specific functions, such as the approaches to Barajas airport. The M-45 (2002) links the A2 from the Henares corridor to the M-40 where it joins the A5 to make movement easier for towns in the south of the regions, such as Leganés, Getafe, Alcorcón and Rivas and to ease congestion on the heaviest loaded stretches in this sector on the M-30 and M-40 [183].

Apotheosis of the roundabout

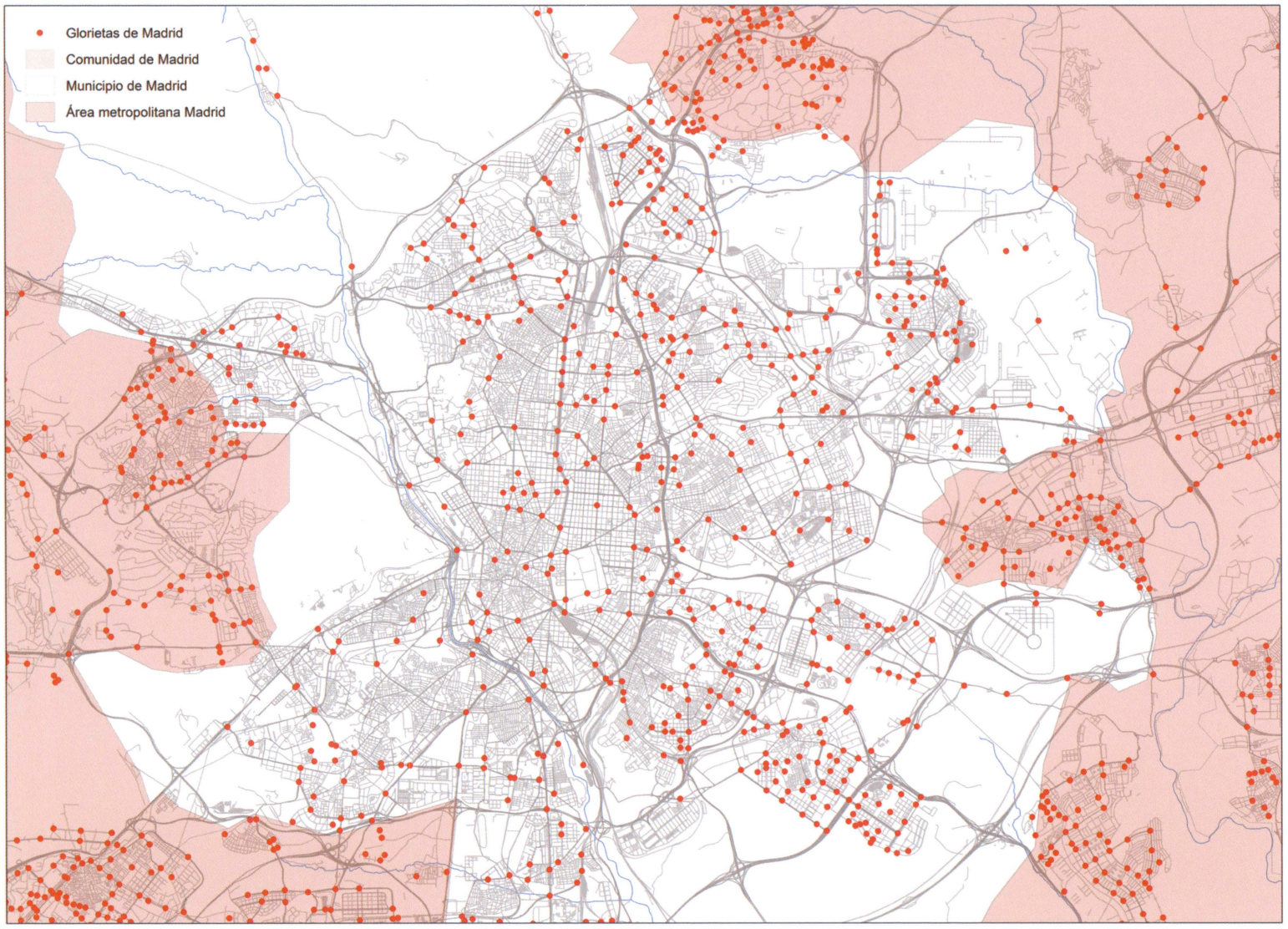
Separately from the layout of the large access roads and ring roads, hundreds of roads, of both secondary level and auxiliary to the main roads, have been built or widened in Madrid's suburbs. There is a wide range of types of junction at the same level or overpasses, but what has been built over the last thirty years has been marked by the appearance and subsequent explosive development of *the roundabout* as an omnipresent solution.

Practically non-existent anywhere in the country before, the roundabout was introduced on a large scale to resolve all kinds of junctions as from the 1980's. Although in principle it appears to be a solution related to the urban square, its massive use occurred to seek solutions for suburban and interurban junctions, importing a solution widely used in the United Kingdom for roads of all sizes. The first examples were promoted from urban planning, driven by Eduardo Leira and Eduardo Mangada in the Town Hall and the Madrid's Regional Government .

Advantages, troubles, proliferation

One of the first roads to include roundabouts was the Avenida de Europa, leading from the Castilla highway to the towns of Aravaca and Pozuelo, which was an area with great growth at that time. But the urban design virtues of clarity in planning and definition of junctions using the irregular islands of the classical junctions, together with the removal of the traffic lights associated with necessary reduction in speed led to a very safe junction[1]. The solution was imposed in spite of the inconvenience to vehicles on the main road and drivers were

[1] Indeed, it is surprising how even now, in 2013, people continue to defend motorways as safer the bigger and faster they are. Speed is the biggest cause of serious accidents and promoting it means accepting greater risks of accidents, as Manuel Herce points out in [128:5].



Roundabouts in Madrid urban area
[Prepared by María José Ramiro Nuño]

obliged to go around eight or ten of them with the corresponding out and in steering on their daily journey into and out of the city.

The roundabout is suitable for consolidating and humanising the great city's scattered outskirts. Because, despite the improvements in public transport and as Manuel Herce indicates, *The private car will continue to be the base on which fair mobility depends in this region for many years, but this needs profound changes in the types of roads, the methods with which they are conceived and the parameters used to design them, which have until now been focused on speed, safety (which goes against the maximisation of the former) and capacity* [128:1]. The roundabout also started to be used to anticipate new junctions to be developed in the future or as an entry and exit link to overpasses over motorways, with which their number grew exponentially.

Underpass

Within the city, the initial solution of overpasses (see page 17) was replaced by tunnels. All sorts of factors contributed to this: aesthetics, noise, land occupation and construction technology. Despite the acceptance of a few overpasses as engineering structures which were successful in themselves and beautiful as constructions, the citizens opted to bury the problems.

Bridges are fine, but driving cars up into the air was very noisy. The presence of these structures filled a large part of the field of vision in the affected areas and the cars passing over them were very conspicuous. People on the first floor

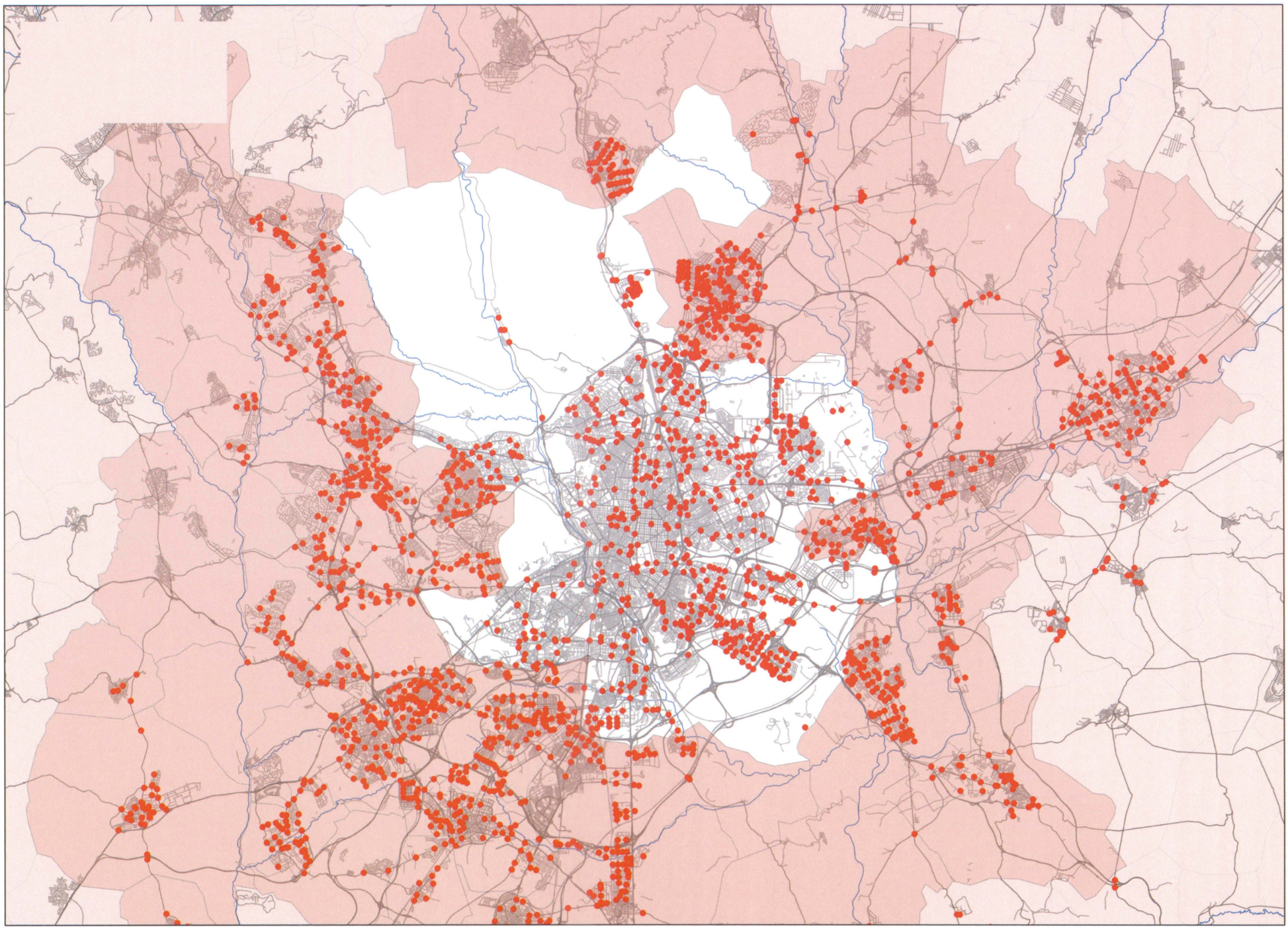
in the access streets complained that they could not open their windows. For a long time, it appeared better to hide the problem underground, where you could not hear or see the cars.

Cristo Rey underpass

At times the topography favoured the construction of tunnels or underpasses, such as in the Plaza de Cristo Rey underpass, which answered a very specific traffic problem. The arrival of the La Coruña road in Madrid caused enormous jams when the cars reached the first set of traffic lights in the city. An initial solution was to fork the exits and place traffic lights after each fork. This divided the long queue and gained space to form several smaller queues, reducing entry time considerably.

At the other end, the way forks towards the street named Cea Bermúdez to enter Madrid and towards the street Islas Filipinas from where it goes directly to the A6 road. The traffic in both directions along Paseo de San Francisco de Sales and Calle de Isaac Peral runs on the surface.

Roundabouts in Madrid's road network
[prepared by María José Ramiro]



On the other hand, the technology for constructing underpasses and underground car parks improved considerably. Without interrupting the traffic, they were able to construct lateral screen walls with parallel piles which were then connected by a strut at the top. The ground surface was then smoothed between the screens and the concrete slab poured between the two. This was done in two phases, so as not to stop the traffic, or in one if the completion date took precedence.

Technology for underpasses

Then, with the surface completely finished, the soil was removed from between the screens under the slab with excavators working from below. Lorries left loaded with soil covered with tarpaulins from one end, causing the minimum disturbance to the neighbourhood. As the soil corresponding to a storey was removed, the screens were anchored laterally to empty the whole excavation. Another option was to progress storey by storey, shoring up the screens with the slabs for the intermediate storeys built from the top down.

With this technique, excavation works were cheaper and less bother to neighbours, who happily greeted the replacement of bridges by underground works. Councillors and specialists found a way of tackling traffic problems without generating virulent rejection from the neighbours. The only controversial stretches were the entry and exit cuttings, where pedestrian and vehicle traffic were impeded.

Underpasses proliferate

The proliferation of this type of underpass fitted a peculiar idea of traffic operation. It was thought that the best way of emptying Madrid's centre of cars was to build one-way tunnels leading out towards the radial motorways.

Several underpasses of interest were built in this way, such as the Ríos Rosas – Islas Filipinas in 1998, the high cost of which was partially defrayed through the concession of car parking spaces. The initial idea was to build a long tunnel from the start of the street named Ríos Rosas in Nuevos Ministerios to the La Coruña road itself, at the other side of the Plaza de Cristo Rey square. This was to be a tunnel of more than 2 km in length and, after some controversy, it was decided to divide it into two parts; one under the streets Santa Engracia and Bravo Murillo; and the other connecting the street Islas Filipinas to the existing Cristo Rey underpass.

Ríos Rosas - Islas Filipinas underpass

The mouth of the first tunnel was moved to the Calle Ponzano, near the School of Mines and the telephone exchange opposite it. As these were non-residential properties, the tensions and disputes were minimised over the central entry cutting, which was not excessive in itself as Santa Engracia is a watershed and the road passed 22 m below grade there. Then there is a stretch under several storeys of car park, after which it crosses Bravo Murillo and, after curving to the left, emerges opposite the underground water tank for the canal, alongside which the exit runs with very little trench effect.

The Islas Filipinas - Cristo Rey tunnel is two way and runs under a Metro station and another car park. Both works were very complex, with stretches under the streets executed as tunnels and others like car parks. It was also necessary to span numerous highly important water and telephone services, demanding specific solutions, with very carefully planned direction and construction[2].

Another tunnel that shared the same philosophy of easing exits from the city, also built in two phases, is the María de Molina junction under the Calle Velázquez. The initial underpass had a novel cross section, with banks and cylindrical columns at the base.

María de Molina underpass

The branch towards the A-2 motorway, to ease transit towards the A2 and Barajas airport, was tackled later. In total, the tunnel is over 2 km long. Its entrance is practically located alongside the Paseo de la Castellana and the first stretch after this was built using a reinforced concrete slab in three spans, supported on two intermediate columns and the top edge of the two banks that start at their base. The top left edge is supported on a screen wall and the right edge on piles. The subsequent bend towards the street named López de Hoyos

[2] The works directors were Fernando López Ortún, Ricardo Castro Canseco and Manuel Bretones. The contractor was ACS. See: The Ríos Rosas and Islas Filipinas underpasses in Madrid. *Revista de Obras Públicas*, 3374 (1998): 51-57.

was built in a similar way, later using a tunnel with screen walls for protection in various areas until it comes out at the A-2 [64], [74].

The attention paid to the car left public transport, above all the railway, in the shade, in spite of the large amount of resources the State had poured into them. For Indalecio Prieto, the State's contributions to improving rail networks in the hands of private concession holders were already *heavy and disproportionate*, but it was necessary to continue to support them because he foresaw their reversion of ownership in a short space of time: *I predict that they will pass to the State very soon*, he said in 1932. Indeed, that happened when RENFE was set up on 24/1/1941 [201], [106:215].

Suburban transport was also a matter announced early on, but was only resolved as on the 1990's (see page 17). In his speech *How the State will cooperate in the transformation and expansion of Madrid. Railway links and electrification. Access and the suburbs*, of 1932, Indalecio Prieto anticipated that it would be necessary to transport *masses of suburban passengers, not just on holidays, but daily. Because*, he argued, *it can be foreseen that with easy, comfortable and cheap transport, an enormous number of Madrid's residents will move their homes to hygienically ventilated places,* [so] *early electrification is essential* 1941 [201], [106:217].

Neglect of the Paseo de la Castellana axis

No attention was paid to the railway within the city either until well into the 1960's. The nickname of "laughter tube", after a popular fairground ride, with which Madrid's residents christened the railway tunnels continued to be used, as they remained empty from the time of the Second Republic until, in the late 1960's Chamartín station was made[3].

Antón Capitel criticised *the blindness of the Franco government, incapable of exploiting such an important construction, either for suburban rail connections or as a Metro line* [59:11/1/2010]. Its use was recovered with the later importance attached to suburban lines, but in a rather residual form. When the AVE high-speed train showed the need for a good connection between the two stations, it was already too late and the technological demands appeared incompatible with the old layout and the decision was taken to build a new one.

City and new railway

In the 1980's however, urban planning gave new consideration to transport by rail. As Antonio Hernández Gil stated, *one significant thing was achieved; getting town planners and heads of new infrastructure ministries together to work in parallel, something which did not happen in the 19th century or during a large part of the 20th century.* This bore fruit in operations such as the tunnelling works for the Madrid outline way, executed as part of the Green Corridor Operation, *which were decisive in regenerating the south of Madrid, meaning that the residential function of the area planned by Castro in his 1860 plan can, finally, start to be put into effect*.

Above all, though, the expert in high-speed rail stated, *in the rebirth of the railway with high speed, the most visible aspect is the new stations. The remodelling of Atocha, in two phases completed until now and at least two more to come and the incipient Chamartín operation, will not only improve access to and the image of the high-speed trains, but they will have a considerable impact on the city's urban framework* [17:161]. He believes too that this impact of the stations on the city will increase greatly in the future [95].

Suburban station at Sol

In this regard, another of the most recent railway actions of great scope is the construction of a large underground suburban rail station at the Puerta del Sol itself, connecting by two large tunnels to Atocha and Chamartín stations. The North – South suburban connection, running until then under the Paseo de la Castellana (see page 67), also runs through the Puerta del Sol, while the High-Speed line connects under the street named Serrano.

The urban design rationale of the decision has been questioned through criticism, but it has been endorsed by successive governments of differing persuasions. *Locating a big suburban station in the old city centre was such an obvious mistake that Secundino Zuazo, at the start of the 1930's, already warned against it to ensure it was*

[3] During the Civil War, it was used temporarily as an arsenal for explosives and ammunition.



not made, wrote Antón Capitel. *The Puerta del Sol is not the city centre, it is the centre of the old city quarter ... The city centre, if you want to find it, is in the Paseo de la Castellana and it is linear. You could site it, more or less, between the Plaza de Colón and San Juan de la Cruz squares[...] The Paseo de la Castellana should never have been overlooked as the ideal place for railway links*, Capitel continued. *If there were not enough tunnels, they should have built two or three times the number parallel to the existing ones* [59:11/1/2010].

The railway cavern

Regardless of its location, the connection with the Metro is better at Sol and the construction of the great cavern for Sol station is a real technical feat. This is a cavern for platforms 207 m long, with an internal width of 20 m and a maximum height at the axis of 14.45 m. The soil coverage at the key is 13 m under the Puerta del Sol and around 23 m under the Calle Jardines.

The cavern fit was conditioned by the presence of Metro Lines 1, 2 and 3 and the connecting hall between them built in the 1980's. The attempt was also made to ease connection to Metro Line 5 in the Gran Vía. The new suburban layout runs parallel to Metro Line 1, following the line of the Calle de la Montera. The cross section is high enough to give space for a mezzanine to rationalise access to the platforms and allow improved exploitation [206:73].

High-Speed railway

In long-distance mobility, Madrid continues to gain advantages from its position at Spain's geographical centre. When the Madrid – Seville started, the railway was understood as a point to point connection that, at the most, would be extended to Barcelona and the French border. The success of the AVE to Seville, however, spread demand for high speed to all Spanish cities and gave rise to the change to a network model.

Logically, progressively added on top of the connection to Cordoba and Seville were those to Valladolid, Barcelona, Valencia, Alicante and the cities in Asturias and Galicia. That represents a great advantage for Madrid as an addition to boost the benefits of its centrality, with fast connections to the whole of Spain [15:67].

High-speed rail link

To avoid repeating a historical mistake of disconnected lines, it was essential to establish the North - South connection for the AVE high-speed train. To do so, a solution outside the Paseo de la Castellana was chosen again, this time under the Calle Serrano, where the street has been subject to extensive renewal. Some 7 km long, the tunnel connects Atocha and Chamartín stations to allow interconnection of all the lines that pass through Madrid. One of the greatest difficulties was to transform Atocha station itself, where the AVE trains are above the suburban, into a through station. To do this, the two platforms located at the southern end of station were set aside. From there the tracks pass through the station and curve to the right under the Botanical Garden towards the Calle Alfonso XIII, then running straight along the Calle Serrano and under three or four floors of underground car park. Its arrival at Chamartín is parallel to the Paseo de la Castellana tunnel and around 400 m away.

It will not be possible to extend that possibility of connecting without shunting to all high-speed trains, but it is a fundamental advance compared to what happens in other cities. Madrid will as such enjoy the privilege of having its high-speed stations connected, something which other large European cities still have not achieved. Passengers will be able to choose their high-speed station for departure or arrival, being able to opt for Chamartín or Atocha for certain routes and trains [15:225].

The AVE to Barajas airport

The AVE high-speed train connection to Barajas airport remains outstanding, as the planners still have not seen it as being essential. The feeding of intercontinental air travel from high-speed rail lines has been left to the suburban rail connection. This has been shown to be an enormous error in the perspective of the planners, made clear 15 years ago, that has still not been tackled[4]. The rail and flight operators, Renfe and Iberia, have jointly and insistently requested a direct connection between AVE train and plane at Barajas.

The recent decrease in traffic at Barajas Airport has set alarm bells ringing and the matter is back on the table. For a citizen of Valencia travelling to the United States, the best solution is to combine the two means of transport, with no other change. The two operators are in agreement on offering joint tickets with added services, such as baggage check in at source.

Public transport boosted

With all these actions, the improvements to streets and roads have been substantial. Public transport service conditions have also improved too though, considering the Metro and suburban rail as an unquestionable option for a great city like Madrid. In 1977, the first democratic government of Aldofo Suárez showed renewed interest in public transport conditions. A few months later, in 1978, the Ministry of Public Works took over the management of the service, as the construction of the infrastructure had already been assumed since 1955. To exercise this management, it named the Civil Engineer Juan Torres Piñón as chairman and he raised the need for a great technical and company management transformation (see page ++++).

In the early 1980's the Metro was used as a last resort, i.e. only when there was no other viable transport alternative. New democratic representatives, though, started to draw citizens towards a more favourable public assessment. One of the first to do this was the first chairman of the Comunidad de Madrid, Joaquín Leguina, who used the Metro to get to his office [172:276]. The city council was more reticent, but the mayor Tierno Galván did not go without saying *the defence of the Metro is an act of chivalrous justice* [172:269].

The Metro and the city

The heads of the company launched a public transport promotion campaign. Support for public transport was inseparable from the reforms proposed for the city and all its urban area, considering it as an instrument for regional cohesion. On the occasion of the Madrid Metro's 70th anniversary in 1990, its chairman, Guillermo Vázquez stated: *the birth and progress of the Madrid Metro responds to, supports, justifies and explains the city's evolution over the last seventy years* [172:7].

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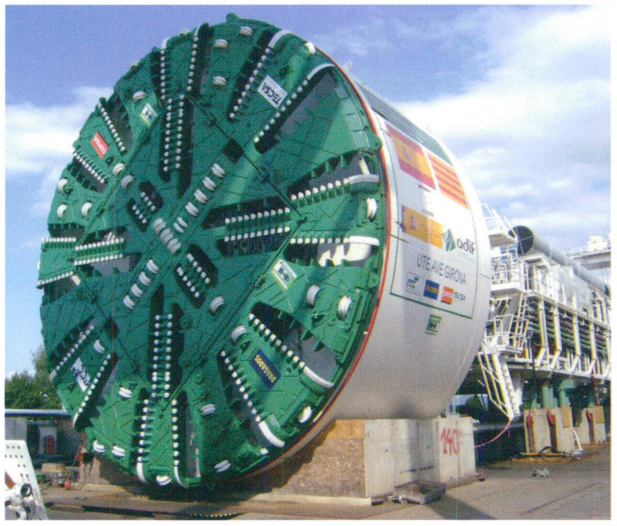
[4] The author warned of the need to bring the AVE closer to the plane in 1999, in Paper published in the *II Civil Engineering Conference, Barcelona* (24-26.11.1999), volume I: 147-150.

In 1990, the Madrid Metro's technical experts forecast continued expansion of the network in the years to come. They appeared to aspire to *maintain the allocation of resources at a maximum rate of 3 km/year* to meet the growth commitments assumed [172:306] and they predicted *between eight and fifteen new stations* [172:310]. In the 1985-1995 decade 15.9 km of network were built. Profound changes were also expected in the fare structure, with an *increase in automatic ticket sales, reduction in the single ticket and increases in season tickets for transport, entry through turnstiles separated from sales* [172:317].

Unprecedented boost for the Metro

The Metro's main promoter was, undoubtedly, Alberto Ruiz Gallardón, from the time of his election as chairman of the Madrid's Regional Government, where he had been leader of the opposition in previous legislatures. As from that time, the Madrid Metro accelerated its development in a broader and more complex context. Between 1995 and 1999, 56 km of tunnels and 37 stations were built, with a construction effort unprecedented in the world. A further 40.5 km of tunnels were built between 1999 and 2003 for the MetroSur, connecting the towns of Alcorcón, Fuenlabrada, Getafe, Leganés and Móstoles, making up a closed circuit of 28 stations[14:453], [228], [68].

Also incorporated in the set of metropolitan railways is the suburban railway to San Martín de la Vega, adding a further 15.5 km of lines. Totalling the two and other smaller works, 75 km of new lines and 38 stations were connected to the network between 1999 and 2003. That meant a total of 131 km of tunnels and 75 stations, of which 12 were interchanges, in just eight years, in an unprecedented construction effort, piloted by the civil engineer Manuel Melis (see page 59).





Tunnelling machine for the Madrid Metro

Excavation with tunnel boring machines

The expansion of the Metro and rail networks has provided significant advances in tunnel construction methods, with the use of tunnel boring machines being widespread, generally Earth Pressure Balance, EPB, machines with shield. A high percentage of the new network was built with these shield tunnel boring machines; large machines that work like earth drills with very high performance and full safety for personnel [9:121].

Several tunnel boring machines were used simultaneously, christened as *La Almudena*, for the Móstoles tunnel, *La Paloma* which had already worked on line 7 at Fuenlabrada, *Mares del Sur* at Getafe and the best known, *La Chata*, which had tunnelled on Madrid lines 4 and 8 at Leganés, with a performance of around 20 m of tunnel per day and practically without incident.

The MetroSur novelty

The purpose of MetroSur was to offer a rather uncommon line for Madrid, with a ring connecting several large towns without linking them directly to Madrid. The project was intended to *improve transverse relationships between the main towns in the southern area, interconnecting them with a quality means of public transport.*



Puerta del Sol MetroSur station

However, the connections were added immediately: *also improving radial travel in communication with Madrid the capital and the rest of its Metropolitan Area* [228:7].

The improvement in journeys to Madrid is implemented through connections at some crossings of suburban lines C3, C4 and C5 and via the extension to Metro line 10. The connecting stations were built with rather more ambitious designs than on the Madrid Metro, where they went for strict functionality.

Suburban lines

Although the long distance railway was certainly marginalised until the appearance of high speed, the suburban railways are the services with the greatest demand. Of those services, Madrid receives half the demand and its regional centrality is powerfully reinforced thanks to them (see page 65).

However, mobility in the areas with disperse occupation around Madrid continued to be based on the car and this was not tackled seriously until the 1980's. Interurban buses provide the transport system with great, flexible coverage by enabling new urban developments to be attended to with the setting up of new lines almost instantly. The railway, though, requires greater concentrations of lines, stations and services and needs the private vehicle at its periurban origins and effective points of transfer on its arrival in Madrid to be efficient.

The first of these was dealt with by building car parks at the suburban stations, with these known as '*disuasorios*' (deterrent) due to the interest en avoiding trips to the station extending to Madrid. A large number of car parks were built, although the capacity of some proved insufficient. The transfers, on the other hand, received all the planners' attention and interest and, as will be seen later, were dealt with as a priority by the Transport Consortium at stations and interchanges (see page 70).

Urban buses

In 2007, in its best times and before the cuts due to the crisis, the municipal transport company, the EMT, had around 2,000 buses running on some 150 lines. In later years, great importance was attached to replacing old



Puerta del Sol MetroSur station

buses, with two priorities; height of the deck above the carriageway and the type of fuel. In June 2007 the whole fleet had been transformed to buses with floors that descended at stops and tilted towards the pavement to make entry easier. Around the same date, 20% of the fleet ran with less polluting fuels, such as biodiesel, natural gas, ethanol or hydrogen. The latest additions are hybrid buses – fuel oil/electric or natural gas/electric – which use electric traction inside the central core and fossil fuels outside it.

The commitment to longer articulated buses or smaller minibuses only affected 5% of the fleet over the long term. In 2012 there were around 80 articulated buses of 18 m, 30 minibuses of 8 m and 20 electric minibuses of 5.5 m. The old depots which house the fleet have been reconverted progressively. There are now five in service, located at Fuencarral, La Elipa, Entrevías, Carabanchel and Sanchinarro.

Ambiguous support for the car

However, the proposals and actions of successive people in charge of the City Council and Madrid's Regional Government were not that univocal. With the aim of dissuading people from using their cars in the city, they invested in the Metro like never before and embarked upon a profound reform of regulated street parking system. But at the same time they committed to improving conditions for car use. As well as building underpasses and connecting tunnels, they located large car parks alongside them, promoting the entry of more private vehicles to the city centre. The multi-million euro reform to the M-30 also decidedly boosted car use and discouraged the use of public transport.

To many, this double dealing, committing to public transport and the car at the same time, was both contradictory and excessive. Indeed, Madrid probably has better mobility than any other great city, but the investment effort has left it overindebted and without the capacity to invest for many years. Without going into what may or may not have contributed to the economic crisis, the current budgetary restrictions combined with the fall in the use of the Metro and car parks make the maintenance of so much construction difficult. The citizens and the construction sector itself would probably have benefited from more coherent planning of works over a longer period of time.

Transport Consortium

With the creation of the Comunidad de Madrid in 1983, Madrid transport entered a phase of coordination between the various modes of transport and with neighbouring towns' transport systems, hand in hand with the Consorcio de Transportes de Madrid (Madrid Transport Consortium, see page 70).

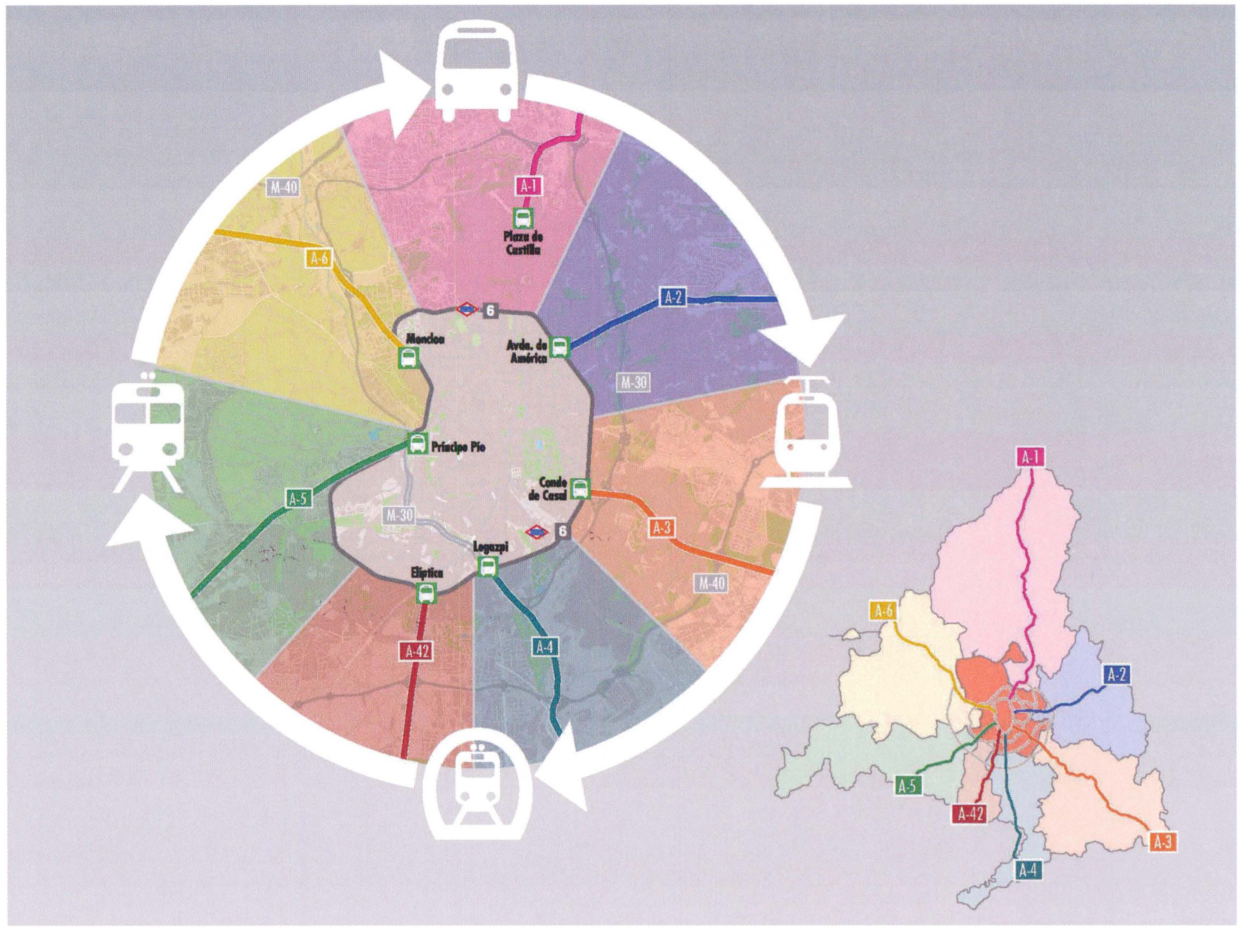
This showed itself to be vital for public transport in Madrid and made it a model to be imitated or a benchmark to follow for many other cities [72]. As professor Vasallo points out, *Without doubt, a great deal of the success of public transport in Madrid is due to the reform carried out in 1985. Since then, the governments involved have ceded powers for planning, concession management and setting of fares to a new body which, since that time, has acted as the main authority for transport in the Comunidad de Madrid: the Madrid Regional Transport Consortium* [235:43].

Intermodal Stations

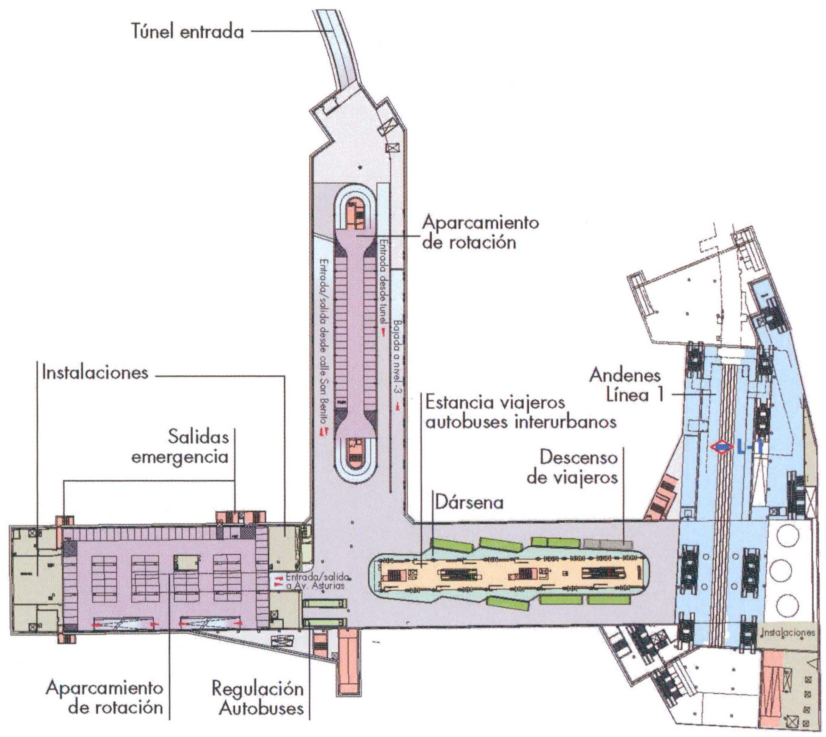
The physical key piece in this integration of Madrid's transport is its intermodal stations. These are joint stations for interurban buses and the Metro, sometimes also linked to the suburban or intercity railway, with immediate access to the network of city buses. This minimises total journey time, in which departures, arrivals and transfers have significant weight.

Since its foundation, the Transport Consortium has placed great importance on connections to promote transfers between different lines or between different modes of transport. Although its actions are numerous and dispersed, its most visible embodiment is the five main intermodal stations of Chamartín, Plaza Elíptica, Avenida América, Moncloa and Plaza de Castilla [71] and the conditioning of the stations to make transfers easier.

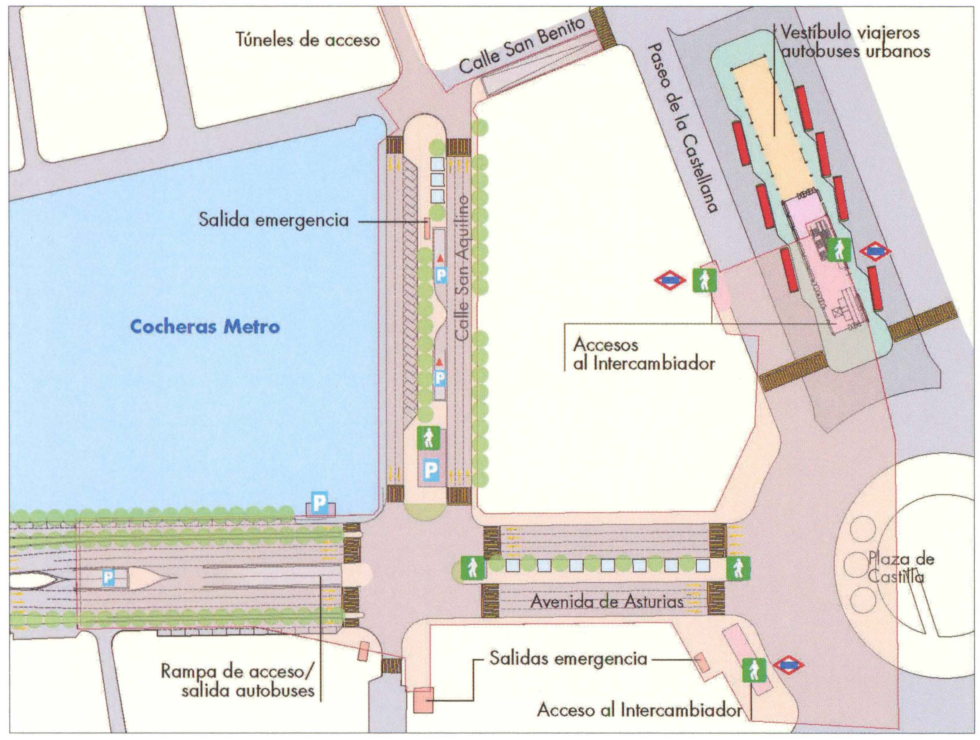
Independently of the unquestionable convenience for citizens, the interchanges and the Consortium's work in general ensure better mobility for Madrid. In Vasallo's words, *Thus it can be said that the transport system in*



Map of Madrid's intermodal stations [21:100]



Plaza de Castilla intermodal station [21:122]

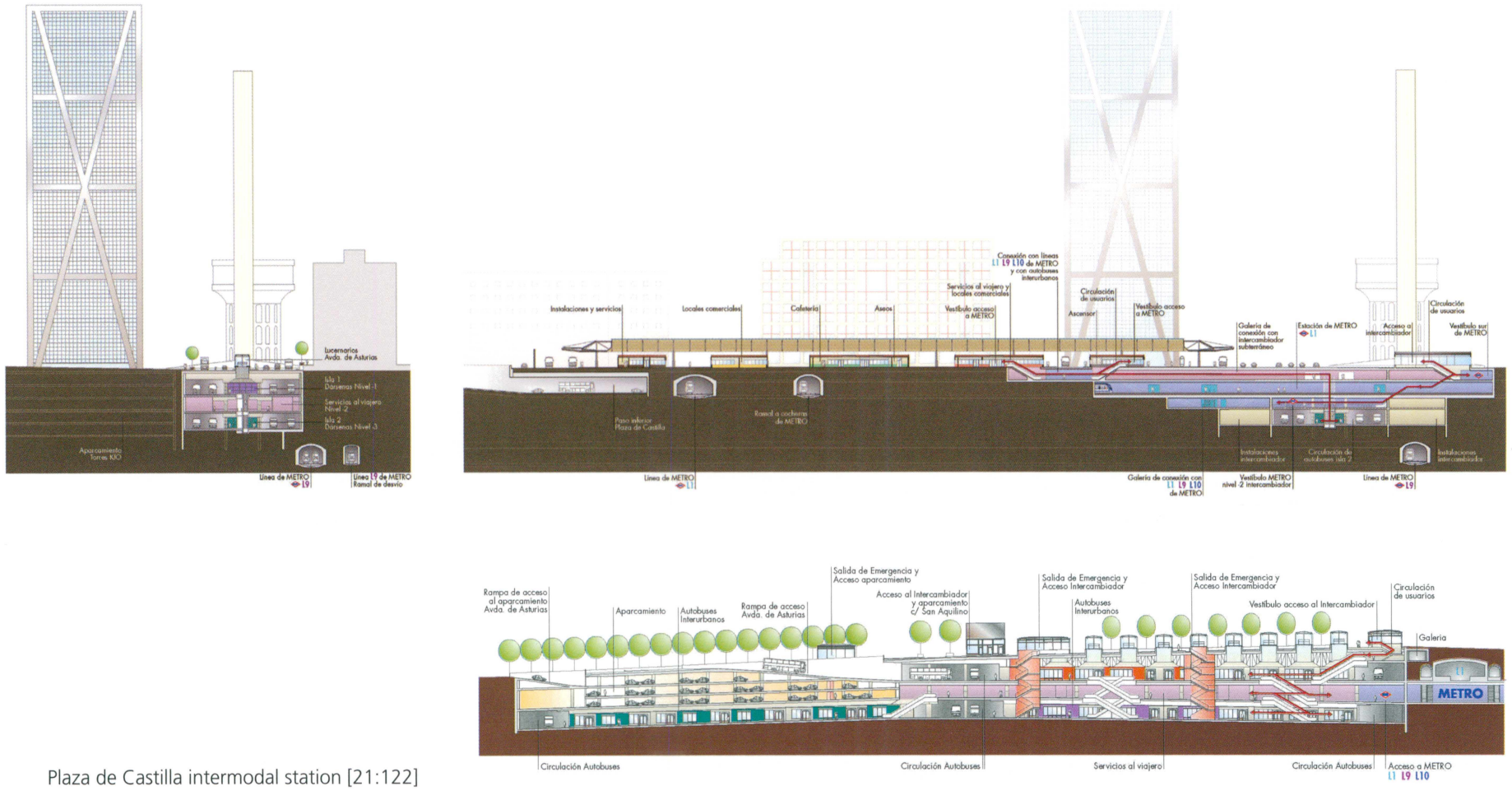


Level - 1. Interurban and car parking:

▶ Area: 20,350 m² ▶ 10 bus stops for interurban lines ▶ Metro L-1 platforms
▶ Entrance tunnel: Paseo de la Castellana ▶ Service area for 5 buses ▶ 133

Street level Accesses:

▶ Area: 2,550 m² ▶ 10 bus stops for urban lines (EMT)
▶ T6 pedestrian accesses ▶ 2 ramps for buses



Plaza de Castilla intermodal station [21:122]

Madrid is integrated at three levels: administrative, fare structure and modes, the latter thanks to the existence of the transport interchanges [235].

Transport season ticket

In parallel with the intermodal stations, the greatest exponent of promoting public transport in Madrid can be identified as the "transport season ticket". Its implementation considerably encourages the use of public transport and, consequently, contributes to reducing external income for transport. From this point of view, this type of subsidy aimed at frequent users of public transport can be seen as a success, although it is true that this measure leads to a substantial reduction in takings from the users [235:51].

The high level of subsidy to the "transport season ticket", together with the increase experienced in its use, have led to a coverage ratio (income from users/operating costs) for the Madrid public transport system which has been falling over the years. As a result of this, the subsidies to public transport from Governments have also not stopped rising [235:57]. With the economic crisis and as a consequence of unemployment, the use of public transport has decreased greatly starting in 2008, which makes the deficit substantially worse.

Centrality and the insufficiency of Barajas

In air transport, which in principle favours dispersion more, centrality continues to carry weight. Because, although there are direct flights from one airport in the South to another in the North, they are usually rather underdeveloped. Since its beginnings, air transport policy has always given the greatest importance to Madrid's airport and almost all the air companies' lines make stopovers at Barajas. Added to this are the already oft-repeated reasons of its nature as capital and economic, industrial, commercial and cultural centre, as always linked to the city's high population volume. The new *Low Cost* flights do not need to promote centrality like the old national airline networks, although they do benefit from Madrid's better range of available hotels and services.

For a long time, the situation of Barajas in Spain's capital made it the essential objective of planning attention. When Spain became a leading tourist power and Madrid recovered its old rank of great European capital, Barajas airport was small in practice. Since the mid-1970's, Madrid desperately needed a bigger airport to be able to double traffic increasing dizzily. *Its saturation is undeniable*, wrote the geographer Margarita Dastis in 1973: *with a maximum of 45 flights/peak hour such a level of saturation occurs that it is almost impossible, during these times, to think of a landing without delays* [79:354].

Continually delayed expansion

In spite of this, the adaptation of the airport to the capital's air traffic needs was delayed for many years. The foreseeable scale of the expansion probably needed an investment amount that was very difficult to finance. Also though, or perhaps because of this, there was great indecision and conflicting interests when defining the most suitable solution.

During the transition to democracy and in the early years of the 1980's, the priority focused on improving roads and only in the early 1990's was the urgent need to reform Barajas airport tabled. The first options were formulated by an ephemeral Ministry of Transport, segregated from Public Works and with a short lifetime thereafter.

Options for growth and reforms

The first major decision was that to expand Barajas or to build a new airport. Central government and the airlines were on the side of expanding Barajas, while the regional government proposed a new airport at Campo Real and the City Council discussed the two. The two sides took the initial decisions to reserve land to make the two options possible, but the decision was delayed by several years.

Meanwhile, Barajas' management needed to undertake significant alterations to the terminal building and the terminal apron to house traffic that was growing continuously. At the end of the 1980's and the beginning of the 1990's the apron was expanded substantially, as it reached the point of not being possible to land aircraft as there was no space to park them. The terminal was expanded too, with a new building for international flights and a new "north dock" to house domestic traffic growing similarly.

Split and parallel runways

The political coincidence of having the same party in national and regional governments led to agreement on expanding Barajas, with the Campo Real option being abandoned. The layout for possible expansion was already highly developed, with two parallel runways to the north in the North - South direction and another two further to the south, in the North-west - South-east direction, to avoid overflying San Fernando and Coslada. This avoided the existing crossing of takeoff and landing strips present at Barajas since its beginnings and permitted an evolutionary layout to continue growth.

First the takeoffs and landings were segregated with the construction of the most westerly pair of runways and then capacity was doubled by splitting them in parallel towards the east until they were nearly on top of the river Jarama, which needed to be channelled and diverted. In this way, Barajas airport gained sufficient capacity to deal with 70 million passengers per year and perform 120 operations per hour, making it the European airport with the greatest capacity for traffic growth. The crisis of the late years of the 2000's, however, hit with the cancellation of business flights and Barajas is suffering from a significant reduction in flights and passengers.

The new Barajas terminal T4

In addition to the expansion to four runways and the corresponding parking space for the aircraft, the brief included a terminal building of 500,000 m^2 for 35 million passengers per year, a satellite building of some 300,000 m^2 segregated from the aforementioned terminal for security reasons for flights not covered by the Schengen Convention, but connected to it by a service tunnel and also a 310,000 m^2 car park with capacity for 9,000 spaces [132].

In spite of the enormous investment in runways and aprons, the most spectacular action in the expansion of Barajas was the building of the new terminal T4, which was delayed by more than five years. The wait was undoubtedly repaid in the excellence of the design and construction of this impressive set of buildings (see page 17).

THE M-40 AND ITS RELATIONSHIP WITH MADRID'S URBAN STRUCTURE AND ROAD MOBILITY

Justo Borrajo
Civil Engineer

General context

In mobility studies, urban structure usually represents a subsidiary factor, with the distance/time taken given priority, without recognising that the creation of new roads conditions land use by linking it to its access options. For this reason, road sector planning, independently of transport in general and urban planning in each city, irreversibly conditions urban growth and collective transport requiring high demand to be profitable.

In the pre-industrial city, its structure was conditioned by the difficulty of transporting goods over long distances. This led to dense urban growth like an oil stain, but the appearance of suburban means of transport – on rails initially and in private vehicles later – changed this model to another of linear development along corridors. This led to suburban settlements, with expansion and suburbanising processes being overlaid and brought about a territorial model of city growth in general, above all in the case of Spain, that was increasingly disperse and dependent on its individual motorised traffic mobility. This trend was reinforced with the arrival of major retail outlets in peripheral locations and, in general, close to road junctions, increasing mobility problems at peak times.

The European Union report on Cities of Tomorrow (October 2011) indicated the causes of and threats from the growing dispersion of European cities. It spotlights that this makes essential services, such as teaching, more expensive, demands greater investment in infrastructures and energy consumption, contributes to the decline in historical centres, produces spatial and social segregation by dissociating the place of residence from the place of work and leads to overexploitation and degradation of natural resources. As a solution, it advocates a compact settlement structure, with limited urban expansion and a high level of environmental protection and quality within and around cities, resolving problems in a holistic and integrated manner with dialogue between citizens and governments.

Planning of Madrid's urban road system in the 1984/91 General Road Plan

The Preview of the 1984/91 General Road Plan, prepared in 1983, was mainly dedicated to providing Spain with a high capacity road network (Highways Programme) to resolve the congestion problems on the existing radial roads and the Mediterranean and Ebro arteries, improving accessibility to the whole country and its connection to Europe. Meanwhile, the Actions in the Urban Medium Programme, the objectives of which were to guarantee continuity of national routes and to ease access to the main cities and ports and airports of general interest, mainly covered the reduction of journeys in towns of less than 50,000 inhabitants. It allocated only two pages of the report to roads in large urban areas and an index of the 60 cities in which interventions would take place, for an amount of €477 million of a total of €4,400 million (10.8%)[5].

In its diagnosis, the Preview emphasised that the arterial networks policy developed in the 1970's, although it had been more ambitious in projects than in implementations, had enabled the majority of Spanish cities to be provided with fast roads with bypass and access functions, although with significant physical impacts, such as noise, visual disturbance, hazards and urban segregation due to the barrier effect. In addition to not having adopted measures to contain the growing development of contiguous buildings along the roads, which was stimulated by expectations of the appreciation of neighbouring lands, all the above problems were amplified.

The actions on roads in urban areas had significant planning and management problems, showed by stoppages to numerous works due to disagreements between the urban planning and highways organisations, mainly due to discrepancies in layout and design of the new roads to be built. The long maturing period needed for planning and programming these types of roads, of around twice that for interurban roads, meant that the actions to be carried out were not specified until the agreements between the affected Local Councils were signed, which also meant that breaches did not occur as the actions to be executed were not specified. The final version of the 1984/91 General Road Plan, approved by the Cabinet on 11 January 1985 and by Congress on 20 March 1986, saw an increase in total Plan investment from €4,400 million to €4,800 million (736,000 million 1983 pesetas to 800,000 million 1983 pesetas), but the Actions in the Urban Medium Programme only increased by €64 million, despite including the Agreements signed with the Granada, Valladolid, Seville and Madrid City Councils and being involved in negotiations on those with Barcelona, Malaga and Vigo.

It also needs to be borne in mind that planning of national urban roads in 1983 took place in an economic context of stagnation, where no significant growth in traffic and, therefore, congestion in the short term, was anticipated. All this meant that in the four-year period from 1984/87, urban actions for an overall investment of only €102 million (17,000 million current pesetas) were completed.

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[5] Editor's note. Spanish pesetas have been converted to euros, also maintaining the original figures when the reference year for the peseta was indicated.

Three years later, in 1988, the commitments undertaken with the Agreements signed in the big cities, mainly Madrid, Barcelona, Seville and Malaga (with investment of over €900 million), amply exceeded the budget resources in the 1984/91 General Road Plan, due to which Royal Decree 3/1988, of June, increased the Plan's overall budget by €3,000 million (500,000 million 1988 pesetas), basically due to urban actions committed to in approximately 60 cities and large towns.

In 1990, the rapid growth in annual private car registrations, from 689,000 in 1986 to 1,149,000 in 1989, together with particularly low fuel prices, falling from 90 pesetas (1988)/litre in 1986 to 72 pesetas (1988)/litre in 1989, made the problems of congestion on urban roads in the big cities worse. Due to this, on 4 May 1990, the Cabinet approved the so-called "Plan for Transport in the Big Cities", commonly known as the "Felipe Plan", although from a rigorous point of view, rather than a Transport Plan it was more a set of actions in cities of over 500,000 inhabitants for the 1990/93 period, mainly prioritising the needs in those to be locations of cultural and sporting events in 1992: Seville, Madrid and Barcelona.

Total Plan investment in the 1990/93 period was €7,200 million, of which €3,980 million were under the then Ministry of Public Works and Urban Development.

The M-40 in the context of Madrid's urban development: the "Plan for transport in the Big Cities" and the Madrid Agreement

Until the seventies, Madrid's urban growth remained within the limits to the municipal area, which housed the great majority of the region's population and economic activity. With the acceleration in the process of national economic development and intensification of migratory movements from the country to the city, Madrid's metropolitan expansion led to growth of the city along all the radial arteries, leading to the classic model of star growth.

The sector lying between the Extremedura and Andalusia roads received the greatest impact. The first wave of metropolitan growth affected, above all, the municipalities in the first ring of Getafe, Alcorcón and Leganés and then extended to the second in Fuenlabrada, Móstoles and Parla. These settlements predominantly fulfil the function of dormitory towns.

The second axis of expansion in significance was the Henares corridor along the N-II, which acted as the base for numerous industrial activities and a large number of homes.

Second homes were established around the N-VI, evolving to become high quality dormitory towns with the setting up of tertiary activities.

Finally, development along the N-III axis was more modest and later.

The development process summarised led to the municipality of Madrid, with less than two-thirds of the Autonomous Region's population, holding 75% of the jobs and over 85% of the services, resulting in very high daily movement between the centre and the periphery.

At the beginning of the 1980's, all Madrid's access roads had traffic intensities of over 40,000 vehicles/day, with very little communication infrastructure between the municipalities in the metropolitan ring.

In the situation described, the Preview of the Madrid General Urban Development Plan of 1981 stated in the conclusions to its diagnosis that: "the Madrid region is tending to consolidate itself with global demographic growth at decreasing rates in the next decade and with differential distributions of this in its region and particularly between the central heart and its metropolitan surrounding... the conditions which led to the remarkable growth of the metropolitan area are unrepeatable".

Ignoring these forecasts, economic, population and traffic growth in Madrid took off from 1986, due in part to Spain joining the European Communities in 1985, leading to jams on all the entry roads and the part of the first ring road (M-30) built. Without planning or anticipation of new actions, it made the urgent signing inevitable of a Collaboration Agreement between the State, the Autonomous Region and the Madrid City Council to resolve the existing mobility problems, which included the previously mentioned "Plan for Transport in the Big Cities".

The Agreement included the completion of the M-30, which was incomplete in the north and was brought to a standstill by urban traffic and overspilled by the city's growth. The opening of the so-called Avenida de la Ilustración in the initial years of the Plan meant this ring road was completed, together with the Puente de los Franceses – Puerta de Hierro – Zarzuela Link stretches.

The M-40 was devised (1984) as the second highway around the metropolitan area, at around 75 km in length, including links between the first ring (M-30) and the periphery of the Madrid municipal area. The distance between the two ring roads varies from around 500 m in the north-west arc, due to the presence of the protected area of the Monte de El Pardo park, to a maximum of 9 km in the west.

The disperse high cost urban developments in the north-west led to high demand for private vehicle traffic, inducing the proposal for a denser grid in that area.

The construction of the M-40 meant that the M-30 was relieved of the functions of channelling through traffic, as well as movements resulting from inter-peripheral

relationships (ring to ring), but without resolving all the problems. In the traffic studies carried out for its planning, it was predicted to become a road collecting through traffic and distributing the movements generated in Madrid's periphery and some relationships between them and the central areas, as well as becoming an instrument generating numerous urban developments around it, on bringing value to accessible peripheral lands, as in the case of the Coslada and Madrid Transport Centres, the new showgrounds, the Campo de las Naciones, Valdebernardo, the Olympic City and the new Urban Development Plans in the south, north-east and west of Madrid.

The forecasts made of traffic capture and inducement of other new traffic were very much lower than the true levels a little after its opening to traffic, in spite of the fact that it was decided to built it with three lanes, regardless of the results of the service level studies, which had indicated that two would be sufficient. This shows, once again, how difficult it is to predict traffic, above all in urban areas, and to be optimistic in depressed times and vice versa.

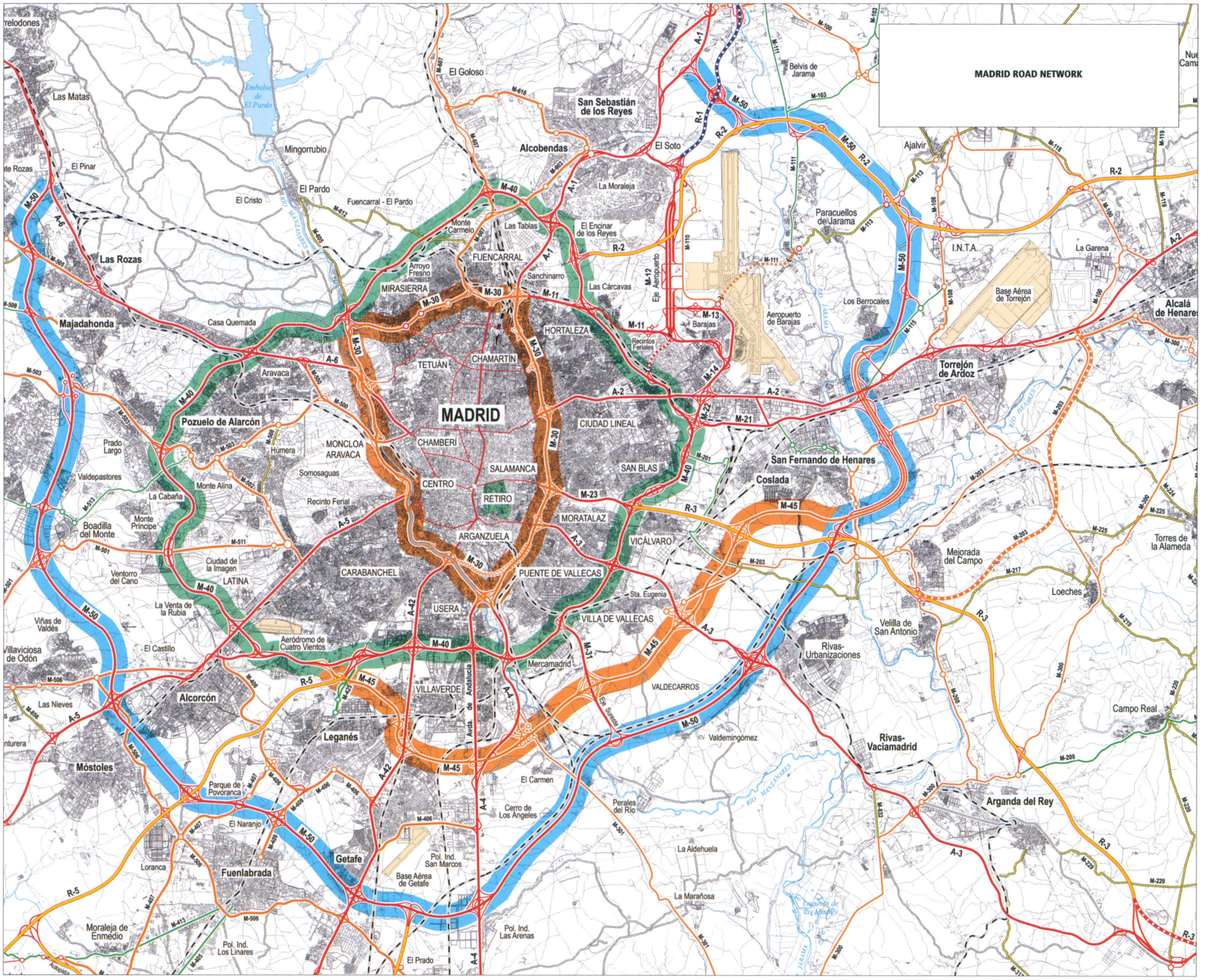
When the 1984/91 General Road Plan was closed, two years later, 44 km of the M-40 was in service, between the Manoteras and N-V junctions and the north and west distributors were under construction, due to planning problems owing to the existence of consolidated urban areas alongside the N-I, N-V and N-VI and of the protected area of the Casa de Campo and Monte de El Pardo parks.

The planning problems in completing the northern part between the N-VI and El Pardo (Zarzuela link) roads are representative of the planning difficulties in urban actions involving several branches of government. It was laid down in the Madrid Agreement that compulsory purchases would be charged to Madrid City Council and the planning studies proposed and compared alternatives outside the wall of El Pardo park, affecting three detached houses which would need to be subject to compulsory purchase for an amount of over €1.8 million or tearing down the existing wall and running parallel to it through a deforested area where channels for the Canal de Isabel II ran and then building a new wall. Ecologists considered that, although the existing wall was not historic, as it had been built with the water supply channels referred to, no reduction in the protected area should be allowed on principle. The City Council's refusal to pay for the compulsory purchase of the houses and of the ecologists to accept the reduction of the protected area in El Pardo led the Ministry of Public Works and Transport to a solution of carriageways overlaid with structure between the existing wall and the houses that was much more expensive than it would have been to purchase the houses. Additionally, the completion of the M-40 was delayed until December 1996.

In 1992, traffic on the M-40, which was still incomplete, exceeded 100,000 vehicles/day on the majority of the stretches in service, with a proportion of between 24% and 55% of access and distribution traffic compared to 16% of transverse traffic and 26% of residual traffic. This produced jams on many of the stretches, above all near to the junctions, as occurs on all roads in urban and periurban areas when through traffic mixes with other urban traffic itself.

To reduce local traffic on the existing carriageways of the M-40 and dedicate them to channelling long or medium distance traffic, the preparation of an information study on the construction of service roads, over its whole length, was ordered in 1994. This was to reduce entries to the central lanes and channel local and residual traffic, reducing the distance travelled by these at the same time. In turn, a study was ordered on the option of increasing capacity on the trunk road by increasing the number of lanes.

The planning of new urban developments increasing traffic loading on the M-40, at the same time as making widening it more difficult, and the growth of urban developments increasingly close to the M-40, even involving reducing the building limit lines (Moratalaz), have made the construction of service roads or increases in the number of lanes ever more difficult. Hence the solution adopted was to make another ring road further out (M-50) at 15 to 20 km from the central core, to serve relationships on the ring and avoid through traffic using the M-40, so reducing the load on it. However, its great distance from the latter and the increase in journeys it led to have meant, in practice, that the reductions in M-40 traffic have not been significant, as happened at the time with the forecasts of improving traffic on the M-30 with the construction of the M-40, as building new roads gives rise to new traffic, without reducing congestion on the existing roads and without resolving congestion problems, although it does ease accessibility to new land and the associated speculation and corruption which became clear with the great economic/financial crisis which began in 2008.


MADRID ROAD NETWORK
MADRID
Las Matas
Mingorrubio
El Pinar
El Pardo
El Cristo
Fuencarral - El Pardo
El Goloso
San Sebastián de los Reyes
Alcobendas
El Soto
Belvis de Jarama
Ajalvir
Paracuellos de Jarama
La Moraleja
Monte Carmelo
Las Tablas
El Encinar de los Reyes
FUENCARRAL
Arroyo Fresno
Sanchinarro
MIRASIERRA
Las Cárcavas
Las Rozas
Majadahonda
Casa Quemada
HORTALEZA
Recintos Feriales
Barajas
Aeropuerto de Barajas
I.N.T.A.
La Garena
Base Aérea de Torrejón
Los Berrocales
Alcalá de Henares
Torrejón de Ardoz
TETUÁN
CHAMARTÍN
Aravaca
Pozuelo de Alarcón
CIUDAD LINEAL
CHAMBERÍ
MONCLOA ARAVACA
Húmera
Prado Largo
Valdepastores
Monte Alina
La Cabaña
Somosaguas
Recinto Ferial
CENTRO
SALAMANCA
RETIRO
SAN BLAS
MORATALAZ
ARGANZUELA
VICÁLVARO
San Fernando de Henares
Coslada
Boadilla del Monte
Monte Príncipe
Ciudad de la Imagen
Ventorro del Cano
LATINA
CARABANCHEL
PUENTE DE VALLECAS
Sta. Eugenia
USERA
VILLA DE VALLECAS
La Venta de la Rubia
Viñas de Valdés
El Castillo
Aeródromo de Cuatro Vientos
Villaviciosa de Odón
Mercamadrid
Rivas-Urbanizaciones
Velilla de San Antonio
Mejorada del Campo
Loeches
Torres de la Alameda
Alcorcón
VILLAVERDE
VALDECARROS
Las Nieves
Leganés
Valdemingómez
Campo Real
Rivas-Vaciamadrid
Móstoles
Parque de Polvoranca
El Carmen
Cerro de los Ángeles
Perales del Río
Arganda del Rey
El Naranjo
Getafe
Pol. Ind. San Marcos
La Aldehuela
Loranca
Fuenlabrada
Base Aérea de Getafe
La Marañosa
Moraleja de Enmedio
Pol. Ind. Las Arenas
Pol. Ind. Los Linares
El Prado
Lagunas de Titi Merdes
RÍO MANZANARES
RÍO JARAMA
RÍO HENARES
Eje Aeropuerto
Eje Sureste
Avda. de Andalucía
M-30
M-40
M-50
M-45
M-11
M-12
M-13
M-14
M-21
M-22
M-23
A-1
A-2
A-3
A-4
A-5
A-6
A-42
R-1
R-2
R-3
R-5

THE 1995 AND 1999 MADRID METRO EXPANSIONS

Manuel Melis
Civil Engineer

A spectacular change in timescales, methods and costs of Metro construction in the world took place in Madrid during the late 1990's.

When the great expansions to the Madrid Metro began in 1995, I, as the person responsible for them, was under enormous pressure from the tunnelling experts to use what they called modern tunnelling techniques. These were based, essentially, on construction with large open face sections, with the New Austrian Method, the Premill method or big full-section lance shoring machines, protecting the tunnel constructed in this way with a thin eggshell called temporary support.

However, as a result of the many incidents and delays which had occurred with the use of these methods, I took a series of decisions in 1995 to build the tunnels with *very powerful tunnel boring machines especially designed for Madrid's terrain*. In the opinion of the specialists consulted, *it was impossible to build 20 km of underground Metro line in 4 years*. Four years later, though. 37.5 km of underground Metro line with 35 stations and transport interchanges and a further 18.5 km of open air Metro line with another 4 stations had been designed, built and put into service.

This was done with the Administration's own specialists, without looking for any global experts to manage the operation and at costs substantially lower than those common in the world. In November 1999, the World Bank cited it as an example for other cities, saying literally: *The Madrid Metro has been expanding its network at costs substantially below the levels that were internationally considered possible. The whole world could learn from this evidently superb manner of procurement and implementation*. This success for Madrid was repeated and built upon in the following expansion of the Madrid Metro from 1999-2003.

Once the works were finished, the Spanish companies that constructed the two Metro expansions and the M-30 positioned themselves as leaders in European construction and went on to lead large global projects. ACS built an important stretch of the New York subway and other highly significant infrastructure projects in the USA and Canada. FCC built another important stretch of the Athens Metro, another in Panama City and others in Ireland and Panama. SACYR is building a stretch of the new Panama Canal. Ferrovial built other significant infrastructures in England and went on to have responsibility for a large part of the London Underground.

The two stars of the second expansion of 1999-2003 were undoubtedly the great MetroSur ring, linking the five large towns to the South of Madrid of Alcorcón, Móstoles, Fuenlabrada, Getafe and Leganés and the great expansion of the Line 10 gauge to enable broad gauge trains to run on it. I remind the reader that from Alonso Martínez station to the southern end of the line, it had been built as a narrow gauge line. On 11 April 2003, the 41 km of this new line with the MetroSur were put into service and so the legislature had 74.7 new kilometres of network, 38 new stations and 8 new interchanges with Suburban rail lines.

There was no way the MetroSur could be 41 km of ring disconnected from the rest of network and from the other great ring of Line 6 (23 km long). The connection was made via Line 10, which was extended from Casa de Campo station to Alcorcón and the gauge of the tunnels needed to be widened between Alonso Martínez and Plaza de España stations so the new trains designed, the large continuous trains that run on it today, could travel along it. Another connection with Line 11 was planned from Plaza Elíptica and a third with Line 3 to Getafe, but they were not included in

Expansions to the Madrid Metro 1995-2003

Line and Stretch	Km	Stations	Interchanges
1995-1999			
L-10 Príncipe Pío - Plaza España		0	0
L-10 Lago - Príncipe Pío	2.60	0	1
Connection Lines 8-10	1.62	1	0
Connection Lines 7-10 Avenida América - Gregorio Marañón	1.25	1	0
L-4 Esperanza - Mar de Cristal	2.04	2	0
L-8 Branch A, Showgrounds	2.63	2	0
L-7 Dr. Marañon - Canal	1.02	3	0
L-11 Carabanchel extension	2.60	3	0
L-9 Vicálvaro extension	4.60	4	1
L-4 Mar de Cristal - Santa María extension	2.31	2	0
L-7 Canal - Guzmán el Bueno	2.10	1	0
L-7 Guzmán el Bueno - Valdezarza	2.55	3	0
L-1 Vallecas extension	2.83	3	1
L-7 Valdezarza - Pitis	4.21	6	1
L-8 Campo Naciones - Barajas	5.60	2	0
L-9.- Arganda surface extension (Conc.)	18.30	4	0
Total 1995-1999	56.26	37	4
1999-2003			
Getafe tunnelling works	3.10	1	1
Line 9 Rivas tunnelling works	1.51	0	0
L-8 Nuevos Ministerios - Mar de Cristal	5.90	2	1
L-10 gauge widening	1.93	2	0
Prolong. L-10 Extension 1. Colonia Jardín - Cuatro Vientos	3.00	2	1
Prolong. L-10 Extension 2. Cuatro Vientos - Alcorcón	3.29	1	0
Metrosur Contr.1.- Alcorcón	9.65	5	1
Metrosur Contr.2.- Móstoles	5.99	5	1
Metrosur Contr.2.- Tramo 3b-I	1.32	0	0
Metrosur Contr.3.- Total	2.69	2	0
Metrosur Contr.4.- Fuenlabrada	6.51	4	1
Metrosur Contr.5.- Getafe	7.35	6	1
Metrosur Contr.6.- Leganés	6.99	6	1
Renfe Suburban train to San Martín de la Vega	15.50	2	
Total 1999-2003	74.74	38	8
Total Metro expansion	**130.99**	**75**	**12**

this term of office. On writing these pages, almost 15 years later, they have still not been built.

Also included in this expansion were the tunnelling works for Suburban line C-4 at Getafe, making its connection with the MetroSur at the new Getafe Central interchange. These tunnelling works were carried out in just a few months. Included as well was the connection to San Martín de la Vega, which was built with RENFE broad gauge so that it could be operated by Suburban trains from Pinto. The most important decision on the MetroSur was to build all of it underground, in the face of opinions that wanted to build it on the surface because it was cheaper. The table shows the works built during the period.

Curiously, the critical part is not the tunnel – if you use the suitable construction methods – but the construction of the stations. In the initial expansion, 24 stations needed to be built and each station is a complete underground building, with numerous entrances, slabs at different levels, electromechanical machine rooms and sophisticated signalling and point installations, overhead lines, communications and others. After an exhaustive study, the decision was taken to plan the stations in a period of 24 months, with their installations included.

The expansion was planned so as to work with four big EPB tunnel boring machines on the works for twin track tunnels, plus two EPB tunnel boring machines for single track, both of which were already in Spain from earlier works. One of the small ones had just finished the Pasillo Verde tunnel for RENFE in Madrid and the other a stretch of Valencia Metro Line 3[6].

General Works Programme. Projects and Works

In 1995 the Madrid Metro was 120 km and had 158 stations. The Expansion Projects for 56 km of Metro started in August 1995. In December 1998, 20.8 km of network with 18 new stations were already in service and the rest entered service on 15 February 1999. The following table summarises the works carried out in the 1995-99 term of office.

It could already be seen in early 1997 that the expansion was on the pace. The Regional Government, through its Ministry of Public Works, decided to include a new work in the ambitious expansion plan – the connection of Barajas Airport to Campo de las Naciones station. I decided to build it with two tunnel boring machines, with one starting at each end. The tunnel, 5,600 metres long, was built in 7 months and the work went into service on 24 June 1998.

Technical Results of the Expansions

The construction methods and management of this great Project were the appropriate ones. All the works were completed on time. There were no accidents in the underground works for the tunnels and stations, or collapses on the surface or structural damage to the buildings. The following table summarises the duration of the works for each Contract and shows truly exceptional performance, never before achieved in Spain or in other countries[7].

[6] Two of them were Mitsubishi Φ9.40 m and another two were Herrenknecht Φ9.40 m, plus one Lovat Φ7.40 m and one Herrenknecht Φ6.52 m.

[7] Building a civil works like Line 14, of almost 6 kilometres of grand tunnel with two stations in 15 months is a unique feat. A valid comparison would be with the Somport tunnel, of a similar length, in the Pyrenees, the Spanish part of which took more than 5 years to build, in spite of having no stations. The 5.6 km of tunnel for the Airport works was built in an incredible time of 7 months.

Metro Expansion 1995-1999.- Duration of the Works

Project	Km	Start	Opening	Months
1. Line 10 Lago - Príncipe Pío	2.60	10 Jul. '95	26 Dec. '96	18
2. Line 10 Príncipe Pío - Plaza España		10 Jul. '95	26 Dec. '96	18
3. Line 4 Hortaleza extension	2.04	16 Mar. '96	27 Apr. '98	23
4. Connection Lines 8-10	1.62	30 Apr. '96	22 Jan. '98	21
5. Connection Lines 7-8	1.25	10 Jun. '96	16 Oct. '98	26
6. Line 9 Extension to Vicálvaro	4.60	22 Jul. '96	1 Dec. '98	28
7. Line 8 Mar Cristal - Campo Naciones	2.63	15 Mar. '97	24 Jun. '98	15
8. Line 7 Marañón - Guzmán el Bueno	2.48	11 Nov. '96	31 Jan. '99	26
9. Line 7 Guzmán el Bueno - Valdezarza	2.74	11 Nov. '96	31 Jan. '99	26
10. Line 7 Valdezarza - Pitis	4.51	11 Nov. '96	31 Jan. '99	26
11. Line 1 Extension to Vallecas Villa	2.67	17 Feb. '97	31 Jan. '99	24
12. Line 11 Extension to Carabanchel	2.60	17 Feb. '97	16 Nov. '98	20
13. Line 4 Mar de Cristal - Parque Santa María	2.31	20 May '97	15 Dec. '98	18
14. Line 8 Campo Naciones - Barajas	5.60	15 Mar. '97	24 Jun. '98	15

Madrid Metro Expansion 1995-99. Economic Data (€ million equiv.)

Line and Stretch	Km	Stations	Total	Installations	Control & Quality	Civil Works
Line 10 Príncipe Pío-Plaza España		0	19.3	5.0	0.7	13.5
Line 10 Lago-Príncipe Pío	2.60	0	45.9	16.0	1.1	28.8
Connection Lines 8-10	1.62	1	58.7	11.2	1.7	45.8
Connection Line 7-10 Avenida América-Marañón	1.25	1	28.3	3.1	0.9	24.4
Line 4 Hortaleza extension	2.04	2	57.0	10.3	1.5	45.1
Line 8 Branch A, Showgrounds	2.63	2	77.2	6.2	2.1	68.9
Line 7 Marañon - Canal	1.02	3	At Canal-Guzmán el Bueno			
Line 11 Carabanchel extension	2.60	3	73.1	8.8	2.0	62.3
Line 9 Vicálvaro extension	4.60	4	139.1	17.3	2.5	119.3
Line 4 Mar de Cristal-Santa María extension	2.31	2	52.2	6.1	1.6	44.5
Line 7 Canal - Guzman el Bueno	2.10	1	123.2	28.2	2.6	92.3
Line 7 Guzmán el Bueno-Valdezarza	2.55	3	96.4	3.5	2.6	90.3
Line 1 Vallecas extension	2.83	4	98.4	11.3	2.2	85.0
Line 7 Valdezarza - Pitis	4.21	6	155.5	15.3	3.1	137.1
Line 8 Campo Naciones - Barajas	5.60	2	162.8	24.7	1.9	136.2
Total Civil Works, Architecture and Installations	**37.96**	**34**	**1,187.2**	**167.1**	**26.6**	**993.5**

Cost of Metro Expansion 1995-99

The final cost of the civil works, architecture and electromechanical installations for the Metro Expansion was €1,187.2 million, according to the details in the following table[8]:

The rolling stock purchased for this expansion consisted of 144 narrow gauge carriages (now called Series 2000B-bub-

[8] Editor's note. The Spanish year 2000 pesetas in the original have been converted to euros.

bles, 2.3 m wide) and 82 broad gauge carriages, of 2.80 m. As is known, Madrid Metro lines 1 to 5 are narrow gauge and 6 and above are broad gauge. Their total cost, including the so-called "argandización", i.e. the adaptation of some broad gauge carriages to run on the surface on the new Line 9 on the Arganda stretch and the installation of air conditioning are itemised in the table.

Series 2000, 6000 rolling stock and "argandización", €million

144 type 2000 carriages, 2.3 m wide	111.7
82 type 5000 carriages, 2.8 m wide	103.7
Total	**215.4**

Economic results of the Expansion

Between 1982 and 1994, due to the Transport Consortium setting such extraordinarily low ticket prices for political reasons, the Madrid Metro increased its use by residents greatly, from 340.7 to 391.7 million trips. However, it also increased its deficit greatly, rising from €13.5 million to €44.2 million at current values. So, with the 1995-99 expansion increasing the network by 38 km of tunnels with 34 stations and, above all, in less densely populated peripheral areas than those covered by the existing network, this meant that an enormous deficit increase would be predicted.

With the existing Metro structure, this would effectively lead to an unsupportable deficit, financially and economically. Hence the decision was taken to focus on the solution to this problem from that point, so that once the Expansion was complete in 1999, the Metro structure would be ready to exploit it without costs or company organisation rocketing. The following table presents the results of the actions taken in 1996 in April 2001. It can be seen that not only was the expansion of the network to less densely populated areas absorbed, but there was a significant point of inflexion in the previous trends.

My idea was simple; to augment the Madrid Metro's technological developments to the maximum possible so that the increase in the network length in the Expansion did not demand a proportional increase in workforce in track and station maintenance and in operating management. I asked my old Professor at the IESE Business School, the Civil Engineer Juan Torres Piñón, who had also been Chairman of the Metro in the difficult years of the Intervention, for advice and I started to create new teams of young engineers who, together with the experienced specialists from the Metro's Engineering Department, were to develop the technical solutions.

Fundamental figures for the Madrid Metro
Before and after the 1995-99 expansion (Constant year 2000 pesetas converted to €)

Year	Million trips	Ticket cost	Income/ passenger	Costs/ passenger	Subsidy/ passenger
1980	380.7	0.32	0.27	0.57	0.29
1981	347.6	0.46	0.34	0.63	0.27
1982	340.7	0.41	0.35	0.73	0.35
1983	339.2	0.44	0.36	0.81	0.42
1984	327.4	0.46	0.41	0.86	0.40
1985	320.9	0.48	0.44	0.89	0.47
1986	329.0	0.55	0.42	0.87	0.47
1987	340.4	0.53	0.42	0.95	0.52
1988	364.8	0.60	0.43	0.85	0.41
1989	394.8	0.61	0.38	0.79	0.39
1990	415.5	0.79	0.34	0.77	0.36
1991	400.8	0.96	0.34	0.76	0.40
1992	413.1	0.98	0.32	0.80	0.43
1993	391.0	0.94	0.34	0.85	0.45
1994	391.7	0.90	0.35	0.82	0.41
1995	397.2	0.86	0.35	0.80	0.39
1996	408.0	0.86	0.34	0.77	0.36
1997	422.7	0.84	0.33	0.73	0.34
1998	437.0	0.83	0.32	0.72	0.32
1999	480.0	0.81	0.33	0.77	0.36
2000	525.0	0.81	0.32	0.71	0.29

These developments were basically aimed at decreasing maintenance costs. These were basically as follows: the rigid catenary; ballastless track; concrete track equipment; new track sounding systems; train instrumentation and other infrastructure management systems; and the new rolling stock engineering.

With these technical advances, it was possible to put the new lines into service without the need to increase the workforce in the same proportion, except as regards drivers and station staff. All this meant that the ratios of operating cost per kilometre or carriage per kilometre travelled or per station were substantially reduced.

The construction and management methods for the works in the second expansion were exactly the same as in the first. A new tunnel boring machine was designed and built, just like the four earlier ones, as needed to build the Getafe stretch of MetroSur.

Madrid Metro expansions after 2003

The new government of the Comunidad de Madrid continued with the policy of expanding the Metro, with the same construction methods, and it built the works shown in the table, with the public company Mintra.

Some tram lines were also built, but these were a great economic and financial flop, as well as with the public. To reduce the costs of the line in several important areas such as Pozuelo, the tram was located in peripheral, lightly inhabited areas, although they did not build any more of this means of transport in the next term of office, in spite of it being cheaper than the Metro. The serious economic and financial crisis started in the 2007-2011 term of office, so investment was cut. Finally, in July 2011, Mintra itself was closed and the executive team that had managed the Metro over the previous years was dismissed.

(Text and tables by Manuel Melis, head of the Metro and its expansion until 2003)

Expansions to the Madrid Metro and Tram 2003-2007

Line	Underground Metro	Km	Stations	Interchanges
1	Plaza Castilla - Chamartín interchange	6.8	3	2
1-4	Line 1 and 4 Chamartín interchange - Parque Santa María	included in Line 1		
1	Congosto to Vallecas urban development	3.1	3	
2	Ventas to La Elipa	1.6	1	
3	Legazpi to Villaverde Alto	8.7	6	1
5	Canillejas - Alameda de Osuna	2.4	2	
7	Las Musas-Peineta-Coslada-S. Fernando (MetroEste)	12.1	7	1
10	Tres Olivos- Alcobendas-San Sebastián Reyes (MetroNorte)	15.7	11	
11	Pan Bendito to Carabanchel Alto	2.7	3	
	New Station, Line 6 (Bolívar-Arganzuela)		1	
	New Station, Line 8 at Pinar del Rey		1	
	New Station, Line 10 (Darío Gazapo-Aviación Esp.)		1	
	Total Metro	53.1	39	4
Line	**Surface tram**	**Km**	**Stops**	
A	Pinar Chamartín-Sanchinarro-Las Tablas	5.4	9	
B	Colonia Jardín to Aravaca-Pozuelo	8.7	12	
C	Colonia Jardín to Boadilla del Monte	13.7	13	
	Total Tram	27.8	34	

Expansions to the Madrid Metro and Tram 2007-2011

Line	Underground Metro	Km	Stops
2	La Elipa-Las Rosas	4.6	
9	Mirasierra	0.9	
11	Carabanchel Alto to La Fortuna	3.3	
	Total Metro	8.8	

THE FUNCTION OF SUBURBAN RAILWAYS IN THE SUSTAINABILITY OF THE MADRID METROPOLITAN AREA

Javier Pérez Sanz
Civil Engineer

A good idea of the current significance and scope of the Suburban rail service is given by the fact that the Suburban trains run by the state operator, Renfe, transported 410 million passengers in 2012; demand equivalent to transporting an average of 1.4 million passengers each working day.

The Suburban railway is the rail service with by far the highest social demand, as nearly 90% of all travellers who used the railway last year did so on the Suburban service. This demand for Suburban rail in Madrid represents more than 50% of total demand and its service is highly regarded in Spain and abroad and has been put forward as a benchmark for this means of transport.

The current concept of Suburban rail as a highly specialised service managed with a business vision is a relatively recent notion, still short of completing a quarter of a century, but its structural and service basis go back even to the origins of the railway itself.

From its beginnings the railway was created with a vocation as a local transport service. While the railway maintained its hegemony as land transport, the local service was usually provided in an integrated manner subordinate to services of a greater territorial reach. When new means of transport were developed, basically road transport and private motoring, the railway needed to react by specialising its activity in the mobility sectors most favourable to it due to its technology.

From the beginnings of the railway and its biggest boom phase, the current service, in addition to that original vocation of local service, it has inherited very strategic positions and structural components, especially very central spaces and dedicated corridors with high connectivity around which a large part of the population growth was based progressively in the main cities. These bases have been fundamental in configuring a service offer that meets the needs resulting from the urban development which has occurred with economic growth, which in large cities was embodied in their conversion to metropoli and in their mobility.

The factor which triggered the creation of Suburban railways as a specific offer was undoubtedly the conversion of cities into metropoli. This process is inseparable from economic growth and is supported on the private motoring generated by this growth. In the case of Madrid, its process of becoming a metropolis can be seen clearly in the two accompanying graphs. The first shows the historical evolution of population settlement in the Madrid Autonomous Region, by territorial rings. The second shows the trend of that territorial localisation compared with economic growth and the development of motoring.

These graphs help to understand how the dynamics of population growth have progressively modified patterns of mobility in Madrid and, consequently, have guided the evolution of transport networks and services.

In 1970 the population of the Madrid Autonomous Region was close to 4 million inhabitants, after experiencing very significant growth since the end of the Civil War; a mean year-on-year rate of 3%, resulting in an increase in population of 2.2 million inhabitants. Over 93% of this growth was absorbed by Madrid as the capital, which swelled from one to three million inhabitants. The capital's new population settled firstly by clogging the central core, then extending to the suburban orbital ring.

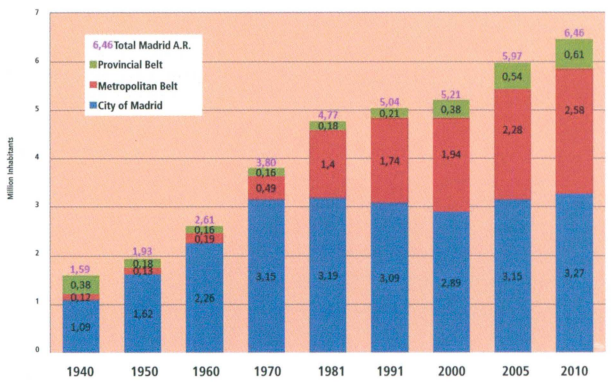
From 1970, the population of Madrid the capital stabilised at around 3 million inhabitants, representing 83% of the provincial total. Subsequently, 80% of the total growth of 2.6 million inhabitants up to 2010 was located in the metropolitan ring and 17% in the provincial ring. Currently, of the 10 million daily trips generated in Madrid's Regional Government, over half have their origin or destination outside the capital.

The railway's response to conversion to metropolis. Network configuration. The forerunners to the current Suburban rail model

Faced with that metropolitan reality, especially set off from 1970, those in charge of railway transport at national level at the time sensed the possibility that local rail services could have the drive to resolve the new "urban" mobility and they promoted specific studies and plans aimed at qualitatively and quantitatively improving what the metropolitan railway had to offer.

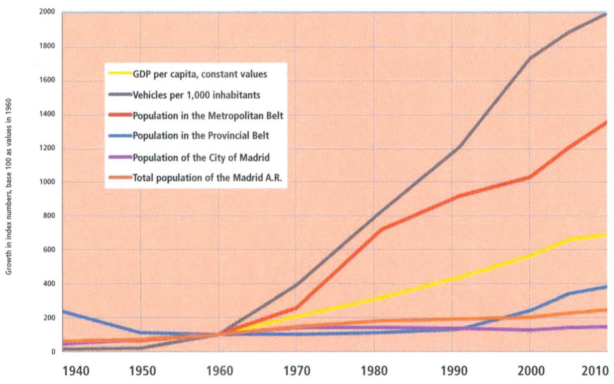
In the case of Madrid, it is appropriate to include as a foreword to this the study Ineco carried out on commission from Renfe in 1972 to analyse the viability of a suburban

Economic growth, motoring and population settlement in the Madrid Autonomous Region



Own preparation. jjps Data: INE. Municipal pattern

Trends in economic growth, motoring and population settlement in the Madrid Autonomous Region



Own preparation. jjps Data: INE. Municipal pattern





from Renfe in 1972 to analyse the viability of a suburban rail network in Madrid and its metropolitan area. Its proposals were the basis for the successive plans and programmes used to define the main projects which have progressively configured Madrid's suburban service. Worthy of highlighting among these plans is the Railway Plan for the Madrid Metropolitan Area which, after a long gestation, was signed and sealed in 1983 and with an investment of 20,000 million pesetas at the time included a set of infrastructure actions that form the pillars for the current network.

The launch of the network and services preceding the current Madrid Suburban system was to begin with the opening of the first Atocha-Chamartín station in 1969 and the inauguration of Chamartín station itself, both devised by Indalecio Prieto at the Ministry of Development. This period was to end with the setting up of Suburban Rail as a differentiated railway brand and business, in which the Madrid railways have constituted the main exponent since its creation in 1989.

During those twenty years, significant modernisation of the pre-existing lines has been carried out, as well as the incorporation of new lines specifically for suburban trains, taking advantage of disused lines running through metropolitan settings experiencing a demographic explosion. The fleet of trains was also subject to thorough modernisation and increases in the number of vehicles by means of the mass acquisition of new electric units which, although not specific, were to be assigned mainly to the provision of Suburban services.

Worthy of spotlighting among the main implementations in this period were: line electrification and introduction to service with the new electric units (UT440) in 1975, on what can be considered to be Madrid's first suburban line – the Madrid-Alcalá-Guadalajara line along the Henares Corridor. Also brought into service in that year was the Canto Blanco branch to serve the Universidad Autónoma. The first stretch, from Móstoles to Aluche, of the current line C-5 line was opened in 1976, which now has the highest passenger numbers. The line was extended to Laguna in 1984 and to Embajadores in 1989. The Atocha-Parla line, the southern section of today's line C-4, was opened in 1981. The increase to four tracks of the Atocha - Villaverde Bajo stretch was put into service in 1986. This makes it possible for trains on the current lines C-3 and C-4 to enter Atocha independently. The Pinar de las Rozas triangle was opened in 1989, creating a connection between Chamartín and Príncipe Pío and preparing for the completion of the Madrid Suburban rail ring. Also put into service that year was the new Villaverde Alto-Méndez Álvaro-Atocha access, which made the Fuenlabrada line independent and was to make the creation of the current line C-5 possible.

The first UT440 units were the basis of Madrid's Suburban services in the 1970's and 1980's and they were maintained with the relevant updates until 2007 when they were replaced by the new Civia trains. Between 1975 and 1985, Madrid's suburban railways received a total of 150 trains of this series, representing an investment of 18,000 million pesetas at 1979 value.

It was also during this period when the tracks and installations at Atocha station were comprehensively remodelled and the current Atocha suburban station was built, to be opened in 1988. This is the system's lungs, through which all Madrid's Suburban services pass, and the main transport mode interchange for the system, where half a million people have come to pass through each day. This public transport network node has become an essential urban element in Madrid's daily life and its architecture has integrated itself into the most characteristic physiognomy of the city's urban profile.

Aware of the importance of the role of multi-mode transport in planning for public transport, as well as to increase and improve interconnections with the Metro and the bus network, in 1987 Madrid's Suburban rail network joined the common fare system implemented by the Madrid Regional Transport Consortium.

In late 1989, the Madrid Suburban network had a total of 316 km of lines, with 150 trains that ran more than 880 services each day with a punctuality rate of 92%. In that year, they transported 80 million passengers, an average of 312,000 passengers per working day, who gained access to the service through the 81 stations in the network and who rated service quality at 6.3 out of 10. With that, the struc-





tural foundations of the suburban network were established at the end of the 1980's.

The Suburban railways are set up as a specific brand and consolidated as a benchmark metropolitan transport service.

The most significant landmark in consolidating the Suburban railways as a benchmark metropolitan transport service, though, was undoubtedly the creation by Renfe in 1989 of the Suburban railways as a specific business to develop this service nationwide. An ad hoc organisation was set up, with full responsibility for managing the Suburban railways as a brand to cover all the components of the service and to which all the company's Suburban rail personnel and economic, technical, planning and control resources were assigned.

The foundation of the service as we know it today started from that time, beginning with product design, the implementation of its brand image, the creation of the first illustrative network map and the installation of access controls, automatic vending machines, indicator panels and information.

The view of the Suburban service as a link in the multimode chain of public transport also had a very important role in consolidating the Suburban service. Not for nothing; the great majority of travellers on suburban rail come from or are going to another mode of public transport. For that reason, Suburban rail supports its development on multimode transport, both through fare integration and by participating in the development of the interchanges. The network now runs to four large interchanges and 20 suburban stations have connections to the Metro.

A spectacular advance in Madrid's suburban service occurred from 1989. In 1990 the Ministry of Transport approved the 1990-1993, Suburban Transport Plan, which was specifically designed for Suburban services existing at the time. In the case of Madrid, this meant an investment of 73,500 million 1990 pesetas. The most noteworthy action was the acquisition of 298 new units, of which 181 were for Madrid. The new Suburban train, the 446 and 447 series, was now designed technically and environmentally for metropolitan services, with its acceleration/deceleration capabilities, rapid access and alighting, air conditioning, advanced design, ergonomic seating, internal connections, ambient music and the new external image.

Outstanding among the actions aimed at the network were: the third and fourth San Fernando - Alcalá tracks; the Canto Blanco - Tres Cantos twin track and its subsequent extension to Colmenar; the Canto Blanco - Alcobendas - San Sebastian de los Reyes branch; the Embajadores - Atocha stretch which made it possible to create the new line C-5 Fuenlabrada - Atocha - Móstoles in 1991; the new branch to the centre of Parla; and the opening of the Green Corridor, which led to the creation of Madrid's Suburban ring in 1996.

Worth highlighting among station improvements were the construction of the Príncipe Pío interchange, the track remodelling work at the heads of Atocha and Chamartín stations, the adaptation of the platforms throughout the network to make access to the trains easier and the expansion of the "Park and Ride" parking spaces, which now have a total of 22,000 spaces split between 59 of Madrid's stations. Finally, under this Plan, significant improvements were made to traction installations, electrification and power boosting, as well as in safety and traffic management systems, Centralised Traffic Control at the Central Suburban Rail Post and the implementation in 1999 of the first automatic safety and traffic control system on a Suburban line, where line C-5 and its trains were fitted with the LZB system, as implemented on the Madrid - Seville High-Speed line.

As from the time of the creation of Suburban Rail as a specific business in 1989, with a definite aim of providing the best customer service, the greatest sustained growth occurred in Madrid's Suburban railways. This was only cut short by the economic crisis since 2007. On the threshold of the crisis, Madrid's Suburban railways had a network 345 km long, on which 1,234 trains ran each working day at a punctuality rate of 98.2% using a fleet of 285 units. Using 99 stations, the service transported over 200 million passengers per year, over 900,000 passengers per working day, who awarded the service an overall quality rating of 7.5. Demand tripled, after growing from 1989 at a mean year-on-year rate of 6%, and Madrid's Suburban rail channelled 50% of public transport demand generated in its field, making it a benchmark for serving metropolitan mobility.

Passage through the crisis and the suburban rail of the future

In 2004, work had started on the second Atocha - Chamartín suburban tunnel, passing through Sol, which, in addition to relieving the initial tunnel and Atocha station, made it possible to bring urban capillarity to all the network's lines and put Suburban rail in the heart of Madrid with Sol station. This work represented an extraordinary challenge in terms of construction technique and control of execution as it was in a densely built urban area, under which the world's largest cavern excavated in urban land was built. Works on the branch to Airport terminal T4 started in 2007. These actions were fully introduced to service in 2009 and 2011, with an investment of €770 million.

The new Civia trains represent a revolution, as their specifications were drawn up from "zero", defining a radically different vehicle, with aluminium instead of steel for the bodies and articulated instead of independent carriages. Their design emphasised passenger accessibility and comfort – they are the first low deck trains adapted for people with reduced mobility – modularity, energy efficiency and high reliability. Between 2000 and 2007, 240 Civia trains were purchased, of which there are now 123 running on Madrid's Suburban lines, representing an investment of €650 million.

In May 2009, the Ministry of Development, together with the Chairwoman of the Madrid Autonomous Region, presented the 2009-2015 Madrid Suburban Rail Plan, including investments of €5,000 million in network extension and improvement works. Some were structural, such as the new 34 km East-South west line through the centre of Madrid and other extension works, with 81 km of new layout. The network would have a total of 478 km of lines and reach towns with new and significant urban developments.

The bleakness of the crisis has profoundly affected both expectations of growth in demand resulting from these significant investments brought into service in recent years and the materialisation of the new Plan, the only action put into service from which has been the access to the airport. The other works have not yet started, as urban developments have been paralysed.

Since the beginning of the crisis, which has already lasted 6 years, demand on Madrid's Suburban rail services has dropped by 11% which is, however, a smaller drop than that suffered by the population employed in the whole Madrid Autonomous Region, which has lost more than 400,000 jobs, equivalent to a reduction in employment volume of 13.2%. This significant reduction in employed population has been even greater in the population living in the municipalities of the metropolitan area where the Suburban railway has its main points of focus for generating demand. For this reason, even with longed for but slow growth, the recovery in employment and, consequently, demand for suburban rail resulting from it will also be very slow.

At the horizon of the end of the crisis, the best scenario for which is very slow recovery in demand, it appears reasonable to pick up the planning again to frame it in Madrid's new "post crisis" reality. In the future, the best possibilities for drawing demand lie more in the optimum exploitation of the current potential and capacity of Madrid's Suburban rail network than in expanding it. The network reaches nearly 90% of the population and has sufficient reserves of capacity to absorb increases in demand of 60%.

At the same time, the car remains the dominant means of transport in metropolitan, non-urban mobility, with a high share of 63%. This situation requires the application of available resources to promoting mode transfers from private cars. To do this, the unifying role of suburban rail as a trunk network for intensive metropolitan demand needs to be reinforced, with integration and coordination with all networks, the implementation of an on-line system of services in real time and the improvement in network installations and equipment to move towards the objective of "zero incidents".

The Madrid Suburban railway is still not twenty five years old, so it is still young, however, as a transport network it has very robust structural support conferring it great capacity and reliability. As a transport operator, it has accumulated an undeniable maturity and professional esteem, with an elevated international reputation and, what is more important, the recognition of Madrid's citizens. Suburban rail is the highest rated mode of public transport in Madrid, achieving an overall quality index of 7.65. This will be its best guarantee of influence in the future, by improving its contribution to the sustainability of Madrid's metropolitan mobility.





THE MADRID TRANSPORT CONSORTIUM

Joaquín Martínez Vilanova
Civil Engineer

When Madrid's Regional Government was established in 1983 and it assumed powers for transportation, the situation of urban and metropolitan transport was highly adverse, both in network extent and in quality of service, investment and coordination.

The damage came from years before: The Metro, the means of transport that should ensure the majority of trips in an urban area the size of Madrid's, not only did not do so, but needed intervention from the State in 1978 as a consequence of the critical condition of the company and its service. Its Expansion Plan, approved in 1967 and revised in 1974, was in fact completely paralysed.

The combination of the Metro and the buses of the Municipal Transport Company, the EMT, had lost passengers over the 1970-84 period. Demand for the Metro, specifically, had dropped by no less than 36%. This was in spite of the increase in population of almost one million inhabitants in the region in that period.

The presence of the suburban railways in Madrid was purely token at the time (160,000 passengers per day in 1980). Apart from the Henares Corridor, the only route with reasonable service was Aluche-Móstoles, which came into service in 1976. Madrid-Fuenlabrada did so in 1980

The "camionetas", or pick ups, the popular name for the buses on peripheral lines operated by private companies, were coming to the end of their respective concessions and the condition of the fleet was highly deficient.

You could not talk about a transport system, as the lack of coordination between the various modes was complete: in terms of infrastructure, services and fares. These were times of advertising campaigns of the "On the bus you can see where you are going" type, making a pejorative reference to transport by Metro. Transfers were penalised in terms of distance, journey, time and cost, as the infrastructures did not appear to take them into account and there were no combined tickets, even between EMT lines.

This coordination was not specific to Madrid, it was general in Spanish metropolitan areas. It is striking, though, that the sole authority in Paris, the *Syndicat des Transports* (now the STIF, *Syndicat des Transports de l'Île de France*), was created in 1959; Germany's big cities have had coordinating organisations with ample participation of private operators since the mid seventies (the *Hamburg Verkehrsverbund,* an integrating organisation, which has operated since 1996 as a subsidiary of the operators, dates back to 1965; and the British PTAs, the *Passenger Transport Authorities* were set up based on the *Transportation Act* of 1968).

The need for coordination in Madrid was already present in debates in the sector and was endorsed by the great majority of transport professionals and leaders. As an example, an explicit reference to this need can be cited in the documents of the General Urban Development Plan (1981-1983) or in the works of the technical team in the last years of the Provincial Office.

It just needed the institutional, political and technical thrust that made it possible to create Madrid's Regional Government.

Indeed, compared to the prior situation, "Madrid's Regional Government provides the necessary legislative capacity, a suitable political framework and an appropriate territorial scope. It has been conferred with full legislative capacity as regards transport and, in addition, has a firm political will to take this project forward." (Law on the Creation of the Transport Consortium. Statement of Reasons, VI)

The Community's first Chairman committed in his investiture speech to set up the organisation to integrate metropolitan transport, which was carried out by means of Law 5/1985, of 15 May, on the creation of the Madrid Regional Regular Public Transport Consortium, which was approved right in the middle of the term of office.

The need was so obvious and the work beforehand (political, technical, in negotiations with various institutions, public companies, unions and employers' associations) was so intense that the law was passed unanimously in the Madrid Assembly.

The new body was set up as an Independent Agency of the Community. It adopted the name of Consortium, though, precisely to highlight the idea of cooperation between governments and managements. It has the authority, the representative nature and technical capability needed to exercise the functions of coordination and control, planning of infrastructures and services, determination of the common fare framework and the economic compensations among the various modes of transport. It became the administration in charge of urban and metropolitan transport services. This was true of those previously under Madrid's Regional Government, plus those of the local councils which voluntarily became members of the Consortium. Only the suburban railway services remained outside. These were to be the subject of a special agreement.

The Consortium plans, orders and regulates, but the assets, legal status and autonomy of management of the transport companies remains.

The significance of the inclusion of Madrid City Council, a founding member of the Consortium, needs to be acknowledged, at a time when it amply exceeded the recently formed Community in terms of powers, resources and budget.

The results of its operation were clear almost immediately. The creation of the Season Ticket, a pass for unrestricted travel based on Paris's *Carte Orange,* to encourage the use of public transport and eliminate the penalisation of transfers, was a success. Sales in 1987 had already reached one million monthly season tickets and in 2011 the combined total of all season tickets exceeded fifteen million.

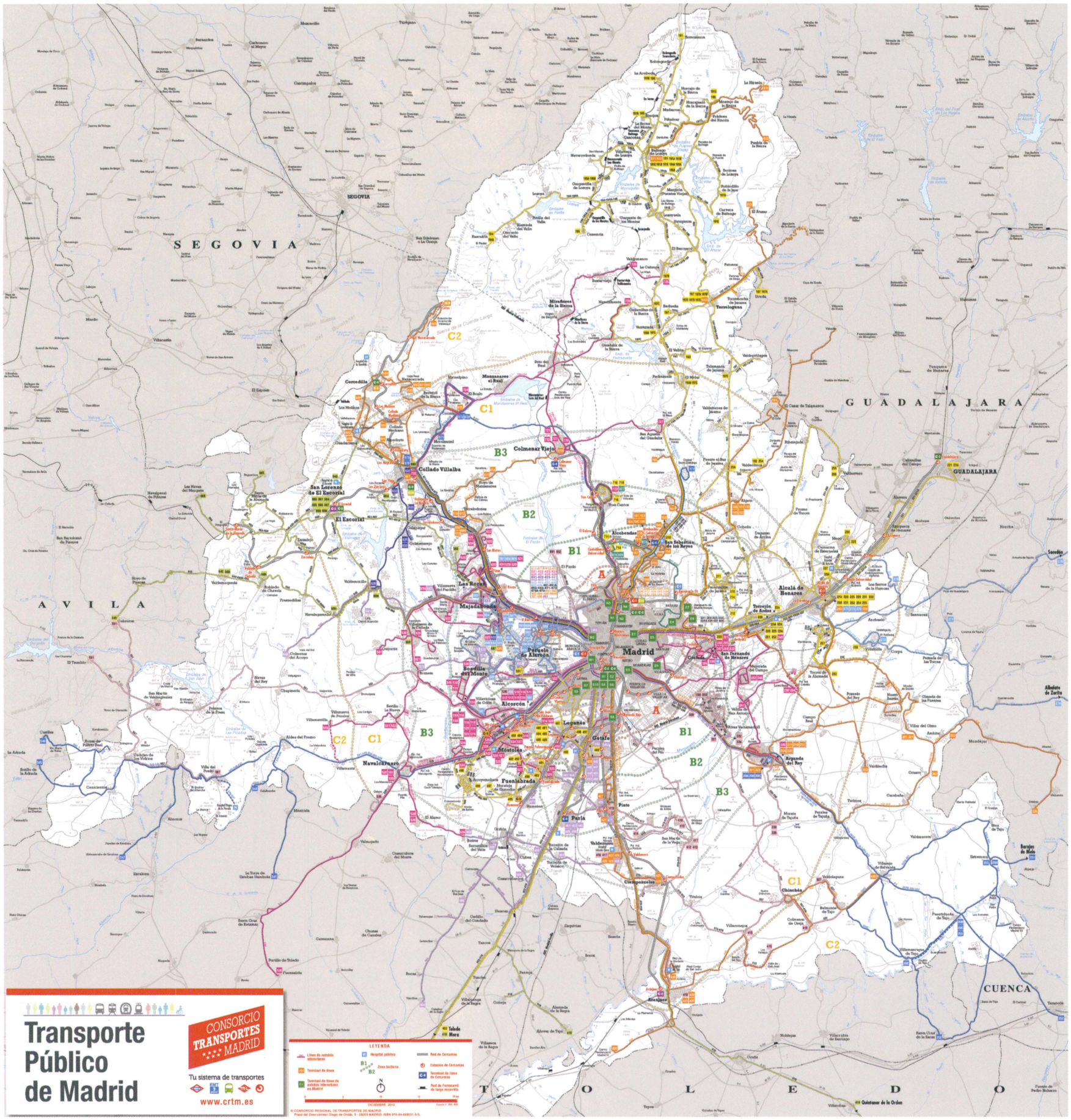
From the infrastructure point of view, the Consortium's great contribution has been the development of the transport interchanges, a European reference, based on a well planned outline, quality architectural and functional projects and differing operating models, including concession.

With over 25 years having passed since it was established, the Consortium handles around €2,200 million annually, with 45% from takings and the rest in transfers from Governments. The Community provides almost €900 million, around €220 million comes from Madrid City Council and €160 million from the State. Of these funds, €950 million goes to the Metro, €430 million to the EMT, €140 million to Renfe, nearly €500 million to road transport concession holders and another €90 million to railway concessions[9].

Madrid's transport system is excellent, to a large extent due to the creation and work of the Consortium and also that of the Governments and companies that make it up. However, the challenge in the current situation is the sustainability of this model, with actions which do not compromise its viability, given the sensitivity of demand both to measures on income and the reduction of costs. There is a margin for this and it is important that the right actions are taken, as urban life itself depends on the sustainability of the transport system.

(Text by Joaquín Martínez-Vilanova, Director General of Transport in the first Government of the Comunidad de Madrid 1983-1987).

[9] Madrid Regional Transport Consortium Annual Report 2011.


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4 | Rising up with Structures

Occupying, raising, extending

Works that rise up and build the world usually satisfy a purpose, but what is built is often more durable than the original function. To understand it you need to approach it in the way its erection is expressed. This can be expressed as vertical, horizontal or spatial, i.e. as a tower, roof or building, regardless of what the construction itself houses. In fact, tower and roof are themed representations of the building, one as a vertical specialisation and the other a superficial. The German language takes these differences into account in the terms Hochbau, to build up, and Teifbau, to build low or extend, combined in Hochtief, with the joint meaning of building and public work.

This conceptual reduction makes it easier to understand the role of the structure, perhaps partial or incomplete for analysing the work as a whole, but useful for observation of the varied world of that built. Each of these three results of the building process responds to specific modes of confronting the world and relocating the structural part in the genesis of that built.

Building, roof and tower

The building is the basic form, based on its comparable height, width and breadth dimensions, defining a space divided up for use by floors and walls. Its structure needs to make the basic elements used to formalise relate to each other comfortably.

The roof, as a protected surface extension, functionally limits the height and releases length and breadth. The length is extended by addition, but the amplitude or increase in breadth directly confronts the strength aspect and needs to overcome the main bending forces, which increase as the square of the separation between supports.

Towers, dominated by their verticality, need to look after their stability by tackling the combination of vertical forces due to gravity and horizontal forces due to the wind and earthquakes, which also increase as the square of the height. The ratio between the height and the floor dimensions is the parameter which governs how difficult this is [19:74].

Monumental Record

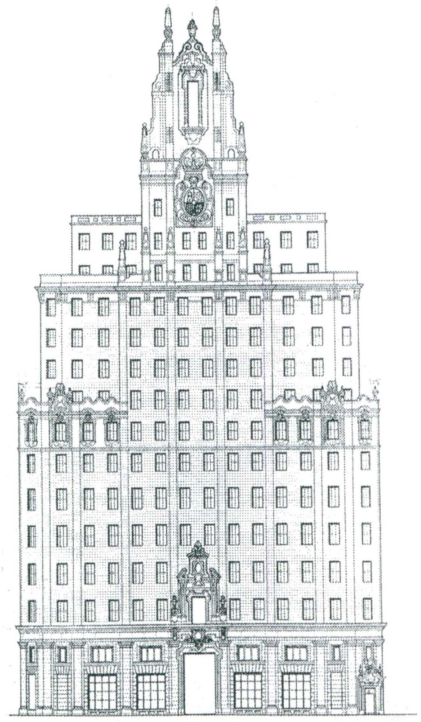
Santa Engracia Water Tower

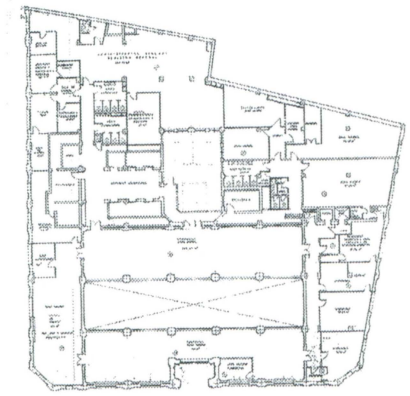
Water also needs height to reach all of Madrid's homes. One of the city's first vertical constructions was the first raised tanks for the Canal, located in the street named Santa Engracia, also known as the "Vaso" or glass by Madrid's residents. It was used to lift the water stored in the underground tanks between the streets of Santa Engracia and Bravo Murillo up 32 m, to a sufficient altitude to provide water to Madrid's buildings located below an altitude of 690 m above sea level, basically the neighbourhoods of Salamanca, Chamberí and Cuatro Caminos.

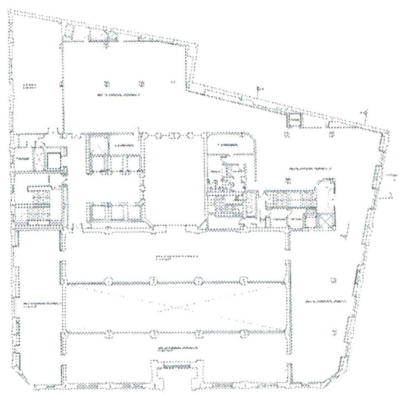
The brick tower with its zinc-covered iron tank at the top is the work of the engineers Luis Moya Idígoras and Ramón de Aguinaga. In its powerful appearance, Antonio Bonet recognises a mixture of modernity and tradition: *On the one hand it has medieval resonances of Mudejar style... On the other hand it is the result of the Vienna Secession, an architectural movement which decisively influenced the Madrid of the time.*

The tower was restored in 1987 as an exhibition space, later specialising in photography, and has become an *authentic urban landmark, a real symbol of modernity. Like Georgio de Chirico*, Bonet continues, *it is a building that enters the most curious passers-by's memory and dreams. The current Calle de Santa Engracia, without the vertical tower of the raised tank, would be an anodyne, amorphous road in the tentacular city* [47:43].









Telefónica Building

The Telefónica Building's location and height make it a real reference for the city. It was designed by Ignacio Cárdenas, who worked first as an assistant to Juan Moya, professor of the School of Architecture and architect who conserved the Royal Palace, then alone when Moya, who aspired to a more baroque building, resigned. Cárdenas travelled to New York to familiarise himself with skyscraper design alongside Louis S. Weeks, the architect for the company ITT.

The building's design underwent few revisions by the American architect. This was not, however, true of the metal structure *which was subject to constant supervision by ITT of New York* [176:28].

For the ornamental finishing designs, Cárdenas relied on the collaboration of the sculptor Rafael Vela and the painter Hidalgo de Caviedes, while the installations were designed by an American firm. It was Europe's tallest building for a few months until July 1929. Once the War had ended, an expansion at the back was completed, finishing in 1955.

According to Navascués, critics have generally ignored this important building, partly due to doubts about the role of the American architects in the project. Also though, probably, because the building *not only exceeded all that had been built in Madrid until then, but also because the conception of the building, as a Latin imitation of North American skyscrapers, observes concepts and typologies not considered in the municipal ordinances* [176:42].





Edificio España
Joaquín y Julián Otamendi Machimbarrena, 1953

Behind a monumental staggered façade, from a certain height the floor plan is structured around five courtyards perpendicular to the façade configuring six constructed blocks. The two end blocks correspond to the façades onto the streets Reyes and Maestro Guerrero and reach a cornice height of around 38 m, corresponding to seven floors, topped off by two floors set back a little.

The two central volumes reach a height of 107 m, while the intermediate blocks end at 74 m. The façade acknowledges these intermediate volumes with a clearer colour, framed by the red tones of the brick in the central and lateral bodies. The play of colours and set backs is partially successful in limiting the problem of such an immense volume which extends its dominion over the Plaza de España. Gigantism certainly was no stranger to the rhetoric accompanying its construction, such as the *biggest building in Spain*, together with the luxury of its interiors on the lower floors which were dedicated to commercial use.

The structure is a traditional skeleton in reinforced concrete, without greater interest than for its size, as the height does not manage to condition the structural behaviour like a tower, given the dimensions of the façade and the sides [12:72-73].







La Zarzuela Hippodrome
Eduardo Torroja, 1935
Restoration of the Zarzuela Hippodrome
Jerónimo Junquera, 2008 - ongoing

Eduardo Torroja covered the grandstand with a great cantilevered canopy with a span of 13 m using hyperboloids which fulfil the functions of primary and secondary structure simultaneously, making transverse elements unnecessary. The roof is supported on a potent central column which orders the whole structure and is anchored at the back which, at the same time, supports a lower vault. The whole assembly explains itself in its transverse section, a real wonder of compositional synthesis which includes the grandstands, the canopy, the supervision aisles, the betting booths and the meeting spaces above the paddock [16:40].

The Restoration Project trusts the Hippodrome's beauty to bring out the essential values of the 1934 project, recovering those lost. The main task is to remove the additions to the buildings and restore the grandstands. Added to this are two missions to improve the functionality of the assembly.

Firstly, adapting the topography to segregate circulations of horses and public onto two levels, as per the 1934 project. The public enter the area through the north and south patios, connected at the paddock gallery. From this level, you can see all the horses' movements at a lower level, without getting in the way. Additionally, the patios are being expanded towards the terraces, with views of the track and the city.

Secondly, the saddling enclosures have been retained in their original position, concentrating race, jockey and veterinary services around it in a new building excavated into the ground and open to gardens. They have independent entrances and direct connection to the paddock and the central grandstand, without crossing public routes.

Work started in 2008 with the restoration of the grandstand roofs, which had deteriorated with the passage of time and had been damaged by water and various constructions carried out in previous steps. While the roofs were being restored, inspection tasks were carried out to uncover and analyse the original values and construction systems, which had been detracted from and lost in expansions and modifications made to the site. This showed significant structural damage calling for works to consolidate and repair the structure.

Restoration credits: Architect: Jerónimo Junquera. Project Director: Clara Eugenia Santana. Structures: Carlos Fernández Casado S.L. Installations: Úrculo Ingenieros. Developer: Hipódromo de la Zarzuela S.A. Constructor: Dragados S.A. Dates: Project: 2004. Works: 2008 – Ongoing.

Santiago Bernabeu Stadium

The Santiago Bernabeu Football Stadium, initially known as the new Chamartín stadium, was included in the Bidagor Plan as a key piece in the Paseo de la Castellana axis. The architects Manuel Muñoz Monasterio and Luis Alemany Soler and the engineer Carlos Fernández Casado won the competition called in 1944. The stadium, initially planned for 70,000 spectators, was built in several phases, reaching a capacity of almost 100,000 spectators with the combination of standing and seated sections. The project was complemented by several independent gymnasium, handball court, 33.33 x 15 m swimming pool and changing room facilities. These are not there now as a shopping centre has been built.

The project emerged as a state of the art work, with a double level stand structure, with the top part slightly cantilevered over the lower, made in reinforced concrete with equidistant supports together with various mass-produced elements giving the building a modular order. The necessary representative nature of the construction means that the façade is subject to clear classicism [44:336].

It has undergone numerous expansions and interventions. In 1953-1954, the same authors designed an increase in height, with a third level of stands flanked by two vertical linking towers. In 1980 Luis and Rafael Alemany Indarte and Manuel Salinas Aracil remodelled it to adapt it to the needs of the 1982 World Cup and lined the initial structure with prefabricated concrete panels. Between 1992 and 1994 Antonio Lamela Martínez executed a second expansion with a new stand and four great cylindrical access towers which recall those of Milan's San Siro stadium. Finally, a new expansion has been proposed which includes a new building in the western façade.



Santiago Bernabeu Stadium, opened in 1949 (1994 photograph)

Torre de Madrid
Otamendi, 1957, 1960

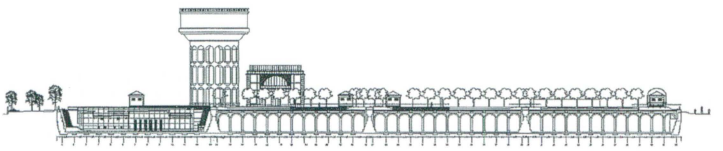
Another tall building was constructed alongside the Edificio España in the same Plaza de España. In this case it was clearly a tower, both due to its over 100 m in height and due to the decided intention to emphasize it in its elevations. The architect Julián Otamendi Machimbarrena stressed the corner calling and the height of the building with two stepped, set back volumes, lower at each side and with vertical lines between the gaps, centred by projecting balconies in the corners and topped off with a recess in the top seven storeys. Only the projecting ornamental finish of the roof for the penultimate floor betrays the ascending emphasis of the composition by placing a kind of hat on a building which does not need to protect its head.

The first phase was completed in 1957 and the second in 1960, giving rise to one of the tallest buildings in Europe until 1967 and in Spain until 1982. The building was constructed using concrete and in its 112 metres houses a large number of shops, apartments and 12 lifts to run to all the floors. The floor plan is distributed symmetrically with respect to the bisecting line for the corner with a centred lift core and supports in the façade.











Plaza de Castilla Tanks

After the first raised tank in the Calle de Santa Engracia, another tank needed to be positioned high enough to supply everything built in Madrid's northern part. The new Canal Alto was completed in 1925 and construction of the underground tank to hold enough water for 12 hours of supply started in 1930, although receipt of the works was delayed until 1940.

The underground tank is 242 x 130 m with a height of water of 6.5 m and a capacity of 180,000 m^3 of water. Its external form was made up of stepped concrete walls and its four compartments were formed by similar very thick walls. With a ground slab, brick columns and arches were built on concrete blocks to support the top slab of prefabricated concrete joists and brick vaults. The assembly represents an *exceptional engineering work that honours the developing organisation and the specialists and workers who built it* [63:19].

A new raised concrete tank was built alongside it, in the form of a cylindrical vat 28 m in diameter, with a capacity of 3,800 m^3, supported by a set of columns with a total height of around 40 m. It was started in 1935 and completed in 1941, but not inaugurated until 1951. Next to the raised tank is the old lift pumping station, built in 1953 by Francisco Parella, Antonio Renedo Fornos and Álvaro Bielza.

The pumping station was remodelled in 2002, as the headquarters of the Canal de Isabel II Foundation, by the architects Gerardo Salvador Molezún and José Ramón Menéndez Luarca. The underground tank was fitted out as an Exhibition Hall in 2004 and a new park was built on its roof, after having restored all the structure.

In time, the technology of raising water to these tanks was replaced by that of pressurising it using pumps against the network itself and the tank fell into disuse[1]. However, the tank is maintained nobly in a setting full of magnificent pretensions of doubtful taste.

The architect Antón Capitel talks of the *horror of the Plaza de Castilla*, where the city's worst architecture accumulates: *the mediocre monument to the first martyr of the pro-Franco crusade, the ineffable inclined towers by the uncouth US architects, the various bus stations that accompany and accompanied it like a formal by-product and, now, the stupid monolith by the engineer/architect/sculptor – anything else? – from Valencia. The horrors of the Plaza de Castilla are architectural then and only an engineering work, the water tank, alone, tries to defend formal quality* [59:11/1/2010].

[1] The Canal has four underground tanks of similar conditions which progressively fell out of use. The first is between the streets Santa Engracia and Bravo Murillo, the second is on the other side of Bravo Murillo, the third is on the street named Islas Filipinas (on top of which a park and a golf practice range were built) and the fourth is this, at the Plaza de Castilla square.

Chamartín Station Buildings

Chamartín station is built on two construction platforms located above the yard of twelve tracks of the first provisional station, as already mentioned (see page 44), being a through station as the tracks continue towards Atocha through the Paseo de la Castellana tunnel. Its entrances are produced with roads climbing from the streets Pío XII to the east and Agustín de Foxá to the west, to overcome the obstacle of the through tracks.

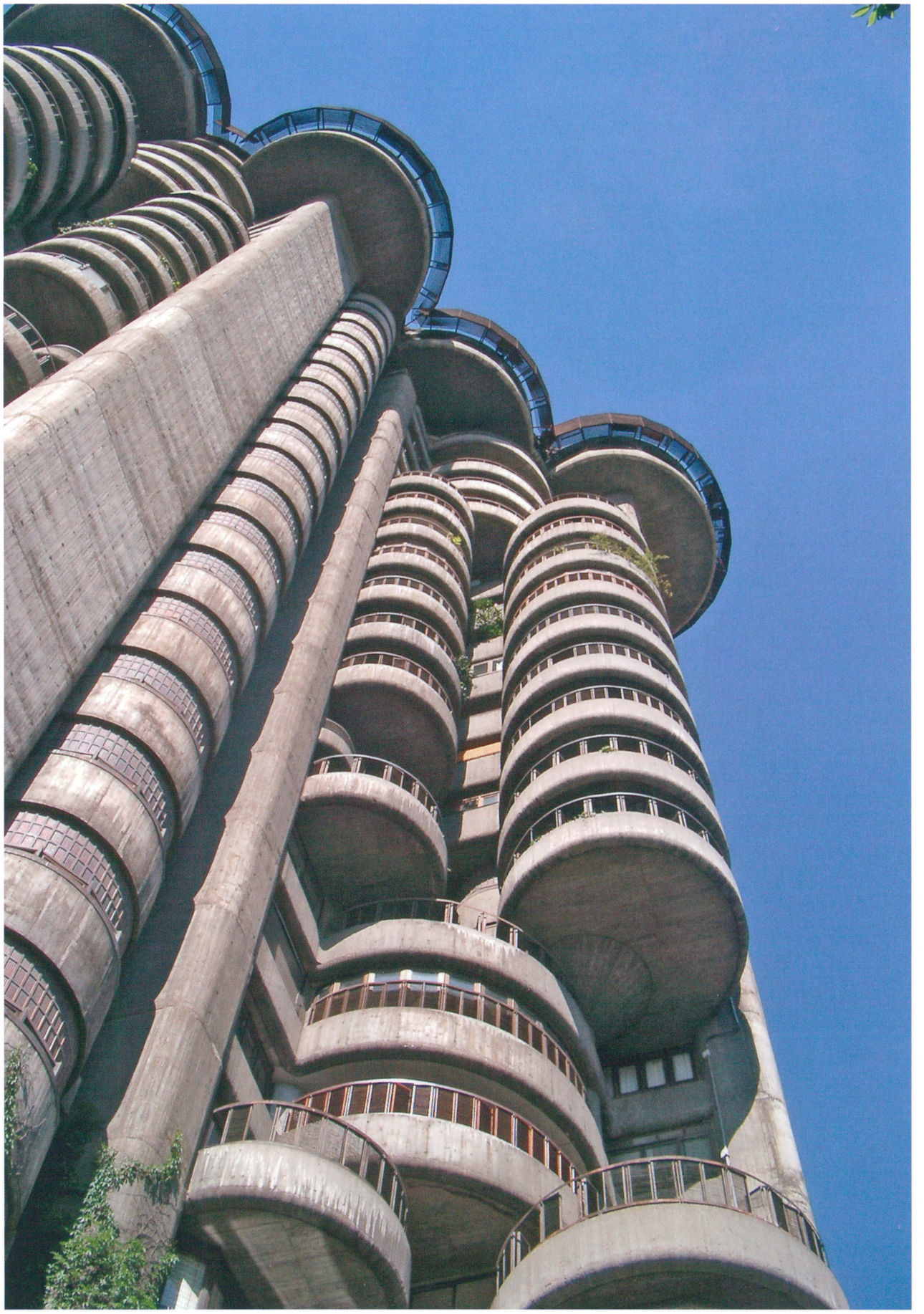
The construction platforms, perpendicular to the lines, are closed off to the west by a large bordering building that extends to the north, limiting the whole yard. The building contains a hotel which grows upwards and forms the station's façade. The tracks define the grid of supports for the construction platforms, with a narrow module of 4.2 m where the stairs for access to the rail platforms are inserted, alternating with wide modules of 12.2 m under which the tracks run. The distance between supports in the direction longitudinal to the tracks increases to 20 m, with large concrete beams to support the reinforced slabs.

The smaller spans are covered with concrete slabs and the larger with barrel vaults built with a metal structure which, according to Alberto Humanes, *create a rhythm of great compositional beauty from the outside, above all from the pedestrian square where their presence is forceful. More debatable*, he continues, *is the creation of an artificial square 13 m high as the centre of the station's life, where the intended urban nature... is nothing but an ingenuous pretension*[2].

[2] Humanes, Alberto; 1980. *Chamartín and its impact on northern Madrid*. In [3:103-120:119].





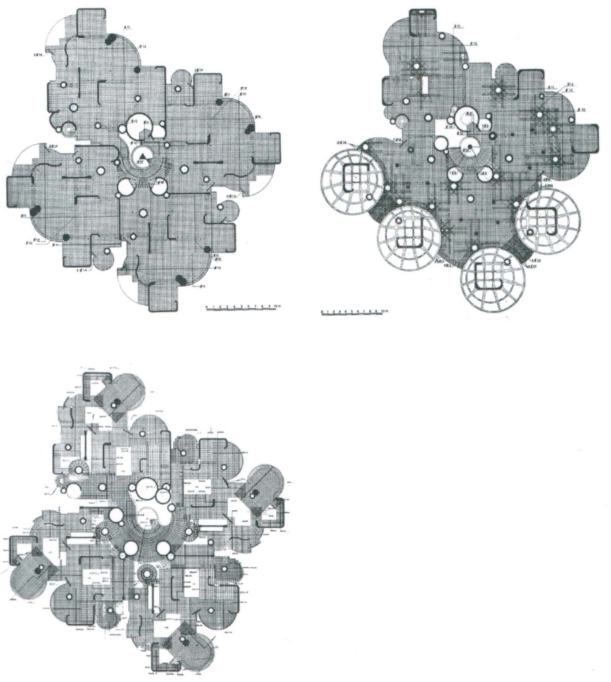


Torres Blancas
Sáenz de Oiza, Manterola, 1976

The first professional work of Javier Manterola was the design of the structure for the Torres Blancas, or White Towers, a large housing building designed by the architect Sáenz de Oiza in the exit from Madrid on the A2. The crucial point of the design lies in the integration of the building's spatial functions in a resistant structure which is shown as an essential part of the tower's sections and elevation. The structure does not impose its presence or show specific details in this play. It is limited to being itself together with the building. The arrangement of the screen walls in plan enables you to appreciate their symbiosis with the building's functional organisation, with an order arising from the project which is fully shared or supported by the structure.

With such a complex floor plan, the tremendous simplicity of the reinforcement plan is noteworthy, where each bar appears to have a natural place. This arrangement has no other aesthetic intention than to respond to a criterion for ordering the floor, transferring the rigour to the plans and the construction process, because the slabs had no ribs and could not show this richness on the outside [22:27].

However, the structure plays an important role in the architectural concept for the building and this would have been more visible if the initial height and the white concrete colour had been respected. William Curtis acknowledges that Torres Blancas combines positions in favour of and against modernity that were at times opposing: a desire to be faithful to the principles of function and technology, but at the same time adhering to an organicist, expressionist and sculptural architectural language [78:552].



Torres de Colón
Antonio Lamela, Manterola, 1976,1992

In the 31-storey Torres de Colón building, the top 20 floors are hung from a rigid platform arranged on the top floor. The concrete slabs, of 19.4 x 17.4 m, are supported on one side by the 7 x 6.9 m central core and are hung on the other side from 18 pre-tensioned concrete ties located in the façades.

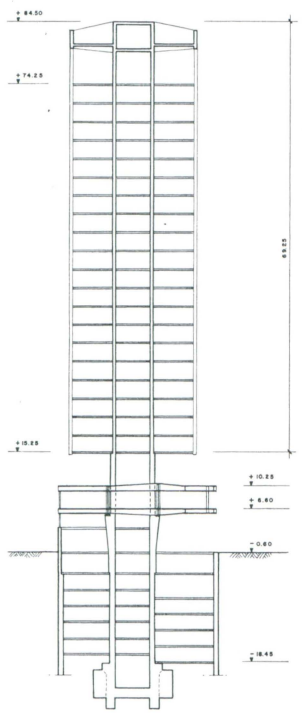
The central core is compressed by the loads from each floor due to direct support on the core and the part which, after being brought to its top part by the ties, goes down it from above. Thanks to this, the core is composed very well to resist wind effects, but it has the problem of levelling the parts supported on the core and those hung from the ties. The lower the floor and the greater the number of floors, the more significant the levelling problem becomes.

The taller and narrower the building, the worse the problem, as height increases the unevenness and the width separates it over a greater distance, reducing the slab's angle of deviation.

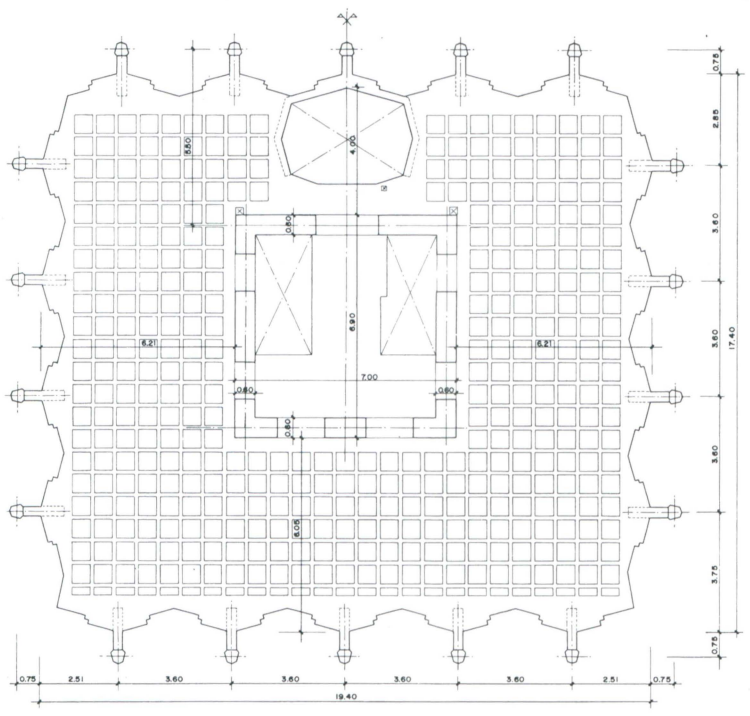
The Torres de Colón are tall and narrow, so the adoption of pre-tensioned concrete ties has many advantages. They do not respond passively to the load, as metal ties do, but rather as active supports. With pre-tensioning, a shortening deformation is introduced which eliminates the imbalance in the permanent load and even averages out the on-loading.

(Summary of a text by Javier Manterola [22:15-17], [12:156]).





section in elevation



typical floor





Banco de Bilbao
Sáenz de Oiza and Manterola, 1972-76

The Banco de Bilbao building heads the list of Madrid's best buildings and has been exhaustively studied [57]. It is worth dedicating a few lines here to the less well-known structure, designed by the engineer Javier Manterola. Manterola worked with Sáenz de Oiza again around 1972, on the headquarters of the Banco de Bilbao, completed in 1976. A 19 m wide tunnel for the railway connections between the Atocha and Chamartín stations passed diagonally below the site for the 35-storey building.

The chosen solution was to position two vertical cores, one at each side of the tunnel, and six large intermediate platforms, each to collect the loads from five normal floors, 30 x 40 m in area and to transfer them to the large screens for the cores. Each platform is supported by two beams 2 m deep supported on the cores. Another nine pre-tensioned rectangular transverse girders are supported on these to form a grid on which five floors are built using a metal structure and concrete slabs.

The structure was functionally integrated into the building, with the cores for the lifts and with the empty spaces produced between the large girders being used to house the ventilation systems. *Oiza*, Manterola says[3], *was very clear, very direct and very emphatic in structuring the building, ordering the structure, ventilation and lifts, configuring the whole building with these* [22. 28].

[3] Manterola, Javier; 29.9.2000. *Discussions on Oiza.*



Torre de Valencia
Javier Carvajal Ferrer, 1973

Regardless of its architectural value, the Torre de Valencia is a product of speculative action by the city council itself in the 1960's, which auctioned an old fire station and permitted the building of 25 storeys on a broader base of another three storeys. The building interrupts one of the city's traditional and emblematic views as it inevitably appears behind the Alcalá Gate from any viewing point located in the hollow defined by the Castellana watercourse along the street named Alcalá. The floor plan was studied to make the neighbouring park of El Retiro visible from the majority of the 90 apartments, with a largely traditional skeleton structure, organised around four stair cores [62].

The floor plan has a somewhat organic character making any structural rationalisation rather difficult, beyond columns, slabs and bracing walls in reinforced concrete. The façade is made up of prefabricated concrete elements which emphasise the horizontal ledges of the terraces against the verticality of the blind buttresses, running up the entire height and which have no overall resistant functions despite their solidity [12:153].

Buildings

M-30 Funeral Services
Fernández Alba, 1984

The product of a competition called in 1981 by Madrid City Council, the building is located at a high point above the M-30, from which it has good visibility in two directions. It fulfils a demanding, precise functional programme with a clearly ordered floor plan which evolves in the elevations to classical forms which are nonetheless indebted to strict modernity, typical of the architect's personal repertoire. The inside houses works of art by well-known contemporary artists, such as Chillida, Palazuelo, Canogar and Saura and it has a fountain designed by the architect Juan Daniel Fullaondo [126:88].



Atocha Station Expansion 1993
Moneo, Manterola, 1993

The expansion of Atocha's vaulted, closed structure was based on an oblique geometry with an open, modular structure. The terminus station was replaced by a through station, a connecting piece covered by a classical, timeless structure, which still reminded of the monumentality of the old station, retained as a greenhouse.

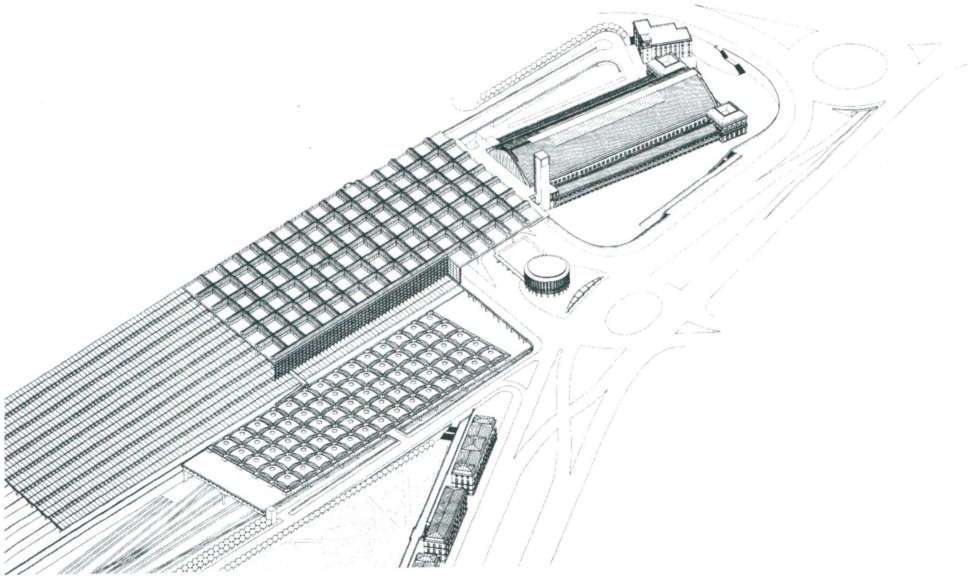
It was tackled as a reflection on the structure of the Palazzo del Lavoro in Turin (Nervi, 1961) [177]. Nervi achieved a cubic volume on a square floor plan, with free-standing columns from which metal ribs irradiate, finishing in an opaque square. The columns are separated from the glazed façades and between the square frames there are strips of light which flood the grid, but also evoke an ancient hypostyle hall [78:480].

The expansion uses the umbrella with a single shaft and ribs, with a trapezium-shaped frame instead of square. In Turin, twenty ribs set out from the shaft, but there are eight in Atocha and a second family of secondary ribs of decreasing length are generated towards the corners. The four primary ribs in the main directions do not divide, while the other four diagonal ones do, three times. The primary ribs and the central rib in each secondary family extend across the whole station and the rest are broken at the strips of light.

The 16 modules used in Turin increase to more than 90 in Atocha. These are organised in turn into groups of 30, leaving a transverse strip of light not crossed by any ribs. The hierarchy plays a fundamental role in maintaining the classicism in the face of the enormous dimensions, which it was not wished to amplify with a single roof.

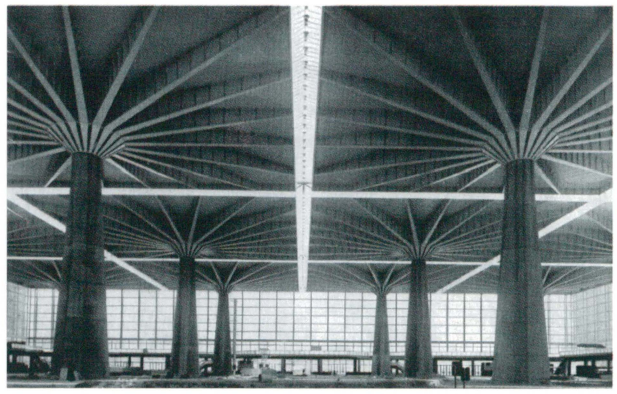
Summary of [12:80-81:].



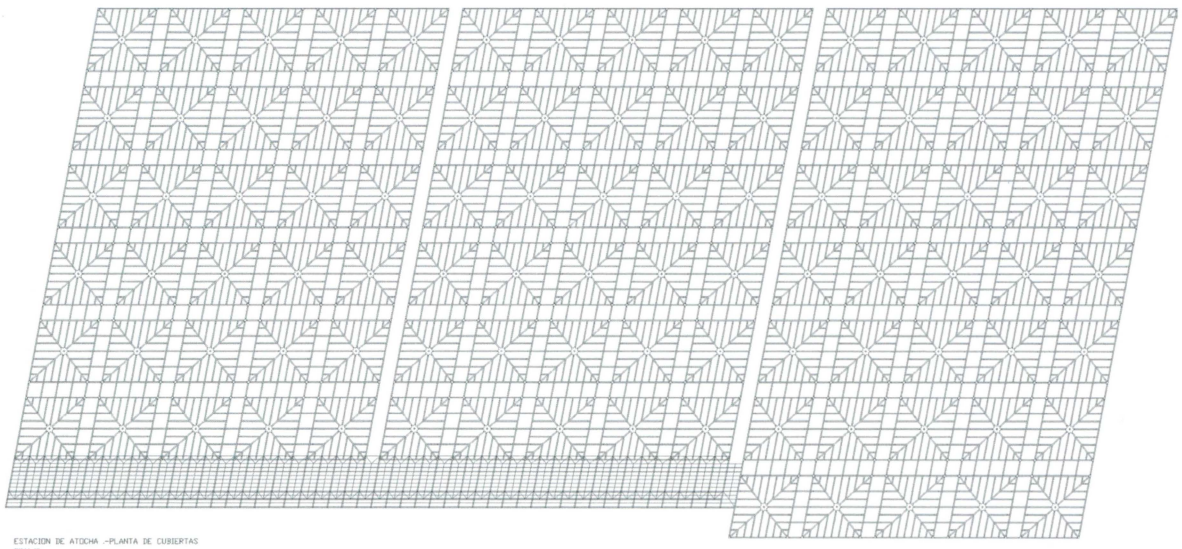




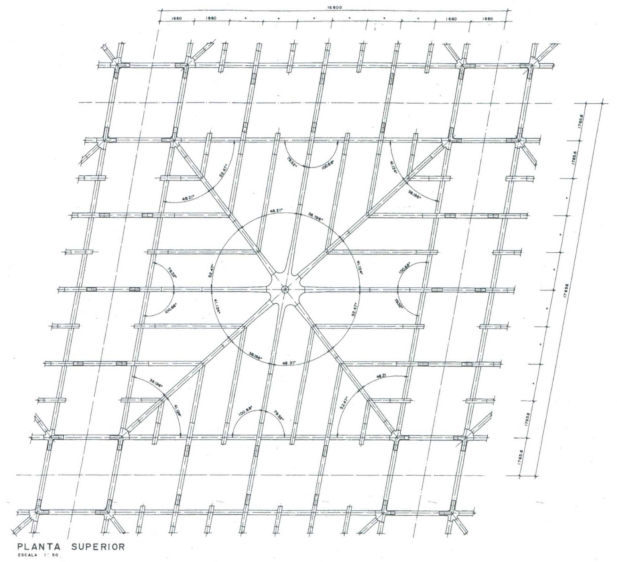




Palazzo del Lavoro, Turin (Nervi, 1961)



ESTACION DE ATOCHA.-PLANTA DE CUBIERTAS



PLANTA SUPERIOR

Expansion and separation of departures and arrivals of 2010

The accumulation of new High-Speed train services at Atocha introduced a level of station occupation which demanded the separation of arrival and departure flows. Passengers alight at the platform end area and go up using mechanical means to an upper transverse platform that will allow them to exit the station in the near future. Temporarily, they need to walk 200 m parallel to the platforms to reach the arrivals hall, located near to, but separated from, the exits. The now empty trains move to the head of the station to receive new passengers.

In this 2010 expansion, the station was extended again and now has a new upper arrivals platform which crosses transversely to reach the new access. On it, the transverse flow of passengers needs to combine with the longitudinal flow of trains, which is reflected and suggested in a roof with ruled surfaces. Its complex geometry allows light from the north to pass and suitably expresses the perpendicularity of passenger and train traffic. Additionally, the roof module fits between the enormously deep lattice girders (motivated by future lateral spans) running across the station laterally from side to side.

The transition zone between the two expansions is resolved using a simple structure of metal columns, which are well differentiated from the powerful neighbouring roofs. The structure, painted white, adds to the stainless steel and slenderness of ramps, stairs and footbridges to produce a clean space, with almost hospital-like aesthetics, almost unknown in the railway world. As the tracks leave the station, the thick lattice beams appear again to support the catenary, full of insulators, cables and technological contraptions, of overwhelming presence. It is like leaving the cleanness of the operating theatre and going back to the packed hospital corridors.

The construction of the expansion and the raising of all the pavements by 10 cm was a real feat of work organisation. The AVE high-speed lines and the rest of the services were operating, so trains passed constantly, leaving windows for work of four or five hours in the early morning. The shortness of the shifts made it necessary to have a large number of lifting platforms and auxiliary resources that barely fitted onto the platforms.

Arrivals Hall

In spite of everything, the upper arrivals hall will only make full sense when the station exit above the suburban rail tracks comes into service, extending the transverse route to the north-east. Meanwhile, passengers arriving at Atocha need to turn left and walk around 200 m parallel to the tracks to reach the temporary departures hall.

The directionality of the arrival route has been carefully fitted into the station's pre-existing structural assets. The spherical caps with square form in plan which cover the suburban rail car park are linked by strips of light to form the long corridor. The temporary departures hall is a great transverse hall, the rather low roof of which disappears into a diaphanous, luminous space without pillars as you move towards the exit. A large lattice beam is the key to this disappearance, as it supports the low roof on its bottom cord, allowing a free flow of passengers under it. Three escalators and a lift occupy the central space to ease the climb to the upper street level.

The double height space is covered by dihedral-shaped beams, with one opaque face and the other in glass, allowing light to pass from the north-east. On the north-east side, these beams extend over the glass façade, seek support on a free-standing frame and extend beyond to form a canopy covering the taxi rank. On the other side, the dihedral forms are supported on the lattice beam, which is the absolute main feature of the arrivals hall. The lack of an upper cord reinforces this role and promotes its integration with the roof, as it receives the dihedral forms of the roof directly on the diagonals.



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Atocha station expansion (Moneo, Fernández Troyano, 2010)

(Summary of [17] and [16:252-255]).

Credits: Architects: Rafael Moneo and Pedro Elcuaz. Engineering: Ineco-Tifsa. Ownership: Adif, Ministerio de Fomento. Architecture collaborators: Andrea García, Pablo López, Sumac Cáceres, Brezo Alcoceba, Tamar Loeb, Juanjo Farrés. Structure: Leonardo Fernández Troyano, Guillermo Ayuso (civil engineers). Contractor, Dragados-Tecsa: Manuel Orea Palomino, manager; Francisco González Fernández, Luis Martínez.

Barajas Airport Terminal T4
Rogers & Lamela, 2005

Rogers & Lamela's project followed a linear modular scheme characterised by the repetition of waves in the form of steel roof wings every 9 m in the north-south direction, with maximum transparency towards the aircraft[4]. The terminal is made up of three volumes with different functions organised in parallel according to the passenger boarding sequence, which progresses in the west-east direction.

The first is the check-in building, where the entrances and desks are located for checking baggage in. The second is the processing building where the security controls are located and the third is for boarding, from which the 37 walkways set out to gain access to the aeroplanes. In front of the three there is a bay zone for vehicles, covered in a similar way, and in front of this there is a row of six buildings for parking connected to the terminal by two elevated walkways.

Between the four parallel volumes covered with the wing module, three canyons or empty spaces are arranged throughout the height, where natural light enters to reach the intermediate floors and where the building's vertical communications are located, which are always visible throughout their route. The two main faces from which access is gained to the aircraft are protected by large projections of the roof, while the light is filtered by sunshades suspended from it[5] [140].

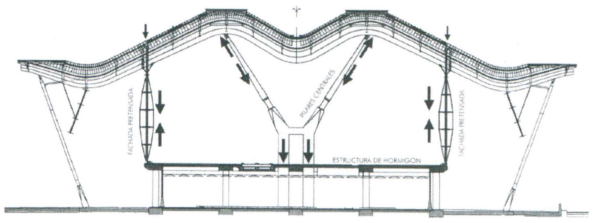
Structure

The whole structure for the floors is from concrete pillars and beams with a generous modulation of 18 x 9 m and uniform sections 1.8 m wide by 0.9 m deep for the beams (which have active reinforcing with post-tensioning) and circular sections for the columns with diameters of 0.8 to 1.2 m according to the loads. The edge beams have ducts for installations and the floors are made from honeycombed slabs with 7.4 m spans and 20 or 30 cm in height, depending on loads. It is a very simple, effective structure which goes somewhat unnoticed in comparison with the spectacular roof.

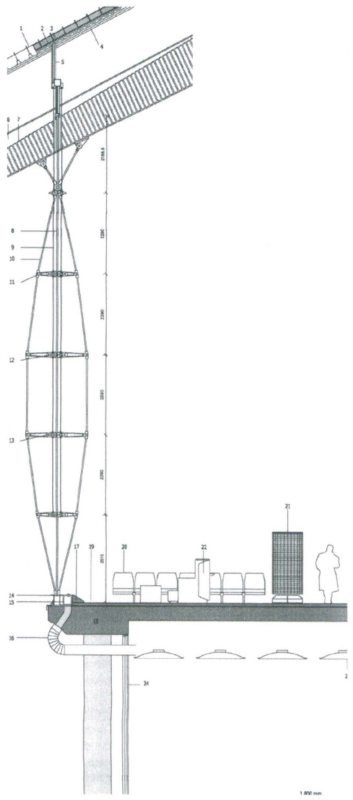
Each roof module is made up of two wing beams separated by 9 m and is supported by a double central column the first section of which is concrete, initially with a double rectangular section which then splits as two props inclined upwards to finish in circular sections. Metal roof props are supported on these sections, dividing in turn in the perpendicular direction to provide four support points for the roof at the highest area of the wings. In this way, the two undulating beams for each module are supported at four high points where there are skylights and leave three low waves, one in the centre and two side ones where the glass façades are housed. The secondary

[4] An international competition was called in the preparation of the project and in October 1997 the choice was made of the proposal from the architect Richard Rogers, together with the Spanish Estudio Lamela and the Spanish and British engineering firms Initec and TPS respectively.

[5] For a description of the whole construction see [131].







structure is made up of metal arches which are supported on the beams with metal straps over them.

Façades and intermediate spaces

In turn, the glazed façade is supported on a tensioned structure made up of a central profile and two external cables which form a spindle and are kept apart by means of horizontal crossbeams. This fusiform section some 13 m high is suspended from the metal structure of the roof and is tensioned against the boarding building's main floor structure. The procedure consists of pushing the roof downwards by means of jacks and, when it is at its lowest point, the section which hangs from it is coupled to the floor structure. The roof is then released, tensioning the spindle as it tries to recover its initial position [238].

The structure has a fundamental role in the configuration of the internal space. This is shown in the undulating form of the roof and the presence of the inclined, multi-coloured metal props. For Javier Manterola, the intermediate concrete pier, divided into the metal props which reach the highest parts of the roof, produce a strange sensation. If the roof had been supported at the low points, two more rounded spaces would have been obtained and not that space sectioned by the plane set by the inclined piers [150:53].

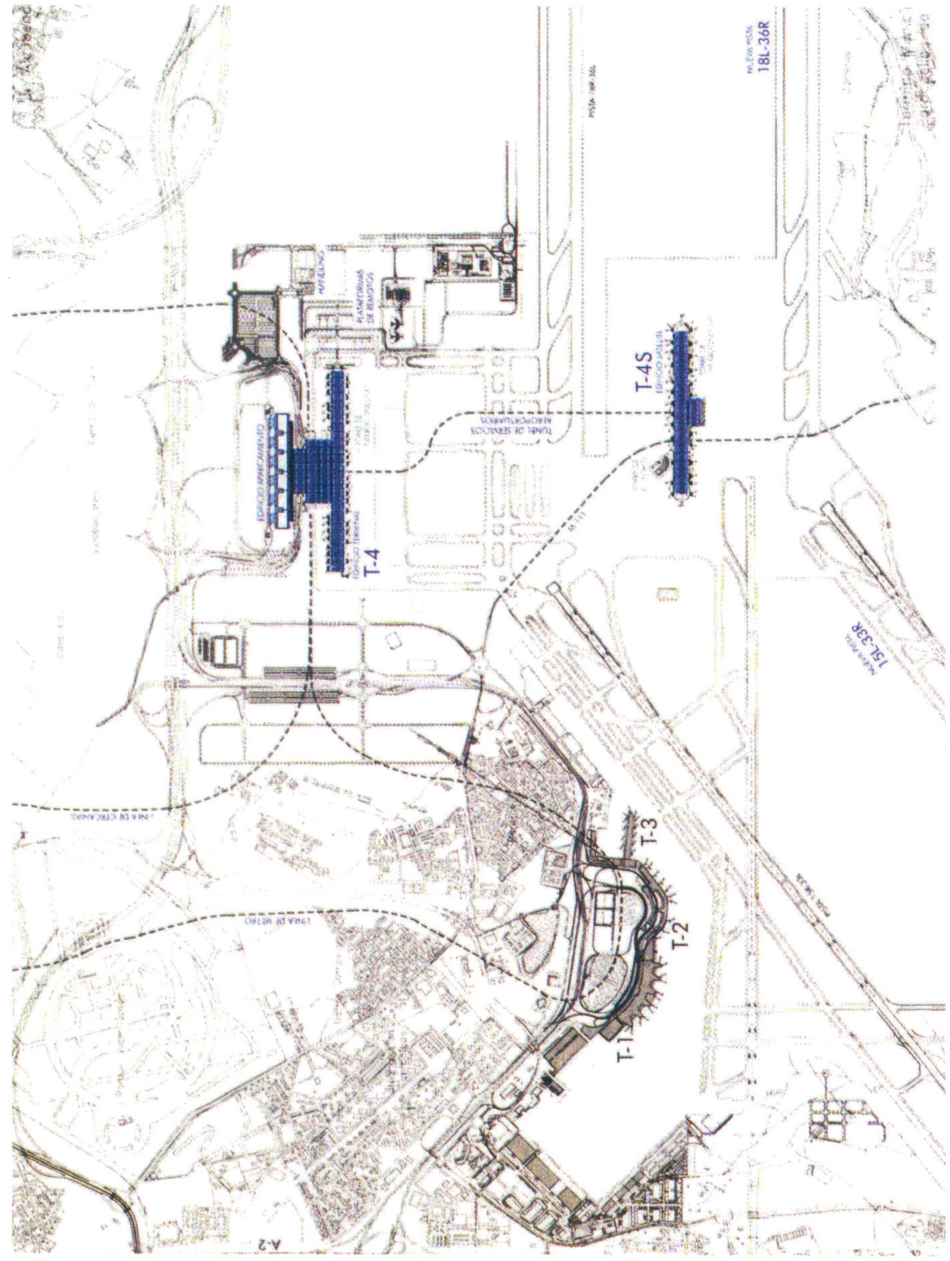
The support at the high points also generates a problem with the collection of rainwater which requires the use of energy for the self-priming pumping system, instead of using gravity as with conventional roofs. As regards the secondary structure, the curved floor structure – formally originated in laminar structures – is mere formal presence here, although the external and internal linings are appropriate.

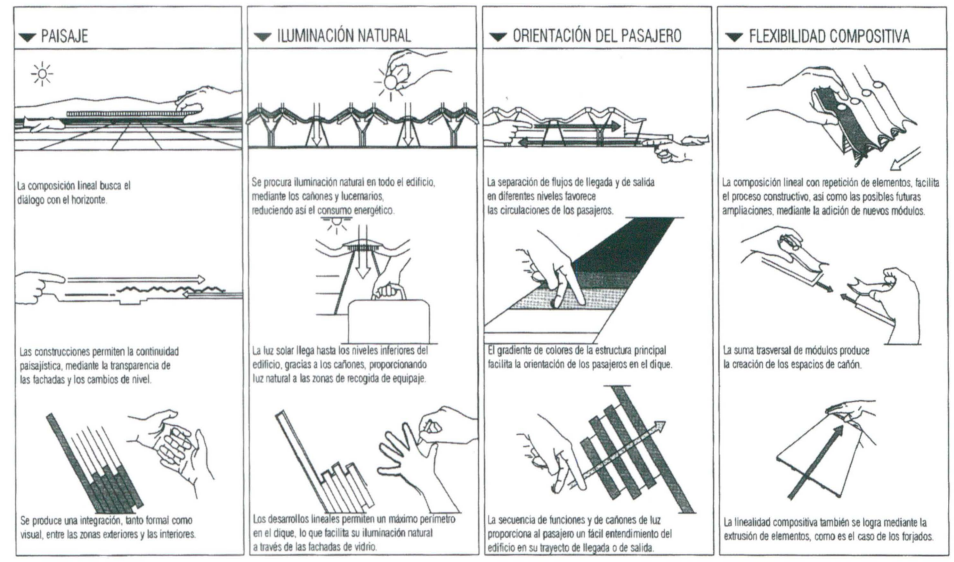
Manterola also views the façade structure with doubts, as converting the horizontal action of the wind into a vertical load at the roof with the consequent increase in flexing makes no sense. It can be done, but it makes no sense and it is what happens to this roof in general, which acts with too many things on it and it appears to remain impassive... If it were flat, all these impacts on it would not matter, but being undulating... [150:54]

All this occurs in the boarding building, but in the canyons or empty spaces and in the other buildings, the coexistence of the roof structure with the floor structure generates certain conflicts that are both construction-based and formal. During construction, the handling of the metal parts of the roof over the already executed floor structure caused a great deal of difficulty due to the impossibility of using the appropriate cranes[6]. The presence of a vertical line of pillars alongside slightly inclined metal props which start on the level below to almost connect with their opposite numbers in the roof is clearly redundant. The small span of the canyon fails to express spaciousness, in spite of the correctness of the choice of the colour yellow for the props compared to the grey of the concrete.

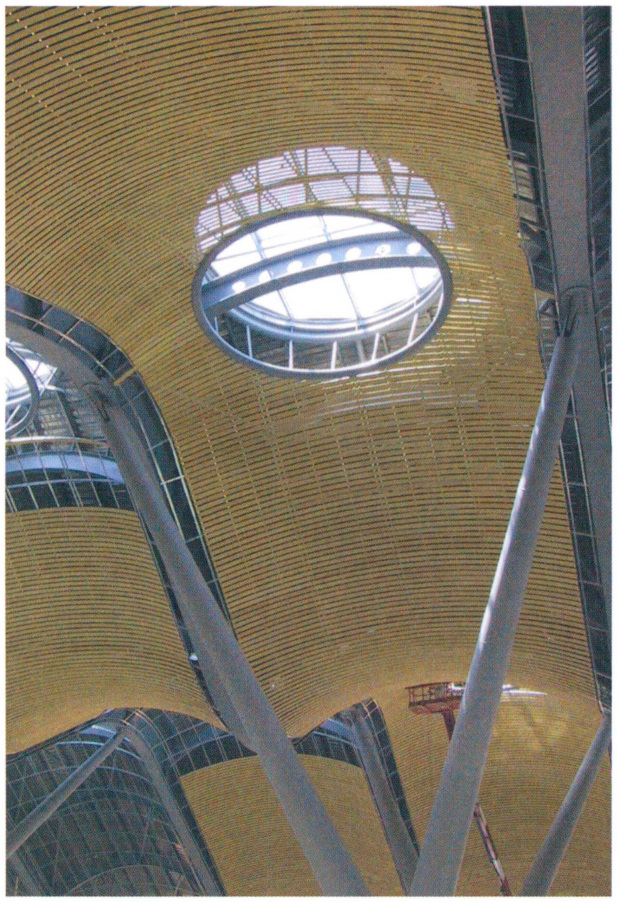
Comfort in use

Regardless of the structure and in spite of its dimensions, the building is pleasant to use. In the whole T4 terminal, the level of noise is lower than in any Madrid bar or restaurant. The natural light is adequate, the air conditioning excellent and orientation is easy, all of which is noteworthy given the

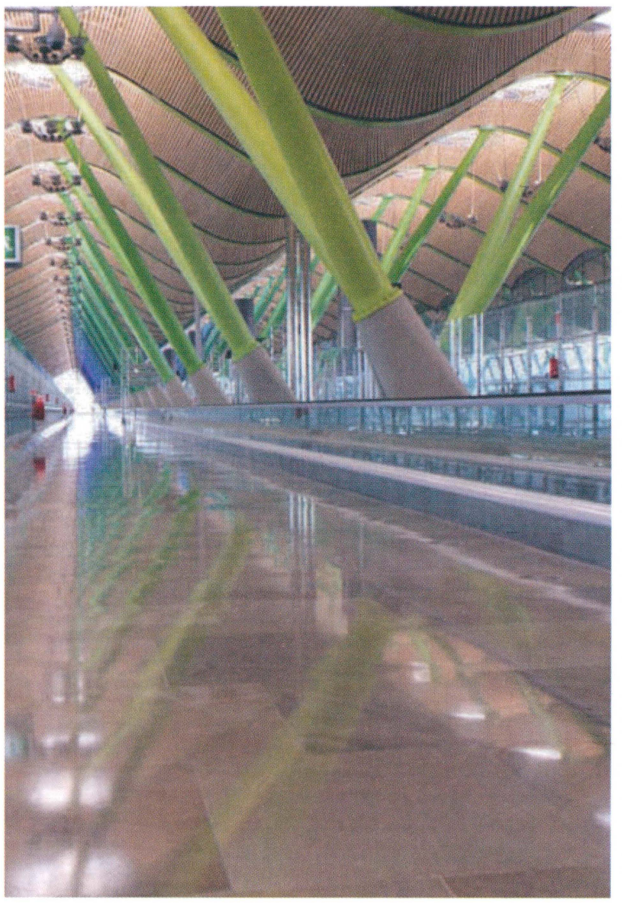




[6] (For construction difficulties, see [36], and the articles by Jesús Gómez Hermoso [117], [118] and [119]).









Terminal T4, Barajas Airport, Madrid





Terminal T4, Barajas Airport, Madrid

constant bustle of passengers. In certain services, such as the shuttle service, the routes from the taxi to the aircraft are minimal and impeccable. Regional services, on the other hand, have been badly treated on placing them at the end of the terminal as, being very short flights, access to the aeroplane should be quicker and easier.

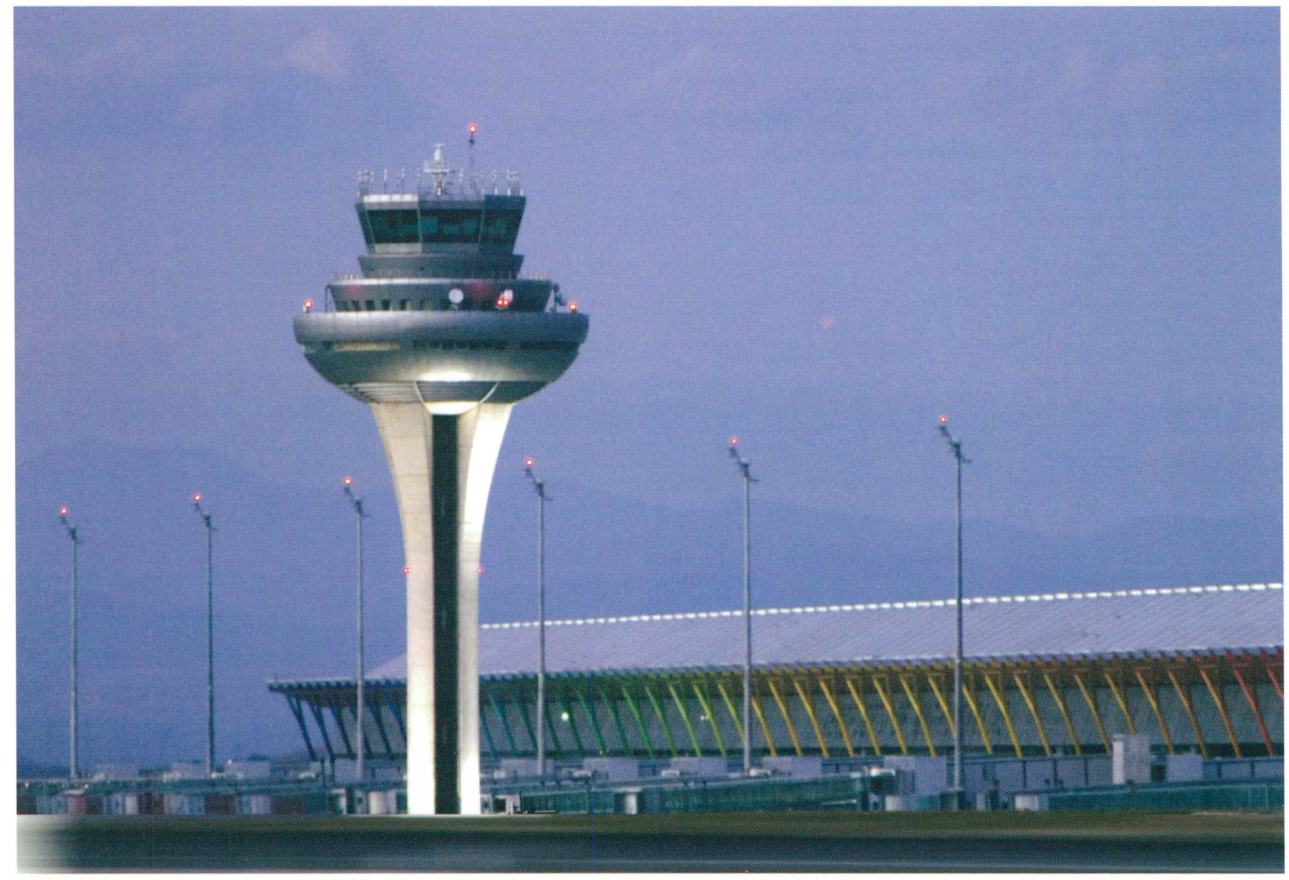
In turn, the car parks are probably the best and most comfortable to use in the whole country, with convenient and safe access, wide spaces and lanes where you can manoeuvre. On the other hand, the satellite building – of an identical design to the departure building – is too far away, with the resulting penalty in use for passengers and baggage for transfers, in spite of the automatic efficiency of the "people mover".

The internal surfaces of the undulating roof are covered with slightly separated bamboo strips. The warmth of the bamboo and the natural light soften the aggressive nature of the truncated cone-shaped metal props, in turn lightened by rainbow colours which mark the building's progress, from the coldest blues and greens at the north to the warm reds at the south. The continuous views of the aircraft and the identification of the colours contribute to perfect orientation for the passenger who always knows where he or she is in an instant.

The roofs of the Terminal and Satellite buildings have all kinds of insulation in overlaid layers, to reduce energy consumption in air conditioning. Great natural lighting was sought in both buildings, both from the sides through the façades and from the top, with large skylights in the roof. Additionally, the open spaces two or more floors high between the buildings also promote the entry of light, even to the basements. This solution creates very comfortable internal environments for passengers and users [140].

(Summary of [12:238-243], [16:220-222]. See also [233] and [78:n.page].)

Credits. Project: Architecture: Estudio Lamela & Richard Rogers. Engineering: INITEC + TPS. Works management: AENA. Technical Support: Técnicas Reunidas. Structures: OTEP, HCA, AHA. External Collaborators: Anthony Hunt for main structure. Contractors: UTE Ferrovial, FCC, ACS, Necso and Sacyr for the terminal building; Dragados and OHL for the satellite; Dragados for the car park. Ownership: AENA. Dates: Competition: 1997; Project: 1998-1999; Construction: 2000-2005; Start of Operations: 2006; Full Operation: 2010 [131:54].







Showgrounds
Pérez Pita & Junquera, 1985-1992

The showground's main doors are located along a central axis, on which you face the pairs of exhibition pavilions at the North and South ends. The Showground's management office and main entrance is also located at the South. The group is surrounded by a traffic ring for service to the pavilions, which are separated from each other by lateral spaces.

This base outline, set by the competition, led to a public building with an inverted layout: the serving spaces are offered outside, while the served spaces are shut away inside. This made the building's relationship with the urban context in which it was set enormously difficult. The other determining factor for understanding the project is its dimensions of 520 m in length by a width varying between 45 m and 60 m, with a height of 14 m.

This centripetal building, turned to the inside and with difficulty in establishing references with the outside, was set out as a series of enormous metal boxes clearly drawn by its artists. The internal route beyond the welcoming space is a sequence of rectangular squares of differing sizes, the dimension of which is intentionally broken up to seek the second scale, that at which the visitor perceives the showground's internal architecture, either in the open squares or the covered rooms attached to the pavilions.

The whole intervention of 150,000 m^2 was completed with a linear building where a thermal power plant is housed and then premises for workshops and stores.

The showground was later expanded with a substantial increase in built up area, which included 90,000 m^2 of new roads and accesses, a new 2,500 m^2 electrical power plant, a new multi-purpose building at the North gate which expanded it to 23,500 m^2, plus two new exhibition pavilions of 21,500 m^2 each, twice the size of the previous ones and with better functional features.

Credits: Architects: Jerónimo Junquera, Estanislao Pérez Pita. Structures: Carlos Fernández Casado S.A. Master builders: Fernando Vasco Hidalgo, Antonio Rodríguez Romero, Lucinio Pérez, Eduardo González Velayos, Fermín Ocina. Installations: TYPSA, Úbeda Ingenieros Consultores. Client: Recintos Feriales Madrileños S.A. Constructors, Dragados and Auxini. Dates: Competition, 1985; Project, 1987; Construction, 1988-1992. Expansion constructors: Necso, ACS.



Creation of the Museo Reina Sofía
Fernández Alba, 1987

In an article that appeared in the newspaper El País on the day of the opening in May 1987 and entitled *The space as place*, Fernández Alba refers to the role of the restoration trade in the construction of the city. It is also very revealing of the principals and ideas which inspired the renovation of the city, undertaken in the 1980's.

To discover the new that tradition contains, to bring abandoned spaces up to date, reveal in our age an attitude which clearly express the role played by the space of architecture, its nature and foundations, as well as the social use that its restoration can mean [90:141].

The restoration of the old Hospital by Sabatini made up a substantial part of the ambitious urban recovery plan, with which Madrid entered the European trend for correcting the excesses of the previous developing age. The building in itself was very valuable, but it was located in the Atocha neighbourhood, an area especially well-known as an emblem of the aspiration for change in the city.

The rather more undervalued factory had undeniable architectural qualities. *The elegance of its spaces, the route of its environmental sequences, the eloquent constructional presence of its factories and the compositional standard of its walls and its internal façades make of these settings a suitable place to be able to consider the beauty architecture encloses when the space is the leading feature of the place. The shape of its spaces has been recovered in its construction sense, highlighting the functional reasons and not forgetting the dimension of its historical record* [90:143].

The restoration of the old General Hospital as a Museum not only dignified the square and the surroundings of Atocha, it also laid the foundations for the concentration of museums which came to be characteristic of the avenue. A manifesto signed by Juan Benet and a group of well-known artists and intellectuals[7] pointed out how *one of Spain's biggest, most dignified and beautiful buildings [...] now presents the opportunity to concentrate Madrid's museum zone.*

Under Operation Atocha, in principle a railway project in nature, focusing on reducing car use and boosting public transport, a great *urban planning operation* was hatched to permit civic use of large areas of land and facilities released from use by the railway or relieved from the pressure of road traffic. The construction of spaces for cultural use to occupy surplus communication routes was already mentioned in General Plan documents edited in 1985 [90:152].

[7] Juan Benet, José A. Fernández Ordóñez, Juan García Hortelano, Antonio López García, Pedro Navascués, Julio López Hernández, Fernando Higueras, Francisco Nieva, Eduardo Chillida, Andreu Alfaro, Luis Revenga, Luis Gordillo, Enrique Gran and Guillermo Pérez Villalta appeared as signatories.



Expansion of the Museo Reina Sofía
Nouvel, Medem and b270, 2004

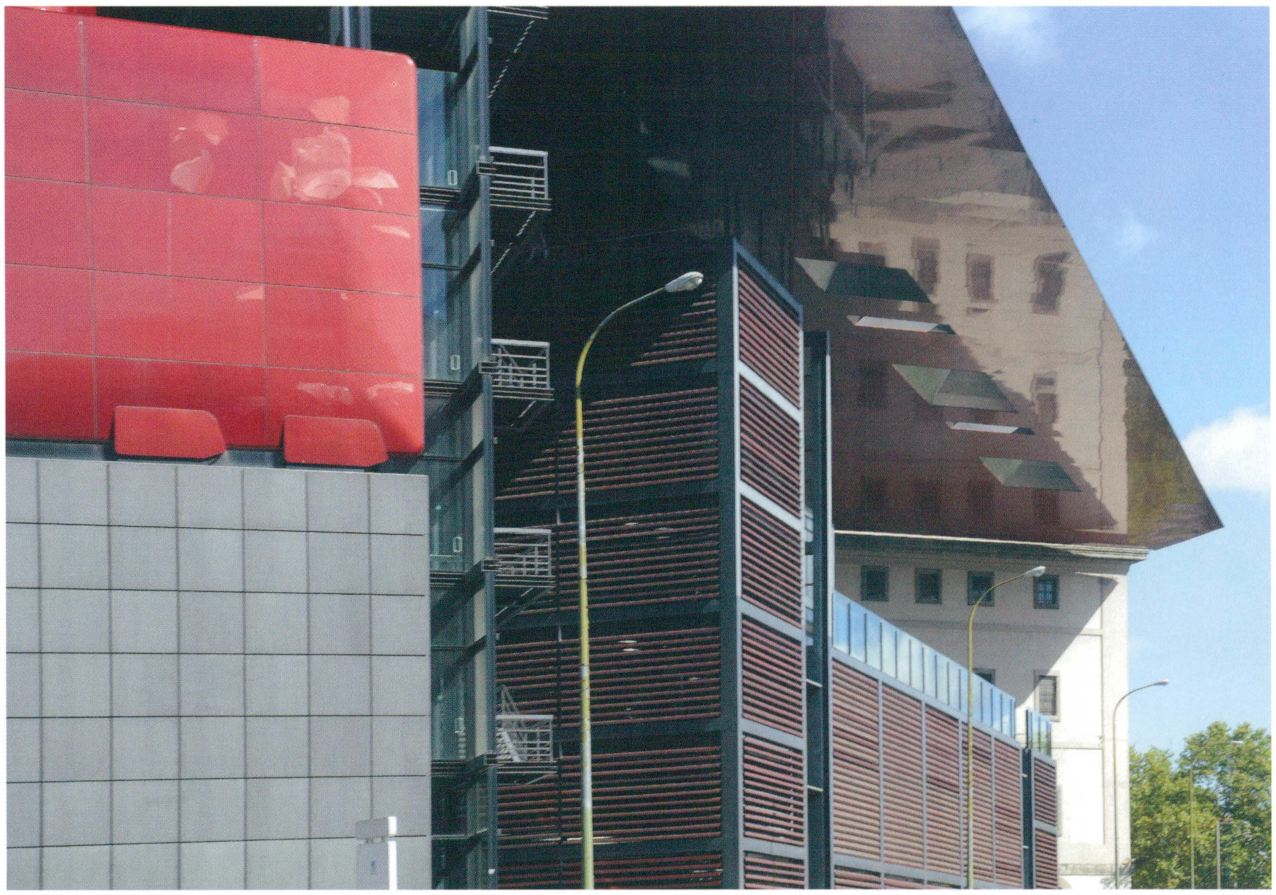
The drive for cultural renewal which emerged with the first democratic governments bore fruit in expansions and alterations to the big museums [108] and in the creation of a broader network in the urban settlements. The success of the Guggenheim acted as a wake-up call for all Spain's cities to aspire to driving their development with the construction of new museums or large cultural buildings, which brought about the emergence of the "star architect", capable of combining all the forces acting [169].

The expansion of the Reina Sofia, designed by Jean Nouvel, one of the most media-friendly architects in the European scene, was settled by constructing three independent buildings around a patio, all sheltered under an enormous common roof, which constituted the most interesting part of the ensemble both from an architectural and structural point of view. This is *prodigious roof that traps and reflects infinite nuances of light*. The expansion has *harvested more public than critical success* [97:84] and the unanimous rejection of the artists who have to exhibit in its rooms and the users of the two auditoriums and the library.

The great roof of almost 8,000 m^2 is positioned at the height of the primitive cornice of the original San Carlos Hospital building and provides uniformity to the group at the same time as establishing a clear separation between the classical and the new construction, without touching the original building. It is supported solely on the porticoes of the façades of the three blocks and exhibits a continuous finish on the bottom surface, made of aluminium sandwich panels, finished in gloss polyurethane, in which the building and the traffic in the perimeter streets is reflected. The points on which its structure is supported are not visible and some large openings are included to emphasise its feeling of immaterial nature.





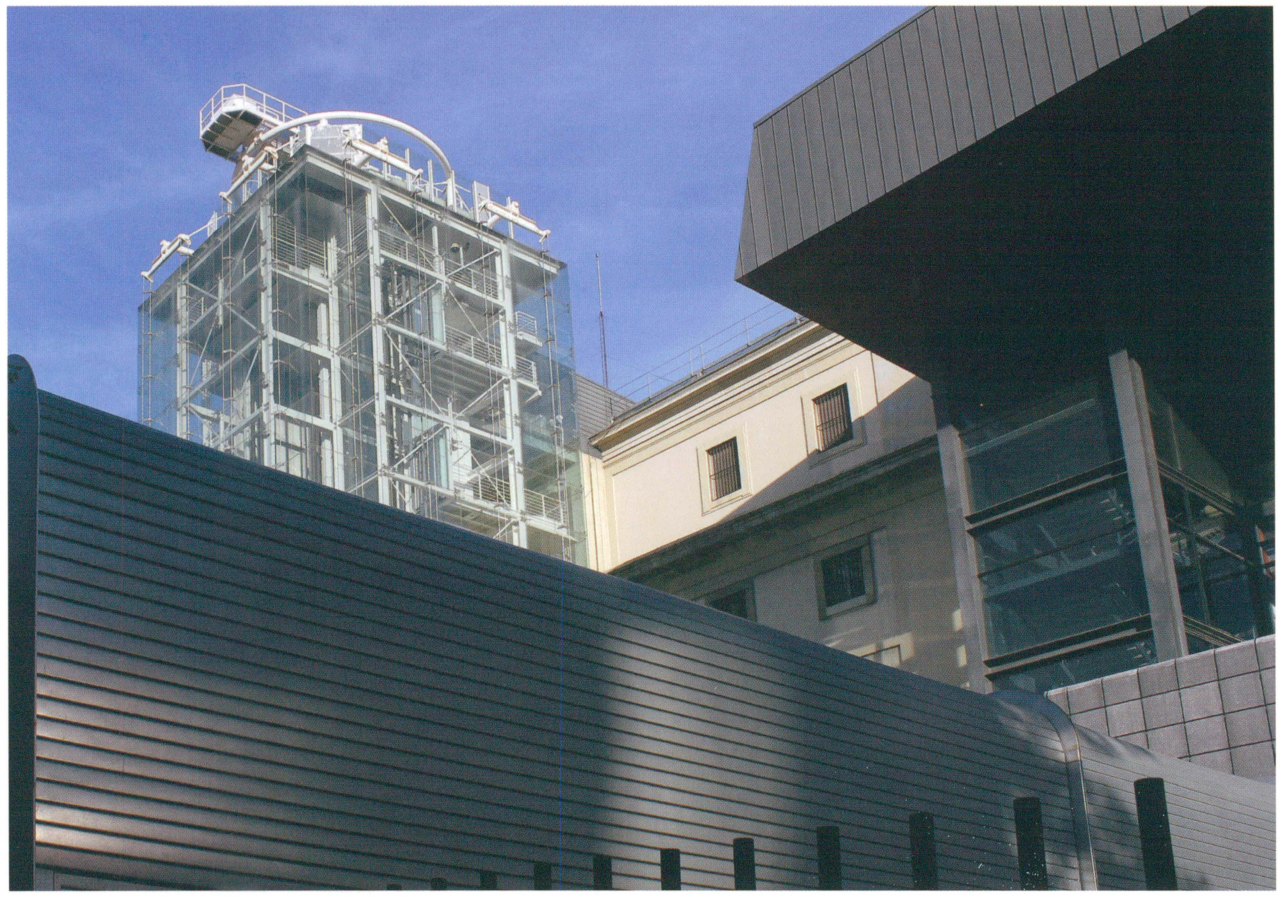




The exceptional character of its structure lies in the enormous cantilevers, at a maximum span of 36 m, con with an initial depth of 3.40 m which reduces until it almost disappears in the façades facing the Ronda de Atocha and Argumosa. The roof was designed with welded lattices, in three cords in triangular section, with circular tubes of 457 and 355.6 mm in diameter, following the eleven main alignments which, extended to the inside of the floor plan, bridge spans of 58 m. Its layout was conditioned by the columns for the three façades and the holes mentioned before and it needed various levels of secondary structure to make lining it easier. Finally, the lattices for the cantilevers, as designed initially, were replaced by large solid-webbed beams, which increased the weight of the roof somewhat, but considerably reduced the execution time, due to the fact that the connections were all bolted.

(Summary of [12:234 and subsequent, 288] and [16:219] see also [193]).

Credits: Architect: Jean Nouvel. Architect Project Manager: Alberto Medem. Structure: ESTEYCO. Quantity Surveyor: Rafael Guijarro. Ownership: Museo Nacional Centro de Arte Reina Sofía. MNCARS. Constructor: Dragados. Design Competition: November 1999; Completion of Works: September 2005.





Madrid CaixaForum
Herzog & de Meuron, Jiménez Cañas, 2007

The CaixaForum building, located in the Paseo del Prado facing the Botanical Gardens, consists of the restoration and expansion of an old electricity power station as a new social and cultural centre for the Caixa Foundation in Madrid. It connects to the avenue through a square, previously occupied by a petrol station, which is enhanced by means of two potent resources. The first consists of eliminating the bottom of the power station's perimeter wall, so that the volume of the building is "suspended" in the air. The second is the creation of a vertical garden on the dividing wall of some homes located to the North, which acts as a call to the new building and a point of reference. An extensive protected public space occupying the whole area of the available plot is created between the two.

The main structure collects all the vertical loads and transmits them to the foundations without interfering with the public space of the square. A structural macro-system was proposed for this, made up of three powerful concrete cores, unique vertical load-bearing elements, a continuous post-tensioned concrete perimeter wall, attached and connected to the brick wall, and two thick internal structural walls which connect the cores to the perimeter wall.

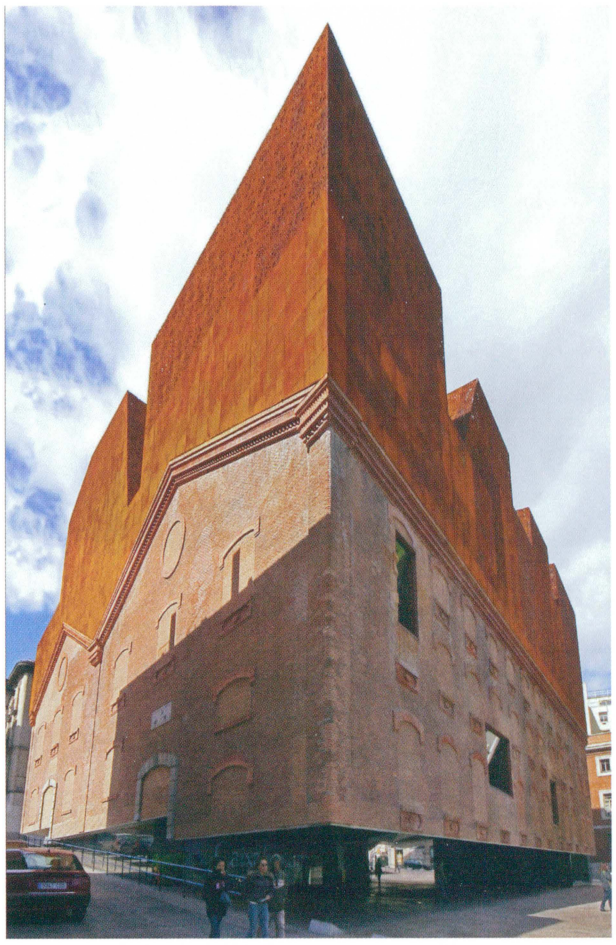
Only the brick perimeter walls are retained from the former power station, with the roof structure and all the internal floor structures and walls being demolished and dismantled. The new 50-cm thick perimeter wall, built up against the brick wall on its inside face, starts at the first floor level and reaches the third floor, with a total height of 11 m. The wall is post-tensioned with uniformly distributed horizontal cables which generate uniform compression across the whole height, of around 35 - 40 kg/cm^2. Deep beams are arranged perpendicular to the wall and are supported on the cores. Some are 12 m high between the second and fourth floor levels and the others are 17 m high between the first and fourth floors.

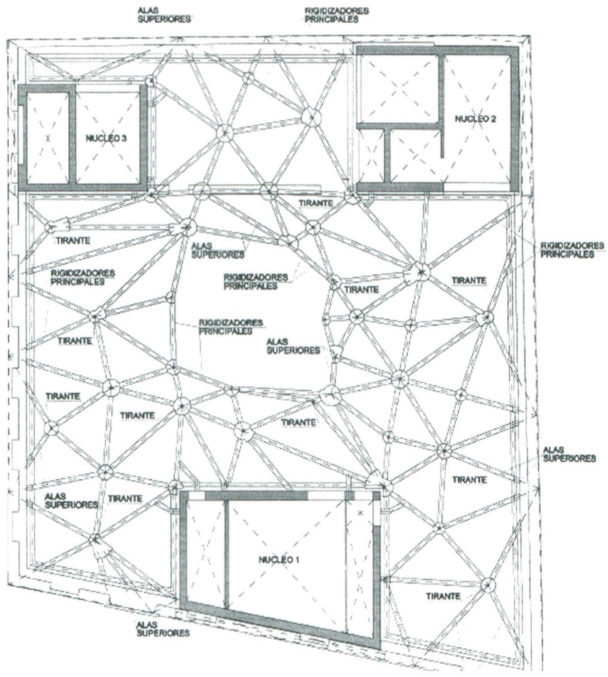
The floor on the upper levels is made up of three communication cores, the perimeter wall and the internal wall beams, defining a central space for the main exhibition hall of 20 x 36 m and three lateral spaces attached to the cores. The floor slabs are made using honeycomb metal beams with spans of 20 m and 110 cm deep (to allow installation ducts to pass) and a ribbed concrete slab as a compression head. On level 2, some of the beams support the suspension of the first floor slab, which requires rather greater depth and web thicknesses of up to 80 mm in the most heavily loaded metal beams.

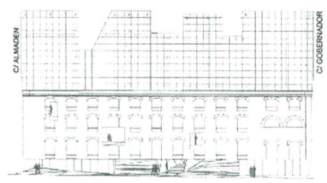
The first floor slab (the roof of the public square) is resolved with a three-dimensional metal structure with depths between 22 cm and 183 cm and a concrete compression layer 15 cm thick supported on the general macro-system and on a series of internal points where it is suspended from the higher level.

On the front of the dividing wall of the neighbouring housing building is the vertical garden, made up of 15,000 plants of 250 different species. At 24 m high, it is arranged on a self-supporting, independent vertical structure to prevent interference with the wall, acting to resist the horizontal actions as a large cantilever beam embedded in its base.

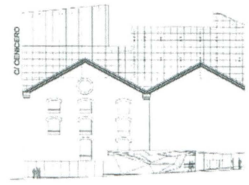
(Summary of [12:256-259:] [135])



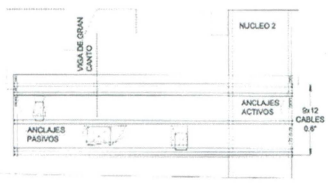




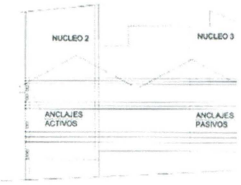
FACHADA DE LADRILLO. CALLE CENICERO



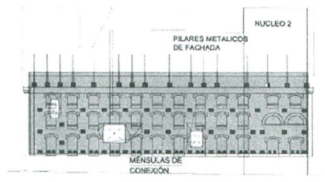
FACHADA DE LADRILLO. CALLE GOBERNADOR



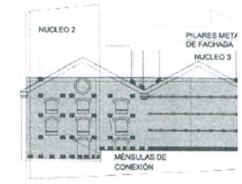
MURO DE HORMIGÓN POSTESADO. CALLE CENICERO



MURO DE HORMIGÓN POSTESADO. CALLE GOBERNADOR



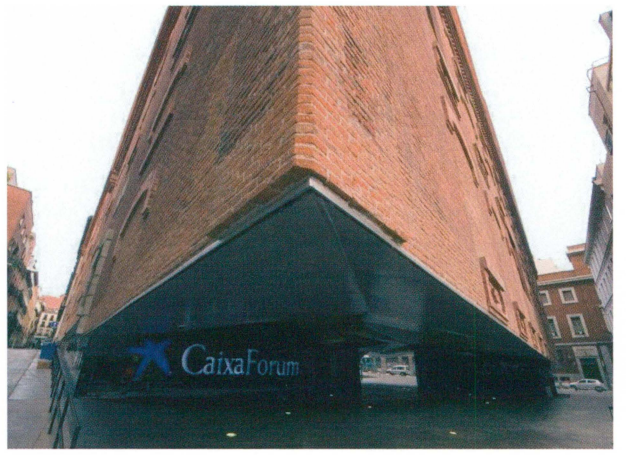
CONEXIÓN MURO DE HORMIGÓN POSTESADO CON FACHADA DE LADRILLO. CALLE CENICERO



CONEXIÓN MURO DE HORMIGÓN POSTESADO CON FACHADA DE LADRILLO. CALLE GOBERNADOR







Credits. Old Mediodía Power Station: Architect: Jesús Carrasco y Encina (1899). Restoration and Expansion: Architects: Herzog & de Meuron, with the architects Mateu i Bausells. Structure: NB35. Engineering: Jesús Jiménez Cañas and Alejandro Bernabeu and WGG Schnetzer Puskas. Garden Wall: Patrick Blanc. Construction: Ferrovial. Dates: September 2003 to January 2008.

Expansion of the Museo del Prado
Moneo, Jiménez Cañas, 2007

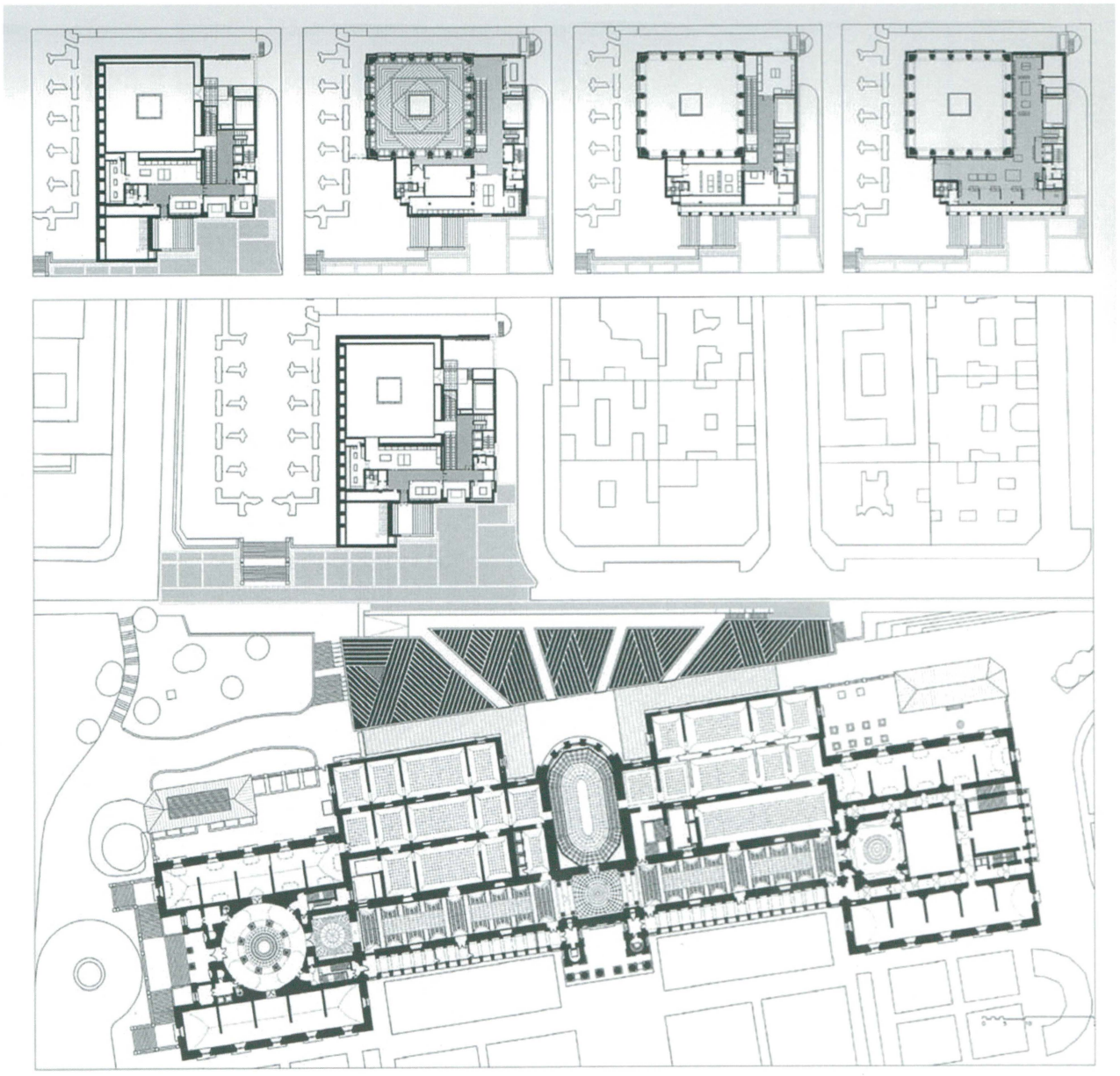
The most visible scope of the intervention is the brick cube enclosing the cloister, the presence of which has been the target of criticism on Moneo's project [97:84]. This is not one of the relevant aspects in the remodelling, which was correctly focused on improving the functionality of the entrances to the museum, located behind the old building and below grade of the street named Ruiz de Alarcón, alongside the adapted Los Jerónimos cloister. The new entrance also connects the whole expansion to the existing museum and makes it possible to restore its main door to the Paseo del Prado, which was occupied by exhibition rooms beforehand.

The solution adopted relieves the lack of existing space with new halls for temporary exhibitions and improves the conditions in the old Museum, while respecting its genesis, its surroundings and the neighbouring structures. The permanent exhibition will continue to occupy the original building while its whole system of circulation is thoroughly reformed. At the lower level, access will be from the north (Goya zone) and the south (Murillo zone), while the connection between the expansion and the current Museum takes place through the sides of the apse of the old building, passing through a hall where the old assembly hall was. This was a two-storey space which has now been reinforced to leave a single height. The ticket offices and left-luggage, shop and library area, cafeteria and restaurant are located entrance hall, along with the changing room and toilet services for staff.

The structure in the cloister zone of the Monasterio de los Jerónimos was dismantled stone by stone to excavate three levels, with ascending/descending construction with the use of hydraulic jacks to compensate displacements between screens and floor structures. Inside, a second skin has been created of coloured concrete, which shrouds the old stone cloister, relocated after cleaning and restoration.

The stores for paintings, sculptures and objects, as well as the restoration workshops and the documentation rooms are located in this new space. The cloister is to be used as an exhibition room. The library and a VIP dining room are located on the same floor as the cloister. The roofs used are a skylight for the cloister area and a flat roof tiled with limestone tiles for the rest. An assembly room was also built, with capacity for 500 people, located below street level, between the cloister and the foyer area.

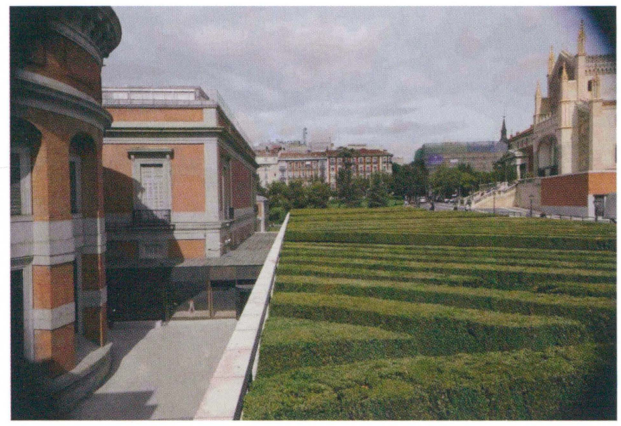
The most unusual *structure* is a steel and glass lantern which extends over the internal zone of the old cloister between the slabs at elevations of 646 and 640. It is accommodated in a 6 x 6 m space in the centre permitting the passage of natural light from the upper skylight to the floor slab located at an elevation of 634, since the inside of the cloister is clear between the roof and the floor at 646.



The structure is responsible for transmitting a large proportion of the load from the 646 floor slab to the perimeter band in the 6 x 6 m hole in the 640 floor, which it transmits to four pier/piles which end in it. Part of the slab at the 646 level rests on eight metal columns in the lantern structure, of 300 x 60 mm and some 6m in height, which are braced horizontally using metal plates. The load-bearing framework of the group is completed by 40-mm diameter steel bars located in the corners of the lantern box. [12:250-253:]

Credits: Architect: Rafael Moneo. Structures: Jesús Jiménez Cañas (NB35). Constructor: Dragados. Client: Spanish Ministry of Education and Culture.
















MUSEO DEL PRADO







Canal Theatres
Navarro Baldeweg, Martínez Calzón, 2008

The intrinsic nature of the plan for it makes reference to the creation of a place of illusion, a world of fantasy, that is, to the imaginary as the substance of the project. The building which appeals to this imaginary world is located in rather faded and neglected urban area, calling for a strong, formally rich response with an intrinsic vitality to brighten up the intersection between the streets named Bravo Murillo and Cea Bermúdez and make it shine. It houses theatre activities that need integration with and segregation from surrounding daily life.

This dual divergent demand translates to an integration with and continuity of the street in the level of the lower floors and the rest of the scheme by elevating the foyers for the theatre auditoriums and the dance classes to the first floor. The lower floors with the large foyers, the shop and the cafeteria are transparent and visible from the street, incorporating their activity into the city and inviting participation.

On this ground floor, which is the threshold between the building and the street, a lively play of volumes is created which is seen as a zigzagging display of shapes in the air provoking contrasting experiences from concave to convex, like flags fluttering in the breeze, emptying or swelling and showing or hiding the inside from view from the street.

The skin enclosing these floating volumes is like paper, capturing light and reflecting it with attenuated brilliance. All this corresponds to a deliberate tectonic idea, understandable as a suitable "mask" for the character of theatre or dance and which translates to the pre-eminent value of the pure appearance and the lively play of forms. The skin deployed in the space consists of a glass surface which is opaque in parts and translucent and transparent in others. The opaque glass is black, red and silver, with a matt, velvety appearance thanks to a surface treatment, toning down its colour and surface brilliance. The colour is treated as a basic construction material, something which appears cut with scissors or carved directly from rough blocks. The handling of this chromatic substance reminds you of Matisse's cut-outs, where the painting takes on a sculptural nature.

The stage houses inside the two theatres are like the stone in a fruit and the intimate cell set in these inflated textile volumes. It is also the stage houses which act as the main organised support and the physical structure of the building is based on them.

The dance theatres are laid out around the western side of the plot. Their own patio gives natural light in abundance to the rooms, without undermining their privacy. A large ramp connects the various floors, integrating them into a foyer which closes one side of the great cleft of the main entrance from the street to the theatres. The drawings show the connection made between these dance classes and theatres and the stages without conflicts between private and public circulation, as could occur.

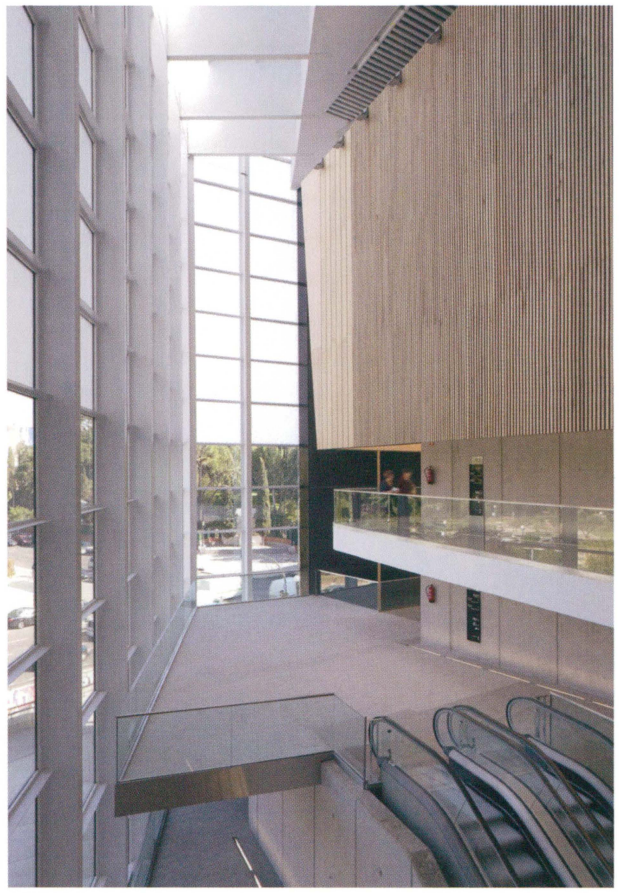
[Summary of the text by Juan Navarro Baldeweg in [12:114-115] and also in [97:104]], [223].



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Structure

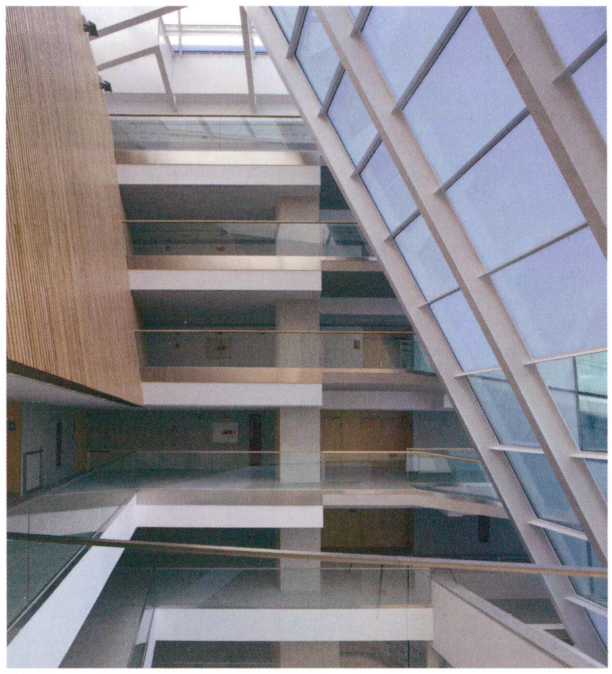
The structure of the two theatres is resolved by means of large vertical reinforced concrete structural screens, connected monolithically with solid, reinforced and in some case pre-tensioned, floor slabs, combined according to the zones with reinforced concrete beams and concrete or metal supports. In the case of large spans and in places at great height, composite solutions were used with solid-webbed or lattice metal girders to enable them to be executed without using falsework.

In the dance zone, concrete is only used in the lower floors, in the area for vehicles to pass, loading bay, car park, tanks, etc. Metal supports and solid composite concrete slabs are used in the rest of the areas.

The theatres' screen structure projects over the lower perimeter of the ground floor and the construction system was adopted to remove the temporary shores in a controlled manner, with thorough monitoring of movements, deflections and inverse deflections.

(Summary of the text by Julio Martínez Calzón in [12:115]. For the structure, see also [155] and [222])

Credits: Architect: Juan Navarro Baldeweg. Structure: MC2, Julio Martínez Calzón, Miguel Gómez Navarro. Dates: Competition, 2000. Construction, 2002-2007.



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Building at Gran Vía, No. 48
Rafael de La-Hoz, 2013

Created at the beginning of the 20th century as a "sventramento" of old Madrid's country house, the road named the Gran Vía was made in such a short space of time that it has a compositional homogeneity that can only occur in something produced in unison.



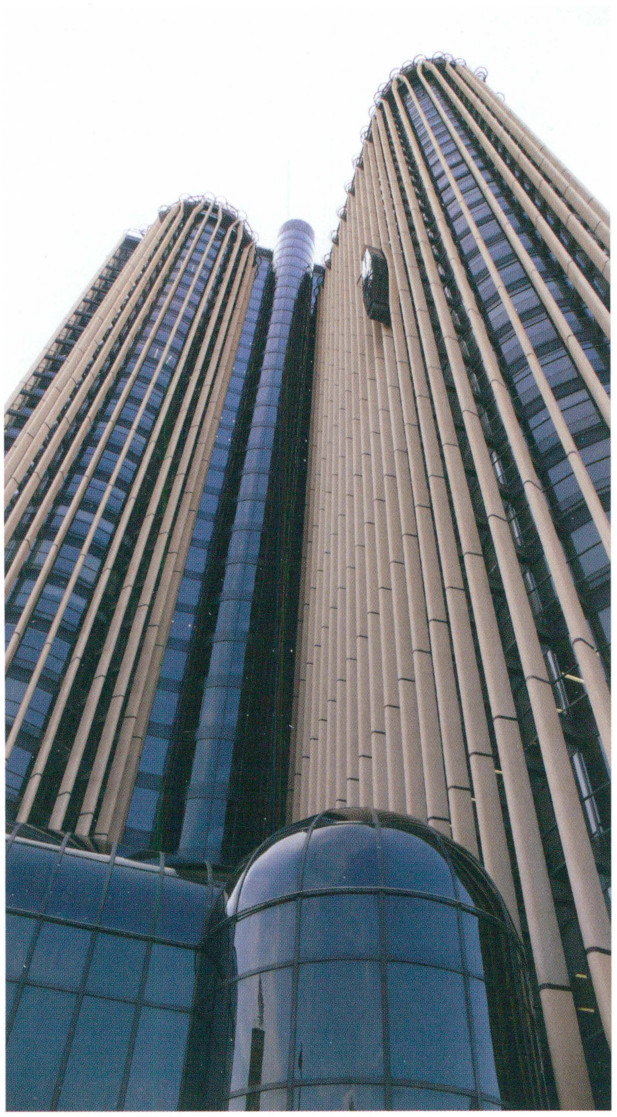
Only at very rare points is the eclecticism of its façades interrupted by dislocated architecture. The proposal was to replace it with new architecture that accepts the challenge of restoring the urban artery's perceptive identity, without falling for stylistic anachronisms. The balance of openings, the meeting of axes and chromatic blending are the architectural elements used.

In 1931, the architect Muñoz Casayús planned the Nueva York Hotel for number 48 Gran Vía, on the ground floor of which S. Ularqui was to locate the Actualidades cinema, in Art Deco style, as was becoming to this stretch of the Gran Vía known as Madrid's "Broadway". In 1960, this building was partially demolished, converted to a bank and lined with an anodyne glass curtain wall. In 2011 the head office of the Banco Atlántico was demolished completely, to be replaced by a block of luxury homes, representing the first new building constructed on the Madrid avenue since 1932.

The new façade of the building, designed by the architect Rafael de La-Hoz, is produced using joinery from floor to roof on which a grid pattern of stylised granite pilasters is superimposed, giving a degree of movement and depth to the façade. The intention with this is to emulate the rhythms of the Gran Vía, without needing to repeat them. Its intervention is crowned by a volume that dialogues with the niche in the neighbouring Palacio de la Prensa and, therefore, promotes the labelled play required by the Gran Vía at this point of inflection. Its lattice was drawn taking note of the double floor order that can be appreciated in neighbouring buildings.

In the words of De La-Hoz, this project was "a stimulating challenge".

(Text: Rafael de La-Hoz).



Towers

Torre Europa
Miguel de Oriol, 1985

Located at the corner of the Paseo de la Castellana and the street named General Perón is the AZCA (Asociación Mixta de Compensación de la Manzana A de la Zona Comercial de la Avenida del Generalísimo) complex. This zone has a surface of 190 hectares and its origin dates back to the General Plan of 1946, as a large block of offices with the separation of traffic – vehicular below ground and pedestrian on the surface – and a large railway station (the current Nuevos Ministerios station). This large financial and shopping complex is located in the city's northern expansion zone, alongside the Nuevos Ministerios building, with rail, bus and Metro connections, inspired by New York's Rockefeller Center.

The 1975 project was by Miguel Oriol e Ibarra and the works were completed in 1985. The semicircular tower with its 121 m of height is one of the capital's tallest buildings and forms part of its skyline. The building has 30 storeys for offices, with premises for restaurants and leisure on the ground and basement floors. Worthy of highlighting is its load-bearing façade with large vertical prefabricated concrete columns with black glass windows, reminding of the towers of the now toppled World Trade Centre in New York. It has a large oval clock inserted between the columns in the centre of the façade facing the Paseo de la Castellana. The inside of the building is diaphanous between the lift core and the load-bearing façades and allows free arrangement of the office zones [44:626].





Torre Picasso
Minoru Yamasaki & Genaro Alas, 1988

The tower was commissioned from the architect Minuro Yamasaki, the author of New York's Twin Towers (1977), and construction started in 1984. The project which won the competition included a hotel and offices, but it was rapidly decided to omit the hotel and the elevation separating the two uses was remodelled.



It is a 150-m high tower with a clear vocation as a skyscraper and a typical structure of core and façade columns. The metallic condition of the structure is translated to the façade with continuous vertical aluminium strips framing other vertical bands of glass which are also continuous up to a very restrained light upper ornamental finish in the form of an aluminium cornice.

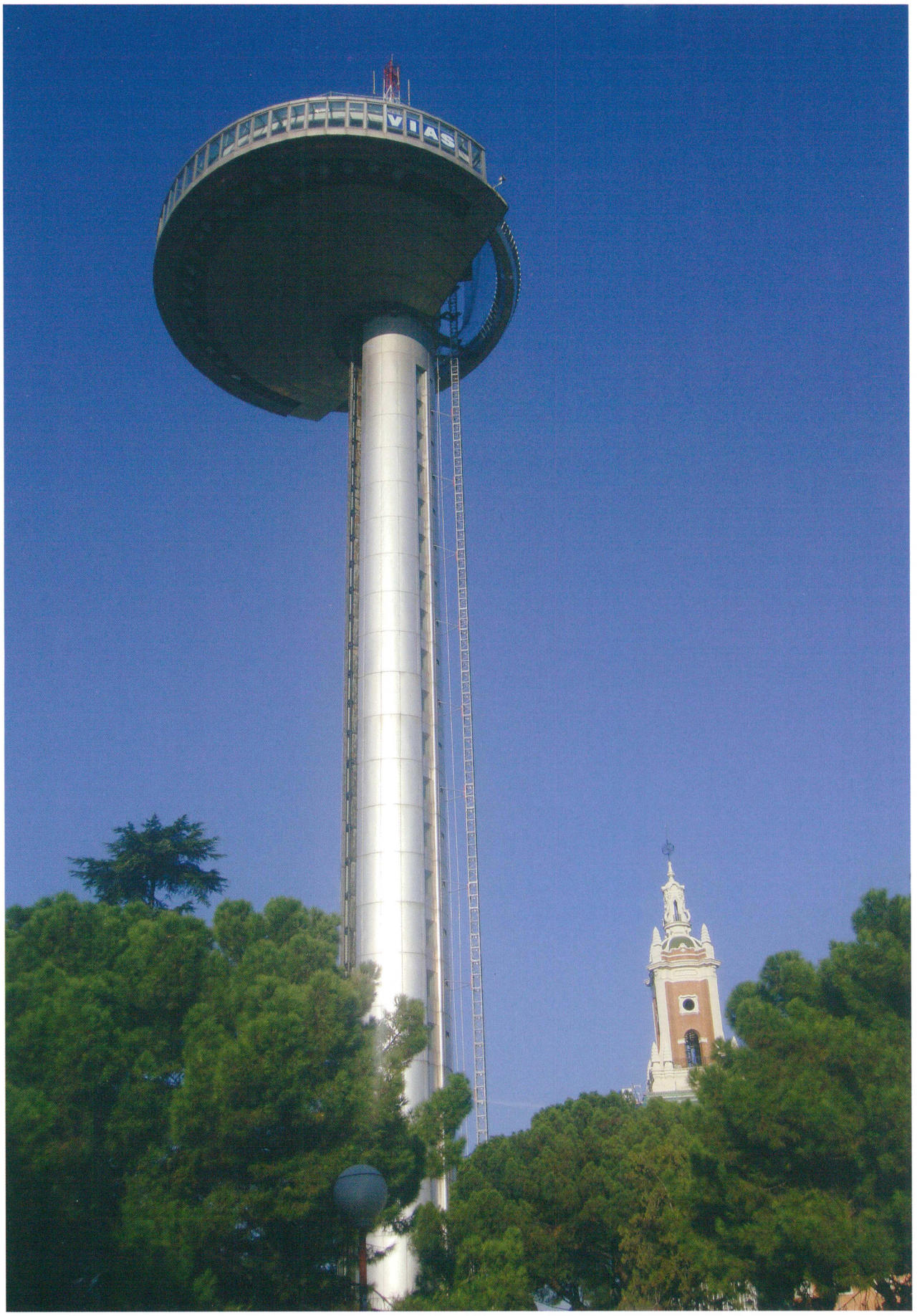
The base of the tower is more robust and plays with a height difference with respect to the terraces of the AZCA business district complex encircling the building, giving access to it via a projecting walkway which leads to the entrance to the building through a circular arch with a span of 30 m. Vehicular access to the tower takes place via the two levels of traffic rings for the complex. In fact, this submission of the building to the land sets access problems for fire fighting vehicles, as well as functional problems for normal access [12:155].



Torres Puerta Europa
Philip Johnson, 1998

The Puerta de Europa towers, commonly known as the KIO towers (developed by the Kuwaiti firm KIO, Kuwait Investments Office) are works by Philip Johnson and John Burgee. The design for these two symmetrical constructions and leaning towards the axis of the Paseo de la Castellana at 15°, dates to 1990, the works being completed in 1996. The aim was to establish a dialogue between the two towers, which proved difficult due to their excessive separation, so the option was taken to incline them, forming a great gate between the two. These structures, with their technological nature and complex load-bearing structure, are 114 m high and each has 26 floors for offices. They were initially going to be constructed in glass and pink granite, but due to the excessive weight, they were constructed in glass, aluminium and stainless steel in the end. The latter can clearly be seen in their large façade bands which give them their characteristic appearance.



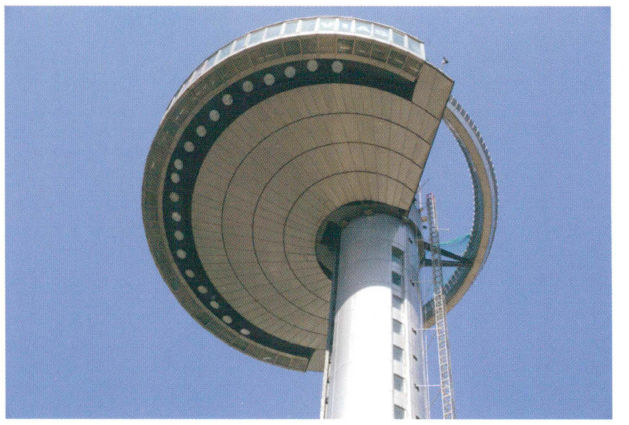


Faro de la Moncloa
Peréz Arroyo, 1992

The Faro de Moncloa is a viewpoint over Madrid with some supplementary features. It was devised as an incomplete circular platform with a metal structure supported eccentrically on a concrete shaft. The whole platform and shaft assembly is covered with stainless steel. The great projection of the platform is balanced by a post-tensioning system of cables contained inside the shaft on the side opposite the cantilever.

The cantilever is also amply balanced by an external concrete ring closing the platform circle. The shaft contains an evacuation staircase and a service lift. There is also a panoramic lift on the outside of the shaft. New evacuation and safety requirements demanded the expansion of the staircase and the location on the outside of a new panoramic lift. It has been increasingly well received in the city since its construction due to its dissociation from any contemporary style. It was designed with great formal independence, according it greater vitality and independence in its history.

(Summary of text by Pérez Arroyo [12:162-163]).



Torres de la Castellana

The latest episode in the Madrid skyscraper scene is the completion of the Torres de la Castellana. These are four towers giving a total of 300,000 m^2 of gross floor area, which occupy the site of the old facilities of Real Madrid's Sporting City and which forcefully dominate the city's silhouette. Each of these is taller than all those which went before.

The towers can be considered in two highly distinctive groups. The two located further to the north, the Torre Espacio and Torre de Cristal, are representative of the American way of tackling the problems of height, while the Torre Sacyr and Torre Repsol tackle them from a more European vision.

The former denotes familiarity with the problems of skyscrapers, with a very efficient treatment of the lift cores along with some indifference to the difficulties of variable floor plans, which results in a formal appearance founded on the iconic. Over a century of constructing tall buildings has left its impression in the comfort some designers have in the exercise of translating simple, emphatic images to the complex construction of gigantic buildings.

It does not matter whether the floors are different or whether the resources for construction need to be doubled or tripled depending on the inclined or warped façade surfaces. Everything can be tackled and, as experience teaches, the possible increase in cost caused by construction difficulties induced by the shape is irrelevant in the total amount of waste.

The two towers sited to the south hold more traditional design positions, of greater rationality. The building's floor plan is glimpsed in the project's origin and has clear connections with the structural layout. It is not easy to distinguish which came first, if the floor plan is a consequence of the structural approach or whether the latter emerges from the desire to rationalise the former. Although it makes no difference, the mere suggestion gives the idea of the deep interdependence of the floor plan, elevation and section characteristic of the rigorous architecture present in these two towers.

(Summary of [12:158-159]).





Torre Espacio on the Paseo de la Castellana
Pei & Cobb & Fred, Martínez Calzón, 2008

The Torre Espacio has 43 floors of offices, two floors of corporate offices at the top, three floors for commercial use at its base and six floors of underground car park. The floor plan expresses its evolution in height, always inscribed inside a square, which is complete at the base and becomes a lenticular drum at the upper part. The main core is located on a diagonal which becomes the axis for the drum in the upper zone and lift shafts are abandoned as the height increases.

The tower starts from a square base and evolves to a final tapered shape, achieved by means of the intersection of two 90° circular sectors. The building's central core has four banks of lifts and organises both vertical and horizontal traffic. In addition to the public lifts, it houses the services, the technical installations galleries and two service lifts.

The façade is a double skin with horizontal perforated slats which allow natural light to pass, protect the privacy of the internal spaces and give transparency to the façade. It consists of a double-glazed curtain wall designed with an active façade concept in which the internal return air circulates through the space between the outer cladding and the inner glass panel, returning the air to the forced ventilation system.

[Summary of text by Pei & Cobb & Fred and José Bruguera [12:176-177].

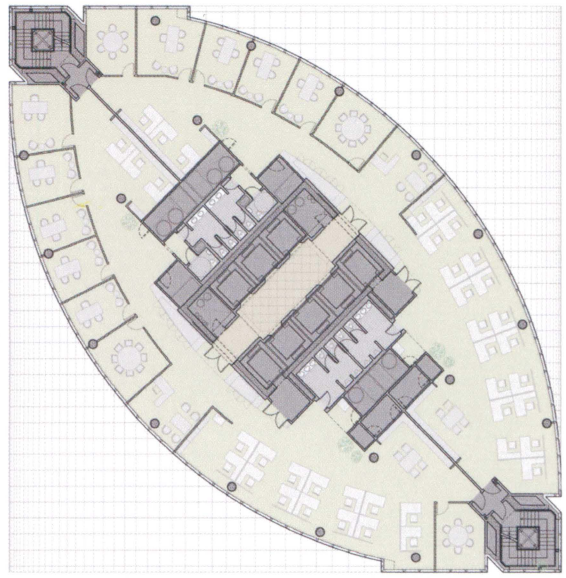
Structure

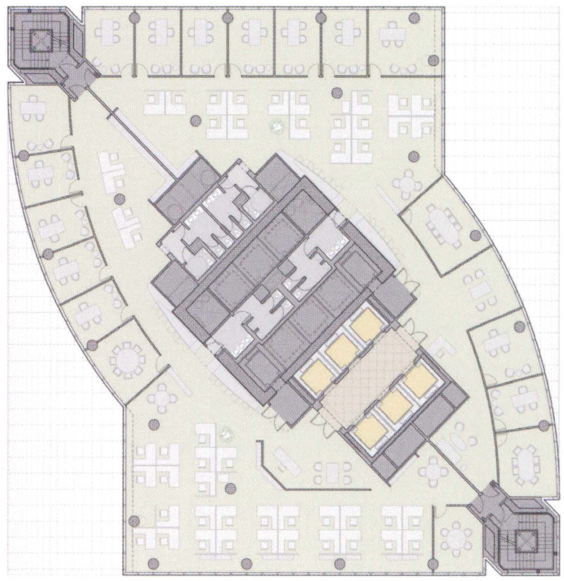
The building's basic structural design includes central core with a hollow box section, with perforations at each floor for access and with around 120 m^2 of ideal enclosed section. The wall thicknesses are variable, with a maximum of 1.50 m and a minimum of 0.40 m. The main supports are located around the oval perimeter of the building's upper floors and are continuous throughout its height. A "belt" is included on a floor near to two-thirds of its height, which connects these supports to the central core with great rigidity to increase the system's horizontal stiffness.

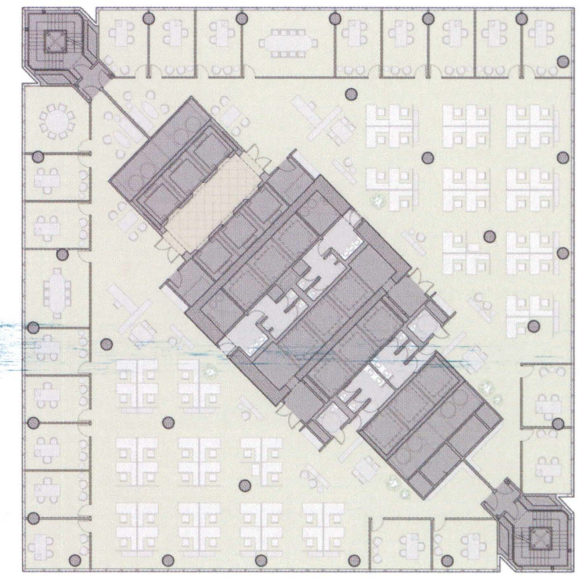
Its resistance to horizontal actions is ensured by the combination of the central core, lateral cores, columns and the stiffening belt. The latter is made up of a set of metal lattices embedded in concrete screens which make it possible to connect the most important radial supports to the central core rigidly. This structure is located on a machinery floor in order to interfere as little as possible with building functionality. It is made up of three types of screens: the perimeter screens which connect the pillars for each façade together; the radial screens which carry the forces from individual points on the façade to the arrises on the core and the core screens which ensure the transmission of the cleaving forces between the screens for one façade and another.

(Text: Julio Martínez Calzón. Summary of [12:178-179], [49], [153], [120], [24]).

Credits: Architects: Pei, Cobb, Freed & Partners: Henry N. Cobb, José Bruguera. Associated Architects: Mark Fenwick, Javier Iribarren, Alberto Sotodosos (Project Manager), Alfredo Vilches. Structures: MC2, Julio Martínez Calzón, Miguel Gómez Navarro. Client: Torre Espacio Castellana, S. A. U. Contractor: OHL. Dates: Project: 2001. Construction: 2003.-2008.











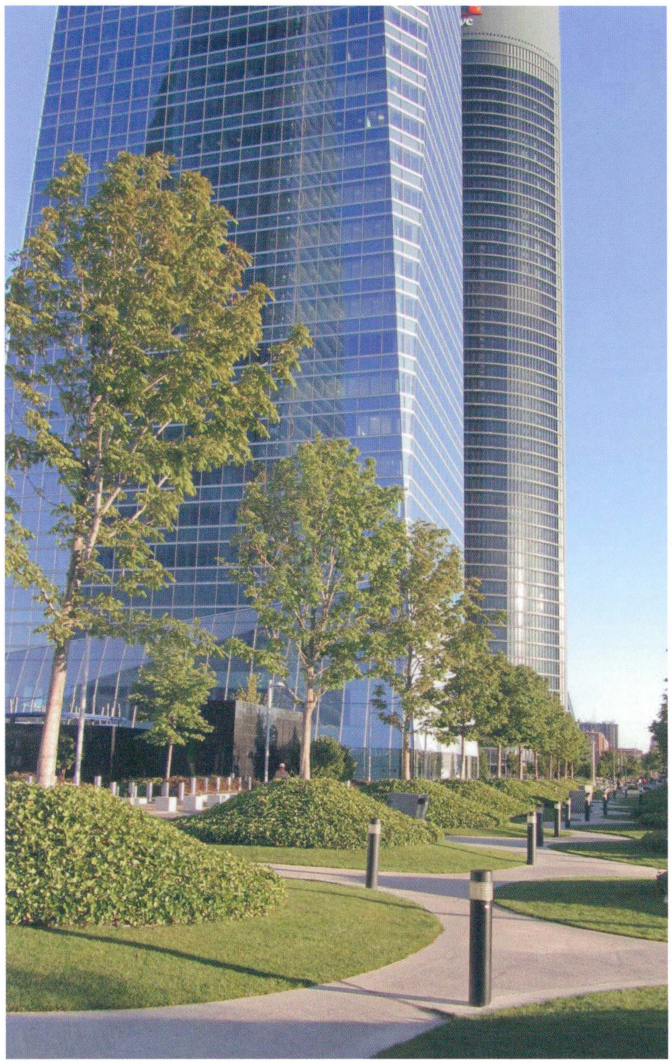
Torre Cristal on the Paseo de la Castellana
César Pelli, Juan Blanco, 2008

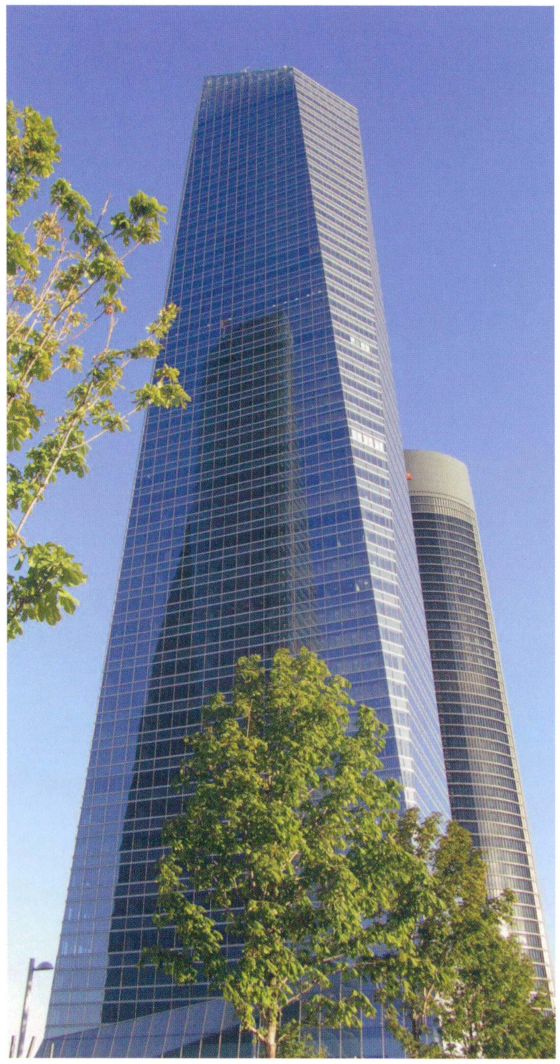
The "Torre Cristal" has the shape of a cut diamond, finishing in a vertex which houses a winter garden, the lighting for which acts like the lamp in a great lighthouse. With a height of 249 m above the level of the Paseo de la Castellana, it has six basement floors and a ground floor that occupy the whole plot (100 x 75 m) and a tower set eccentrically with 46 floors for offices and 5 floors for technical use. The tower's structure is composed of a central core, some internal composite slabs and external or office slabs. The core is rectangular in plan view, 35 m long, with four connecting diaphragms, defining three enclosures. Its long walls spring from the foundations at 1.2 m thick, decreasing to 0.7 m at the highest zone.

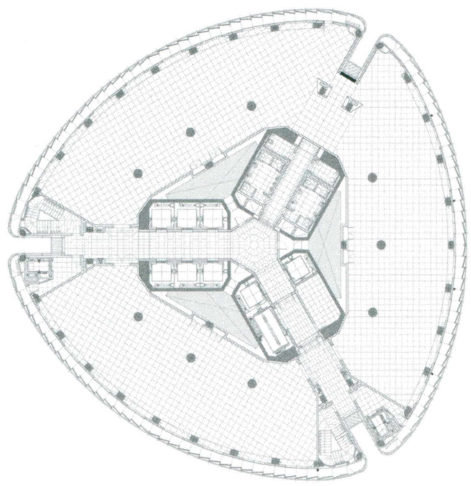
The external slabs are supported on 18 composite columns positioned 1.10 m from the outside edge, connected to the core by means of metal girders bound together by means of a perimeter piece parallel to the façade. To top off the tower, a complex stereo metal structure was designed, with a weight of 490 tonnes, supported on one side at the 210.33 m level, corresponding to the last floor of offices and on the other side at the 215.02 m level, coinciding with the next technical floor.

(Text by Dragados, summary of [12:182-183, 287]). (See also [185], [45], [237]).









Torre Sacyr on the Paseo de la Castellana
Rubio & Álvarez-Sala, Martínez Calzón, 2008

For the distant view of the group of four towers, the volume's slenderness of proportions is considered more important than the height. Following this, the building was broken up into three bodies by fissures to increase the feeling of verticality, allow light inside and create the illusion of a grouping of parts.

The arrangement in plan makes the discretisation of the hotel rooms near the base compatible with the transparency of the upper offices. The vertical core for lifts and installations runs throughout the building, but double height technical floors were included between the foyers and the hotel, between the latter and the offices and at the top. A double façade makes the building's image uniform and protects the inside from excessive sunlight.

The structure consists of two concentric rings of columns, with cross sections which are circular first, then rectangular in the hotel and circular again in the offices, with a Y-shaped central core in plan view. The central core was constructed using climbing formwork and the rest of the composite structure grows in a spiral.

The number of façade and internal supports is reduced by half on the first technical floor, to achieve a more diaphanous space for entry to the building. At the top, at the height of 215 m, a stiffening belt, triangular in plan, is located to link the central core to the vertices of the general floor edge structure. The slabs extend as a perimeter concrete tray to support the façades and for maintenance and cleaning. With this, each of the levels acts as an independent fire sector.

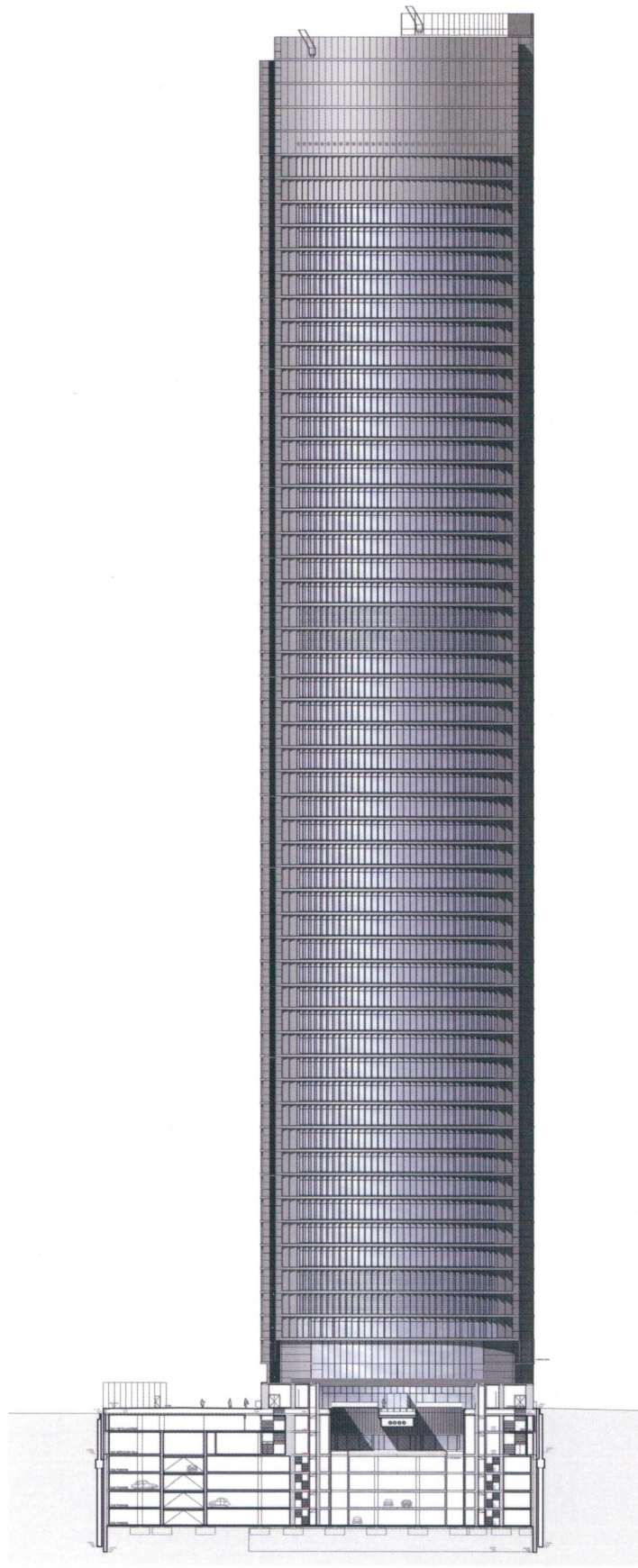
The building is enveloped in a double wall based on glass sheets, arranged like scales, the reflections, shadows and transparencies of which make the building shimmer. An internal façade resolves the closure, waterproofing and acoustic insulation. The external skin disappears in the lower regions of the building to make the inside visible. This inside emerges from the darkness of the sculpted black stone in the plaza and where the patios are to be found for lighting and ventilation for the uses below grade.

(Summary of text by Rubio & Álvarez-Sala in [12: 180-181], [28], [154], [217]).

Credits. Authors: Carlos Rubio Carvajal & Enrique Álvarez-Sala Walther. Architect in Charge of the Project: Juan José Mateos Bermejo. Quantity Surveyor: Jesús Fernández. Structures: MC2. Engineering Studio. Developer: Testa inmuebles en renta S. A. Constructor: SACYR.




pwc



Torre Bankia on the Paseo de la Castellana
Norman Foster, Halvorson & Partners, 2008 [Antonio Sarabia]

The Torre Bankia is intended exclusively for office use with its corresponding provision of car parking below grade. It is organised as three packets, with two technical floors below each one and eleven, twelve and eleven office floors respectively. Two more technical floors are located on top of the third packet and within the arch-lintel crowning the building. The typical floor is made up of a rectangle of 32 x 42.5 m with another two rectangles of 23.5 x 10 m attached at the east and west sides where the communications cores are housed. The height between the finished floors in the basement is 3.3 m and in the above grade floors it is 4.7 m.

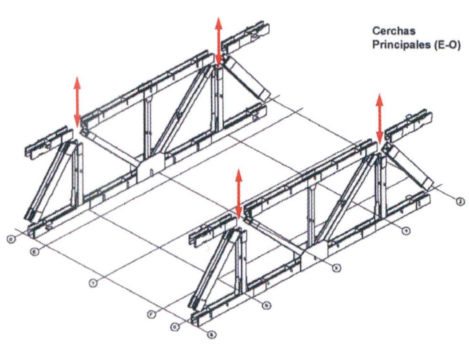
The intention is to reinforce the city's image with an emblematic building the appearance of which becomes more powerful as the clarity and simplicity of its concept is transmitted better, embodied in two types of elevation: One articulated, glazed, open and extensive facing south and north, framed by the vertical cores on the sides, The other fluid and continuous facing east and west, made up of a narrow solid core in the foreground, with the glazed floors in the background.

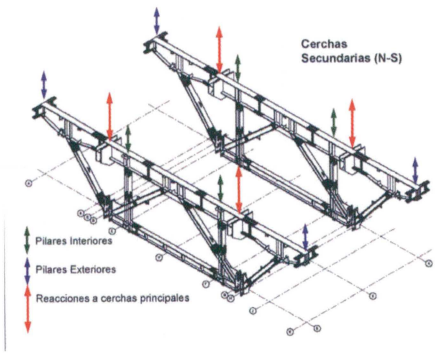
The two vertical cores are joined together by the upper arch-lintel and by three main trusses spanning the two technical floors and supporting the eleven or twelve office floors located above them. In the N-S direction, each core resists its part of the wind loading and in the E-W direction the two work together, braced by the intermediate trusses and the upper lintel.

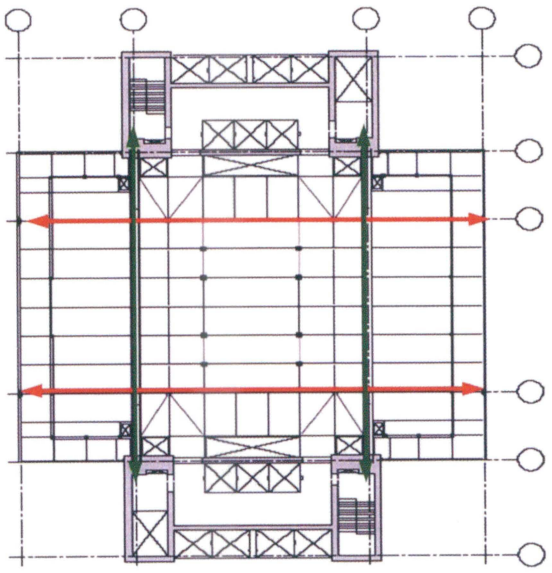
On the typical floors there are only four internal pillars separated by 15 m in the N-S direction and 18 m in the E-W direction, supported on the trusses. The columns and slabs are eliminated at the base of the tower to create a diaphanous glazed reception space of quadruple height. At the top of the tower, a 20 m space is left, forming an arch-lintel, to lighten the crown visually. The columns deposit their loads on secondary trusses lying N-S, which fit spatially into the main trusses lying E-W, supported on four steel columns embedded in the concrete cores. A Vierendeel truss runs around the perimeter of each floor, forming a frame with the façade columns for each block, also supported on the columns embedded in the cores.

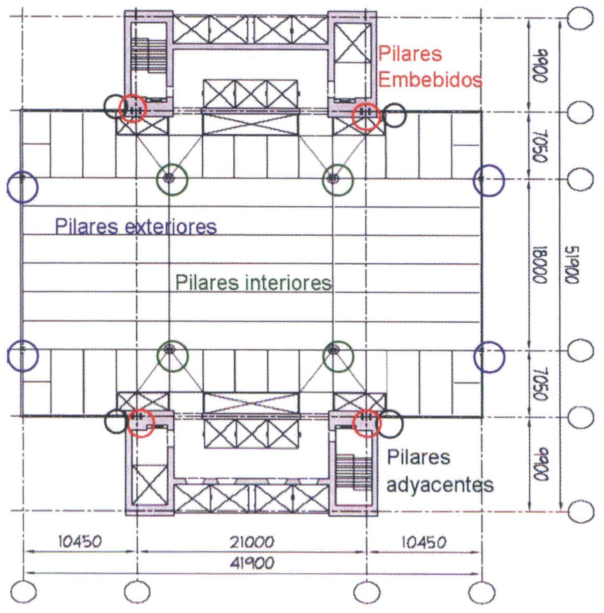
The tower was designed after the attacks on the World Trade Center on 11 September 2001 and incorporates criteria of solidity and redundancy to make each of the blocks of eleven or twelve floors independent. The system of trusses and columns was calculated to resist the load of two of those blocks and if the first level trusses were to be removed, the columns for the first block would start to work in tension and







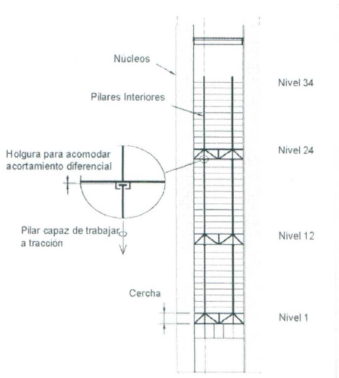


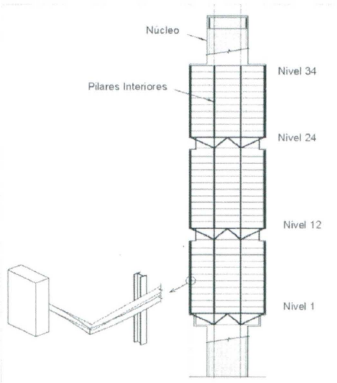


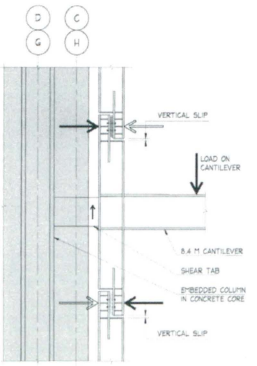












the eleven-storey block would be suspended from the second level trusses. If the second truss fails, the block located on it could rest on the first or hang from the third. If the third truss failed, the third block would rest on the second. Complete collapse would be prevented by this, although the deformation would be so great that the office floors would be rendered unusable.

Summarised texts from: José Ramón Burgos [50] and Gregory Lakota & Arántzazu Alarcón [139]) [12:184-187] , [50], [138], [162]).

Roofs

La Peineta Stadium
Cruz & Ortiz, Martínez Calzón, 2006

Located to the east of the city – between the M-40 and the end of the Avenida de los Arcentales – the Athletics Stadium was the central piece of a group of facilities which would be integrated into the Sports City for the Comunidad de Madrid. A unitary solution was adopted, with a square platform on which the stadium and the future sports pavilions rest. This plane supports a grandstand that is silhouetted against the horizon and identifies the group from a distance.

Its position, alongside the finishing straight, concentrates the majority of the spectators there, where the most important moments in athletics happen, as well as permitting the holding of musical events. On the outside, the grandstand is supported on a series of concrete walls of differing curvatures, perforated by narrow horizontal slots which permit lighting and ventilation, at the same time as producing unexpected light effects at different times of day.

(Summary of text by Cruz and Ortiz [12:74-76]).

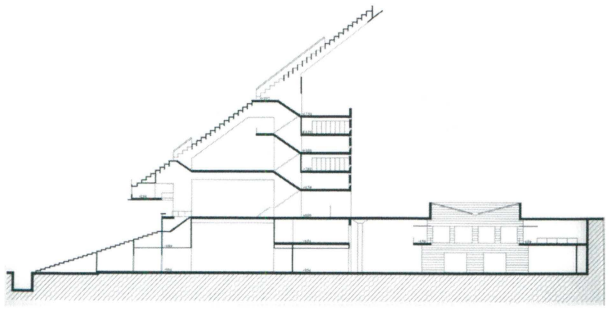
An expansion to the stadium has been designed, aimed in principle at the then possible awarding of the Olympic Games to Madrid[8]. The expansion may result in the disappearance of its characteristic silhouette, which gave it its nickname of *La Peineta* (the ornamental comb) on hiding the single stand below a large annular roof of the stretched membrane type. The roof is located at a uniform height in the grandstand area and rises gently as it approaches the stand from both sides. This gentle undulation gives it a dynamic, spatial nature, both from the inside and the outside. The roof is supported on the existing structures by means of powerful concrete supports approximately 45 m apart.

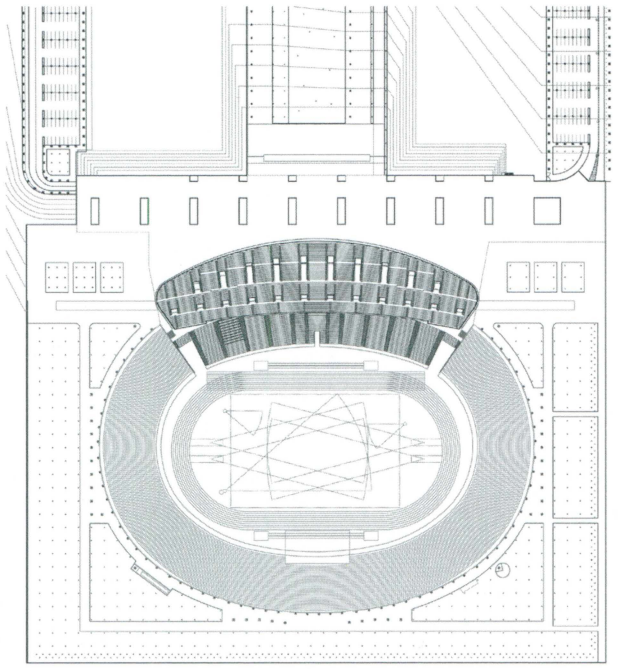
(Summary of text by Julio Martínez Calzón [16:145]).

Credits. Architects: Antonio Cruz / Antonio Ortiz. Structure: MC2, Julio Martínez Calzón. Constructors: Foundations: Entrecanales S. A., Dragados, OCP, Ferrovial; Roofs: MZOV. Client: Community of Madrid. Dates: Project; 1989. Start of Work; 1990. Completion of the Works; 1994.

[8] Expansion project drawn up by the architects Antonio Cruz and Antonio Ortiz, the structural engineer Julio Martínez Calzón and the firm Schlaich, Bergermann und Partners for the specific design of the annular stretched membrane roof.

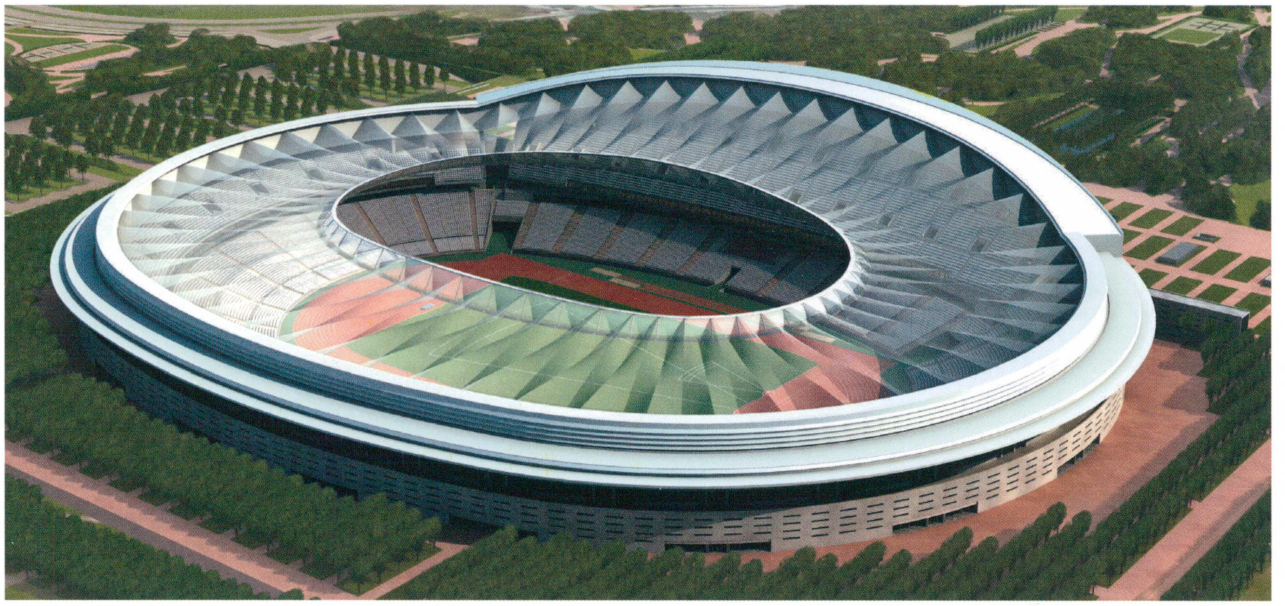






Madrid community sports stadium

cruz y ortiz arquitectos





M-30 Funeral Home Roof
Castillo-Puche, Cesma, 2003

The roof for M-30 funeral home's central patio, at 47 m long by 10 m wide, takes the form of a vault with a rise/span ratio of 1/5. It is divided into five longitudinal strips in different materials. The central strip of 4.5 m is in glass, the adjacent 1.50 m strips in sandwich panel and the side strips are open.

The structure is made up of tubular arches 4.66 m apart, supported on steel box girders located on top of the lateral building and connected together by four straps, the axes of which coincide with the separations between the various covering strips. As the separation between the arches is greater than the maximum span of commercial glass, an intermediate support was inserted, made of stiffeners with cables to reduce its span to 2.33 m.

The two cables for each stiffener are tensioned against each other by means of three compression connecting rods which keep the cables apart in the centre of the span, while their ends are held by the end straps of the glass strip, this being above the structure.

(Summary of text by Peter Tanner & Juan Luis Bellod [16:204-205]).

Credits: Architecture: José Luis Castillo-Puche Figueira. Structural engineering: Peter Tanner & Juan Luis Bellod, CESMA Ingenieros. Ownership: Servicios Funerarios de Madrid, S.A. Constructor: Murillo-Muriel, S.A.





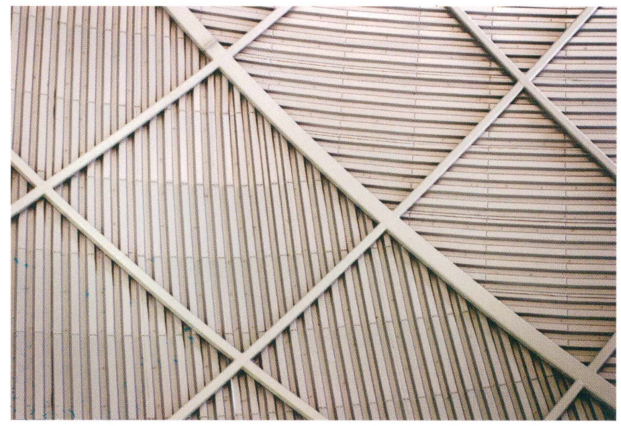
Astronomical Observatory Dome
Fernández Alba, Cesma, 2004

The dome of the building for the Herschel telescope located in El Retiro Park in Madrid covers a square area with sides of 13 m and reaches a maximum height of 5 m above the crown of the building. The concept for it was based on a series of structural ideas aimed at combining the effectiveness of the solution with functional, aesthetic and construction criteria. As such, each of the structural elements, including the edge arches, are made up of a meridional arc with a radius of 11 m, hence the form of the dome was obtained by means of the intersection of the spherical surface with four planes, each defined by two adjacent corners of the square to be covered and the centre of the sphere. The arches were fabricated from tubular profiles, while the sheet metal for the roof, which is corrugated and has double curvature, is supported directly on this structure. The dome's structural behaviour can be likened to a membrane, in which the continuous surface is replaced by metal ribs. The conceptual solution adopted, without unnecessary bracing and with welded joints, leads to a structure with a very clean form. Aesthetically, the result was so pleasing that it was decided not to install the false ceiling initially planned.

(Tex by Peter Tanner & Juan Luis Bellod) (Further information in [16:210-211]).

Credits: Architecture: Antonio Fernández Alba. Structural engineering: Juan Luis Bellod, Peter Tanner, Cesma Ingenieros. Ownership: Instituto Geográfico Nacional, Observatorio de Madrid, Ministry of Development. Constructor: EJUCA, S.A.







Rockódromo Arena
Cano Laso, Martínez Calzón, 2005

Based on the dimensions and the oval shape proposed for the floor plan (120 m by 110 m and a perimeter of 350 m), a roof was arranged with an upper radial system of six radii of great power, dividing it into six peripheral zones with a central window. In each of the zones there is a stereo spatial structure made up of bars and spheres that give the assembly a hierarchical structure and confer it expressiveness.

The roof is supported on twelve pairs of supports located on the lines of the main radii and at the intermediate points. The external ones cross the lower space of the stands and entrance like columns and the internal ones form a part of a discontinuous screen of piles, to permit the excavation of the site in a second execution phase without additional operations.

This second phase consisted of obtaining the depth for the construction of the final terraces for the arena, which played host to the second edition of the Madrid Tennis Masters Series from 13 to 21 October 2003, already with capacity for 12,000 spectators. Once the Masters was over, the works restarted and were completed before summer 2004.

The main element of the third phase is the auxiliary pavilion in zinc, an attached multi-purpose building with capacity for 1,700 spectators, equipped with retractable terraces and suited to a variety of uses for all kinds of exhibitions and shows, with excellent acoustics and great versatility to enable any type of event to be put on.

(Summary of text by Ricardo López Pietsch and Luis Catalá Burón [16:224-225]) See also [214]).

Credits: Architect: Estudio Cano Lasso. Structure: MC2-Julio Martínez Calzón. Project Directors: Javier Martínez de Miguel, architect Sara de la Mata Medrano, architect; Enrique Ramírez Guadalix, civil engineer. Ownership: Empresa municipal Campo de las Naciones, S. A. Constructor: ACS-ORTIZ, FCC Joint Venture.



Palacio de los Deportes
Hermoso, Martínez Calzón, 2005

After a fire burnt down the old Palacio, or sports centre, in 2001, Madrid's Regional Government decided to rebuild and alter it, conserving the lateral terracing that survived the fire and seeking to convert it into a functional, modern multi-purpose space.

The structure was produced using an ascending-descending process to execute the concrete slabs for the car parks and the frames for the roof at the same time. The latter were made up of curvilinear space lattice tubular beams with a triangular cross section, embedded in the inclined transoms which support the stands and the cantilevered access platforms. The structure of the stands is in reinforced concrete and three basement levels were made under the old track.

(Summary of text by Julio Martínez Calzón [214] [16:223]).

Credits: Architect: Enrique Hermoso Lera. Designers: AEPO Ingeniería. Conceptual Design for the Structure: Julio Martínez Calzón, MC2. Client and Constructor: NECSO and FFC Joint Venture.



Retractable Roofs for the Caja Mágica
Perrault, Typsa, Viñuela, 2010

The roof gives the form of the "Box" imagined by the architect, with opening "covers" that allow each of the three courts to be completely uncovered, giving the chance to hold competitions or events in the open air or under cover. Each of the three movable covers is supported on the fixed roof which unifies the whole and they project beyond it in all its depth.

The building's roof needed to be resolved with spans of nearly 100 m and a mandatory depth of 4 m, with the capability to lift and move to fully uncover the courts.

The general structure is divided by a structural joint in the zone of arena 1 and that for arenas 2 and 3. The two zones are resolved using an orthogonal grid of lattices capable of meeting the determining specifications of depth and span thanks to the bidirectional bending of secondary lattices, perpendicular to the main ones.

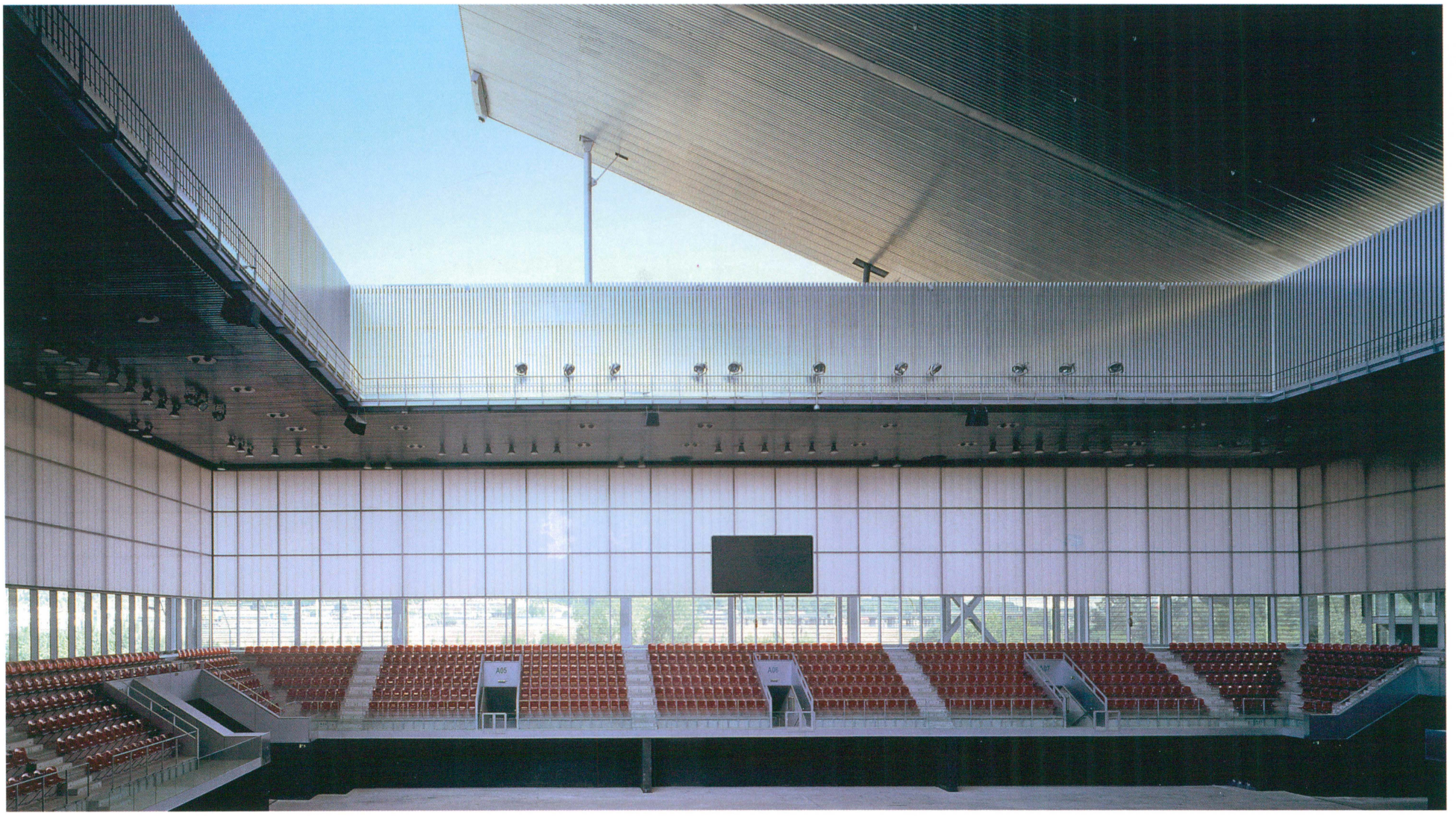
The type adopted for these lattices consists of the execution of the structure's bars using rolled profiles in cases of lower loads and reinforced profiles in the case of the most heavily loaded lattices, so as to give a uniform geometry to the structure, good use of material and easy manufacture. The webs of the profiles were positioned horizontally so as to simplify the joints and crossings of lattices that have no reason to have the same dimensions in their cords.

At the sides of the fixed roof in this zone, in order to allow movement of the movable covers for arenas 1, 2 and 3, there are composite beams that hold the rails on which the mechanisms for cover movements will run. These enable effective reduction of possible noise and vibrations to the structure when movement takes place, as well as giving an effective platform for access to the lifting and movement mechanisms.

Cover 1 (73 m), which tilts and moves, has dimensions of approximately 103 x 73 m. It opens to 12° by rotating around the hinge of 103 m and moves by 65 m perpendicular to the hinge. The time to open by rotating is 15 minutes and the speed of lateral movement is 5 m/minute.

[Summary of text by Salvador Fernández Fenollera [16:160-161]).

Credits: Planning Architect: Dominique Perrault. Structural and Installation Project: TYPSA. Roof Project: Luis Viñuela (FCC Construcción). Developer: Madrid Espacios y Congresos. Madrid City Council. Constructor: FCC. Dates: Start of Works: April 2006. Completion of Works: April 2009.



Salón de la Villa at Cibeles
F. Partearroyo, D. Márquez, A. Martínez, F. Martínez, 2010

The roof for the outdoor patio of the Palacio de Cibeles meets the need to achieve a connection between what is public and what for administration, between the outside and the inside and it converts it into the great assembly room for Madrid's residents. The first covered square in Madrid. A roof was proposed in the form of a self-supporting water bubble with a triangular mesh, supported on the only impost common to all the patio façades, which was the ornamental top to the building, located at a height of 21.60 m above ground level. The perimeter of this cornice is an irregular polygon which it is difficult to break down geometrically. We proposed ourselves the form of a uniformly pressed elastic surface which fits the form of the patio at its edges to cover and acquire greater cant at the zones with the greatest span to bridge and flatter in the narrow zones.

The roof does not project beyond the current volume of the building, so it cannot be seen from the outside; it is a covered square surrounded by higher building. The support on the roof is made on the perimeter walls to the patio under different conditions, In its majority, the wall is load bearing with metal pillars from the height of the support for the roof.

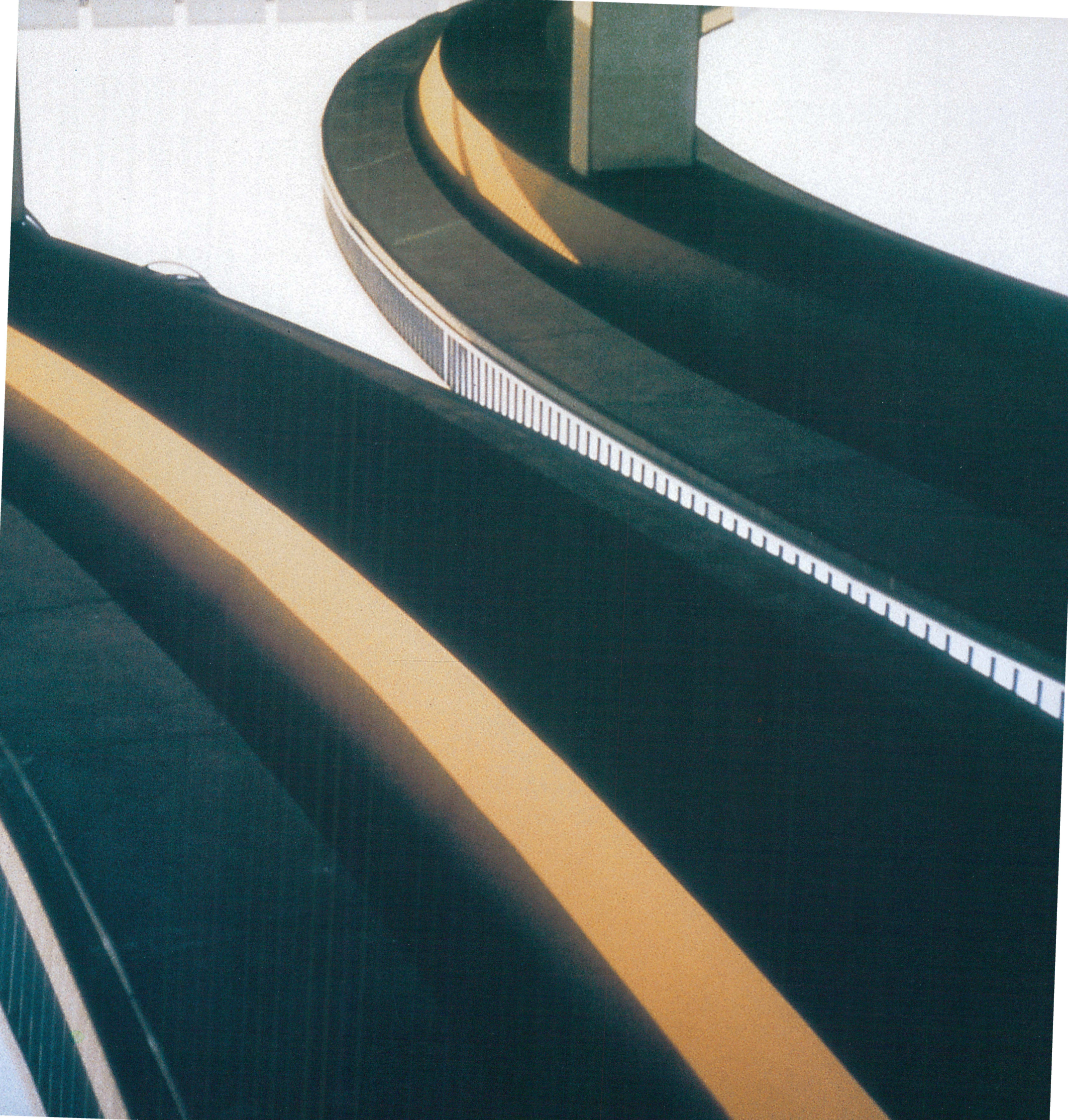
The triangular mesh is resolved with bars of 1.60-1.80 m in length and a cross section of 120 x 80 mm. The edge beam of the glass roof houses the gutters and is made with a tube of 0.76 m in diameter, supported using 43 feet on the building's buttresses and the structure of pillars and beams of the ambulatory.

In parallel to the construction of the new glass roof, two basement levels and a technical floor were made. The first basement level is for stores, workshops, changing rooms and dressing rooms, an auditorium for 300 people and the second for installations, stores and a loading and unloading zone. The technical floor is used to expand the machine room and the duct galleries. The second basement level connects under the Pasaje de Ruiz de Alarcón to the car park and the ramps core under the street named Montalbán towards the Paseo de Recoletos.

(Summary of [16:256]).

Credits: Project Authors: Arquimática SLP Architects: Francisco Rodríguez de Partearroyo Conde, David Márquez Latorre, Ángel Martínez Díaz, Francisco Martínez Díez. Vault Structure: Mike Schlaich, Luis Casas of ARQUING SLP. Constructor: Dragados and FCC Joint Venture. Vault Execution: Lanik S.A. Client: Madrid City Council.





5 | Spanning with Bridges

The crossing road creates the place

The bridge stands out among what is built due to its privileged meaning, as the symbol of the link over the obstacle. It corresponds to a simultaneous vertical and horizontal advance. The road, a product of the will to extend, finds obstacles to overcome and has to leave the ground. It confronts gravity and distance to span the obstacle in one go or with several leaps. As the most frequent obstacle is rivers, the bridge confronts the water and faces up to the river's current at its piers. As a resistant structure it needs to resist the bending introduced by its span.

The bridge crystallises the possibility of crossing the river or spanning the obstacle and with that builds a place. On being embodied, it gathers the landscape around it by the river and means passing spot as a place. Indeed, the bridge was chosen by Heidegger as a theoretical image for constructing habitation and its fruition in place [19:53].

Names, centrality and nature as capital

The radial configuration of the entrances to Madrid and their influence on its urban structure are also felt in its bridges, starting with their names themselves and extending to their locations and articulations. Madrid's two "great" historical or classical bridges appear to disregard the river and are known by the names of the cities where their roads go: Segovia Bridge and Toledo Bridge.

Others have been baptised with the sanctified name of the monarch of the time, following the rule or custom for forts, arsenals or great buildings of State. The San Fernando, del Rey, de la Princesa and Reina Victoria bridges also appear separate from their places and are indebted to those who ordered them built. Centrality and nature as capital continue to mark the course of what is built in Madrid, except for its railway stations, which are more attentive to neighbourhoods – Atocha, Chamartín, Delicias... The railway crossing over Manzanares river significantly also receives the name Los Franceses bridge.

Appropriating the territory

Repeatedly, Madrid tends to appropriate what surrounds it, in all likelihood not out of grandeur or because of monumental character, but rather for practical, everyday reasons. Madrid brought itself to calling a derided M-30 motorway Calle 30, just because it was easier to refurbish and appropriate it. From this way of understanding territory emerges some names such as the Segovia and Toledo Bridges, the start of the royal road for identical reasons. The El Rey (King) bridge was built in order for the monarch to cross over to his gardens of the Casa de Campo, although it was used later for other connections.

Classical river Manzanares bridges

Likewise, many bridges in the outskirts of the city acquire relevance because they lead onto the road system that irradiates the Court's dominance over the entire country[1]. The Arganda Bridge crosses the Jarama and the Fuentiduña Bridge crosses the Tajo (described together with those of the river). Both serve the road to Valencia. The long bridge over the Jarama or the suspension bridge over the Tajo connect the capital to the Royal Site of Aranjuez, and open the way towards Andalusia. The Guadarrama Bridge fulfils a similar function for the Royal Site of San Lorenzo del Escorial, as does the Buitrago Bridge over the Lozoya for the Burgos and France Road. Only the viaduct over Calle Bailén has a character that is independent of the approaches, which arises from its urban development role in the configuration of the most emblematic district of the city [11:401].

The distinction put forward by Fernández Casado between the two main bridges, Segovia and Toledo, as complete representatives of the pure Renaissance of the 16th century and the Baroque of the 18th, continues to be completely valid [92]. These are two bridges of the same length, with almost identical technical solutions, nine arches of a similar span, but they present themselves in different languages.

In the Segovia Bridge, Herrera turns to the classical composition of Roman bridges, with flat tympanums and cutwaters that are bevelled downriver and semicircular upriver, with caps at the springing level. In the Toledo Bridge, Ribera takes bridges such as the Almaraz as the basis for finding elements as round as the towers,

[1] For historical bridges in the Comunidad de Madrid see [99].

crowned by means of overhanging balconies that act as capitals and approach the roadway as stopping places. A fillet marks the springing and trims the shape of the pier, and goes beyond some minor pointed cutwaters upriver.

That different conception made it necessary to treat them differently to expand them. In the Segovia Bridge the fronts are flat, with attached cutwaters that are independent of each other. In the second bridge the composition is volumetric and the transverse interlocking is deeper than the longitudinal one. Due to this, the former could be widened by moving the front and building a new central section, while it was not possible to transform the Toledo bridge in the same way and it was split in two [92:843].



Gardens at classical bridges

Madrid-Río gardens at Segovia Bridge

Segovia Bridge has been declared an Heritage of Cultural Interest. It was built at the end of the 16th century by the architect Juan de Herrera, under a commission from King Felipe II. The landscaping project for its surroundings is an exception in the Salón de Pinos area, constituting a widening of the latter and offering a different way of approaching the river. The gardens are arranged using a series of organic layout lines modelling successive terraces that descend towards the river. These lines are built using large granite pieces which also serve as benches. Between them a lawn with grass with low water consumption extends, planted with various species of luxuriant riverside trees from the *Populus* family. Close to the dressed brickwork of the bridge, two clean water pools have been built, in which, on one side a monumental fountain of 16 jets in the form of cypresses rise and, on the other, a small garden of water lilies extends. Access can be gained to the pools by means of stone steps which approach them and continue until submerged.

(Text by Ginés Garrido & Francisco Burgos).



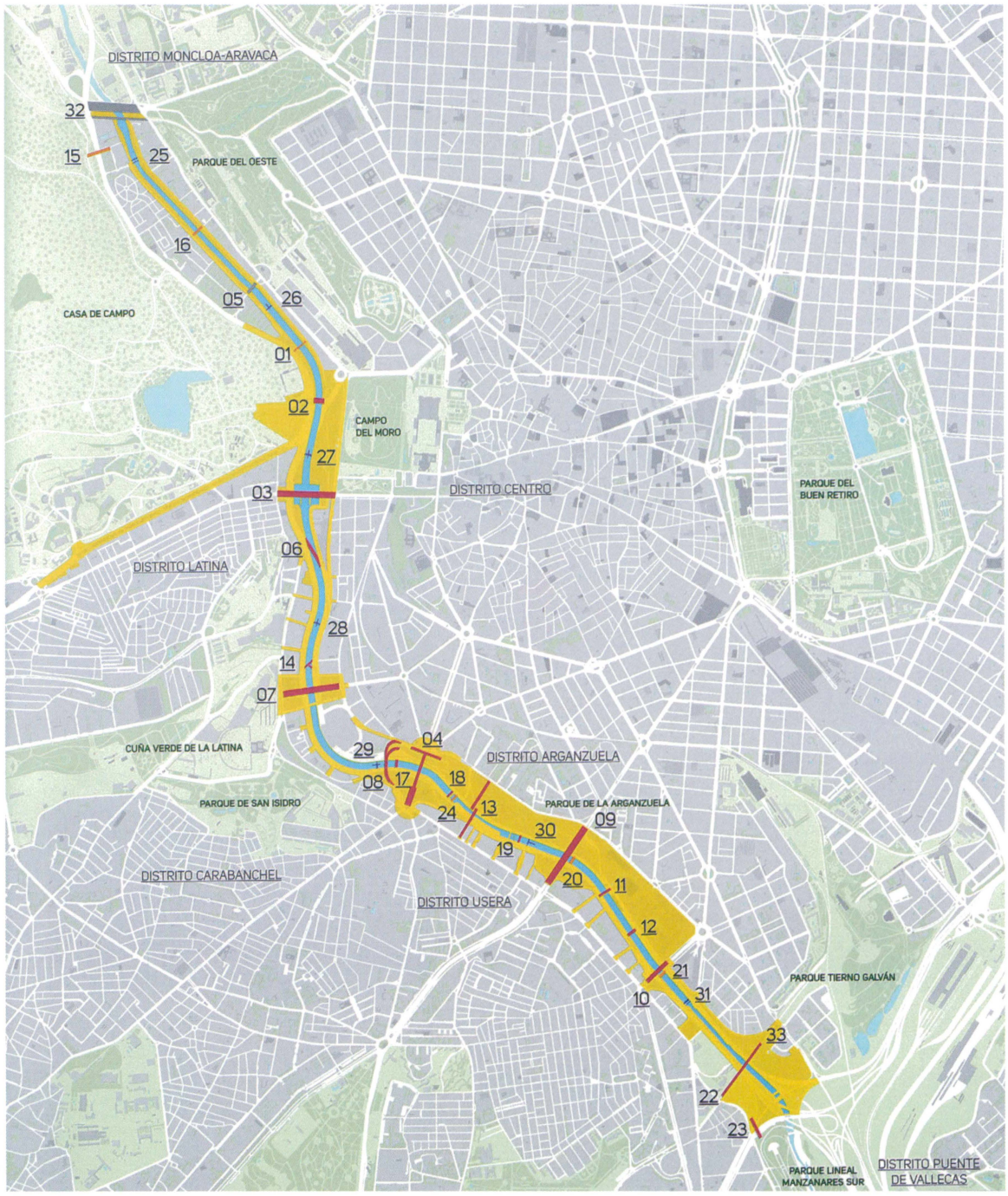
Madrid-Río gardens at Toledo Bridge

The Toledo Bridge gardens represent one of the most significant areas in the Madrid-Río Project, as they are located in an enclave of exceptional importance in which the Salón de Pinos meets one of Madrid's monumental bridges, Toledo Bridge, built between 1718 and 1732. The project takes advantage of this monument in two ways. On the one hand, a space was devised to be seen from above from the bridge, making it a privileged viewpoint. In this way, the gardens offer a new and unexpected general view of Madrid, as its layout sketches an enormous tattoo extending like a carpet over the surface, representing a figurative plant motif. On the other hand, the gardens incorporate Toledo Bridge, a Baroque structure designed by the architect Pedro de Ribera, as an object to be admired, to touch and under which to pass. The arrangement of the hedges is organised so as to shape a series of lines that take their reference from the baroque gardens of the age of the Bourbons, although they are planned in a contemporary language. A terrace was also built at the same point to enable you to get as close as possible to the sheet of water in the river and give a better view of the arches of the old bridge.

(Text by Ginés Garrido & Francisco Burgos).

Owing to the modifications to the M-30 in its western stretch and the execution of the Madrid-Río gardens, the complete list of all the bridges, footbridges, crossings and dams on the river Manzanares on its urban stretch has been updated. The list classifies the 33 crossings into categories, according to their role in its remodelling.

The list leaves out several crossings located in Madrid, such Fernández Casado's El Pardo Bridge, El Pardo dam, El Pardo urban bridge, San Fernando Bridge, Fernández Casado's bridge under the A-6, the nearby footbridge near INIA, the Club de Campo footbridge and Javier Manterola's Los Franceses road bridge and all those upstream of the Los Franceses railway bridge. Downstream of Madrid-Río until the last crossing located at the municipal limit at the El Rey waterwheel, with no public right of way.



Location map of urban crossings over the river Manzanares [Madrid Río:++++]

List of crossings of the River Manzanares

MADRID-RÍO CROSSINGS OVER THE RIVER MANZANARES

RESTORATION OF HISTORIC BRIDGES
Aniceto Marinas Footbridge (01)
El Rey Bridge (02)
Segovia Bridge (03)
Toledo Bridge (04)
Reina Victoria Bridge (05)
REMODELLING OF VEHICULAR BRIDGES
Oblicuo Bridge (06)
San Isidro Bridge (07)
Vehicular bridge north of Toledo Bridge (08)
Praga Bridge (09)
La Princesa Bridge (10)
ARTISTIC AND MONUMENTAL BRIDGES
Sheet Footbridge opposite the Madrid Abattoir I (11)
Sheet Footbridge opposite the Madrid Abattoir II (12)
Arganzuela Monumental Bridge (13)
Y-shaped Footbridge (14)
PEDESTRIAN AND CYCLE FOOTBRIDGES
Los Franceses Footbridge (15)
Almuñécar Footbridge (16)
Footbridge-pontoon north of Toledo Bridge (17)
Footbridge south of Toledo Bridge (18)
Arganzuela Footbridge III (19)
Footbridge next to Praga Bridge (20)
Footbridge next to La Princesa Bridge (21)
Footbridge at Salón de Pinos Sur (22)
Footbridge in Manzanares South Linear Park (23)
Arganzuela Historic Footbridge (24)
REMODELLING OF HISTORIC DAMS
Dam No. 3 (25)
Dam No. 4 (26)
Dam No. 5 (27)
Dam No. 6 (28)
Presa n.º 7 (29)
Dam No. 8 (30)
Dam No. 9 (31)
RAILWAY CROSSINGS
Los Franceses Bridge (32)
Southern Junction (33)

Source: Madrid City Council.



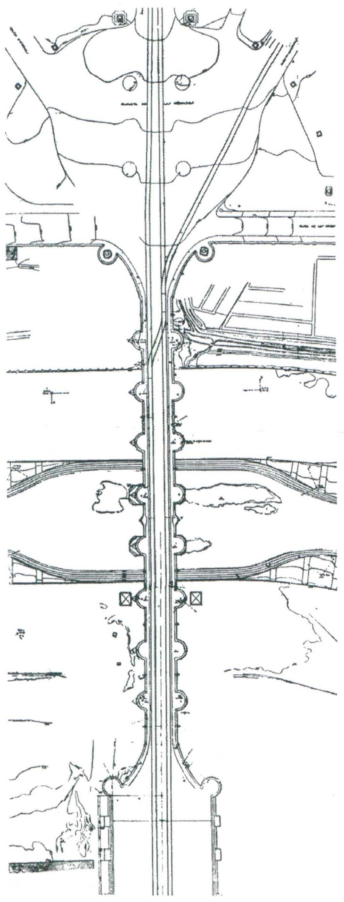
Segovia Bridge in Madrid
Herrera, 1584

Built by Juan de Herrera after completing Escorial, it is divided into nine brick arches with spans from 9 to 12.8 m. It has an austere and solid air, with a simple dressed block and some stone balls typical of the late 16th century as its sole decoration.

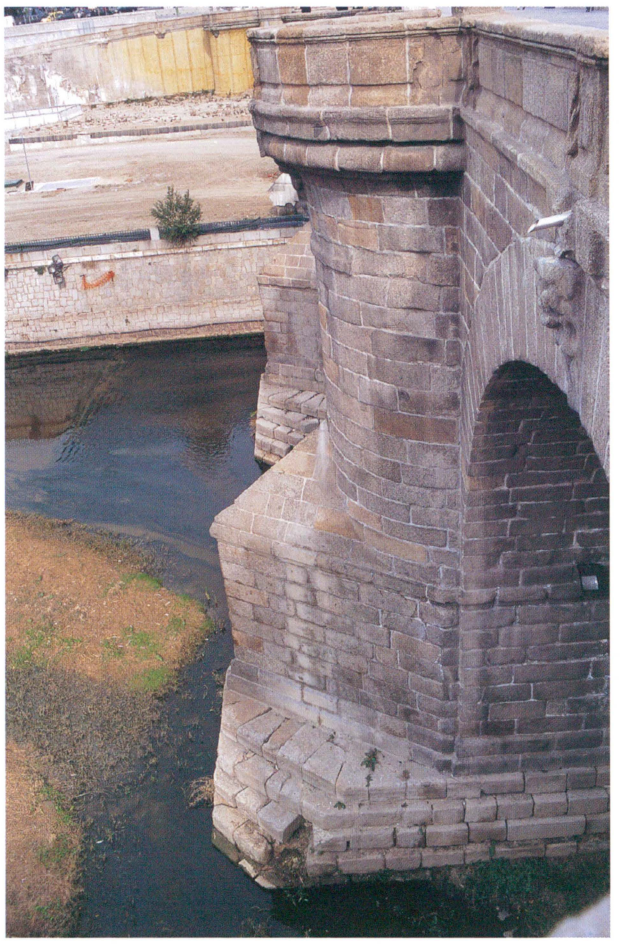
Fernández Casado [92:11] confers it the status of *the first modern bridge*, as the horizontal grade introduced by Herrera *gives tension to such an apparently serene work*. The brickwork is very homogeneous, with robust piers in relation to the arches and semicircular cutwaters with conical caps. In 1933 the Viveros Bridge was built, in parallel to the Los Franceses Bridge, in order to provide access to the Castile Road, relieving the Segovia Bridge of this function. It was destroyed in the Civil War and rebuilt subsequently with the same project.







Toledo Bridge, according to Fernández Casado [92:607]



Toledo Bridge (1732)

Toledo Bridge also leads to the roads to Andalusia and Fuenlabrada. Its construction started in 1682 and was completed in 1732, due to various sudden administrative changes and the damage caused by the 1720 floods. The work is attributed to Pedro Ribera with the collaboration of the sculptor Juan Ron. It is also divided into nine semicircular arches with spans of 11.2 m, with piers that extend to the deck as passing places and it is all built from granite blocks.

Fernández Casado distinguishes [92:606] an essential Baroque nature, probably attributable to the contribution of Pedro Ribera, in the perfect match of straight and curved alignments, from the 9.5 m of the roadway garlanded with the passing places to the 35 m of the entrances, by means of wide symmetrical curves that link the parapets with the walls of the Plaza de las Pirámides. An adventitious Baroque, arising from the Baroque decoration which stands out independently of the structure like something overlaid on it, like the statues located on the parapet at the central arch and the fountains that finished off the curves expanding the floor plan.



San Fernando Bridge (1750)

It is located at km 7 on the La Coruña Road and was built in two sections, joined by a large buttress situated on an island. The left-hand section has four arches, two of which are semicircular ones with spans of 6.2 and 5.7 m and two are surbased with spans of 8.45 and 7.95 m. The right-hand section had two arches, but the repair after a flood was carried out with three arches with spans of 9.75 m. In 1921, José Eugenio Ribera widened the right-hand section with reinforced concrete, preserving the forms.

It replaced one of the four original wooden Green Bridges, so called because of the colour in which they were painted. The oldest was replaced by the El Rey Bridge, another was in San Isidro, another was in the San Antonio Hermitage and this one was called Los Rastrillos Bridge [92:837]. The approach to the bridge was closed by the Puerta de Hierro, which served as an entrance to the El Pardo Mountain and was only opened when the river was swollen, making it impossible to wade across the Jerónimos ford, in order to provide a short cut to the road to the Castile road.





Los Franceses Railway Bridge (1857)

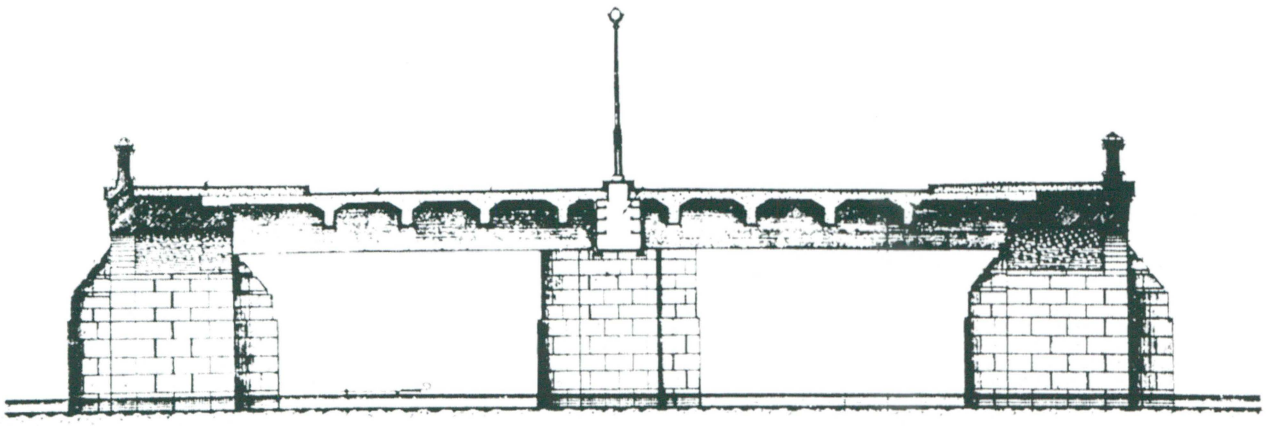
It was built by French technicians and contractors from the Northern Railway, with five oblique arches with a span of 16 m and a height of 11 m above grade. It was widened in the 1920s with two pavements of reinforced concrete.



Reina Victoria Bridge (Ribera, 1909)

It is located close to San Antonio de la Florida to link the old Castile Road with the La Coruña Road and replaced another of the so-called Green Bridges. It was built by José Eugenio Ribera, with a central arch with a span of 30 m and two lateral girders with spans of 5 m for spates, all in reinforced concrete.



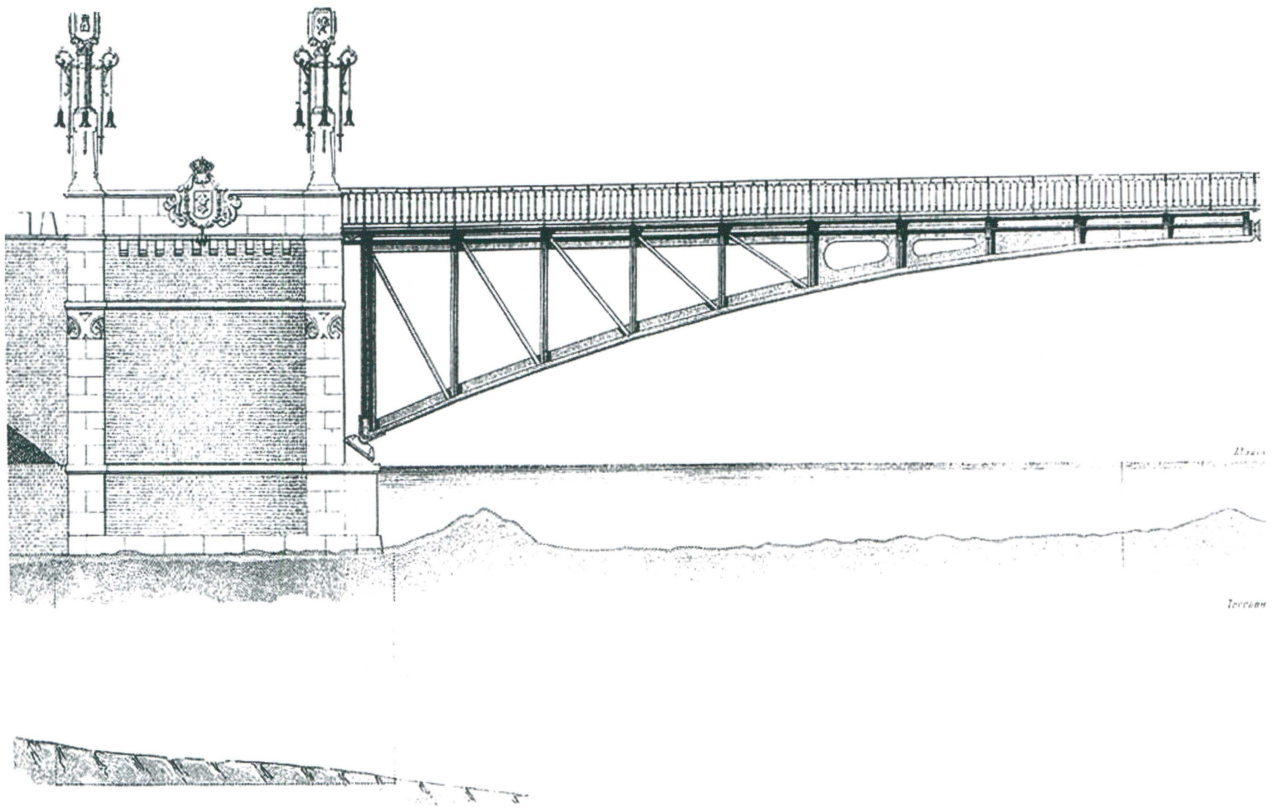


Widening of the El Rey Bridge [ROP 1974: 84]

El Rey Bridge
(Silvestre Pérez, 1825)

Commissioned by King Fernando VI from the architect Silvestre Pérez to connect the Royal Palace gardens to the Casa de Campo. It has six surbased brick arches with 8 m spans, with abutments, piers and arch rings in masonry. At the left-hand entrance there was a door and two urns on granite pillars that still remain.

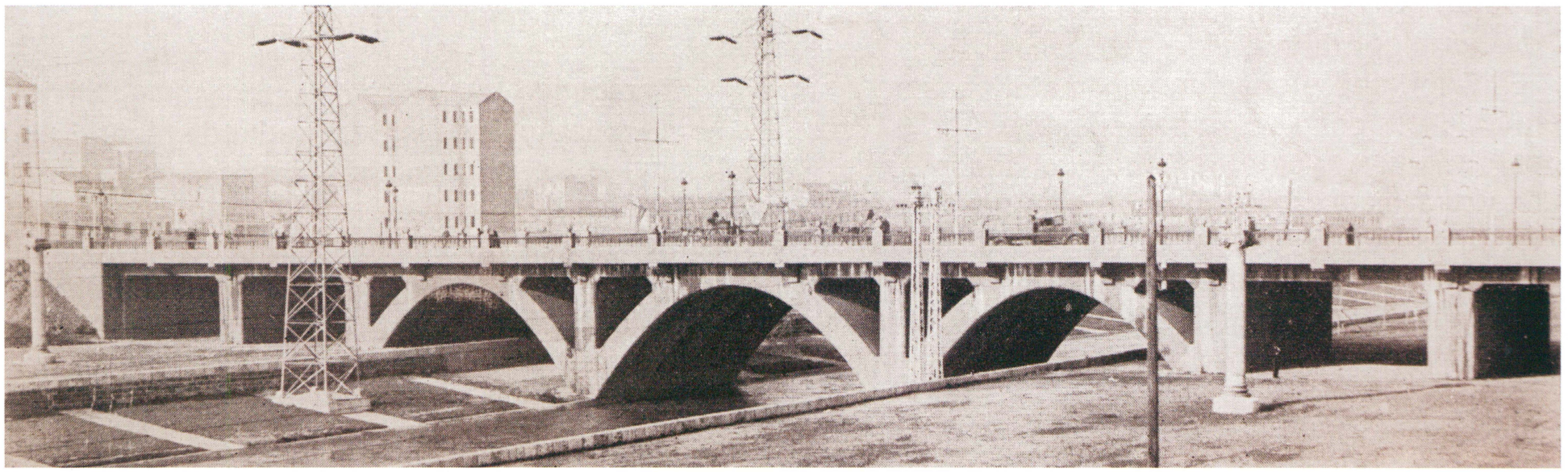
The cutwaters form cylindrical bodies with smooth surfaces, while the conical caps are cut into three horizontal bands, each protruding out from the one above. Encrusted on the caps is a projecting disk made of Colmenar stone, like the crown voussoir. The bridge has been altered greatly, with a downstream widening which reproduces the upstream elevation and an intermediate strip resolved with girders.



Princesa de Asturias Bridge in Madrid (Machimbarrena and Beamonte, 1910) [146:1]

Princesa de Asturias Bridge in Madrid
Machimbarrena and Beamonte

This connects the Paseo de las Delicias to the Andalusia road. The 1910 bridge had a single span made with three metal three-hinged arches with spans of 50 m, surbased to 1/10 and supported on masonry and brick abutments [146:400]. This bridge was made obsolete immediately by its limited width of 8 m and was replaced by another (Alberto Latón, 1929) with three canted parabolic concrete arches, with two trabeated spans on each side. Its 18-m wide concrete deck was also found wanting and it was again replaced by a continuous beam bridge.



Princesa Bridge of 1929 [92:149]

Channel crossings

Subsequently, on channelling the river, a series of local crossings were built over Manzanares river. These were now urban bridges and not for access to Madrid, although they are included here, together with the most important.

These are the Praga Bridge in the extension of the Paseo de Santa María de la Cabeza, with two 21 m spans and five footbridges with four spans of 10 m: two between the Los Franceses Bridge and Reina Victoria Bridge; one between the latter and the El Rey Bridge; another between the Segovia and Toledo Bridges, replacing the old San Isidro Pontoon; a fifth between the Asturias Bridge and the Madrid, Caceres and Portugal railway bridge; and, last of all, two equal footbridges with a span of 17 m each for connection to the island, which form a further crossing 160 m upriver from the El Rey Bridge.

The bridge is 12.4 m wide (2.2+8+2.2) and the five footbridges are 5 m wide (1.25+2.5+1.25), while those of the island are 1.6 m wide, all composed of straight metal sections with a low deck position, given the low height of the grade. With these works, the average distance of 610 m in the part around the built-up area is acceptable [100:38].

The cable-stayed footbridge over the river Manzanares and the M-30 ring road (Manterola, 2003) in Madrid was located at the junction between the street named Virgen de Puerto and the cross street Ruy González Clavijo on the left bank and next to the street named Daimiel on the right bank. The structural layout chosen consisted of a single tower located on the right bank from which two circular stretches with 147 m spans hang, with these two joined in the middle.

The structure was an exercise in structural mastery, the result of which expresses the atypical bending forces in the horizontal plane well. Due to its curvature in plan, they are perfectly legible in the asymmetric configuration of the cross section and in the lateral reinforcement for the supports to the lintels in the approaches. As with the Cuatro Caminos Bridge, the work was condemned to be demolished, this time due to alterations to the M-30 in the area.



Praga Bridge

Los Franceses Bridge
Manterola, 1998

This portal frame sits at a place which has always been a crossing point, where the road from Castile used to enter Madrid, although the presence of the railway and the M-30 motorway sited practically on top of it manage to overwhelm the crossing. Surrounded by all this, the bridge shines out like a jewel and stands by the primacy of the beautiful and impeccable. It is made up of a composite lintel, which divides to lead to the university campus and the Parque de Oeste, with a triangular section in plate painted in a highly polished white. Its main span of some 40 m is supported on inverted metal tripods arranged according to the division in the lintel, with their arms reaching a separation of up to 25 m.

The brightness of the white in the sun, the lights at night or the reflection of the damp roadway makes it stand out from the concrete background. The perfect finishing of the edges in a blade with a low railing cancels out the section's great depth and turns the lintel into something light, floating. The whole design shows an enormous capacity for innovation in the service of a purified formal expression of its resistant design. With all this, the bridge manages to make the most of this rather unattractive site and flow cleanly and brilliant to deposit vehicles in Madrid.





Iron viaduct over the Calle Segovia

To span the brook running alongside the Calle Segovia near the Royal Palace, Sachetti planned a palace gallery on a stone bridge to Vistillas, which was never built. The crossing had to wait until the 1870's to find a solution, in a project which faced up to understanding the Calle Bailén, at the edge of the Palace at the time, in a new way. The bridge's position was set from an urban planning point of view, with a new road (the Calle Bailén) which was intended to be one of the capital's best, with views over the river Manzanares and the Royal Casa de Campo[2].

The crossing itself was made with an iron bridge using solid-webbed girders on composite piers in cast iron with masonry bases [170]. From its official opening in September 1872, the viaduct became notorious due to the large number of people committing suicide by throwing themselves from Calle Bailén down onto Calle Segovia. Seventeen cases were recorded in the first four years and the City Council took measures such as raising the height of the railing and putting a security service in place.

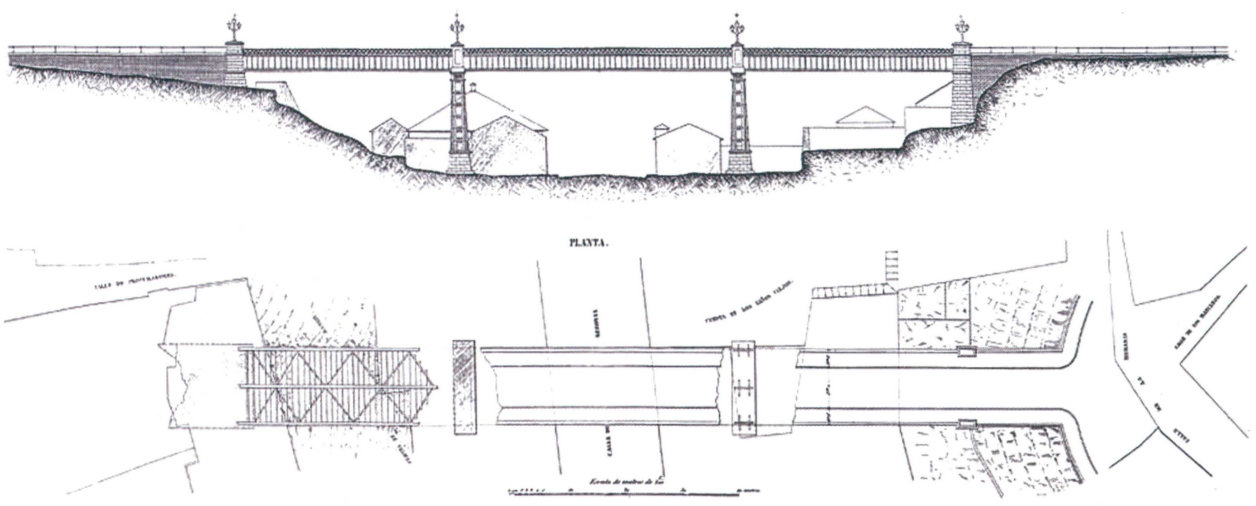
1932 Competition

At the end of the 1920's, the iron viaduct was in a poor condition and Madrid's residents did not consider it to be a sufficiently dignified structure to be located alongside the Royal Palace. What was wanted was a *beautiful, light, solid bridge, with elegant, monumental lampposts, so as to constitute one more thing to admire among the many good things contained in the capital of Spain* [152:473].

In the 1930's the decision was taken to build a new viaduct and a competition was called. As was to be expected, a design and build competition for a bridge on this site in the high-spirited year of 1932 generated extremely interesting proposals. Among them was an especially attractive one by Eduardo Torroja and Secundino Zuazo, made up of a continuous concrete beam with a 75 m central span and 30 m lateral spans, on two very slender piers. The open box section housed the service galleries. The authors opted for a beam, *not only due to the pleasing effect the horizontal lines connecting the hillsides produce, but also because it would never be possible to see the whole arch*[3].

The viaduct of 1942

The work was delayed until after the Civil War and it was built using an arch as the solution, which is, indeed, very difficult to see in its entirety. Its, rather dark, reputation does not come from its formal design, but rather continues to lie in its attraction for people who want to put an end to their lives.



Iron viaduct on the Calle Bailén in Madrid (Barrón, 1872) [ROP 1861,271]

[2] Madrid: Extension of the Calle Bailen and iron bridge over the Calle Segovia. *Revista de Obras Públicas*, 1861, 9, volume I (18): 217-224; (19): 229-233.
[3] Project competition for the new viaduct over the Calle de Segovia. *Revista de Obras Públicas*, 1932, 80, volume I (2611): 564-570; 1933, 81, volume I (2612): 18-22; (2613): 46-49; (2614): 70-71.



New Madrid viaduct
Aldaz, 1942

The project by Luis Aldaz, José Juan-Aracil, the architect Francisco J. Ferrero had been drawn up in 1933 for the design and build competition. Very technological in nature, it proposed three rather economical arches with spans of 36 m. The only concession made in terms of a monumental character was to take the vaults or outer ribs to the walls, but it soon became clear that the layout was arranged in such a way that it is possible to give the pavements a two metre overhang on each side, *easily and without altering the structure or the aesthetic effect in any way*[4].

[4] *Revista de Obras Públicas*, 1933, 81, volume I (2613):49.





The first overpasses

Bridges were the first to incorporate new design influences, in a rather bleak scene until then. Two important precedents, both urban bridges in Madrid, marked formal references of some importance in the whole country [14:415]. In the decade of the transition to democracy, the Juan Bravo and Cuatro Caminos Bridges, both built in 1969 to resolve a functional problem that was new to Spain, the urban overpass, shone out brightly.

This involved the resolution of a series of potentially problematic points on the busiest roads, basically the ring roads (M-20) and the Paseo de la Castellana axis. Although the aim was mainly functional, to overcome traffic problems in Madrid, the City Council had the good judgement to award the bridges by tender. This was the habitual practice before 1936 and was restored from that time.

Cuatro Caminos Bridge

To a similar functional problem, the winning projects responded with solutions inspired by very different contexts. At Cuatro Caminos, Javier Manterola plumped for a straight lintel in pre-tensioned concrete, offering the minimum material obstacle to citizens' movements. Plan view, elevation and cross section are arranged so that the mass disappears visually from the urban scene. In spite of its width, the section tapers in the lateral cantilevers that spring from a central pier, which in turn is dematerialised by the disappearance of its arrises, while the abutments taper to minimise visual disturbance from vehicles and for pedestrians. All of this is executed in a smooth, impeccable concrete to soften its presence in a rather unattractive square, which would not improve with such a light, elegant design.

With the passing years, the general premise that cars are a nuisance to pedestrians and neighbours triumphed over such an excellent achievement and the bridge was to be replaced by a tunnel, which was then rejected due to its high cost. With this, the roundabout recovered its previous anodyne appearance and Madrid's residents have been robbed of a great public work. However, the success of the Cuatro Caminos Bridge was the starting point for Javier Manterola's brilliant career in the design of bridges of all types and conditions.



Cuatro Caminos Bridge in Madrid (Javier Manterola, 1969)

Juan Bravo Bridge

The Juan Bravo - Eduardo Dato Bridge over the Paseo de la Castellana (1971) also represented a significant commitment to aesthetic, urban and civic values, far above the previous primacy granted to the functional. With a technological solution of radical novelty, based on the use, for the first time in Spain, of a concrete/steel composite structure, José A. Fernández Ordóñez, Julio Martínez Calzón and Alberto Corral achieved a respectful design that dignified a rather neglected spot in one of the city's best areas.

Careful selection of materials, seeking contrast between the dark brown colour of the novel weathering steel and the white of a concrete from polished formwork, together with a configuration of serene appearance supported by the classicism of the pier capitals and the stepped ground, generated an inhabitable setting under the bridged which was enriched years later when an outdoor sculpture museum was made. Ordóñez completed the museum in the mid-seventies by hanging a piece by Eduardo Chillida from the bridge. This brought about a passionate controversy that mobilised the support of Madrid's cultural classes.

The two bridges were the starting point for a professional career, shared or individual depending on the case, that was to produce good examples of bridges throughout Spain in the following decades.



Juan Bravo Bridge over the Paseo de la Castellana in Madrid (Fernández Ordóñez, Martínez Calzón, Corral, 1971)

Raimundo F. Villaverde Bridge

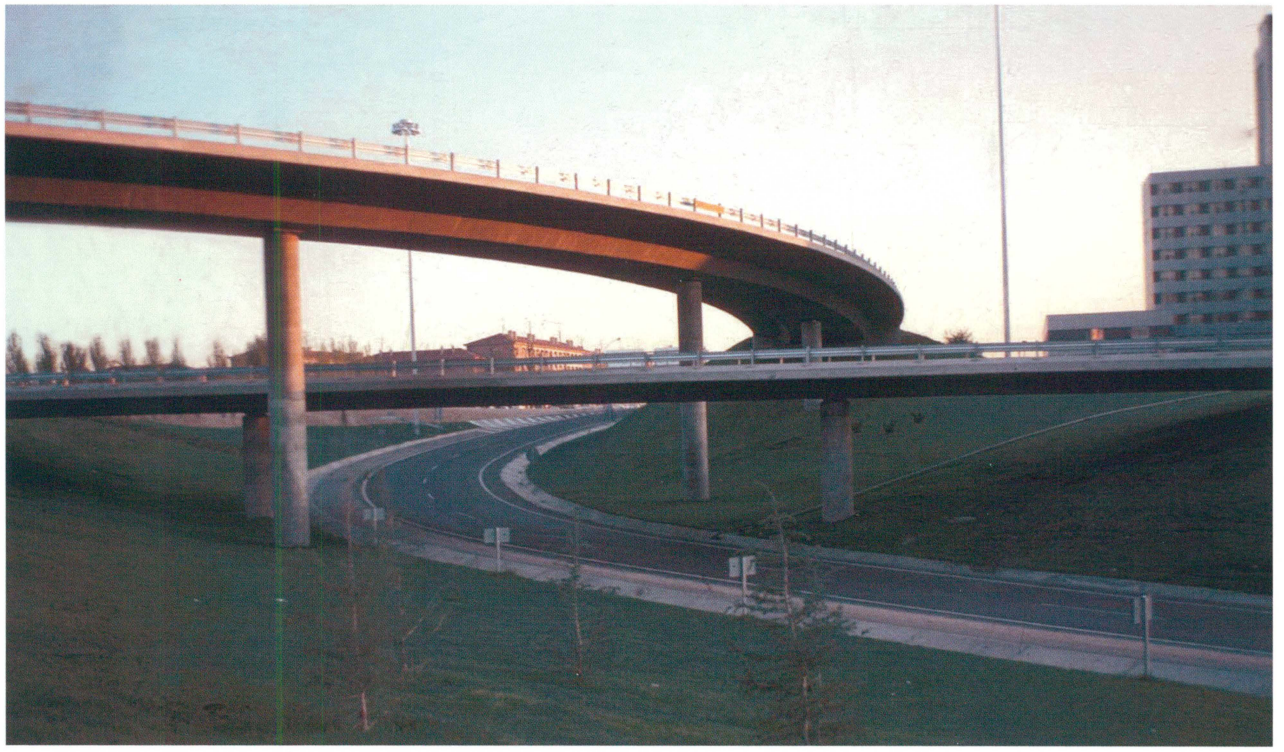
The crossing of the first ring road over the Paseo de la Castellana was especially troubled on two accounts, given the heavy traffic on the road above and the one below. Given the length of the crossing, it was decided that it would be for vehicles only, with no pavements for pedestrians. This gives it a less urban nature and, given the channel-like morphology of the Paseo de la Castellana, it presents itself as a true bridge.



The Paseo de la Castellana ends, rather abruptly for such a noble road, at a connecting junction, the Nudo Norte or northern junction, where it crosses the M-30. As structures, the overpasses designed by Javier Manterola are impeccable, but the great avenue does not deserve to end this way. There is a project to extend the avenue, linked to a profound restructuring of Chamartín station, which has not yet been fully resolved.

Meanwhile, Antón Capitel indicates that *the great avenue, with the significant omen of two tunnels, resigns as an urban element at its end, becoming nothing more than a complicated roadway contrivance. Traffic engineering has spuriously and once again replaced urban planning* [59:11/1/2010].

Northern Junction



Northern Junction in the Paseo de la Castellana
Manterola, 1973

At the beginning of the 1970's a relevant new urban intervention was proposed in the north of Madrid at the meeting of the end of the Paseo de la Castellana and the M-30. The so-called Nudo Norte is a junction on three levels, one of the first put forward in Europe, with very well resolved geometry, but with sufficient complexity to condition the design of the various bridges included in the junction. Manterola chose a box girder cross section on a circular pier, the neutrality of which with respect to the changes in direction and curvature of the decks produced a very clean structure from any point of view.

The generous projections of the slab on a box girder of rather small width and the careful design of the abutments and embankments generate a light, clean structure. In spite of the passage of 40 years since it was built, it still holds its reference value as a structure, regardless of what the junction means as an abrupt end to the great avenue of the Paseo de la Castellana.



Access to Chamartín station
Manterola, 1973

Almost at the same time as the Northern Junction and very close by, Manterola designed and built the accesses to Chamartín station as equally strict spans resolved using the same box girder and overhanging slab cross section, where the layout geometry clearly plays the leading role. Worthy of highlighting is the enrichment of the solution to forking two stretches in Y-shape, the diverging carriageways of which circumscribe an inverse curvilinear triangle, formed with stiffening ribs.

Colmenar road overpass
Tanner & Bellod, 2005

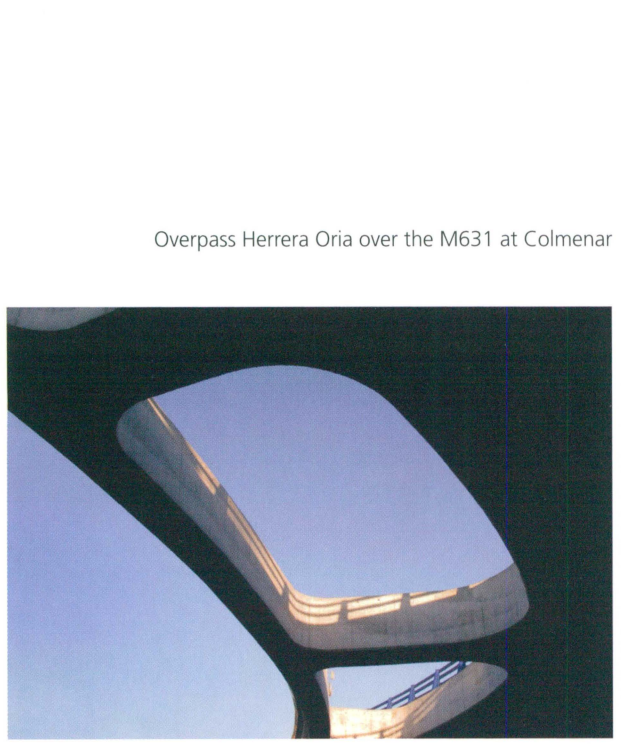
The crossing of the Avenida del Cardenal Herrera Oria over the Colmenar road runs over a vaulted structure with two cells. The need to widen the roadway below made it necessary to demolish the existing structure and build a new bridge, allowing the traffic to continue on the affected roads at all times. The solution adopted consisted of the construction, before the existing structure was demolished, of a lightweighted pre-tensioned slab with two spans of 25 and 34 m. Each abutment is made with a pile screen embedded in the deck, while the piers are made up of isolated piles topped off with neoprene supports. In the larger span, the deck is widened with pronounced curvature due to the presence of a branch in the road. To limit horizontal movements in the abutment area, where the thrusts are unbalanced, an unusual pre-tensioned curved girder is connected to the deck by ribs, forming attractive lightening.

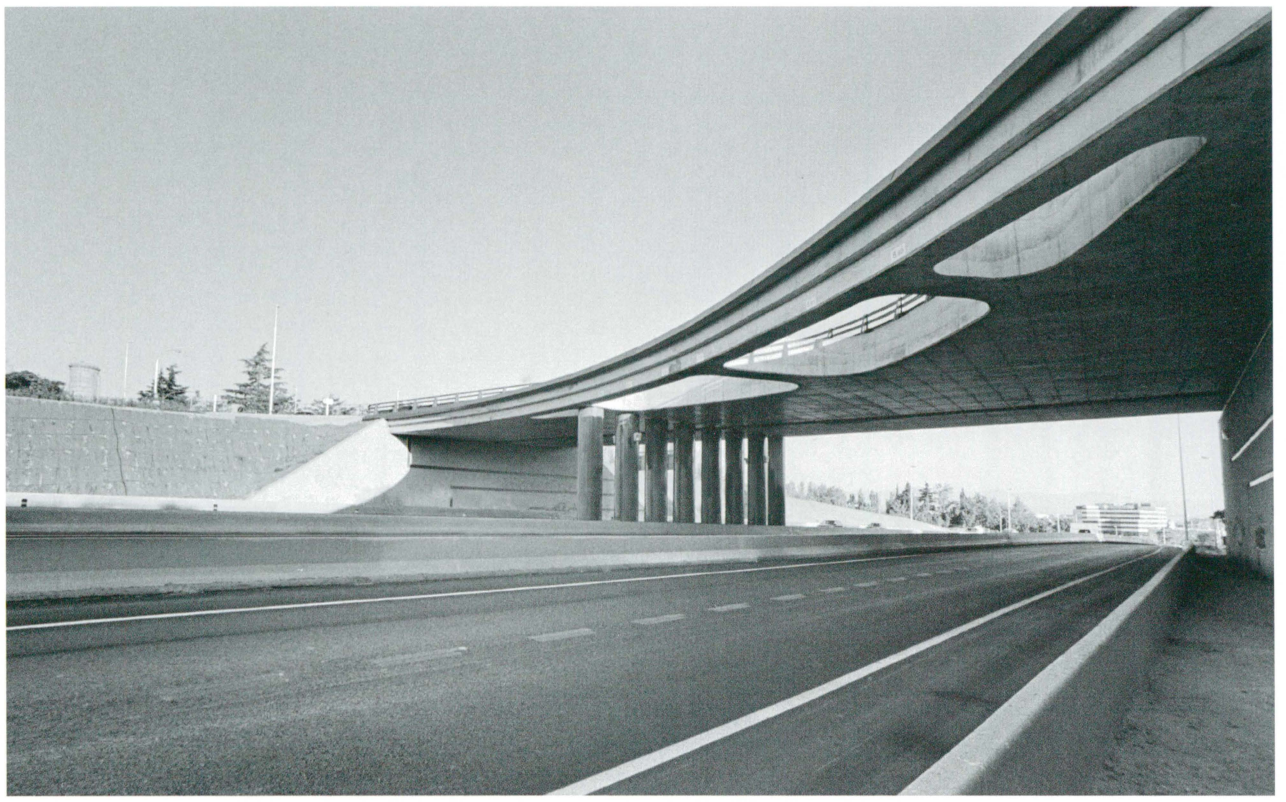
The pre-tensioning called for careful analysis due to the imbalance in spans, the great widening of the roadway towards the side with the greater span, the embedding of the deck in the abutments and the need to limit the horizontal deformations so as to avoid damaging the vault for the railway alongside the right-hand abutment.

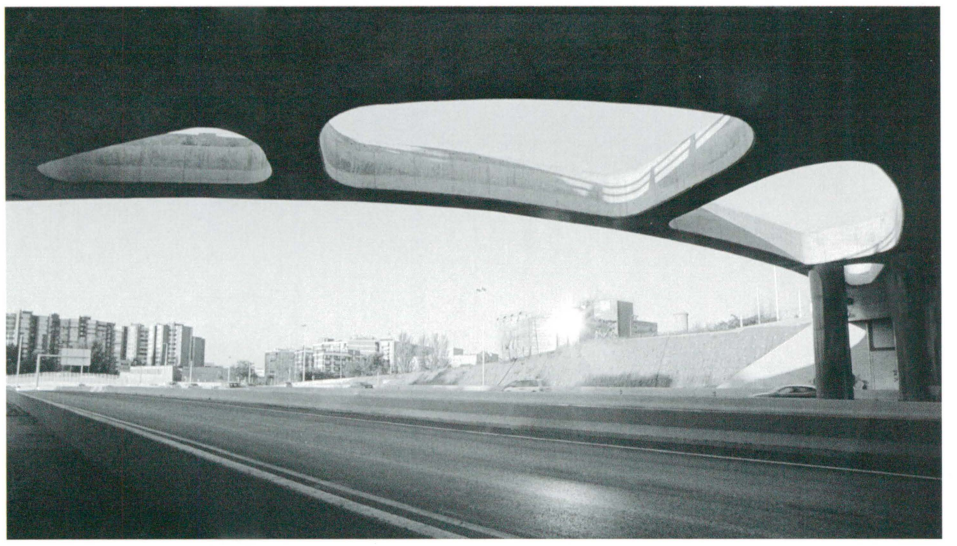
(Text by Peter Tanner & Juan Luis Bellod).

Credits: Construction project and technical assistance: Cesma Ingenieros. Constructor: OHL.

Overpass Herrera Oria over the M631 at Colmenar







Bridge over interchange at Vallecas
Tanner & Bellod, 1998

The Sierra de Guadalupe interchange at Vallecas enables a connection between the Suburban railway line and Metro Line 1. Outstanding among the work carried out is a composite structure which allows four railway tracks to pass over the circular gallery surrounding the interchange. The conditions of execution in phases, with stoppage and diversion of railway traffic, as well as the strict clearance which called for reduced depth, gave rise to the adoption of a solution with composite box girders connected at the bottom by transverse composite girders and a concrete slab to support the tracks. The top concrete slabs, supported respectively on the two intermediate box girders and on the end box girders, in this case with overhangs, act as the platform and waiting area for passengers. The composite box girders have constant depth and rectangular section and a double composite action was established in the area of the support on the piers by concreting the base of the metal box girder.

(Text by Peter Tanner & Juan Luis Bellod).

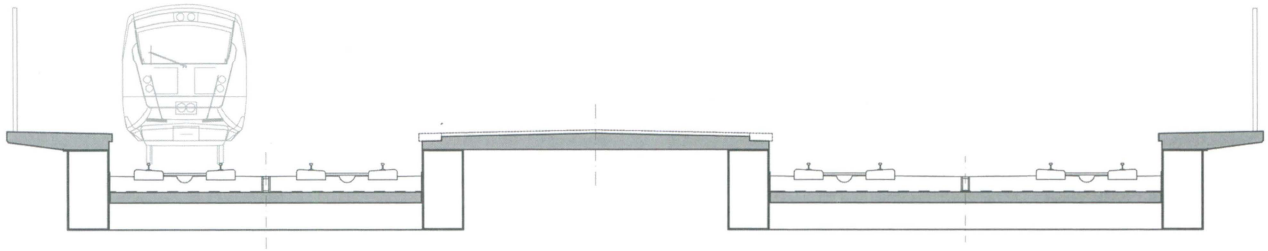
Credits: Construction project and technical assistance: Cesma Ingenieros. Constructor: Agromán - Auxini-ACS Joint Venture.



Sierra de Guadalupe interchange at Vallecas

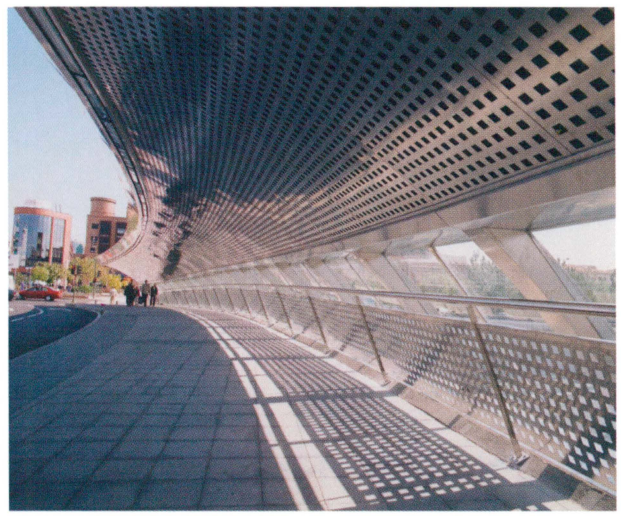








Ring Road Crossings



Ventas Bridge over the M-30
Manterola, 1997

The urban nature of the M-30 called for overpasses and underpasses and numerous footbridges. One of these was the Ventas Bridge (Manterola, 1997), with a novel type of roundabout bridge outlined by Manterola in the El Pilar Bridge in Zaragoza in 1992 and which was later to culminate in the magnificent Cizur Bridge in Pamplona in 2002.

The initial use of curves in plan in the El Pilar Bridge in Zaragoza is made more compact in the Ventas Bridge in Madrid, where the two curved bridges now merge into one. The layout pays great attention to pedestrians to create an urban space, with sheltered pavements and a new central upper arch, the only role of which is as a gigantic light fitting.

The curve in plan and the roof generate interesting problems for edge design. In a traditional type of bridge, the edge needs to be tapered to show the slenderness of the deck, but in a covered bridge the structure shows rotundity at the edge, That is combined with the greater presence of width than span (90 m compared to 60 m) resulting from the use of a curve in plan, which is projected upwards with the use of a free-standing arch above the work to house the lighting. All of this gives a bridge which is certainly atypical, the premises for which were later to be refined and developed in other later bridges by the same author, as significant as the Cizur roundabout, where the curved crossings are unified in a single disk, supported at four points [151:26].

M-45 overpasses over the N-II
Azcón, 2002

The project sought a solution to *present singularity in form and aesthetics in accordance with the significance of the site* for which reason it was decided to choose a *deck supported on piers with a triangular profile lightened in the centre, inspired by the El Diablo Bridge at Martorell, designed by J. A. Fernández Ordóñez, J. Martínez Calzón* [40:2].

The structure consists of two independent carriageways 18 m wide and 130 m long, with two lateral spans of 35m between the pier axes and the abutments. Each deck consists of two box girders in Corten steel of a trapezoidal shape, open at their upper face, at 1.50 m deep and with bases of 2.80 m at the bottom and 3.40 m at the top.

As each bridge has two box girders and two piers, the motif is repeated four times on each side and has much smaller dimensions than the memorable *inverted tetrapylon* of the pier for the Martorell bridge. As you pass under the bridge, the piers "fatten" by combining with the ones in front and behind, without being able to appreciate their volumetric richness which is reduced to a mere "motif" due to their small size and the repetition.







Vallecas expansion bridges over the M-45
Manterola, 2005

These are four composite bridges with a maximum span of 42 m and a width of 26 m over the M-45, made using a box girder with a curved lower face and large overhangs, supported on inclined piers in pre-tensioned concrete on piles. Bridges 1 and 3 are straight, while 2 and 4 are curved in plan view, with inclined piers following the design route opened by the El Pilar Bridge in Zaragoza, but with metal decks. These are, in reality, two bridges making up a roundabout with an internal radius of 60 m. They have four lanes plus a 6 m pavement, producing a total width of 26 m.

The central span of each is 42 m, set by the width of the M-45 trunk road, with variable compensation spans depending on the additional roads to be bridged, The new decks are made up of a box girder with inclined external webs, a central internal web and the curved lower face. The overhangs are made using I-profile ribs with the lower wing following the curvature of thecentral box girder. The depth of all the bridges is 1.90 m, including a slab 0.25 m thick. The curvature of the deck's lower face means that the bridges appear more slender [149].





M-40 crossings over the A1
Pantaleón, 1999

Connection from the M-40 to Las Tablas
Tanner & Bellod, 2007

For a long time, the most widely used structural solution for viaducts built over existing roads, with significant pier heights, decks with pronounced curvatures, marked skewing or spans greater than 50 m has been the composite box girder, although in recent years solutions in concrete, whether continuously prefabricated or made in situ using falsework, have presented strong competition. The refinement of classical composite solutions and in-depth analysis of the details of stiffening, welding, connection and slab concreting have enabled improvement of the competitiveness of composite bridges in the medium span range.

One example can be found in the connection from the M-40 to the urban development of Las Tablas in Madrid, where a significant viaduct of 288 m in length, with seven spans up to a maximum of 52 m, was built. The deck, at 14.8 m wide, was made using a single bicellular composite box girder of constant depth and with inclined webs. The piers are rectangular in section, with semicircular edges separated in form from the shaft core by a metal profile embedded in the concrete.

(Text by Peter Tanner & Juan Luis Bellod).

Credits: Construction project and technical support: Cesma Ingenieros. Constructor: San José-Vías y Construcciones Joint Venture.









M-30 footbridges

La Paz footbridge over the M-30
Manterola, 1976

This was the first cable-stayed work by Javier Manterola and served as the starting point for tackling such significant works years later as the Barrios de Luna Bridge (1983) which was to set the world record for cable-stayed bridges. The crossing had a span of 86 m and was resolved using two A-frame piers between which the deck is inserted, supporting dual pairs of cables which start out from a single point at each abutment [22:38].



Footbridge over the M-30 at the Calle Miguel Aracil
Ruiz and Ruiz of Gopegui, 2002

This replaced a footbridge made from prefabricated concrete girders with two spans to bridge the M-30 and the new service road at the left margin. It is a composite footbridge with spans of 6.0 - 45.0 - 9.0 m, with active vertical ties at the ends of the short spans. A procedure to dish the metal structure was used before concreting the compression slab, such that the release of the stress in the composite assembly generates indirect pre-tensioning in the concrete. The eventual aim of such a method is to use all the concrete's stiffness in the composite section, to achieve appropriate behaviour for the serviceability limit state due to vibrations which, according to the study carried out, is the most limiting.

Footbridge over the M-30 at the La Paloma junction
Tanner & Bellod, 2010

The La Paloma footbridge over Calle 30 provides the response to all the setting's determining factors and the functional requirements defined in the terms and conditions of the competition called by Madrid City Council, including the requirement to provide users with comfort and protection from the sun. In plan view, the layout is defined by lateral spans of 43 m which are straight for the majority of their length and a curved central section with a radius of 68 m, made up of two spans of 52 m each. The deck is continuous in four spans, with a total length of 190 m. The transverse section of the footbridge is C-shaped and both the inclined web and the flanges are made up of trusses, with the diagonals and the cords formed by structural steel box sections. It has a useful depth of 3.9 m and the width of the upper and lower flanges are 4.0 m and 5.5 m respectively. Supported on the latter is the 0.23-m thick composite slab, on which pedestrians and cyclists travel. The Y-shaped piers are made up of two inclined diagonal trusses which become a single shaft of variable section until its embedding in the pile cap.

(Text by Peter Tanner & Juan Luis Bellod).

Credits: Construction design: Cesma Ingenieros. Constructor: Intersa.



THE SYSTEM OF FOOTBRIDGES IN MADRID-RÍO

The establishment of bridges over the river Manzanares takes place as part of an overall strategy, i.e. as a whole in which each element resolves isolated problems detected in its immediate neighbourhood, but also in turn forms a part of a comprehensive system for transverse connection according to the relationship between the city and the river. The units in this set differ in nature: restored or recycled bridges and dams, existing bridges for vehicles adapted to the new system of cycle and pedestrian traffic, exceptional bridges that represent milestones in the river's course, functional footbridges located at nodes where crossing traffic is at its maximum and bridges with large spans linking the route of the park to lands outside the city to the north and south, making the project's main territorial aspiration a reality.

Outstanding among the existing bridges is the operation carried out on the seven dams which have been converted into footbridges by means of comprehensive restoration and the inclusion of an accessible wooden deck. Secondly within this series, the recycling of the M-30 vehicular bridge crossing the river south of Segovia Bridge needs to be highlighted. This has been converted to a bridge for cyclists and pedestrians incorporating a bank planted with pine trees. Among the unusual bridges, the Y-shaped bridge built with metal profile boxes is worth mentioning, evoking the language of the railway bridges of the 19th century over forested gorges, and the twin concrete bridges leading to the Abattoir complex, designed as crossing elements which are also capable of configuring a space to which they lead, like pavilions that loom over the river, but really belong to the park.

(Text by Ginés Garrido & Francisco Burgos. See Madrid-Río on page 17).



Almuñécar footbridge

Manufactured in a single piece from carbon fibre to bridge a span of somewhat over 40 metres. It is located over the only stretch of the watercourse without a concrete side wall. Its final design obeys the capabilities of the material from which it is made, extremely light and strong.

Restoration of dams

The seven dams that control the river as it passes through the city have been restored and put to use in the new system of river crossings. Their mechanisms and locks have been repaired and an accessible wooden deck has been incorporated, along with a fish ladder to promote the continuity of aquatic fauna throughout the river.



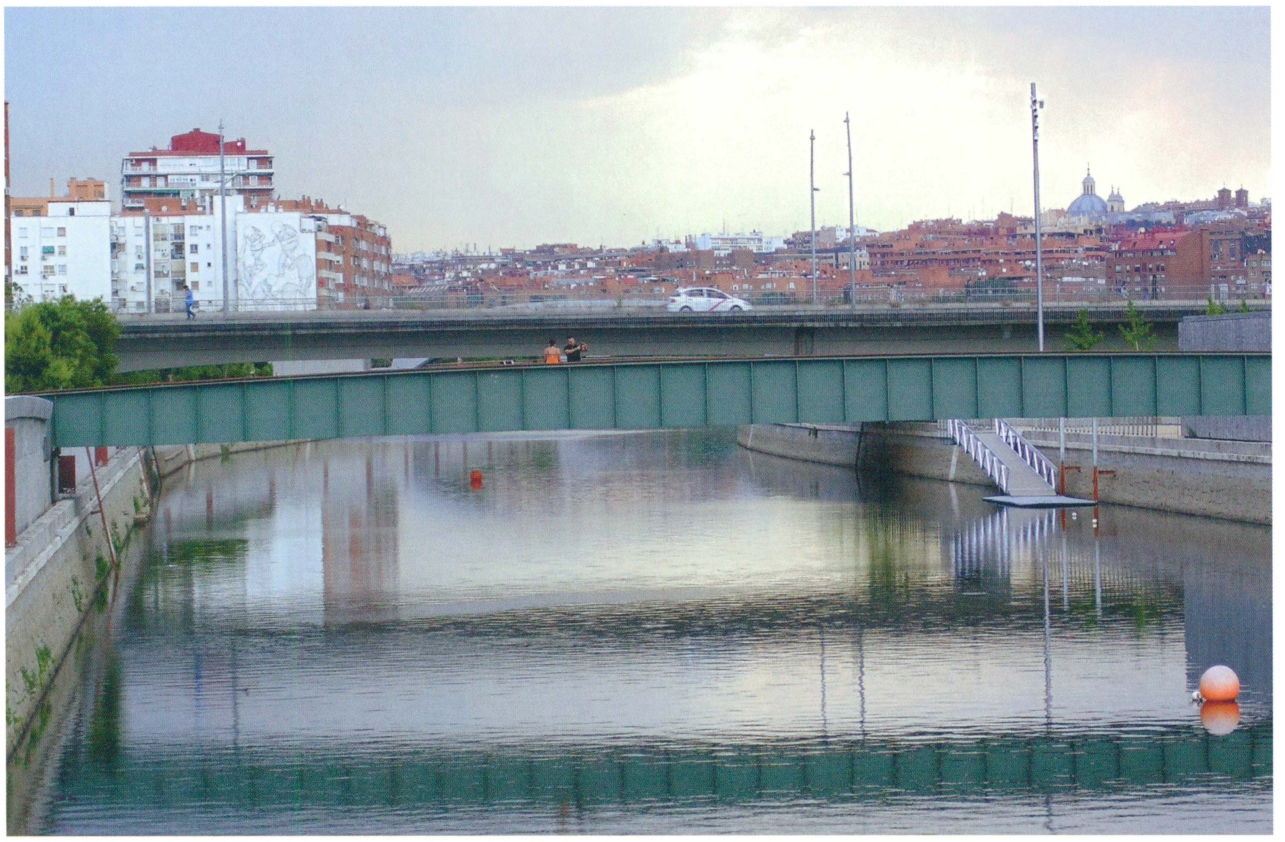


Oblicuo Bridge

This contemporary M-30 road structure, the Oblicuo, or oblique, Bridge has been recycled into the Madrid-Río park to incorporate it into the tree-lined promenade of the Salón de Pinos as a privileged crossing over which pedestrians, cyclists and the trees pass from one bank to the other. The lightweighted slab that made up the post-tensioned concrete deck was cut and braced, reinforcing it to support the loads due to its new use.







La Princesa footbridge

The depth necessary to make the footbridge work is incorporated into the railings which, in reality, form a pair of solid-webbed girders and vertical stiffeners. The language of the footbridge is intentionally sober.

Sheet footbridges

These are twin bridges built with a 15 cm self-levelling concrete sheet forming a surface with double curvature from which the deck hangs. They were devised as two pavilions entered to cross the river. Their vaults are decorated with a mosaic created by the artist Daniel Canogar.

Y-shaped or Principado de Andorra footbridge
Tanner & Bellod, 2011

The footbridge was formulated as a metal lattice-beam structure with a form in plan like a letter "Y", the arms of which have a truncated cone-shaped volume. Two of its arms rest on the left bank and the other on the right bank. The west arm and the north-east arm make up the footbridge's main trunk, with the south-east arm supporting approximately one third that of the main trunk. At the point where the arms join, there is an opening in the lateral lattice as a lookout over the river. There is also a balcony projecting from the footbridge that forms another point of discontinuity in the side lattice.

The lattices are made up of four main cords with T sections and diagonals with an I section. These elements are also used in the frames or diaphragms both for entry to the bridge and at the discontinuities in the lattices. An auxiliary structure was designed on top of the lower cords to support the flooring. This is made up of I profiles on which tubular stainless steel laths are supported, forming the base for the wooden plank flooring.

(Text by Peter Tanner & Juan Luis Bellod).

Credits: Construction project and technical assistance: Cesma Ingenieros. Architecture: MRIO Arquitectura. Constructor: Dragados.



Beam footbridges in Madrid

Although the footbridge on the street named Sinesio Delgado in the Saconia district of Madrid is cable stayed, the homogeneity of the design with the footbridge located in the Cuña Verde Park and the limited importance of the tying as against the robust presence of the metal girder suggest that they be dealt with together as closer to the girder type than the stayed type. This is a design problem which is very particular to footbridges, as discussed in the panel below.

FOOTBRIDGE DESIGN

Jiménez Cañas

The first element to be considered in designing a footbridge is its scale. The condition of being used by people limits their length to the minimum to get over the problem. The transverse dimension is also relevant: if it is excessively narrow, it causes psychological discomfort, as well as complicating significant aspects of its form. If it is excessively wide, care will need to be taken with the relationships with the other elements to avoid making it inhospitable.

As the additional load in use is less than or comparable to the structure's own weight and the permanent loads, significant distances between supports and slender compositions can be considered. It also offers the chance for careful consideration of the structural materials to be used, avoiding the heaviest for this. As regards longitudinal and transverse geometries, it appears logical to propose structural solutions with a lower deck to avoid increases in structural depth and ramp length, which could exceed 70 m.

Cable-stayed or closed box girder solutions do not give rise to significant problems and offer good options for expression in form. If a section with an open box girder is selected, the problem of lateral buckling of the compressed cord can be resolved by increasing the transverse inertia of the upper edge of the structural girder which, additionally, usually coincides with the rail and could be considered as the handrail. The coexistence of the structure and the railing offers the added advantage of reducing the frontality of the ensemble.

The access ramps are, without doubt, the perverse elements in these bridges. Excessive length, zigzag layouts, unfortunate support sequences and difficult to resolve profile and elevation inconvenience pedestrians and do not encourage them to use it. Layouts with circular or pseudo-circular ramps appearing close to the crossing point minimise this negative effect and open up interesting expressive possibilities which are worthy of being explored. The most satisfactory thing is the ability to avoid ramps, either due to favourable topographic arrangements or subtle work in accommodating the footbridge into its surroundings.

Other elements such as lighting, the characteristics of the surface for walking on, the opacity or otherwise of the structure, the specific design of the transverse section and the piers, etc. can lead to hideous planned results. Fortunately there are brilliant examples of footbridges in which all or nearly all of these aspects are perfectly resolved, but we also have to acknowledge that simply awful examples exist too.

(Summary of text by Jesús Jiménez Cañas [13:158]).



Footbridge on the Calle Sinesio Delgado, Madrid (Jiménez Cañas, 2008)



Footbridge in Madrid's Cuña Verde Park (Jiménez Cañas, 2008)

The continual works to expand and improve the accesses to Madrid and the rest of the Community's settlements have led to the construction of numerous interesting bridges and overpasses. Among others, it is worth highlighting the San Fernando bridges over the A2 and the most recent bridges for the Puerta de Hierro junction, El Barrial and Las Rozas on the A6 and the M-603 bridge over the M-607 on the Colmenar motorway. The start of the new attitude to ennobling current bridge design lies, undoubtedly, in Carlos Fernández Casado's overpasses for the La Coruña road, which has always been Madrid's most pampered.

Bridges on access roads

These are a series of five bridges or flyovers crossing the A6, composed with different solutions but showing some characteristics in common. They are all resolved with portals with triangular cells formed by inclined columns which repeat in the transverse direction, giving clear unity of character. In some of these the front or rear columns of the cells also incline transversely, forming a zigzag.

The road had been started without thinking about the flyovers or underpasses, so it was not possible to use prefabrication because of the dimensional diversity of the bridges to be built. Two points were maintained in all of them, though: strict height and elimination of supports. In addition, finishing with flat surfaces was favoured instead of ribs as was the use of cylindrical columns, the thicknesses of which do not change depending on the angle of view ++++:855].

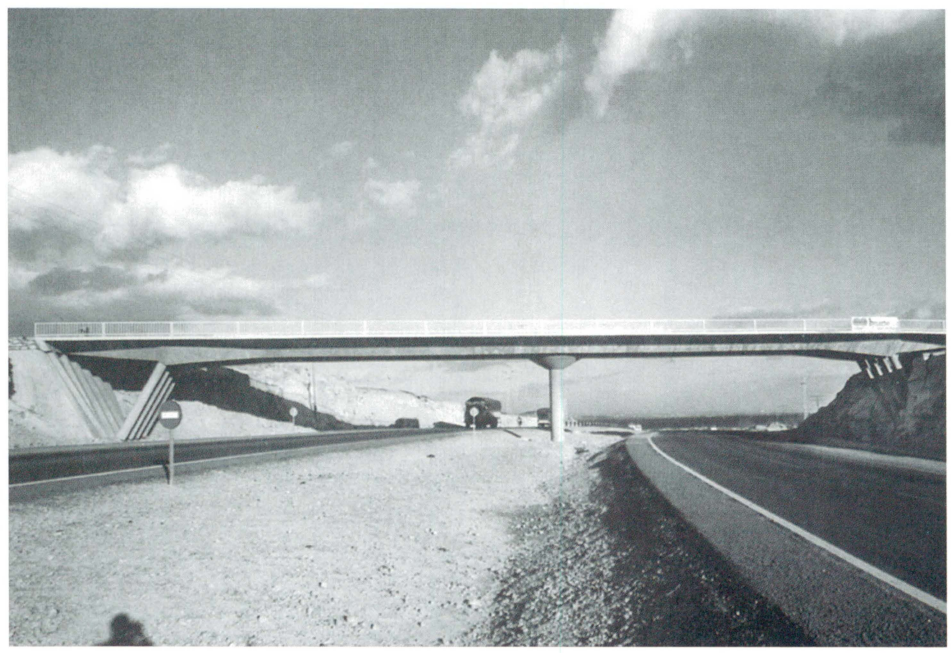
The bridge at Hoyo de Manzanares has a supplementary central pier in the central reservation, with a truncated cone shaped shaft and capital, to divide it into two 30 m spans. The one at Torrelodones shows the deck's variable depth more clearly, achieving a span of 40 m. That at Las Navatas splits into two independent crossings of 25 and 19 m as the carriageways of the motorway separate to go around a central hillock. The one at Villalba has a 50 m span and that at Navacerrada 36 m. Several of them have been profoundly affected by the widening of the motorway carried out in 2007.



La Navata bridges over the A6



Bridge over the A6 La Coruña road at Torrelodones
Fernández Casado, Fernández Troyano, 1968



Bridge over the A6 road at Hoyo de Manzanares

Twin bridges at San Fernando in Madrid over the N-II road
Fernández Ordóñez, Martínez Calzón, 1982

These use mixed sections in the piers and Corten steel in the imposts and railings, achieving full integration of the two materials in the whole bridge.



Puerta de Hierro bridges
Corres, 2003

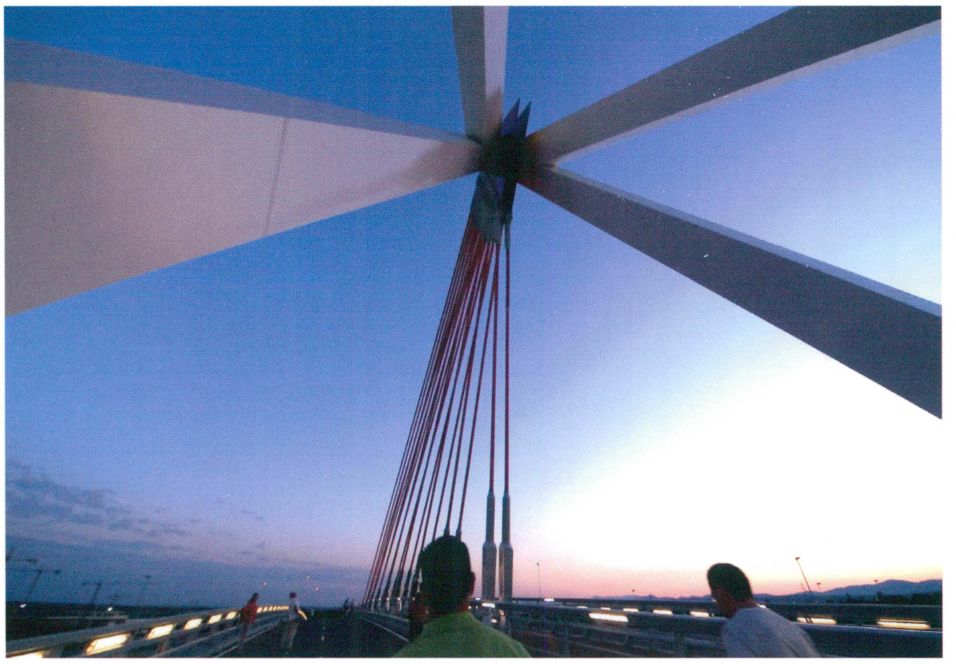
Two parallel structures 265 and 413 m long over the M-30 and A6 roads at Madrid's Puerta de Hierro junction, with spans of around 25 m which reach 40 m over the A6, resolved using 1.25 m deep metal box girders with concrete slab.





El Barrial Bridge at Aravaca, Madrid
Arenas, 1999

A pair of cable-stayed metal arches with intermediate decks, supported on triangular concrete cells, with a clean white image on the La Coruña motorway.



Las Rozas cable-stayed bridge over the A6
Arenas, 2006

It crosses the Coruña motorway with a very aggressive design, where the pier plays the leading role. It is composed of four great converging bars that give rise to a tetrahedron leaning over the motorway, with a metal triangle from which the cables stem that descend to the deck axis. The anchoring is carried out by the rear bars of the pier, which plays the double role of pier and anchor, operating as a triangular cell. The red cables over the white metal bars of the pier emphasise the incisive nature of the bridge [33].

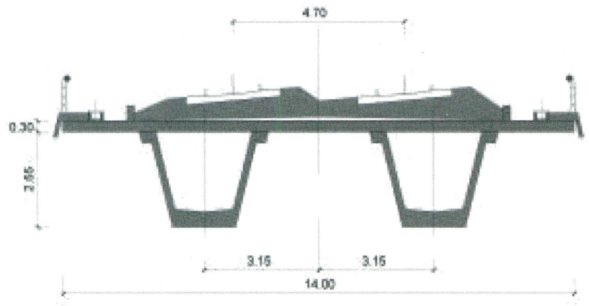


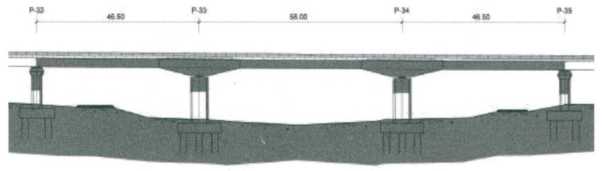
M-603 road over the M-607 highway at Colmenar Viejo
Rui-Wamba, 1986

Given the short period available for the work, it was resolved using two composite girders with inclined webs mounted with mobile cranes and slab concreted in situ with temporary shoring of the box [210:76].





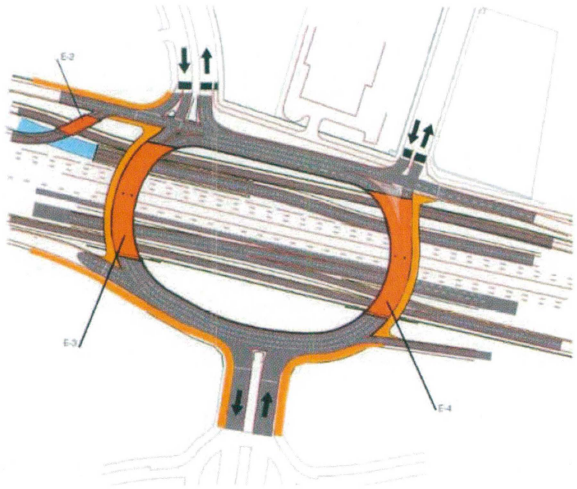




Madrid-Barcelona High-Speed Line viaduct over the river Jarama
Millanes, 2003

The viaduct over the river Jarama is made up of a series of isostatic spans of 35 m and to be able to bridge the course of the river Jarama, the need to increase the dimension of the central span to 58 m was raised. It does this with a continuous hyperstatic stretch of 3 spans of 46.5 m + 58 m + 46 5 m between piers P-32 and P-35. The rest of the spans are made with decks composed of two pre-tensioned prefabricated U-shaped beams with a depth of 2.55 m, separated by 6.30 m between axes and an upper compression slab 0.30 m thick.

To give continuity to the total depth of 2.85m, it was proposed to make the continuous stretch using a prefabricated section similar to that of the rest of the spans, joined to quadrants executed in situ on the two central piers, with a variable depth increasing from 2.85 to 5.0 m on top of the piers [166].





Overpasses over the A1 at Sanchinarro and Las Tablas
Corres, 2005

Within the remodelling works for the service roads on the A-1 Highway between the M-30 and M-40 and its accesses to the new Sanchinarro and Las Tablas urban development plans, the existing bridge over the A-1 (the Renault Bridge) was demolished and replaced by two bridges of semicircular form in plan (Structures 3 and 4), forming an elevated roundabout over the A-1, with four lanes in each direction and their corresponding pavements.

The structural arrangement selected was the continuous beam with two spans and constant depth, with a pier in the central reservation of the A-1. To minimise effects on the traffic during construction, both bridges were designed with composite decks, with the metal beam being laid using cranes on temporary supports, without the need for falsework. These are two composite structures made up of three metal box girders with spans of around 44 m with a reinforced concrete slab. The plan view does not show a single alignment, but rather is composed of several tangential circular alignments. The deck width for each of the structures is 21.50 m [73].

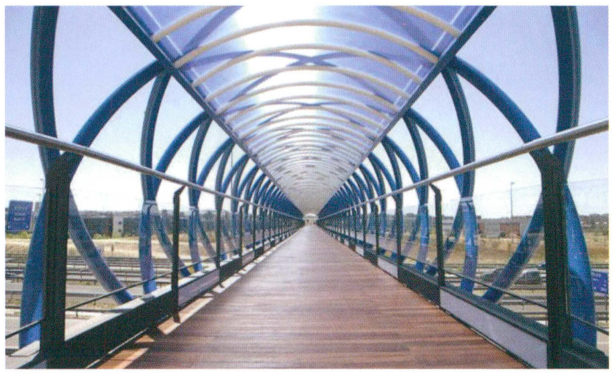
Other footbridges



Cable-stayed footbridge on the access to Barajas Airport
Pérez-Fadón, 1990

This cable-stayed footbridge crosses the new access road to Madrid Barajas Airport. It was built to provide a connection between two quarters of the Barajas district which had been cut off from each other with the construction of the new highway. The footbridge is 58.2 m long, with a main span of 45.5 m with an asymmetric design, as it is supported by cables from a single 25-m high tower.

The ties are arranged in a central plane on the main span and the guys split to the sides. The three ties and the six guys (three in each plane) are positioned in the form of a semi-harp [191].



Móstoles Technological Helicoidal Composite footbridge
Pérez-Fadón, 2008

The footbridge, approximately 95 metres in length, is made up of four spans, where the two central spans are of 35 metres, under which the central carriageways and service roads of the A5 run, and the two end spans are 12.64 m. The pedestrian platform was designed with a free width between railings of 2.5 m.

The structure was proposed as a tubular spatial truss in steel configured by the interlacing of four helicoids in two directions made up of tubes of 139.7 mm in diameter and four continuous longitudinal tubes of 193.7 mm in diameter. The slab was made in reinforced concrete with folded sheet lost formwork. The piers are vertical shafts with a variable diameter circular cross section in steel, filled with concrete.

Given that curving a tube according to a helicoidal directrix was mechanically impossible, as it is only possible to curve following flat directrixes, an arc of a circle was fitted to individualise the directrix of each of the eight helicoids, the plane of which was adjusted by means of breaks at the intersections to fit the theoretical helicoidal directrix as well as possible. Therefore, each curved tube sector between intersections is an arc of a circle with a 2.766 m radius which is repeated throughout the structure.

So, the transverse section is made up of four continuous longitudinal tubes arranged in the theoretical corners of a square with sides of 2.75 m and the four trusses made up of curved tubes with a helicoidal form intersecting with the longitudinal tubes in the corners of this theoretical square every quarter pitch of the helicoid [190].



Footbridge over the M-506 Fuenlabrada to Móstoles highway
Pérez-Fadón, 2005

This is located over the M-506 Fuenlabrada to Móstoles highway in Madrid for pedestrian access to a new urban development in Fuenlabrada. Alongside the current town is a shopping centre and various leisure facilities, conditioning the footbridge's location. Both aesthetic solutions and an exhaustive study of the footbridge's stiffness to avoid resonance phenomena due to vibrations influenced the final design.

The structure has a 52.5-m long deck, of which 41 m correspond to the main span. It is 3 m wide, supported by means of stays anchored to a single tower leaning backwards at an angle of 70° with respect to the horizontal. The stays are anchored to the outside part of the deck by means of corbels coinciding with struts. The deck has two longitudinal metal girders in box form on which a 13 cm concrete slab is built [192].



Footbridge in Butarque Park
Tanner & Bellod, 2010

Restoration of the continuity of the Arroyo Butarque Park was achieved with a footbridge for pedestrians and cyclists. The layout was conditioned by the M-411 which cuts through the park and the viaduct on the R-5 radial motorway for access to Madrid, which crosses the road at the same point. The footbridge spans the four carriageways of the road from the La Fortuna neighbourhood, then continues by twisting its way between the viaduct of prefabricated beams until it sets down in the Park.

The deck is continuous in five spans of 21 - 42 - 42 - 42 and 18 m and a total of 165 m long. The bends snaking one way then the other which characterise its layout in plan have a typical radius of 58 m. The girder of the composite footbridge is made up of a triangular section open metal box, 3 m wide at its upper face and 1.05 m deep, connected to the composite slab made from ribbed plate and lightweight concrete.

The piers, made up of variable section reinforced concrete shafts, rhombus-shaped with the vertices truncated, are arranged at the mid-points of the layout of the arches in plan view. They are embedded in the deck's composite diaphragms such that the lintel's moments of torsion are converted into bending moments in the piers, and these are partially compensated for by the inclination of the shafts.

Credits: Construction project and technical support: Cesma Ingenieros. Constructor: Isolux Corsán.



Footbridge in Butarque Park at Leganés



6 | Regulating Resource Flows

Each city is a living entity thanks to its neighbouring territory, which is obliged to provide and receive all it needs or rejects. It receives resources and expels wastes, which are no more than materials or energy named as such precisely due to their role in the city. Water, air, foods, fuels and energy enter the city with certain characteristics and leave it with very different ones. That generates easements and needs that structure and condition the territory, which need to be met with works, facilities and a variety of management systems.

Water structure

Water has traditionally been the first thing to be sought outside. The great concentration of population in the Madrid Urban Area leads to high consumption which unbalances the natural water cycle of its nearest rivers. The focal point of consumption generates such a need for water and discharges such a quantity of waste that it structures the province around those relationships of water production, consumption and discharge.

Madrid exports its pressure to its own region and outside of it, obliging each portion of the territory to perform a water role depending on the place occupied with respect to Madrid. This also extends to restrictions on uses or the worsening of local resources in each zone, which are not desirable but are necessary for the city to work.

Four zones

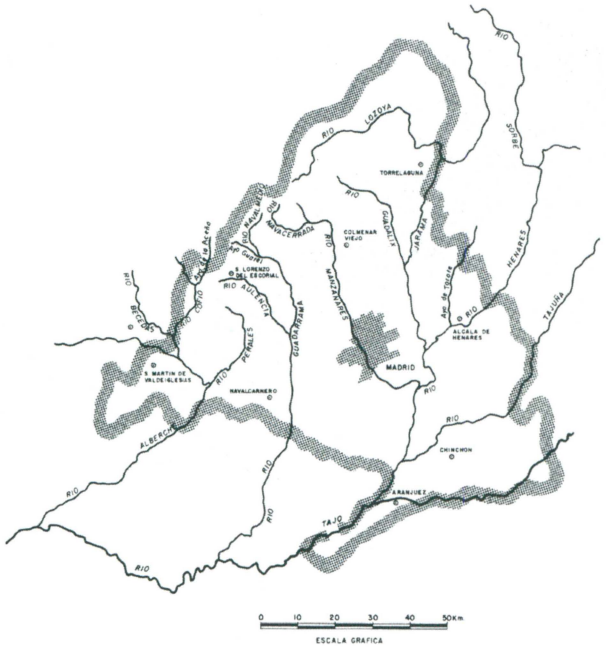
In Madrid's water planning prepared in 1983, four zones of influence were determined:

— A strip producing fresh water, made up of the headwaters of all the tributaries of the river Tajo, the waters of which are diverted towards Madrid and the surrounding settlements. In this, land uses are limited to guaranteeing water quality.

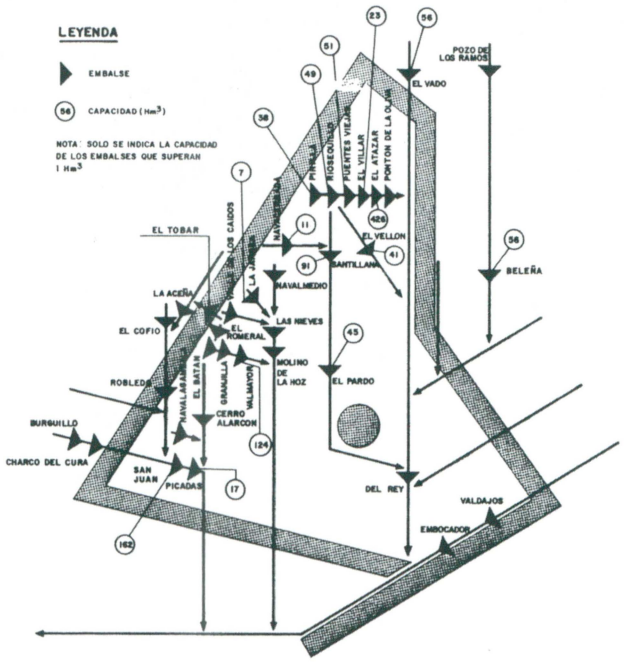
— A zone deprived of water which, without producing for others, has reduced flows running through it, having been removed from upstream through pipes. The self-purification capacity of these stretches is minimal and there are serious circulation problems at low water levels.

— A consuming focus, made up of the capital and the municipalities in the Urban Area, where the resource is used massively and is returned to the system totally spoiled.

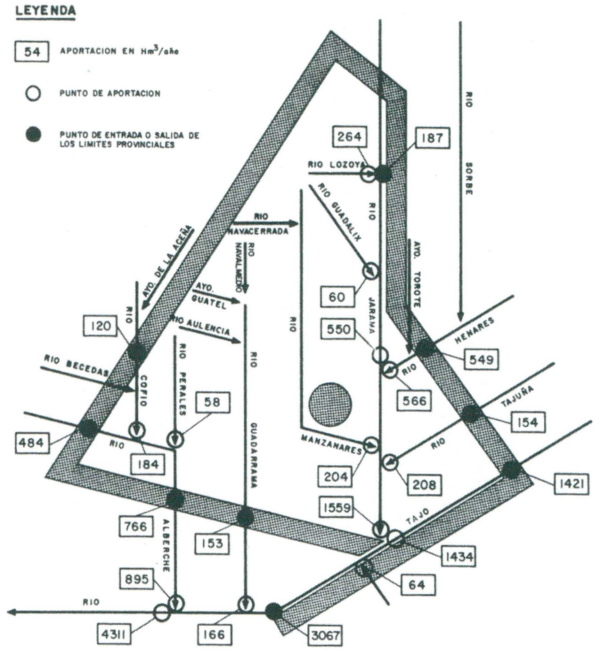
— A receiving zone, located downstream of the consuming focus, which suffers from its discharges of dirty water and wastes. Recreational options and use of riversides are radically negated [5:19].



Province of Madrid river network, main rivers



Dams and reservoirs



Natural regime supplies

Water footprint

The great population concentration in the Madrid urban area generates even greater tension in the behaviour of water resources. Until now, the effect of the system of supply on the natural surface water cycle has been studied in depth and the underground water cycle rather less. This concentrated high consumption makes reservoirs for storage and canals for transporting the water necessary, regularly and independently of the spatial and seasonal oscillations due to natural rhythms.

In 2009, a careful study by the Canal de Isabel II company, coordinated by José Manuel Naredo, showed its greater repercussions when agriculture and industrial products are taken into account. Madrid consumes water directly from the supply system, but it also does so through agricultural and industrial products produced inside and outside the urban region.

Blue and green water

Start by distinguishing two classes of water: *blue* and *green*. Precipitation comes into contact with the earth and goes on to be stored in the form of green water, in the soil and vegetation, or to flow in the form of blue water, forming part of watercourses and natural (lakes or aquifers) or artificial (reservoirs) retention, while it is progressively lost by evapotranspiration [175:118].

The large mean annual volume of water stored in reservoirs indicates the importance of water stored in reservoirs compared to green water stored in the soil and vegetation. But, in addition to taking the water contained in the soil and vegetation into account, added to the blue water from the region of the Comunidad de Madrid itself which is diverted for irrigation and storage are supplies diverted from outside the region. That volume represents somewhat more than half the water supplied for irrigation and close to one third of that provided for urban and industrial supplies.

CURRENT SUMMARY OF "COLOURS OF WATER" IN MADRID, MEAN YEAR

Component	hm^3
(1) Precipitation	4,195
(2) External supplies	1,267
(3) Real evapotranspiration that would be generated in the Region of Madrid with soils and vegetation in natural climax state	3,991
(4) Blue water that would be generated in the natural state = (1) – (3)	204
(5) Increase in blue water due to loss of absorption capacity and "sealing" of soils	495
(6) Estimation of blue water really generated in the Region of Madrid = (4) + (5)	699
(7) Evaporation in reservoirs	57
(8) Total blue water available in the Region of Madrid = (2) + (6) – (7)	1,909
(9) Evapotranspiration induced by the handling and use of water over the last five years	302
(9) Estimate of water leaving the Region of Madrid region	1,607
Pro memoria:	
— Green water stock (approximate annual mean)	700
— Reservoir stock (approximate net annual mean)	500

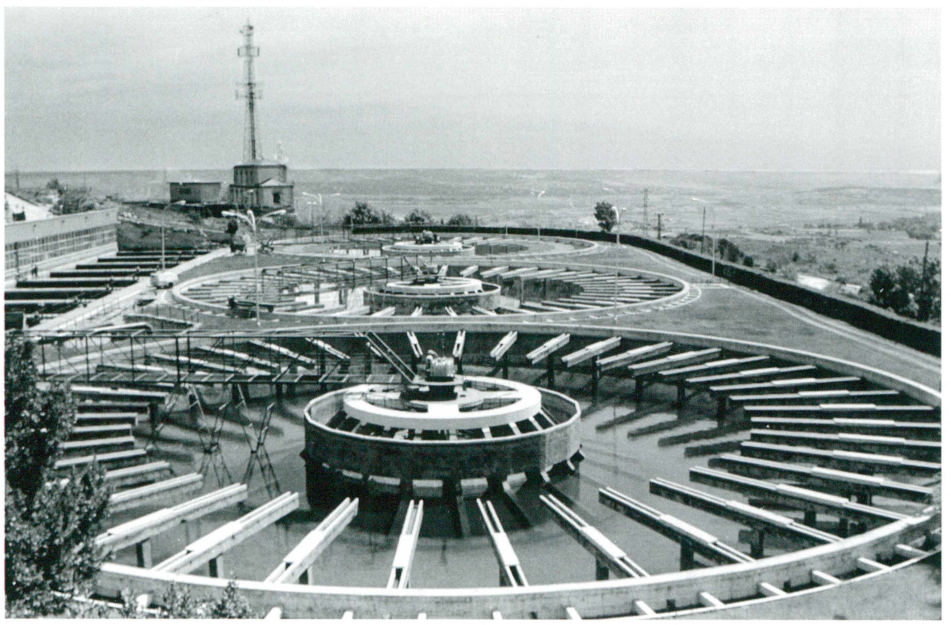
Source: Canal de Isabel II [175:table 22].

Regulation and consumption

The above table shows the order of magnitude of the main headings making up the blue water and green water in the Region of Madrid region. The flow of blue water is subject to annual seasonal variations and climatic variation from year to year, hence maintaining the average requires the complementing of natural regulation with



Entry of water to the lower tank at Plaza de Castilla



Torrelaguna water-treatment works [Photo: Antonio Sarabia]



Manzanares River at the overflow from the Santillana dam [Photo: Antonio Sarabia]

reservoirs. Seasonal (lakes, reservoirs and aquifers) and spatial (rivers and canals) regulation are key elements in Madrid's system for attending to urban, environmental, agricultural and industrial uses.

The stock of green water bound to the soil in the Region of Madrid in spring (917 hm^3) represents almost ten times (9.2 times) the stock of green water bound to vegetation (around 100 hm^3). Green water in crops barely reaches 15 hm^3/year. The stock of water retained artificially in reservoirs occupies a significant place in the system [175:65].

Intake and discharge pressure

The above shows the significant pressure on the region exercised by the intake of resources, as nearly 30% of the blue water received in the region annually is diverted towards the usage system. The pressure from discharges is even greater, as added to the diversion of its own water are the external supplies which go on to swell the discharges. The immense river of discharges deriving from uses increases by 65% the total flow of blue water running through the surface and underground watercourses, deteriorating their quality. Still in 2009, current treatment systems do not manage to return the water to its original quality, with the most difficult to clean pollutants persisting.

As a result of the above, the mere 204 cubic hectometres per year of blue water the Region of Madrid would have generated in natural climax state have been converted into 1,607 cubic hectometres per year of grey and blue water generated by erosion and human intervention, as summarised in the following table [175:118].

BLUE AND GREEN WATER IN THE REGION OF MADRID IN A MEAN YEAR (hm^3)

(P) Precipitation 4.195 (Equation: ES + P = ET + RI)				
	Retained blue water (mean vol.) 500	Green water ~ 700	ET (1) 3,553 ET (2) 302	Total ET (1) + (2) = 3,855
(ES) External supplies 1,267: (to Urban 195) (to Irrigation 186)	Blue water 1,909	Diverted irrigation 327 Diverted urban 609		Reused 6
Blue water 973		Grey water 634		(RI) Final run-off and infiltration 1,607

ET (1): Real spontaneous evapotranspiration from the soil and natural vegetation and from unirrigated crops.

ET (2): Evapotranspiration induced by uses; including consumption by evapotranspiration from irrigation, as the consumptive part of urban-industrial use, like the real spontaneous water from the soil and natural vegetation and from unirrigated crops.

Grey water: Includes both urban and industrial discharges and agricultural leachates.

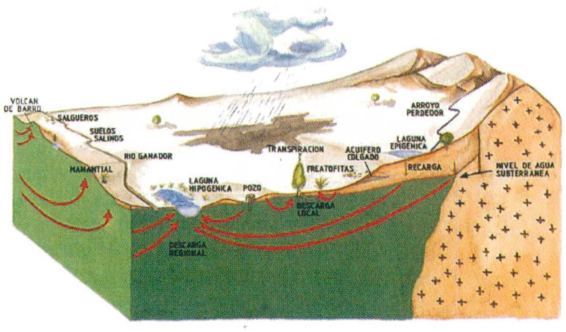
Mean flows over the last 14 years and mean diverted water over the last 5 years.

Source: Canal de Isabel II [175:fig. 21] .

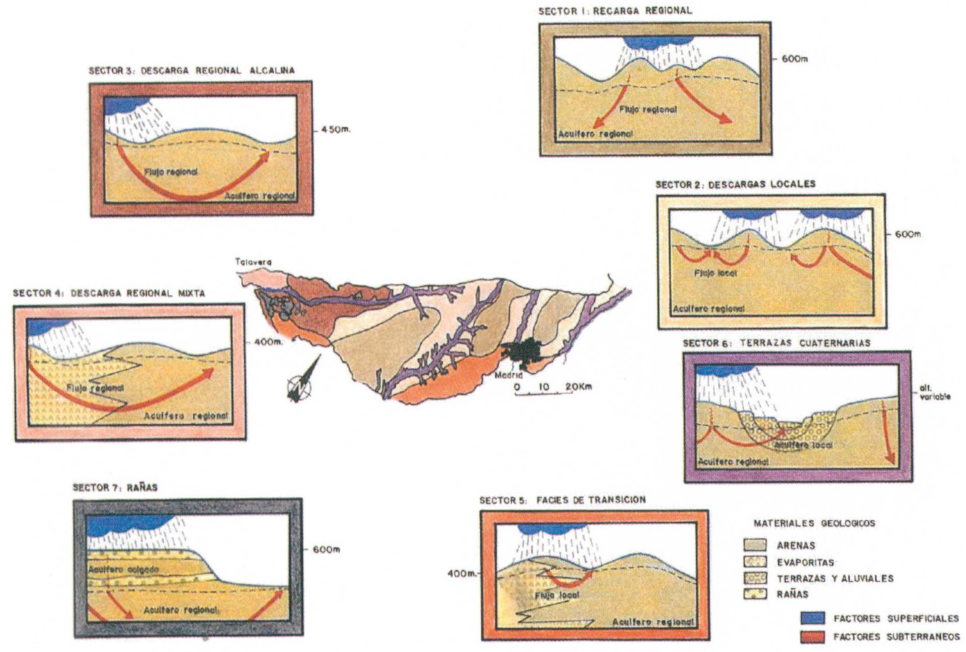
The matter of underground water

The water footprint takes surface and underground water into account, but the role of the latter in Madrid's supply has not received similar consideration. From olden times the use of underground water has constituted one of the most controversial subjects in supplying Madrid. Defenders of the environment were led by hydrogeologists' eagerness to give greater relevance to this manifestation of the resource compared to the "indiscriminate use of concrete" by engineers.

In the judicious use of such an important resource, the contribution of the ecologist Fernando González Bernáldez was definitive. Without going into the capacity or overuse of the aquifers, the professor focused on the operation of flows of underground water and showed their importance to the conservation of Madrid's wetlands



Interaction between underground and surface water



[123]. In a very precise and didactic way, he explained the nomadic nature of underground water and how its extraction would interrupt the flows feeding springs and wetlands.

Until that time, the discussion had focused on the excessive attention paid by water engineers to surface resources, ignoring the existence of underground water. They attributed absolute scorn for rivers to those professionals, accusing them of distorting their natural operation and ignoring a resource that was there and easy to exploit. Writings about the subject multiplied exponentially and would constitute a bibliography that it is impossible to include here and, as González Bernáldez showed, it would be of little use[1].

The Manzanares river basin

Although Madrid's greatest influence is noticeable directly in the flows of the river Lozoya and the upper Jarama, it is appropriate to pay some attention to the water of the city's own river. The upper Manzanares river basin runs into the Santillana reservoir. The significant summer settlements which drain into the river and its tributary streams, when not to the reservoir itself, already damage the quality of the water retained.

The diagnosis of 1985 was conclusive. The presence of industrial discharges in the zone was not considered significant, but the clean water at the dam, relatively self-purified in the vessel, then receives wastes from Colmenar Viejo. There, added to its domestic discharges are those from the most important industrial abattoir in the Region of Madrid, as well as toxins from tanneries and chemical and photographic industries.

El Pardo reservoir and the urban zone

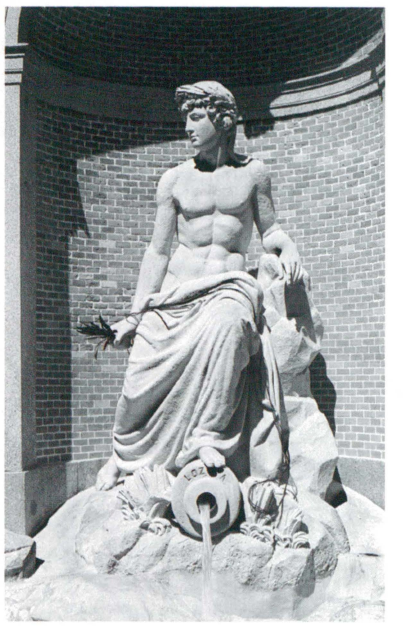
The water reaches the El Pardo reservoir in this condition, at the gates of the municipality of Madrid. In turn, the Trofa brook, a tributary of the river Manzanares in its middle stretch, receives significant discharges from villages and urban developments that cause serious pollution situations and ruled out the possibility of using the Los Peñascales reservoir for drinking water.

The Manzanares reaches the Madrid municipality with its very limited flows, regulated by the El Pardo dam. The discharges from the northern zone of the capital, together with those contributed by its tributaries the Butarque and Culebro, greatly reduced the quality of the water flowing through the urban stretch. The flow of fresh water was very little to dilute the waste water and if the discharges had been collected in sewers to carry them downstream of the city, the river would always be dry.

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[1] The most prolific author was, undoubtedly, the Civil Engineer and Hydrogeographer Ramón Llamas Madurga, but he abandoned the matter after the appearance of the study on the wetlands.



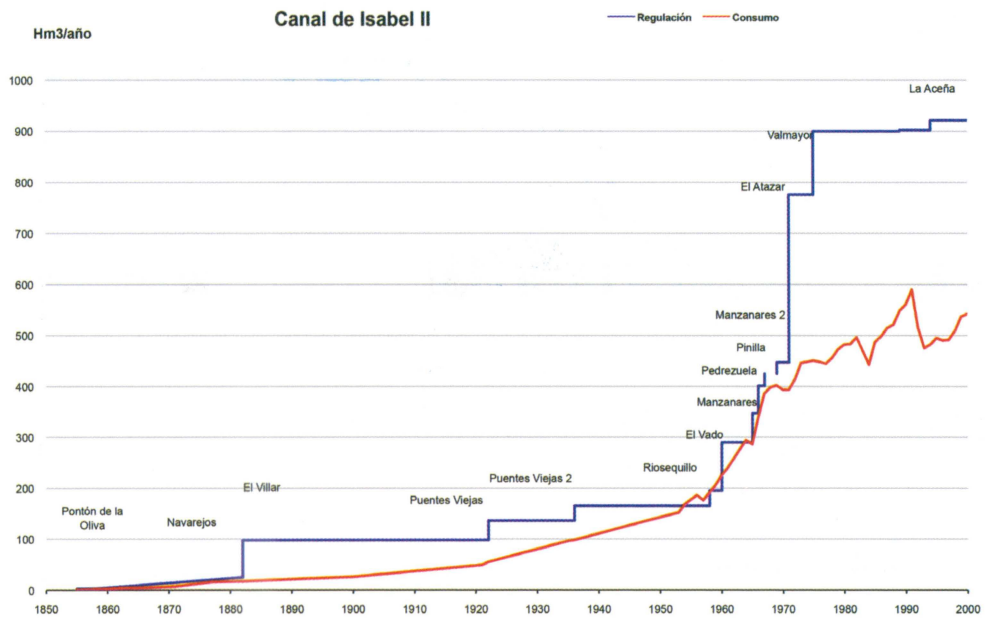


Lozoya fountain [Photo: Antonio Sarabia]

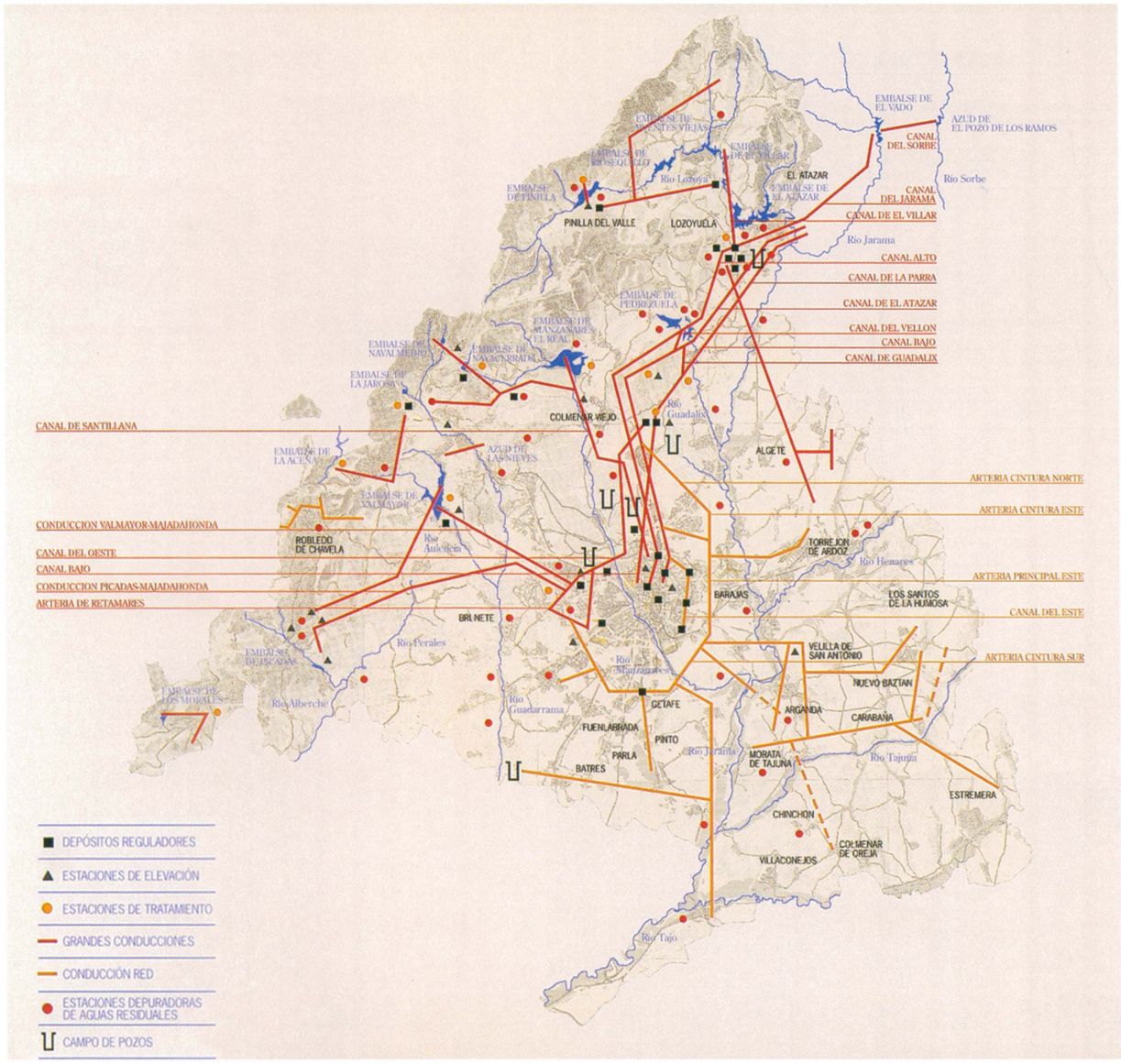
El Villar dam

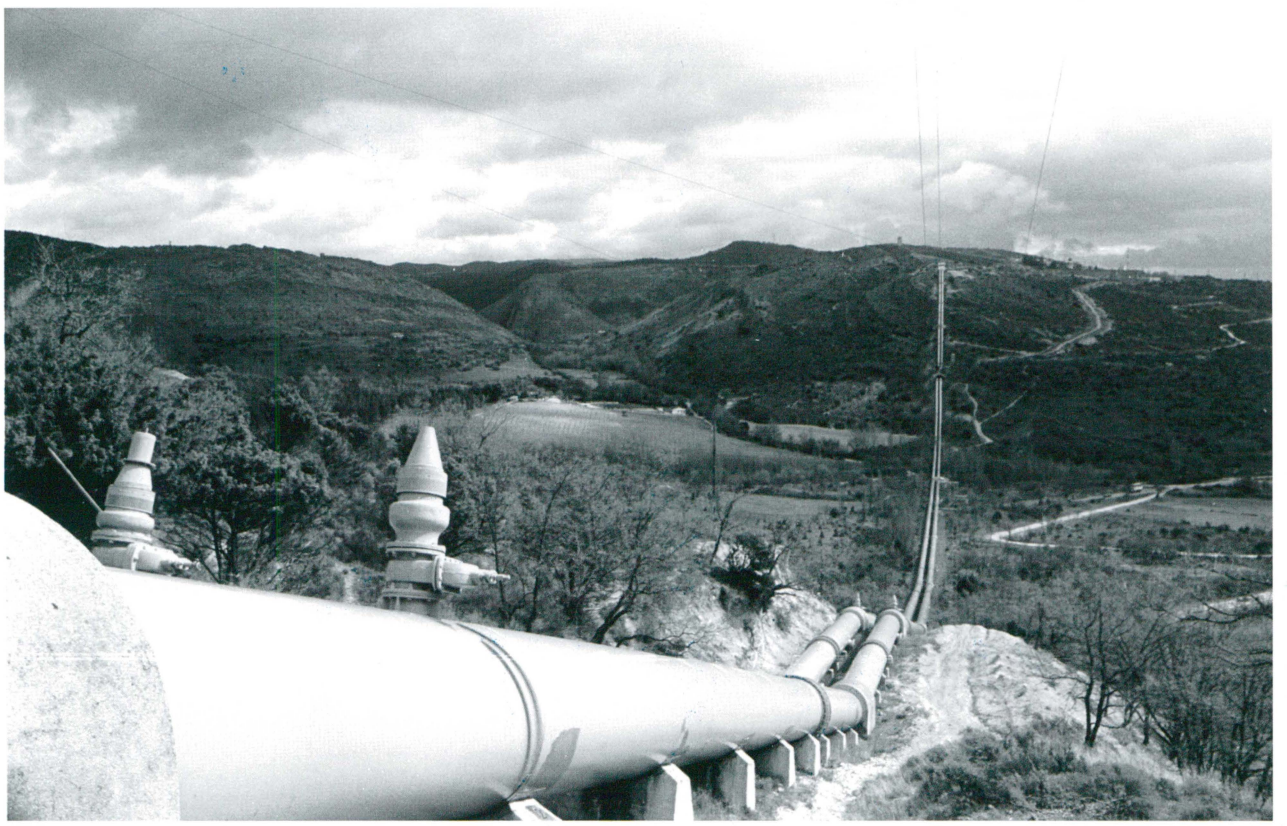


Evolution of demand and Canal capacity



Canal de Isabel II supply network





San Vicente siphon [Photo: Antonio Sarabia]

Presence of the Canal de Isabel II in Madrid

The first installations of the Canal de Isabel II water company in the city were built on land known as Altos de Vallehermoso. The first tank occupied the so-called Explanada de los Guardias and was framed by the offices to the south and the lift pump and elevated tank to the east. On the west side ran the road to France, now the Calle de Bravo Murillo, and at the corner with the street named Cea Bermúdez a wall fountain was installed to serve as a façade in the Roman style. The marble fountain on the brick façade was the work of the sculptor Sabino de Medina and represented the river Lozoya [48:111].

There, in the Lozoya, the Canal started to resolve supply in Madrid with a Roman-style system, of running water, as they did in all big cities once it had been shown that wells and waterwheels were never enough [213], [20]. After initial difficulties with the small Pontón de la Oliva dam (1858) the Canal found the solution with the advanced El Villar dam (Elzeario Boix, 1873), the reservoir of which was capable of storing sufficient water for the city [46]. The first photographs bore splendid testimony to the efforts, with albums basically dedicated to the Canal works [80].

Since that time the Canal has adapted its systems to faithfully track the evolution of Madrid's needs [34], [25], [160]. And it will continue to do as, as Vicente Palacio Atard points out, *But the construction of the Canal is a kind of unfinished symphony of water. It is a work that can never be complete, because the increase in needs demands continual attention to supply and drainage works and services* [182:15].

A robust water supply

Indeed, the Canal was a definitive work for the future of Madrid, but the task of guaranteeing supply to the city is not simple and has seen difficult times. In the 1960's, the combination of scarcity of rain and of financial resources led to a series of periods with water restrictions, which cost the then Minister of Public Works his job. That precipitated a series of determined actions to place capacity ahead of demand.

The completion of the El Atazar dam in 1972 represented the culmination of the regulation of the river Lozoya. With its 425 hm^3 of capacity, it consolidated the supply guarantees of the Canal de Isabel II and enabled growth in population to be absorbed until well into the 1990's [7]. Subsequently, it improved the conveyance network

Alcalá Oeste industrial waste water treatment plant



grid to handle its stored resource more efficiently and increased intake with pumps and supplementary pipes to tackle situations of drought.

The set of dams and their connection to the tanks located on the periphery of the city via various canals shape a real landscape of water, sprinkled with pontoons, bridges, aqueducts, take-off dividers and return ditches [219]. The majority of these water works were built in the mid-19th century, but there are some from the late 20th century that manage to maintain that character in the eastern part of the large area between the city and the mountains of the Sierra de Guadarrama. The Canal company has developed a series of routes to show its extensive facilities [105], [161] and its rich heritage Error! Reference source not found.].

Condition of each stretch of the rivers

Already in the 1980's, the pollution of the rivers and reservoirs represented the territory of Madrid's most serious environmental problem. Untreated domestic and industrial discharges into rivers and streams damaged water quality to alarming levels. The ratio between the abundant flows of untreated discharges and the low flows circulating extinguished the natural self-purification processes and converted some stretches of river into true sewers. The diagnosis given at the time was rather dramatic and, although many measures have been taken to resolve the most serious, the basic problems continue to be the same, qualitatively [4]. It is worth remembering that diagnosis, briefly.

In the stretches where there were discharges from the large settlements, water quality was dreadful. This was the case in the lower Manzanares and extended to the mid and lower reaches of the Jarama and Tajo, in Henares

after receiving discharges from Alcalá and Torrejón and in Guadarramma after receiving discharges from the villages of Hoya de Villalba. The seriousness of the situation in these areas was at its maximum, in both winter and summer, and the difficulties produced by such large amounts of domestic discharges progressively increased due to the presence of significant, sometimes toxic, industrial discharges.

Industrial and toxic discharges

In this area, the problems raised by discharges to the Butarque and Culebro brooks, collectors from the south of the Urban Area, were particularly serious. In 1984, the Butarque was an open air sewer that brought with it a large proportion of the domestic and industrial wastes from Alcorcón and Leganés. In the Culebro brook the drains were already insufficient at rainy times and systematically flooded at the connection with the new industrial estates at Getafe.

Additionally, industrial discharges from Madrid, Leganés, Alcorcón (part), Getafe, Fuenlabrada (part), Parla, Pinto and Humanes led to high levels of toxic and hazardous products that it was necessary to consider thoroughly, both to reduce them and to guarantee the operation of the facilities under construction or functioning [3:89].

Comprehensive Sanitation Plan

In 1979, Madrid City Council started out on a significant investment effort to build a series of waste water treatment plants, framed in the Comprehensive Sanitation Plan for Madrid (PSIM). Interest in pollution was still not a significant urban matter, but the city council recognised its importance. In 1981, the Professor of Sanitation Engineering Aurelio Hernández Muñoz significantly entitled an article in the Spanish public works journal, the Revista de Obras Públicas, *And pollution arrived* [130]. Madrid was Spain's pioneer city in matters of waste water treatment.

According to its driver, the Civil Engineer Jesús Espelosín, the Plan was the first determined action to tackle the condition of the river, with the construction of several large capacity treatment plants and the necessary drains to lead the city's sanitation networks to them [85:745]. The treatment works at Viveros [51], La China [174], Butarque [141] and Valdebebas [29] were built and the plant at Rejas [236] was expanded. Additionally, the Arroyo del Fresno [187] drain was constructed and the Rejas [58] drain was doubled in size.

Clean water for the river in the city

One of the Plan's most important decisions was to site a large treatment station at Viveros, alongside the Puerta de Hierro city gate. This involved treating all the discharges upstream of Madrid before the river entered the city, to discharge clean water to guarantee the continual presence of flows of sufficient quality in the whole urban stretch [75].





Viveros (Madrid) waste water treatment plant

At the same time, all the discharges to the sewer network in that urban stretch were intercepted by two large parallel drains at the banks of the river. The commitment to treating the water before the city and removing urban discharges was highly novel and worthy. There were two main problems, functional and perceptional. On the one hand, the treatment operation needed to be impeccable, as any fault could be seen and suffered immediately throughout the city.

Viveros water treatment plant

On the other hand, the water treatment plant is located a short distance from the official residence of the president, the Palacio de la Moncloa, and the University City, in a very awkward area. That called for a very careful functional, aesthetic and environmental design, making the Viveros treatment plant a model installation in many ways, but also deeply questioned when things were not going well.

The design of the installations resulted in the first water treatment plant with high level construction. The design of the buildings and development was very well set out, in complete formal harmony with the industrial treatment equipment. That attention was later passed on to the first water treatment facilities installed by the Canal de Isabel II company, which was not responsible for the city's sanitation when the Comprehensive Sanitation Plan was set out [51].

Comprehensive Plan for Water in Madrid

The enormous flow of waste water and its very limited dilution without doubt constituted the main water/sanitation problem for the city, its whole urban area and the whole surrounding environment. For this reason, the Regional Government of Madrid assumed full powers for the water cycle in the Comprehensive Plan for Water in Madrid (PIAM), approved in 1984.

Supply was guaranteed in the heart of the city and in a large proportion of the towns around it, but problems endured in the smaller towns. Just a few kilometres from the city there were population centres with periodic restrictions and without distribution and sewage networks. Given the scarcity of technological and budgetary resources in Madrid's smaller municipalities, Madrid's Regional Government assumed control over the whole water cycle in its whole territory. In this way, Madrid's supply and sanitation system became a clear exponent of rationality and quality of service and an example to the world [209:42] and was acknowledged by the World Bank as an example of a company to follow for comprehensive water management [163].

In turn, the few water treatment plants built with technical and financial assistance from the Tajo Basin Water Authority, which reported at the time to the Ministry of Public Works, were passed to the Local Councils for operation. However, once the guarantee period of one year, during which they were operated by their constructors, had passed, they were abandoned because they lacked a flow of income to pay for their operating costs.

Condition of watercourses and banks

The poor condition of the water in the rivers directly impacted their surroundings. Riverbanks play an important role in Madrid's territory, with three levels of meaning: ecological, recreational and landscape. In general, pressure from uses is high and is greatly conditioned by the quality of the riverbanks and water. The upper reaches and some of the mid-reaches suffer significant recreational pressure, which is only deterred by difficulty of access.

Refuse and wastes are dumped at isolated points and drainage points from urban developments and villages are common. The presence of numerous reservoirs attracts urban developments, in spite of the protection accorded them due to their supply status.

In the middle reaches, the impacts due to discharges multiply and the nearby presence of the large urban settlements generates speculative expectations, with crops abandoned and plains with great agricultural potential occupied by legal or illegal urban developments and industries. In reaches where there is more haulage, the extraction of aggregates is widespread, with the loss of fertile land and the complete alteration to the course and the landscape [14:22].

Madrid's Regional Government initiated a programme to recover the riverbanks within the Comprehensive Plan for Water in Madrid, with a significant number of actions to correct damage preventing Madrid's residents from



Gavia (Madrid) waste water treatment plant

enjoying the rivers. Ecological studies were also promoted, such as the one on the middle reaches of the river Manzanares, to determine appropriate measures for protection and criteria for reclaiming the worst affected stretches [171].

Law for water in Madrid

Madrid's regional Law on Water Supply and Sanitation enabled local councils to voluntarily receive the service provided by the Canal de Isabel II water company, which was transferred to the Community shortly after its foundation. The advantages were unquestionable and all the municipalities in the region – except for Alcalá de Henares, which received water from the river Sorbe association – joined the Canal system.

From that time, the water company has continued building Madrid, with the provision of new resources, distribution networks, treatment plants and advanced purification works. To provide service to the large number of homes built, it laid a second supply ring of 140 km in length parallel to the M-50 motorway, has doubled its

treatment capacity and has improved waste water quality. To tackle the increase in run-off from the new paved and built-up areas, it has optimised the drainage network. To improve discharges from the eight existing water treatment works in Madrid, it has included treatments to remove nutrients and has committed to reuse.

Improvements to drainage along the M-30

Recently, the M-30 remodelling works gave Madrid's sanitation fresh impetus. As the road runs partly underground on its route alongside the river Manzanares, the work made it necessary to reconsider the drains at the banks and the rainwater evacuation systems.

The works also allowed consideration of the matter of storm water flows as a matter of some importance. Temporary storage tanks and systems to prevent direct flow into the water treatment works were built (see page 129).

MAIN WATER TREATMENT WORKS AFFECTED BY MADRID, BY GEOGRAPHIC LOCATION

Course of the Manzanares			
111	Santillana	1988	PC-BAS
82	Navarrosillos	1987	PC-BAS-TERT
145	Viveros	1983-2001	BAS-zonified
56	La China	1932	BAS-nutrients
58	La Gavia	2008	BAS-nutrients
17	Butarque	1983	BAS-nutrients
118	Sur	1983	BAS-selectors
35	Culebro bajo	2008	AS
36	Culebro alto	2007	AS
119	Sur oriental	1983	BAS-nutrients
Course of the Jarama			
107	San Agustín de Guadalix	1990-2008	PC-BAS-tertiary
125	Tres Cantos	1988	PC-BAS
9	Arroyo de la Vega	1986-1990	PC-BAS-tertiary
128	Valdebebas	1982-2000	BAS-nutrients
66	Las Rejas	1977-2000	BAS-nutrients
23	Casaquemada	1987-2000	PC-BAS
135	Velilla de San Antonio	1996-2008	PC-BAS
62	La Poveda	1987-1994	PC-BAS-tertiary
Jarama downstream of the Manzanares			
117	Soto-Gutiérrez	1991-2002	BAS-dehydration-tertiary
121	Titulcia	2005	Prolonged aeration
8	Aranjuez norte	2010	XX
7	Aranjuez Tajo	1989-2000	BAS-nutrients-tertiary

Source: Community of Madrid – 2013 (http://www.madrid.org).

WATER TREATMENT WORKS AFFECTED BY MADRID ON THE RIVERS MANZANARES AND JARAMA, BY YEAR OF CONSTRUCTION

La China	1932	BAS-nutrients
Las Rejas	1977-2000	BAS-nutrients
Valdebebas	1982-2000	BAS-nutrients
Butarque	1983	BAS-nutrients
Sur	1983	BAS-selectors
Sur oriental	1983	BAS-nutrients
Viveros	1983-2001	BAS-zonified
Arroyo de la Vega	1986-1990	PC-BAS-tertiary
Navarrosillos	1987	PC-BAS-TERT
La Poveda	1987-1994	PC-BAS-tertiary
Casaquemada	1987-2000	PC-BAS
Santillana	1988	PC-BAS
Tres Cantos	1988	PC-BAS
Aranjuez Tajo	1989-2000	BAS-nutrients-tertiary
San Agustín de Guadalix	1990-2008	PC-BAS-tertiary
Soto-Gutiérrez	1991-2002	BAS-dehydration-tertiary
Velilla de San Antonio	1996-2008	PC-BAS
Titulcia	2005	Prolonged aeration
Culebro alto	2007	AS
Culebro bajo	2008	AS
La Gavia	2008	BAS-nutrients
Aranjuez norte	2010	XX

Source: Community of Madrid – 2013 (http://www.madrid.org).

AS: activated sludge with anaerobic digestion; BAS: biological activated sludge; PC: physicochemical; tert: tertiary treatment.

SANITATION IMPROVEMENTS FOR THE RIVERS MANZANARES, JARAMA AND TAJO, OWING TO THE M-30

Manuel Melis, Civil Engineer
Head of M-30 remodelling works

The great M-30 project included a series of improvements to Madrid's sanitation, with particular reference to the evacuation of contaminated rain water and to peak flows caused by storms. After several technical meetings in early 2004, the three serious problems in the course of the river Manzanares in the urban area, which the river Tajo Water Authority wanted to resolve by taking advantage of the tunnelling works for the M-30, could successfully be stated clearly

1. The serious current risk of flooding in Madrid. A spate of 750 m^3/s, corresponding to a return period of 500 years[2], would, if not partially reduced by the Santillana and El Pardo reservoirs, cause extremely severe flooding, with water depths of over 2.5 m from Los Franceses Bridge to the bridges of the Southern junction.

2. The seriousness and illegality of the current discharge of sewage to the river. Run-off discharges from the drains at the river bank, which occur as the network is not independent, show dilutions of less than 5:1, which is the limit demanded in the Tajo Water Plan.

3. The serious deterioration in river Manzanares water quality occurring downstream of the existing water treatment works, from the Sur treatment works to Vaciamadrid, a stretch lying inside the South-east Regional Park.

These old problems had not been studied in depth until the tunnelling works for the M-30 were proposed. In the case of the risk of flooding, the tunnelling works for the M-30 involved a noteworthy improvement in traffic safety conditions, as the sheet of water for a flow rate of 750 m^3/s would remain below the tunnel entrances. In these cases of serious flooding, the control systems would have closed the tunnels to traffic with sufficient notice, but between 750 m^3/s and 425 m^3/s (corresponding to a return period of around 60 years) extraordinarily serious damage would be caused to vehicular traffic and the neighbouring homes.

Contaminated rain water discharges were tackled with three actions: increasing the capacity of the drains at the river bank to a flow rate equivalent to 17 times the peak flow rate of sewage at dry times; the provision of storm tanks at the connection of the tributary drains for each basin to the river bank drains; and the execution of ponds near the water treatment plants with capacity to store, without discharges, the difference between the accumulated volumes of inflows and the outflows treated by the plants.

Finally, the deterioration in water quality was completely outside the scope of work proposed for the tunnelling works for the M-30. Consequently, the budget for the M-30 tunnelling works in the river area was increased to resolve these problems. These were problems which had already been noted by Madrid City Council's Environment specialists, led by the Civil Engineer Félix Cristóbal, but over decades they had been unable to muster the budget needed to solve them.

As a result of the above, the current enormous drains at each river bank, with sections reaching 4.0 x 3.5 m, were included in the M-30 tunnelling work project. The current system of storm tanks, where the dirty rain water is stored and pumped to the water treatment works, were also built. For each tributary drain, a discharge chamber was built to feed both the river bank drain and the corresponding overflow channel. The retention storage tanks, needed to retain the combined water (sewage + rain water) that cannot be treated by the treatment plant as they would exceed its capacity, were also built.

The anticipated 32 tanks had a total volume of 622,000 m^3 on the left bank and 276,000 m^3 on the right bank. They had been designed in the form of large tunnels, the size of the Metro tunnels, buried under the streets. All the tanks required a great pumping height to return the sewage to the drains when the treatment works could cope with the flow. The storm tanks and retention or storage ponds built in the end[3] have a total capacity of 1.35 million m^3.

In addition to these works, the City Council's team tackled and finally resolved the problem of the Abroñigales drains. There are three of these drains from the 1960's and 70's, known as A, B and C, and, as stated, their limited capacity meant that they were frequently under load[4]. The total cost of these sanitation actions for Madrid was over €1,500 million, although without precise data for the works built by the City Council.

(Text by Manuel Melis).

STORM TANKS AND RETENTION PONDS BUILT (CAPACITY IN m^3)

Arroyofresno	400,000	Cantarranas	3,270	General Ricardos	1,950
Butarque	400,000	San Bernardino I	660	Antonio Leyva	1,550
Abroñigales	206,000	San Bernardino II	170	Calle Toledo	2,120
La China	130,000	Marqués Monistrol	680	Santa María Cabeza	1,300
Pozuelo	30,000	Cuesta San Vicente	3,135	Canalización	2,420
Valdemarín	15,000	Paseo Extremadura	2,800	Delicias-Viñuelas	2,900
Total	**1,181,000**	Paseo Melancólicos	1,370	Interceptor, Right Bank	7,870
		San Rufo	1,090	Embajadores	1,200
		San Ambrosio	1,464	González Feito	2,944
		Via Carpetana	2,180	Pradolongo	1,503
		Total	**16,819**	San Martín Vega	434
				Oliva	5,400
				La Gavia	55,000
				Carabanchel urban development plan	15,500
				Estanque Plata-Castañar	27,090
				Arroyo Los Migueles	18,750
				Estanque de Valdebebas	6,400
				Total	**154,331**

[2] The period for which water works must be dimensioned currently.

[3] The large retention ponds for storage until the treatment works can receive the flow rates are those at Arroyofresno, Butarque, Abroñigales, La China, Pozuelo and Valdemarín. Félix Cristóbal's team had left those at La China and Pozuelo practically finished and Madrid City Council's new Environment team, led by the Civil Engineers Pedro Catalinas and Fernando López Ortún built the rest of these enormous installations.

[4] Catalinas and López Ortum's team built an interceptor tank for the three drains and a large new drain of 6.5 m in diameter from there which drains to the new large tank at Abroñigales.

THE CANAL DE ISABEL II IN THE CITY OF MADRID

Adrián Martín, Civil Engineer
Director General Canal management (Canal de Isabel II)

The origin

The Canal de Isabel II water company was created to respond to severe water supply problems in the city of Madrid around 1851. The city and the company have changed enormously since then and a large part of that transformation is the work of those who, in their day, decided to create the company and commit to infrastructures which, a century and a half later, continue to serve Madrid's residents.

At that time, the capital had around 210,000 inhabitants and they consumed around 2,000 m^3 of water per day. The engineers designed infrastructures with capacity to transport 328,000 m^3 per day, so infrastructure that exceeded what was available up to then by over 150 times. At the time it was the largest water works constructed in Europe.

This decision enabled the water supply to the Spanish capital to be guaranteed, at least in terms of quantity, for the next 70 years, when Madrid exceeded one million inhabitants.

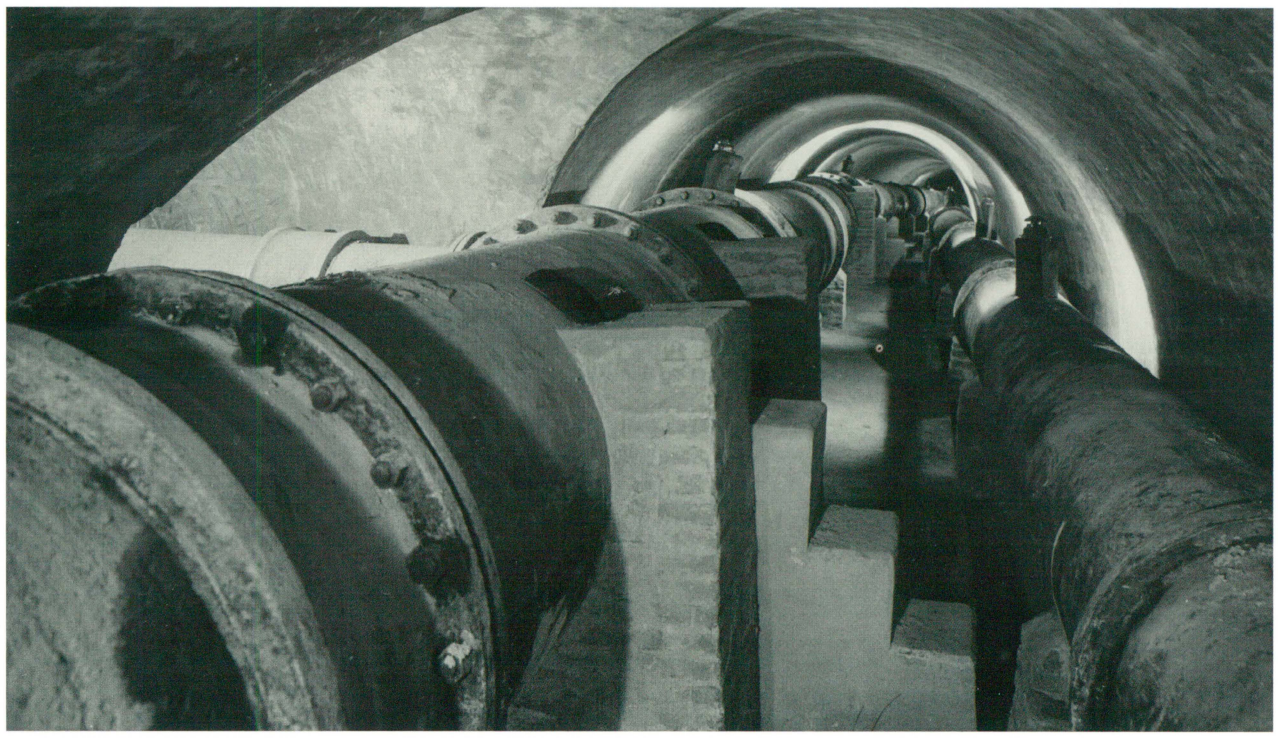
Decisions adopted are often conditioned by the budget or to resolve a problem in the short or medium term. If this had been the approach in this case, today's Madrid would undoubtedly have been different to the one we know.











Planned growth

It needs to be pointed out that water distribution networks, just like those for sewage, serve homes, shops, parks, etc. and not people, as the supply and sewage networks need to exist before you live in a house, go shopping or plant trees in a park.

The planning processes for a city are now highly regulated. Madrid has its General Urban Development Plan, which it modifies progressively as the years pass. Water supply and sanitation services cannot be an obstacle to this modification, but rather need to accompany it to enable the new developments. These are often near already consolidated areas and, therefore, interfere by using part of the infrastructures that were built without taking them into account, logically. Their dimensioning, if it was done correctly, may be compromised and this makes it necessary to recalculate these infrastructures.

Canal de Isabel II Gestión prepares planning reports to indicate which infrastructures are necessary to provide quality service to new developments and that the quality will not be reduced in already consolidated zones. In addition, the value of these infrastructures is assessed and the economic repercussions they will have on each of the new developments is established.

Second distribution ring

Madrid has grown spectacularly over recent years, more in number of homes than in population, and new neighbourhoods have been created. To provide for these new demands, and taking into account the fact that the infrastructures were already compromised, it was decided to build what we have come to call the second distribution ring.

The second ring has its ends at water treatment stations at Colmenar, with treatment capacity of 16 m^3/s, and Valmayor, which has increased its capacity from 6 to 12 m^3/s over recent years. The ring is 140 kilometres long and is made up of two 1,400-mm diameter pipes. In the first phase, a single pipe is being laid, capable of transporting 3 m^3/s, that is to say it would be capable of supplying one million people.

The second ring is based on a large part of its route on the development of the M-50 highway and has branches to both the inside and outside of that route. In addition to relieving the restrictions the strategic distribution network had, this great investment enables the connection of the two main sources of supply to Madrid, as the Colmenar plant treats water from the rivers Lozoya, Jarama and Guadalix and the Valmayor plant treats water from the Guadarrama and Alberche. For this reason, this infrastructure contributes significantly to increasing the guarantee of supply to the region, which will make it possible to reduce episodes of scarcity which, over the last 25 years, have occurred more frequently than wished.













The distribution network: renovation and subdivision

At the beginning of the 1990's, there was a very severe drought in Spain. In those years, the Canal de Isabel II adopted a series of decisions on improving distribution network efficiency which are still valid today; I refer to the renovation of the distribution networks.

Every year between 150 and 200 kilometres of out-of-standard pipes are renewed, because of the material from which they were made, because their diameter is smaller than the appropriate or because they are withstanding a higher pressure than the one for which they were installed. Although the effort being expended for this renovation is very significant, it needs to be emphasised that these renewal rates represent only 1% of the current network, that is to say that, at this rate, it would take 100 years to replace the whole network.

In addition to this investment, work has been going on over the last 10 years to subdivide the network. This involves physically compartmentalising it into 550 zones that make it possible to determine the amount of water introduced to the sector and the maximum water pressure in that zone. This new way of configuring the network, as well as improving awareness of its performance, has enabled us to reduce the number of breakages by 30%, which is undoubtedly welcomed by Madrid's residents.

Excellent water quality

Madrid's water has always been characterised as being of excellent quality. The mountains of the Comunidad de Madrid, which are mainly granite, have contributed to this fact, but it is no less true that sources of lower quality have been introduced over recent years, the most recent of which has its source in the river Tajo. To be able to treat this water, a treatment station was built that uses reverse osmosis to remove the sulphates it contains. This infrastructure has made it possible to increase the guarantee of supply significantly, as the reservoirs in the headwaters of the Tajo have large storage capacity and their inflow regimes are different to those of Madrid's mountains.

The objective set is for the water to have the same organoleptic characteristics – smell, colour and taste – all year round. This is not easy, given that the source of the water changes during the year depending, among other things, on the volume of water in the reservoirs and the greater or lesser presence of algae in the water. To achieve it, the treatment stations are being fitted with active carbon filters. Five plants already have these and they will all have in the future.

Legislation regarding water quality for human consumption, in both Europe and Spain, is becoming more restrictive as the years go by and progressively prohibits or limits the use of certain substances in both treatment and disinfection processes. This means that all the processes are being continuously improved. So, for example, the permitted quantities of free and combined chlorine present in water have reduced significantly. This has resulted in the installation of 44 rechloramination facilities throughout the network.







The importance of the sewer system

The system for collecting waste water and rainwater, the sewer system, is essential On its maintenance and operation depend the absence of bad smells in the city and that flooding when it rains is limited to intensities greater than that for which it was dimensioned.

Two circumstances can exaggerate this problem: the increase in built-up area, meaning an increase in the water that needs to be led to the sewer system and the possible increase in rainfall intensity as a consequence of climate change.

Over recent years, maintenance programmes on these networks have been embarked upon to guarantee their optimum operation. In addition, mathematical models enable us to understand their behaviour in the case of episodes of rain with different intensities and durations. A good mathematical model needs the most precise definition possible of the network. In this regard, work is being carried out on the topography of both the network itself and the wells, as that is where the water comes out if the network comes under load. For the results of the model to reflect reality, the precision of that topography needs to be submillimetre, which shows how difficult it is. The aim is for the city's whole sanitation network, all more than 4,000 kilometres of it, to be modelled by 2015.



Purification and environmental sustainability

The construction of the waste water treatment stations in Madrid started years ago. There are now eight in operation for the whole city and all the waste water generated is treated in them. The latest challenges that needed to be faced in purification have been, on the one hand, the treatment of the initial rain water and, on the other, removal of nutrients.

The first, the treatment of rain water, has been resolved by building more than 60 storm tanks to store the initial rain water, which is the part that accumulates more pollution, so that it can be cleaned once the rain stops and the treatment plants have capacity to treat it. This handling involved notable investment for sporadic use.

The second, the removal of nutrients, has been divided into two: phosphorous and nitrogen. Phosphorous is already removed in all the treatment plants, either by biological or chemical means. A considerable investment effort has been made over the last five years and operating costs have increased too. As regards the removal of nitrogen, the solution is more difficult because, until now, the most efficient way of removing it is by the biological route and, for this, the dwell time in the treatment plant needs to be twice what it is at present. This is only achieved by increasing biological reactor area. The problem is that in the majority of cases the treatment works are in locations where they cannot be expanded, so this is a challenge for the future.








Panter
Vtr 3000


GROVE





Regenerated water

Over recent years, the Canal de Isabel II has firmly committed itself to obtaining new water resources. Outstanding in this regard is its dedicated venture into the regeneration of purified waste water. Reuse has become one of the essential components of comprehensive management of the resource and contributes significantly to the net increase in water availability for Madrid.

For this reason, regenerated water production and distribution activities have been developed at an increasing rate in order to replace drinking water in those uses which do not require a water supply of such excellent quality. Among these are street cleaning and the irrigation of public parks and golf courses, as well as some industrial uses. As such, the regenerated water network already exceeds 300 kilometres, 82 of these in the city of Madrid, making it possible to irrigate over 1,000 hectares in 28 green zones in the capital. In 2012, in the 28 tertiary treatment plants in operation, a volume of regenerated water equivalent to the consumption of a population of 100,000 inhabitants was produced.

Advanced communications and remote control systems

Appropriate management of all the processes and all the installations enabling supply to Madrid's residents and guaranteeing the environmental quality of the rivers receiving the purified water implies the need for advanced communications and remote control systems. Such systems also allow efficiency to be increased.

The company has always been committed to innovation and technological development when facing the challenges posed by integrated water cycle management. For this reason, the Canal de Isabel II was already a pioneer in 1983 in the development and implementation of advanced communications and remote control systems. It currently has a complex and sophisticated monitoring system which is among the most advanced in the world. Thanks to the more than 15,000 measuring instruments installed in the supply, sanitation and reuse systems, generating 12,000 items of data per minute, you can find out, in real time, about the hydraulic condition of the conveyance, distribution, sanitation and reuse network, as well as the water quality status, reservoir status and the intake of underground water.

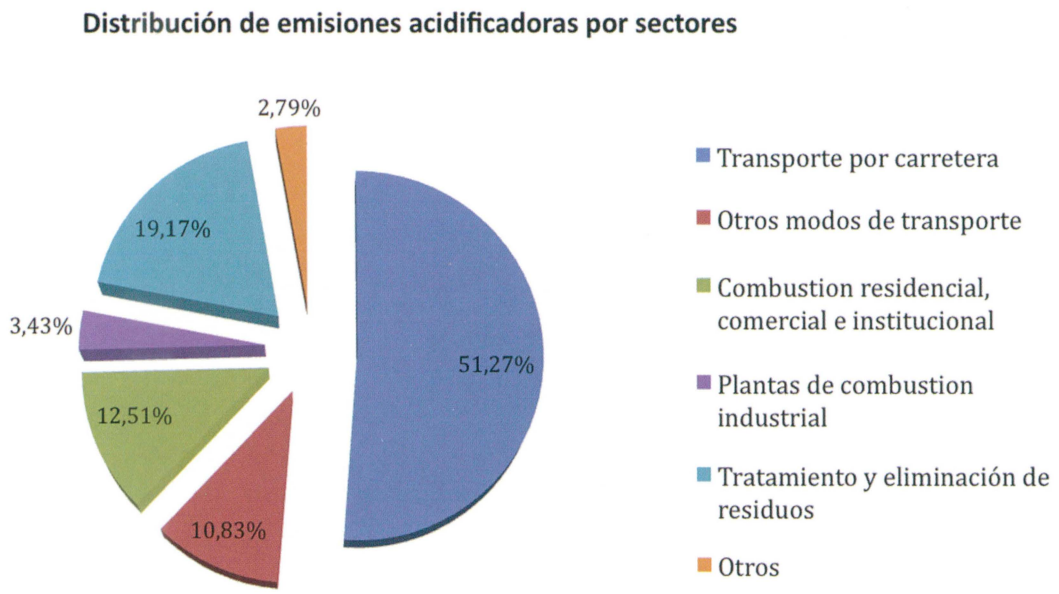
This monitoring takes place from the Main Control Centre, where the system for management of incidents due to lack of water or due to faults in the network is also installed. Calls from the public are received in the call centre, where they are recorded automatically and located geographically using an application produced by the company, built into the geographic information system and with mobile devices.

Commitment to the future

The history of the Canal de Isabel II company and of the city of Madrid have gone hand in hand other over the last 160 years. Demographic growth, combined with the economic development and social well-being of the capital have been possible thanks, among other things, to the guarantee of a supply of quality water and optimum conditions for health. The commitment to the future of this great city is to continue tackling the challenges posed by efficient integrated water cycle management with the same dedication, efforts and excitement as during the more than 160 years of joint history.

To achieve this, the company has just begun a new stage in its management model. This involves separating, on the one hand, the public regulator, Canal de Isabel II and, on the other, the limited company operator, Canal de Isabel II Gestión. This important step gives a more dynamic business model, in line with such a rapidly changing setting as the current one. All of this has the objective of supporting and strengthening one of the best integrated water cycle management systems in the world, Madrid's.

(Text: Adrián Martín).



Distribution of acidifying emissions by sector.

Air quality

Like the rest of Europe's big cities, emissions from traffic, residential emissions from heating and cookers and emissions from activities such as construction and demolition are the main causes of atmospheric pollution in Madrid. However, the urban structure and climate increase the impact of those emissions, particularly from traffic, compared to air pollution levels in central and northern Europe.

On the one hand, the configuration of the city, with a high density of tall buildings, causes a screen effect for vehicular traffic emissions. This makes the dispersion of the contaminants more difficult, increasing their levels in ambient air. On the other hand, the absence of rainfall for long periods prevents atmospheric scrubbing and promotes processes that resuspend particulate matter deposited on road surfaces by vehicular traffic. The high levels of radiation in summer, too, result in increases in levels of secondary particles, oxides of nitrogen and ozone.

Impact of traffic

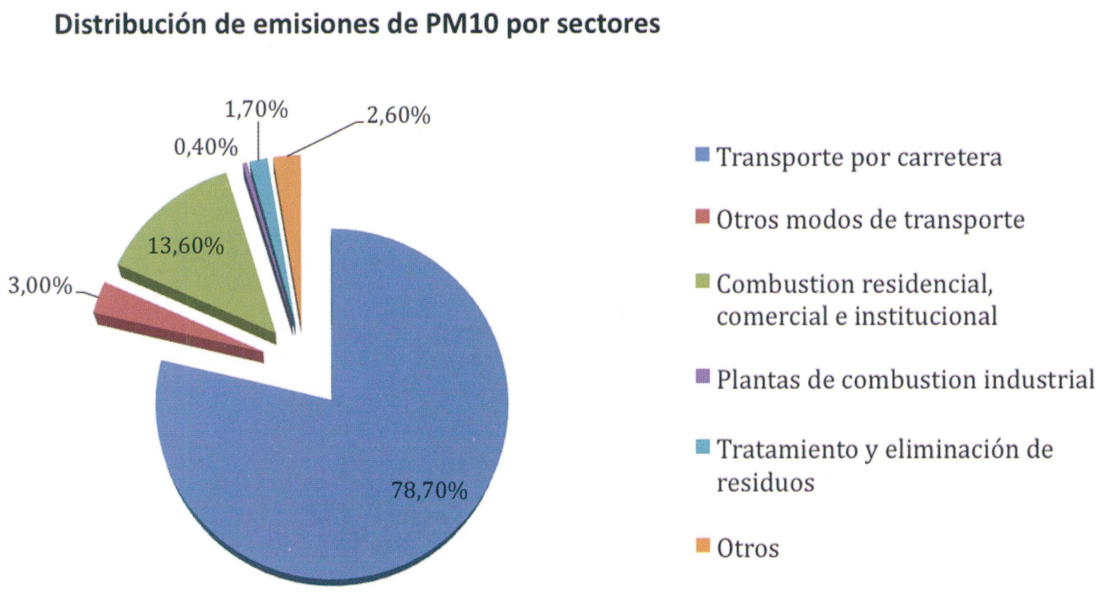
As can be seen in the graph, the transport sector is the main source of emissions of acidifying substances in the capital. If we consider only the generation of oxides of nitrogen (NOx), currently the most problematic pollutant in the city, the contribution of the road transport sector is 64%.

The impact of road traffic on the generation of particulate matter is even higher, almost 80%, as shown in the following figure, which includes the contribution of the different sectors to the emission of particles smaller than 10 µm, known as PM10.

Fixed measurement stations

The pollutants present in Madrid's air are monitored by means of networks of fixed measurement stations, located on public roads and in different types of urban spaces in the city, depending on the sources of emissions present: zones in the city centre with traffic present (traffic stations), urban parks or tranquil zones farther from the centre (urban background stations), large green zones or periurban parks (suburban stations) and industrial zones or logistical centres (industrial stations).

In Spain, the assessment of air quality is the responsibility of the Autonomous Regions and those municipalities with over 250,000 while Central Government coordinates the process and draws the information together for



Distribution of PM10 emissions by sector. Inventory of emissions for the city of Madrid for 2010.

the European Union. For this reason, the air quality in the urban area of Madrid is monitored by two measurement networks with a total of 39 stations (24 in the municipality of Madrid and 15 belonging to the Comunidad de Madrid's network). These air quality measurement stations have continuous automatic analysers or manual sensors for monitoring the regulated pollutants.

Pollutants

The data from the air quality measurement networks for the urban zone show that a notable improvement has occurred in recent years in levels of sulphur dioxide, carbon monoxide, lead and benzene, with their current concentrations being far below the quality targets set by the European Union. However, as in the rest of the big European cities, problems persist related to nitrogen dioxide, intermittently with particles in suspension and with tropospheric ozone in the summer season [37].

The highest concentrations of oxides of nitrogen and of particles are usually reached around the middle of the day, at traffic stations and zones in the urban centre and at periods of atmospheric stability without rainfall or wind.

Ozone

As regards ozone, its concentration at a point on the surface corresponds at all times to the balance between the processes supplying and eliminating it, given that this is a secondary pollutant. On the one hand, ozone forms in situ, due to photochemical transformations of precursors emitted by natural or anthropogenic sources, promoted by solar radiation and with a daily and seasonal cyclic nature. The main compounds which are precursors for ozone are oxides of nitrogen and volatile organic compounds. On the other hand, it is also transported from other places by the wind and can remain in the atmosphere (in the air) for days or weeks.

On the other hand, ozone is eliminated by chemical reactions between compounds present in the atmosphere – where it acts as an oxidising compound – or by being swept away by atmospheric movements of horizontal (advection) or vertical (mechanical or convective turbulence) types. As such, the highest ozone concentrations are reached in summer, at the hottest times of day and in places far from the foci of emission of its precursors, such as periurban zones or green spaces located in Madrid's outskirts [203].

Pollution over Madrid





Station map with characterisation

Waste management in Madrid

Wastes generated in Madrid and its metropolitan area are managed in a differentiated manner. Depending on where they come from, wastes are considered as municipal, industrial, construction and demolition wastes (CDW), etc. They are considered as hazardous or non-hazardous depending on their composition, according to state or European regulations.

They are hazardous if they contain substances which make them so or if they represent a hazard to human health, natural resources or the environment. For example, flammable, explosive, toxic, irritant, corrosive, infectious or carcinogenic substances. The containers and packaging that contained these substances are also considered hazardous. Hazardous wastes are subject to greater control in all their phases and the rest are considered non-hazardous.

Processes, recycling and reclamation

To manage all of these, according to European directives, the preferred method is reduction at source, that is reduction in generation, followed by reuse, recycling and other forms of reclamation, compared to disposal as the last resort.

Industrial wastes are collected and sorted in their places of origin, where they are passed to authorised waste managers for reclamation or disposal. Industrial waste reclamation processes include the recycling or recovery of metallic compounds or other inorganic materials, the regeneration of acids or bases, the recovery or regeneration of solvents or other organic materials, the regeneration of oils and use as a fuel or as another medium for generating energy. Their disposal started to be planned in the Comunidad de Madrid in 1987 [104].

Construction wastes

Construction and demolition wastes (CDW) have made up one of the main waste flows in the Madrid urban area in recent years, reaching a volume of six million tons per year. Of these, surpluses from excavation and earth movements of uncontaminated soils are reused in the same or another work or in restoration or conditioning work or the filling of mines. The remaining CDW, usually generated by the construction sector, is managed in specific recycling plants, where it is sorted and crushed.

There are currently 21 authorised CDW facilities in the region, of which 10 are located in the Madrid urban area, and four inert construction and demolition waste dumps, two of them in Madrid.

Wastes in Madrid

Municipal wastes are managed by the Local Councils, individually, as in Madrid, or jointly. Each of Madrid's residents produces something over 1 kg/day of waste, which means almost two million tons per year of household waste in the urban area. It is managed in a differentiated manner, after separation at sources in homes or the places where it is generated. The main flows of municipal wastes are the selective collection of light packaging, glass, paper and cardboard, pruning waste, etc., which are reused or recycled, and the collection of other urban





Valdemingómez recycling plant [Photo: Iñaki Ábalos]

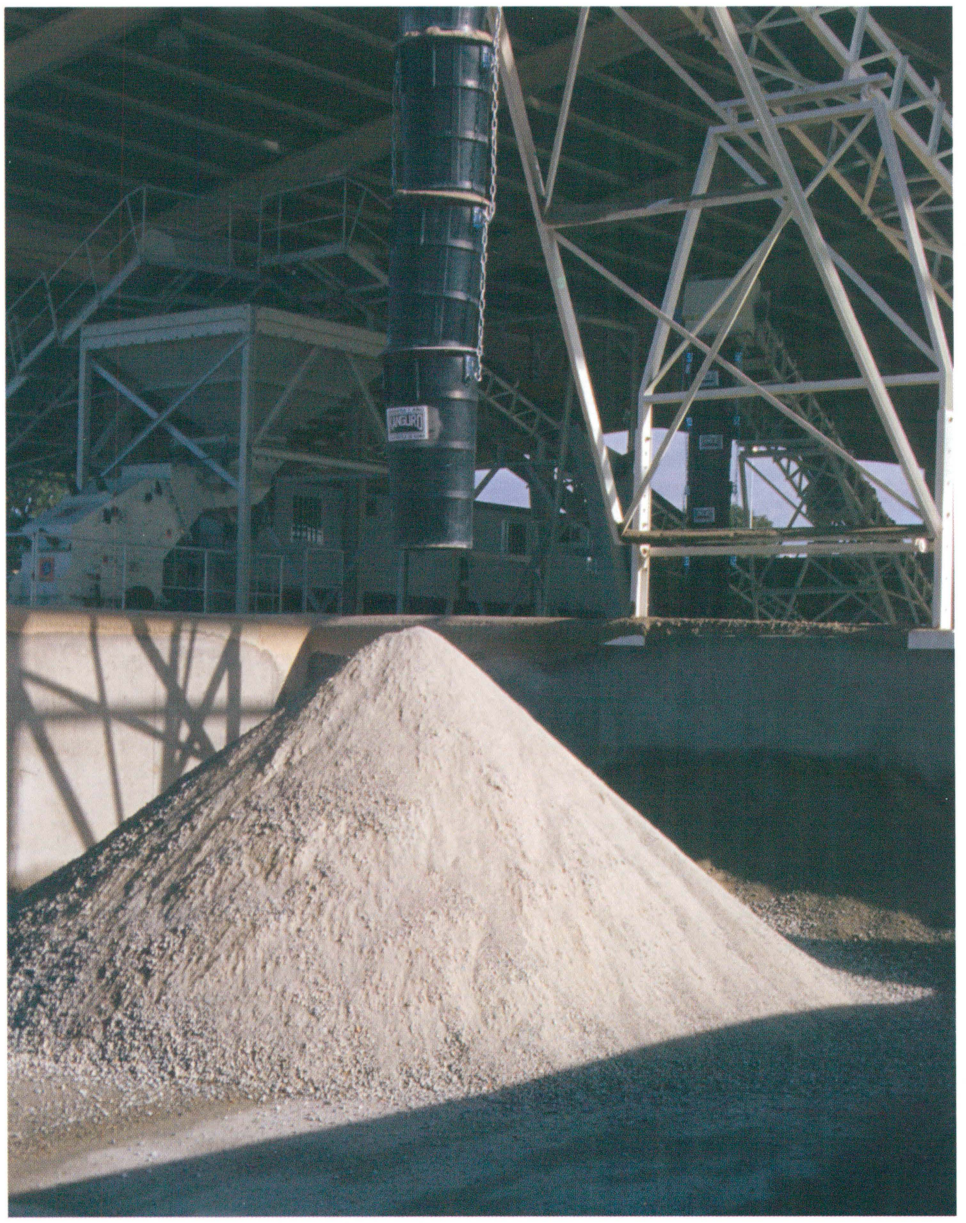
wastes which are destined for incineration or dumping. Hazardous household wastes (batteries, oils, paints) are collected at clean points – municipal facilities where they are sorted and separated to be delivered to the various authorised managers.

Waste glass and waste paper and cardboard are collected in containers located on the public roads and delivered to authorised managers, usually by being incorporated into the production processes for these same materials. They represent, respectively, 3% and 4% of the urban wastes managed in Madrid.

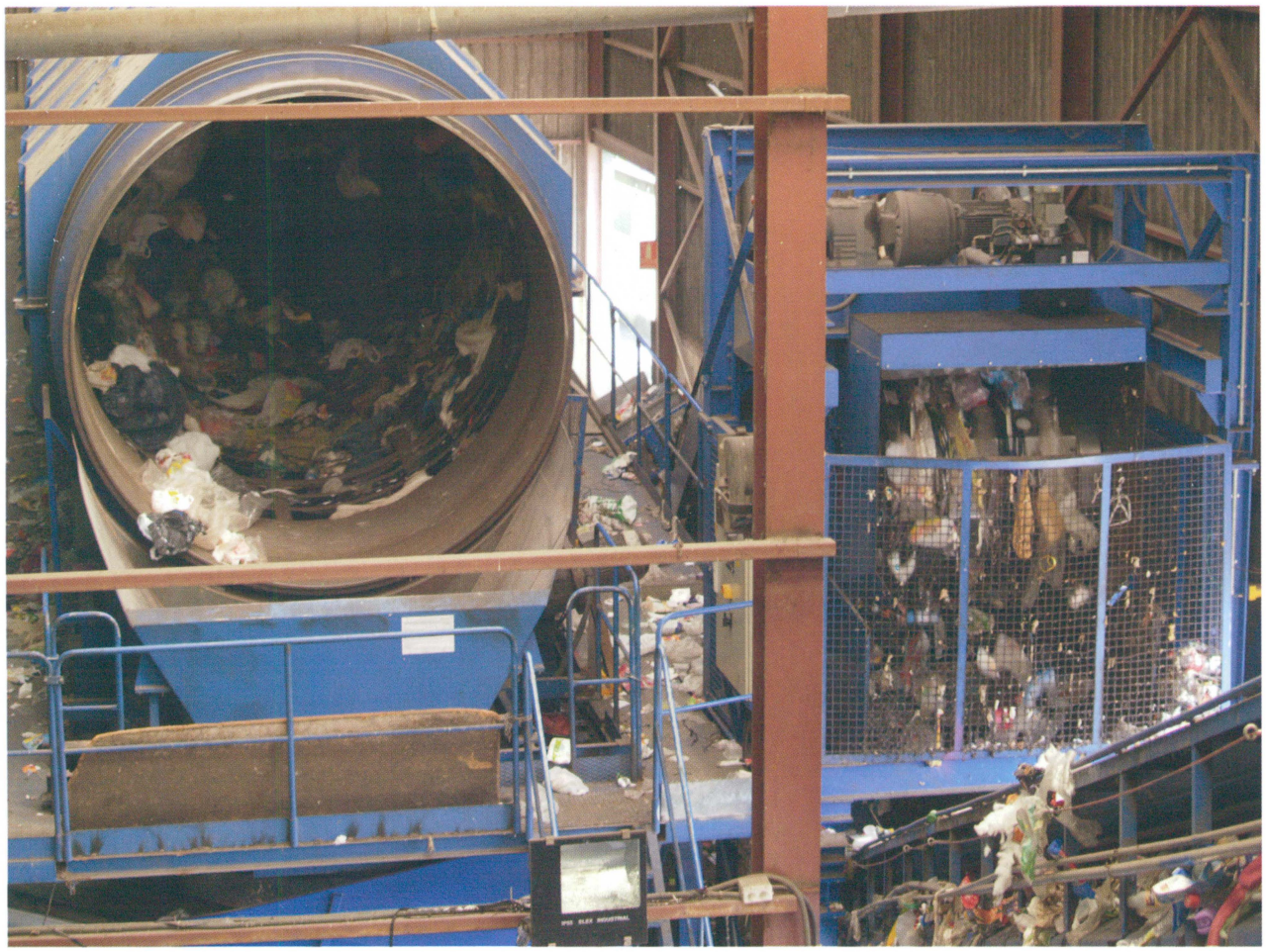
Packaging, sorting and separating

Waste light packaging (5%) is collected in the so-called yellow bag at home or in containers located on public roads and is transported to one of six sorting plants for the metropolitan zone, where it undergoes sifting and sorting with the aim of recovering the fraction that can be reclaimed.

In the sorting process, ferrous metal packaging is separated using an electromagnet, aluminium using an eddy current separator, bricks by means of an optical reader and PET or HDPE packing using filtering, volumetric separation and manual selection processes. Once separated, these materials are pressed and baled to be sent to the corresponding recycling centres, from where they are reincorporated in the commercial cycle.



Aggregate recycled in the Navalcarnero construction and demolition waste plant



Rotary screen for volumetric separation at the Pinto Packaging Sorting Plant

Rejects from the sorting plants are made up of rubbish bags and plastic wrapping, which are collected using large vacuum cleaners at the start of the process, and the rest of the non-recyclable plastics, which are recovered as a mixture to be disposed of by incineration or dumping.

Composting and biogas

Biodegradable municipal waste recovered from the sifting of the first bag or remainder bag, plus those from parks and gardens and sludge from waste water treatment are recycled to produce compost or to be transformed into fuel. There are six composting plans in the Madrid urban area, producing approximately 76,000 tons/year of compost, and three biomethanisation plants, generating around 16,400 m^3 of biogas. This mixture of gases, 2/3 methane and 1/3 carbon dioxide, can be used to produce steam, electricity and heat or, after purification, as a fuel similar to natural gas.

Finally, household wastes collected in an undifferentiated manner in the first bag represent 75% of the total and are collected and transported to the comprehensive treatment centres for the urban area. The destination of the majority of these wastes is incineration, with energy recovery, or dumping in a controlled waste dump, although a part of its organic fraction is also recycled to produce around 270,000 tons/year of compost or 160,000 tons/year of biogas.

Incineration and hazardous wastes

At the Valdemingómez municipal solid waste incinerator, around 230 GWh/year is generated from some 300,000 tons of wastes. At four municipal waste dumps, located in Madrid, Pinto, Alcalá de Henares and Colmenar Viejo, an average of one million tons/year of untreated or voluminous wastes or waste from the first bag, plus 0.5 million tons/year of discards from the rest of the facilities are deposited. These dumps and the one located at San Fernando de Henares – closed down in 2010 – produce between 80 and 90 million m^3 of biogas per year.

Compost produced at the Pinto composting and biomethanisation plant



Of the hazardous wastes managed in Madrid's urban area, 31% is recycled, mainly packaging, solvents, metals and oil. Twenty-two percent is subjected to some kind of prior treatment for reclamation, as in the case of batteries which, after decontamination, are crushed to use the metals that make them up. The rest, representing 47%, is dumped at the San Fernando de Henares repository, where between 50,000 and 60.000 tons/year of hazardous wastes are deposited. A part of these is previously subject to treatment to meet the parameters for receipt at the San Fernando de Henares stabilisation plant and the Valdebebas physicochemical treatment plant [67], [70].

Total Energy balance

As with the rest of the flows, the city of Madrid is a ravenous consumer of energy in all its forms. The following table shows its own generation, its imports and its consumption, with special reference to fuel used at Barajas, the majority of which is consumed during the flight, outside of the municipal area for emissions purposes.

MADRID ENERGY BALANCE IN KETP (2010)

Production	Primary sources	158	Consumption	RCI	1941
	Own generation	73		Industry, Wastes	419
Imports	Biomass	4		Transport	1196
	Coal	27			
	Natural gas	1.019			
	Oil products	1.238			
	Electricity	1.169			
	Biofuels	79		Total	3556
	Total	344.426			
	Barajas kerosene	2.328		Take-offs & Landings	207
	Total with kerosene	346.754		Total with kerosene	3763.0

Note: The sum of own generation and imports is different due to cogenerated energy. Source: Madrid City Council.



Municipal waste management facilities

Strictly speaking, the airport could not operate without that fuel and, if you like, the city could not function without the airport, so it would not be crazy to consider that the city "consumes" all the kerosene with which the aircraft are filled. Without taking this into account, Madrid's per capita consumption in 2010 was 1.15 ETP.

The primary sources are municipal wastes and water treatment sludge. Energy recovery from these by incineration and biogas production gave 30 kETP of electricity. Industry cogeneration gave 9 kETP and sludge drying 28 kETP. Another 6 kETP came from solar energy, giving a total of 73 kETP of own energy generation.

Quality of Life

After this heap of data, it is worth raising what Madrid's residents think of the functioning of their city in terms of resources and material and energy flows. A recent European Union survey of 41,000 European citizens from 28 countries lets you get an idea of the level of satisfaction in terms of the problems of air, noise and cleanliness. The table shows the percentage of citizens who are very or quite satisfied with the state of air quality, noise and cleanliness in 15 European cities selected from among the 83 cities included in the survey, of which 28 are capitals.

QUALITY OF LIFE IN EUROPEAN CAPITALS

	Citizens very or quite satisfied			
	Air %	Noise %	Cleanliness %	Q. of life Mean
Luxembourg	83	79	92	85
Vienna	79	69	81	76
Helsinki	78	74	77	76
Dublin	81	93	49	74
Stockholm	72	70	75	72
London	65	73	67	68
Amsterdam	58	69	64	64
Berlin	66	60	42	56
Brussels	51	55	46	51
Lisbon	50	51	38	46
Prague	39	49	43	44
Paris	33	43	43	40
Rome	34	37	25	32
Madrid	25	21	43	30
Athens	21	33	23	26

Source: Data: European Union (Nov. 2012)-*El País,* 17/10/2013.

According to the survey, carried out in November 2012, only 25% of Madrid's residents are satisfied with the status of air quality, a figure that drops to 21% in relation to noise and rises to 43% in relation to cleanliness. That places Madrid in 25th place of the 28 capitals for air quality, in 27th for noise and in 11th for cleanliness.

These results represent a fall compared to the figures for the previous barometer from three years earlier, in 2009, in quality of life and almost all the parameters. Citizens' satisfaction with public transport, which was one of the city's strong points, had fallen ten points, from 78% to 68%, meaning that it dropped from one of the top places to the middle of the table, which is now headed by London with 84%, Paris with 78% and Berlin with 77% citizen satisfaction.


HOTEL

7 | Using and Enjoying the City

Unitary image

In spite of the city's enormous revitalising changes, Madrid continues to have a unitary image, continuing to be perceived as a whole. Citizens know a part of their city and relate to it more strongly than to any other place. You do not need to have been born or be living there for it to form part of your existential space. It is something you carry with you with pride, you feel willing to fight for and is born from associations between your memories and intentions and the place where they occurred, the place where you lived or live [19:159].

This bond holds to something rather poorly defined, defying attempts to isolate it, but it has some very clear references: a degree of population concentration, a hierarchical setting, some limits and a culture opposing the rural. With the passage of time, that whole sense of what the city is receives meanings from the buildings and monuments it houses.

Meanings and nostalgia

In any age, citizens like to or need to translate their energy and their collective richness into symbols and they express it by building monuments. It is represented in exceptional buildings that show the pride or the ups and downs of their coexistence. With that, they explain that their dwelling is something more than the mere satisfaction of basic needs. Time modifies the original function of those monuments and adapts them to the intentions of new citizens, who use the city in a different way. And the new meanings derived from this process are welded to or overlay the previous ones and testify to the past. With all this, the character of the city is progressively built up.

In view of the importance of what has been built in Madrid, described up to here, it is worth asking first how Madrid's residents use and enjoy them and then, perhaps, what they think of it all. Among so many buildings, so much asphalt and so many Public Works, the first thing they seem to be missing is *what is not built* which, to simplify, can be called, incorrectly but understandably, the natural environment.

Vegetation and the natural environment

The 1980's were also fruitful in progressive attention to vegetation and the natural environment, with publications of all sorts, such as the guide to trees by Antonio López Lillo [143] or the one to meadow plants by Fernando González Bernáldez [124], and the Guides to the Sierra de La Cabrera and to the Monte del Pardo or the map making on the Vegetation and Land Uses of the Comunidad de Madrid by the Professor of Projects in the School of Mines at the Universidad Politécnica de Madrid. In spite of its noteworthy biodiversity, above all in the meadows at the foot of the mountains, Madrid is not an extensively forested territory, as its wooded area does not exceed 100,000 hectares of the 800,000 of the Comunidad de Madrid. About thirty species of trees in the countryside and woods, compared to the more than 150 species in the urban area, indicates the importance gardens have as a reminder or representation of a natural world, foreign to the city.

That scarce vegetation characterises Madrid's landscapes in the zones and seasons in which it appears. Pine groves on the hillsides of the Sierra de Guadarrama, groves of Pyrenean oak in the Lozoya Valley, holm-oak woods in the *pediment* and the Casa de Campo, or now in more urban areas, such as the elm groves in the Casa de Campo itself, the cedars of the Parque del Oeste or the mixture of trees in the Parque del Retiro mark their presence and the deciduous ones make the passage of the seasons clearer in a climate as marked as that of Madrid [143:9].

Sierra de Guadarrama

That relative scarcity promotes a special affection in Madrid's residents towards its "parks and gardens", a bureaucratic name for the plant based, consecrated as a "Department" in Madrid City Council. Madrid has a good expanse of parks and gardens in proportion to its area, with zones such as the Monte del Pardo, Casa de Campo, Jardines de Sabatini and the Campo del Moro, the Parque del Oeste and the Dehesa de la Villa.

But, with a great difference and in spite of its remoteness, the Sierra de Guadarrama mountain range is the natural space most sought after by citizens. As Sáenz de Miera says, *Madrid's residents need that natural space in a way that we could almost say vital* [212:27].

Educators, scientists and mountaineers

At the start of the last century, the mountain range was "discovered" by geologists, botanists and zoologists who, together with mountaineers, were pioneers of a new attention to those mountains. There were noteworthy predecessors, but it would be the Enlightened ones of the 18th and the second half of the 19th centuries, such as

Casiano del Prado [199] and above all Francisco Giner de los Ríos, the founder of the Friends of the Guadarrama Society in1866, who hold centre stage. Some time later Giner involved the Institución Libre de Enseñanza, the Free Institute of Education which, from its first excursion to the Guadarrama on 14 July 1883, mobilised educational and scientific interest in the Sierra [205:223].

Giner was one of the first to combine the scientific characteristics of the landscape with perceptive aspects, more than a century ahead of the concept of *cultural landscape* established in the European Landscape Convention, signed in Florence in October 2000. To explain it he always used landscapes from Madrid's mountains. To introduce *geological aesthetics*, he begins: *Everyone can distinguish the picturesque tooth-like way the rock formations of Las Pedrizas del Manzanares, in the neighbouring Sierra Carpetana mountains, stand out against the blue sky from the soft modelling of the hills around Madrid. Those are granite; these are Quaternary diluvium[…]* [114:109].

But that educational interest in the Sierra, Martínez de Pisón points out, *is not reduced to the knowledge that nature can provide, but rather to the ideas and experience you can gain there, which relates to the attitude of the tripper* [157:101]

The interest of mountaineers was stimulated with the Villalba - Segovia railway, which made Cercedilla the station for the Sierra on the Madrid side and San Rafael on the Segovia side. With the help of the railway, visits increased and the first climbers' and mountaineers' clubs emerged. In 1907 the Twenty Club was founded with a small refuge opposite the Ventorrillo road menders' hut, on the road to the Navacerrada pass. In 1908 the Club Alpino Español was set up to promote the sport of skiing and in 1913 what would later come to be called the Real Sociedad Española de Alpinismo Peñalara was created [84:267].

Excursions, conferences and mountain sports propelled Madrid's residents towards the Sierra de Guadarrama from the 1920's. Thanks to the railway too, summer holidays began in colonies of cottages – now holiday chalets – following the route of the railway and bringing numerous citizens closer the Guadarrama on their days off.

There are already legions of Madrid residents who on holidays go to the summits of the Sierra de Guadarrama, Indalecio Prieto said in his 1933 speech on railway links. With this project, *the mountain would be closer to Madrid, would be like a neighbourhood of Madrid itself.* And he understood that to achieve this there would be no need to build new lines or roads, *using the existing lines would be enough[…] bringing the railway to the heart of Madrid* 1941 [201], [106:208].

The boom in mountain sports represented a new option for outdoor leisure for Madrid's residents and revealed itself as a serious threat to the Sierra. *Because downhill skiing*, writes Martínez de Pisón, *not only appropriates the land, but the landscape too: it requires investments, infrastructures, ski lifts, machinery installations in topmost areas, opening roads for access and tracks for vehicles, car parks which are too small on the few days of maximum influx and deserts for the rest of the year* [158:74].

This is not the right place to start a discussion about the due protection of the Sierra de Guadarrama or about its occupation by second homes early on with successive worsening. It does appear necessary to emphasise, though, that in urban and regional planning in all ages, the Sierra is understood as a *space to project the city* [69:195] which has been integrated into the framework of relationships with the metropolitan [231:292].

A recent Community of Madrid law accepts the possibility of building on plots located in protected areas of the Sierra, with no other requirement than the exceeding of a minimum plot area. This abounds with the idea of "forced vocation". The Sierra continues to be considered now as a reserve for the city of Madrid, which can have it at its disposal for one use or another depending on its urban needs and demands.

For Martínez de Pisón, Madrid has a territorial organising role with such a clear leading part as to determine its arrangement. *The city here has such a star quality in the geographical space of the Comunidad de Madrid that raising the consideration of nature in the mountains, executing and proposing a natural resource plan for that mountain within it, needs to start from that fact* [159:71].



Giner refuge at La Pedriza

Movement towards the Sierra

The Sierra for the city



Views and air for citizens

Without going into it too deeply, Madrid's residents appear to look for some diffuse and difficult to specify intangible qualities in the Sierra. These assets are usually grouped around the quality of life, which is equally illusory, but has the interest of being highly related to what is lacking in the city.

If urban landscapes are short, grey and closed, that would mean an interest in expansive, green and open landscapes. If the air is polluted, quality of life would consist of breathing clean air. If the city is noisy, silence and if it is full of people, solitude. For Ramón y Cajal, air and views is what Madrid's citizens get from the Sierra: *We live at the foot of a mountain, the elegant skyline of which embellishes our horizon and the sweet breezes from which purify our environment* [226:448].

According to this, it is not so much a question of its attractiveness – which is always undoubted – of the place itself, but rather of offering citizens what is scarce or non-existent in the city. Once again, a relationship of complete subordination of the Sierra de Guadarrama to the Madrid area.

Saving the Sierra from the city

From this matter emerges a symmetrical idea: the better things are in the city, the less citizens will need to go to the mountains. The idea took shape among ecologists in the last years of the term of office as Mayor of Madrid of Tierno Galván. The defenders of the Sierra and those concerned about its growing occupation by housing, residences and urban developments joyfully greeted the recovery of fairs, festivals, processions and the rebirth in general of street life brought about by municipal proposals.

When people had fun in Madrid over the weekend, the need to "escape" from the city and its corresponding pressure on the mountains reduced. With this, the traffic problems (the dreaded weekend return) reduced and the mountain villages were less congested. This appeared to be firm, but did not last long. The attraction of investing in second homes became widespread towards the end of the 1990's and pressure from use increased again. This time it did so with a speed of invasion much faster than before and with a boundless abundance of communication routes.



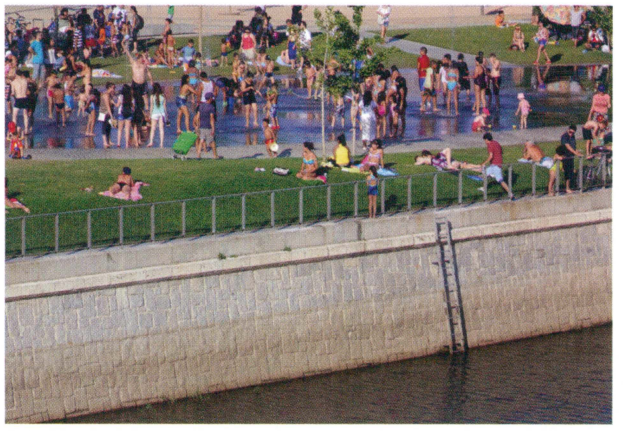


New respect for the city. Disassembly of the "temporary" overpass at Atocha and remodelling of the Carlos V roundabout

Apart from the Sierra, the widespread perception of the landscapes surrounding Madrid was never considered attractive, but rather arid and harsh. Vegetation presumed to have existed before is missed. En 1861, Mesonero Romanos, wrote: *In truth, in passing your eyes over the arid countryside that today surrounds Madrid, you would with difficulty believe that these same hillocks, arid and bare today, were in other times famous for their fertility and beauty* [164:XXVII].

Neighbouring arid landscapes

On the contrary, the researcher Ramón y Cajal defends the beauty of the arid, *You need to have the chromatic sense of a caterpillar to always miss the wet green uniformity of the northern countries and to scorn the penetrating poetry of grey, yellow, grey-brown and blue* [226:223]. But he gets enthusiastic when there is vegetation: *The woods at the Casa de Campo are very pretty and, viewed from there, the Palace of Madrid offers a magnificent panorama. On this side, the city appears very lovely and does not show such complete bareness and aridness as that which disfigures its surroundings on the other sides* [226:453].



Visiting Madrid "beach"

The Casa de Campo park has always been loved by Madrid's residents, but its closeness leads to a level of use that exceeds its capacity. Studies such as the one by Germán Glaría and Pedro Mantilla already revealed the need in 1979 to protect the woods of the Casa de Campo, as a typical example of a periurban wood subject to excessive pressure from use [115].

Madrid builds its landscape

Water and vegetation are cared for, protected and "constructed" in the form of baths, parks and gardens. In April 1803, Lady Holland tells the story of a visit with the lady from Osuna to her house at Alameda, one league and a quarter from Madrid along the Alcalá de Henares road. *Twenty-four years ago, the lady from Osuna found at Alameda the same sterility and lack of vegetation as characterise the surroundings of Madrid, but she has made it into a happy, wooded place. The garden is rather full of a large amount of different ornaments, some of the sentimental style so appreciated by the Germans, others of a more ostentatious style typical of the city[...] There are gardens designed to provide coolness, countless grottoes, pavilions, chaumières, chapels, channels, ports, small pleasure boats, islands, hills, etc.* [226:454].

And she appreciates its river and improves it to enjoy the bathing. At the end of the 17th century, the bed of the river Manzanares was dry in summer and was used as a promenade by elegant people [226:450]. At the beginning of the 19th century, foreign visitors noted this effort: *In the river there are some delicious places to bathe. They are pools made artificially by excavating the river bed and reinforcing the sides with wooden boards so as to exclude all dirt from them. And one is protected from the sun and the rain by mats extended over wooden platforms.*

Compatible uses of the river

The river is divided into several parallel courses; two for bathing, where the water never stops flowing and is filtered through sand to keep it clean at all times; and two streams at either side of the baths which serve for washing and those going to all Madrid's laundresses. While they go about their work, they are protected from the damp by wooden boxes on which they sit and from the heat of the sun by awnings suspended for the purpose [226:451].

The custom of bathing in the Manzanares continued until the 20th century, with the consolidation of massive use of Madrid's "beach". It also had a special splendour in the postwar years, when other options for outdoor leisure were not plentiful. This was boosted by the buildings and facilities of the Parque Sindical.

Climate and the night

The roots of such behaviour appear to be a consequence of a harsh, arid climate which is resisted by bathing, taking siestas and staying up late. Hemingway believed that *Madrid's residents like their climate and feel proud of its abrupt changes. What other city can show such variety?* [226:85].

In Madrid it is cold and it is hot, very hot, above all at night, Hemingway continues. *Nobody goes to bed in Madrid until they have killed the night. To go to bed early at night in Madrid marks you as a little queer. For a long time your friends will feel a little uncomfortable about it. But there is respite: The early morning is the appropriate*

time to sleep. A little before dawn the temperature drops a little and that is when a decent man needs to go to bed. However great the heat of the night, it always cools down at those times [226:85].

The old Arganzuela Park

They are still building parks and remodelling old ones. The (now old) Parque de la Arganzuela (1968-1969) stretched along the left bank of the river Manzanares from Toledo Bridge to the old municipal abattoirs at the Plaza de Legazpi. It was designed in two phases, in line with the projects for new roads for traffic and junctions: the first phase in 1968 with 12 hectares (from Toledo Bridge to Praga Bridge) and the second in the 1980's with an expansion of 25 hectares, resulting from the transfer of Madrid's old Markets to the Entrevías area. The arrangement between the river and the Paseo de Yeserías made it possible to obtain a park of a type composed around a central element made up of an elliptical lake of 110 by 60 m. Placed at its centre was the obelisk – previously located in the Plaza de Roma and before that in the Paseo de la Castellana – commemorating the birth of Queen Isabel II, the work of Francisco Javier de Mariátegui and José Tomás.



Parque de la Arganzuela around the 1960's [Patricia Hernández-Lamas]

In this first phase, as well as the central lake area and the children's area, an area was designed passing over the gardens in the form of a boulevard made up of four parallel rows of wild banana trees to the Paseo de Yeserías, at a total length of 450 m with 350 trees [136:176-178]. The Paseo connects to the gardens by means of ramps and stairs and its high level allows you to look over the lake and the bushy, floral groups of the composition. The parking problems were also taken into account, resolved off the main street for traffic.

It has now practically disappeared with the tunnelling works for the M-30. Only a few structures remain, such as the Clock House and the greenhouse known as the Crystal Palace of La Arganzuela. The livestock and fruit bay of the old municipal abattoir (Luis Bellido and González, 1908-1928) was reconverted in 1992 as a greenhouse of 7,100 m^2 with 9,000 species from tropical, subtropical and desert habitats.

The 25 hectares of the New Parque de la Arganzuela (2011) make it the largest landscaped area of a unitary nature in the Madrid-Río project (see page 176). The project rescues the traditional river paths and triples their original area, going from 84,000 to 232,700 m^2 with 10,000 new tree plantations and 122,300 new shrubs.

Juan Carlos I Park

The construction of new parks has recently been boosted with the recovery of more or less naturalised areas which had still not been built up. Some landscaped areas which had previously been for private use were also opened to the public, such as the Parque de los Pinos in the Tetuán neighbourhood, belonging to the Canal de Isabel II company.

An ambitious park of some 220 hectares was built at the Campo de las Naciones, between the M-11, for access to the airport, and the M-40 motorways, the Showgrounds and the town of Barajas. In spite of the motorways, the park is surrounded by residential neighbourhoods such as Barajas itself, Alameda de Osuna and the new constructions for the Campo de las Naciones, and the decision was made to make a highly designed urban park. The pre-existing assets of the La Hinojosa olive grove, at 21 hectares, and the beautiful El Capricho park (1784) with a further 14 hectares probably influenced this decision too. On top of all this was the rigid geometric design of the zone of offices and the hotel near the Conference Centre and the Fairground.

The park sets its own limits and is detached from the motorways and existing structures with a rather geometric design, enclosed in a circle almost 1,000 m in diameter. Many things have been constructed inside the circle: gardens named Lluvia, or rain, and Tres Culturas, or three cultures, and some large sheets of water. The whole landscaping design, commissioned from Miriam Silber Brodsky, is charged with symbolic intentions.

The circle *refers to the old geometric garden enclosures*; *ziggurats and artificial hills were set out to see the landscape*; there is an *aquatic route* with a canal or "'serpentine" of 2 km between two ponds and another large isolated lake. There are *macrosculptures* and *cybernetic fountains*. Really, there is all sorts.

The three cultures form an area which is also circular and include a *common central point representing paradise*. The area is perceived as a *journey* and each element contributes an *anecdote or a landmark* evoking a Jewish, Christian or Medieval text. The Christian garden evokes a *medieval cloister* with transparent tubes of coloured water. In the Arab

garden or *place of delights* there is a new pavilion and a new fountain with plantations of colour and perfume. The Jewish garden contains the *Shield of David* with another fountain from which the water falls in the form of a snail [87:118].

Also built outside the ring was a very interesting amphitheatre, designed by the architect Antonio Fernández Alba, an area for sporting activities and car parks located between the M-49 and one of its on ramps, spanned by four footbridges.

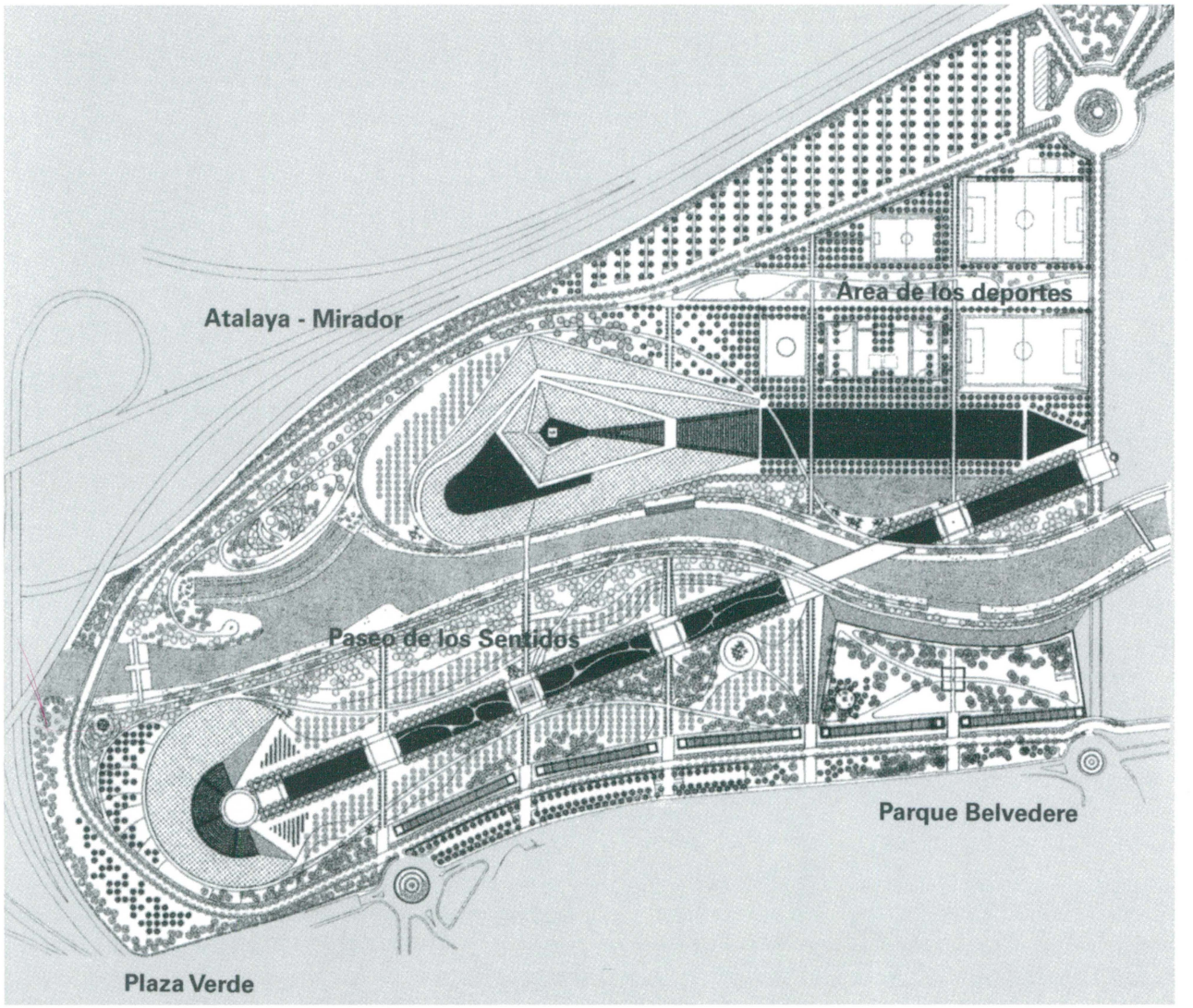
Tierno Galván Park

The final piece in the railway Green Corridor is the Parque de Tierno Galván, in the Legazpi neighbourhood, alongside the M-30. It occupies the so-called Cerro de la Plata, or silver hill, due to its contrast with the carbon deposits from the steam trains that used to leave Atocha and Delicias stations. It was designed by Salvador Pérez Arroyo and Javier Feduchi in 1983, on a derelict area, with industrial tips and obsolete railway facilities.

Included in it are an IMAX cinema, built by Jordi Querol and Guillermo Costa in 1995, a Planetarium by Pérez Arroyo, an auditorium, several ponds and viewpoints and a climbing wall.

Manzanares Sur Park

This was a strategic proposal in the 1985 General Plan, to connect the system of open spaces and green zones with the great green corridor of the river Manzanares Regional Park (or Linear Park) located between La Pedriza and Aranjuez. After an initial general proposal of that year, only a small area came into being, the Parque de San Fermín, designed by the architect Sara de la Mata. The Empresa Municipal de Suelo, the municipal land company, commissioned the Master Plan for the Parque del Manzanares and the design for the first phase from Bofill in 1998.



Parque del Manzanares: a river of big projects:
general plan view. Ricardo Bofill Architecture Workshop, 1998
(Municipal Land Company)

This first phase (1999-2003), between the Southern junction, San Fermín and the extension of the streets named Mezquita and Embajadores was of 35 hectares and reclaimed the course of the Manzanares. It offers an alternative pedestrian route to the river of the Paseo de los Sentidos, complemented by an orthogonal stretch to diversify plantations and uses. Outstanding in the park is a 21-m high grassy pyramid, the Atalaya, created on a mountain of rubble, where the sculpture of the Dama del Manzanares, by Manolo Valdés, sits. The project was executed by Ricardo Bofill, Jean Pierre Carneaux, José María Rocías and the Civil Engineer Francisco Gómez.

The second phase, of 54 hectares, extends to the M-40 and is crossed by the M-602. Some outstanding projects are located in it, such as the Caja Mágica, the Parque Acuático and the Pirámide Mayor, another big mountain of rubble of 32 m in height, made into a viewpoint over the city [52:612].

Madrid-Río park

In the latest remodelling of the M-30, the stretch of motorway running to the west was substantially altered. The decision was taken to make a long tunnel from where it meets the A4 at the Southern Junction to the junction with the A5, with the idea of reclaiming the river with an enormous landscaped area, which was named Madrid-Río. The design was the subject of a competition, which was won by the architects Ginés Garrido and Francisco Burgos (see page 176).

Regardless of the design of the park itself and the impeccable execution of the tunnels, the decision to take this stretch of the M-30 underground, beneath a park, is a committed action. This is true both for the public, due to the enormous investment required, and for drivers, due to the effort of driving through such a long tunnel with such dense traffic. You need to ask yourself about the *sense* of such an enormous work and this sense is where the main criticism of the action lies.

Squares and cars

In spite of those interests and those new "parks and gardens" built, greenery was still absent from the numerous projects to restore squares executed during the last 25 years. The ideas for renewing the city generated during the 1980's were accompanied by the taking of a specific position on the squares, with actions to mitigate the abandonment and disrepute of their roles in the city, as accumulated over the previous years.

The pulse of the previously busy squares was to a degree the heartbeat of the city, said Luis Fernández Galiano, but *all that changed with the car and urban planners: the car declared war on past squares and the urban planners on the squares of the future. The historic square splintered into parking spaces; new neighbourhoods were built with no more squares than occasional garages; vehicles occupied squares for people and walkers became pedestrians* [94:12].

Mutilation of civic life

That fragmented square occupied by vehicles lost its nature as a closed public space, which promoted reciprocal exchanges of public relations. The closing of the space of the square, as Enrique Gil Calvo explained, *produces the impression that external life, public life represented by the square is more valuable and important than internal or private life, represented by the front doors of the houses facing the square* [113:18].

The square parades a supremacy in form over the streets, representative of the priority of common interest over the private domestic interests, which is transmitted to the rest of the city. The square belongs to the whole *urban community* and spreads its effects over the whole city. It is there where the everyday meetings that make living together possible are easier and closer. For that reason, their abandonment represents a real mutilation of the possibilities for interaction between all citizens, beyond the neighbourhood of their homes in the street, which is an essential characteristic of civic life.

The new squares

The reaction against this abandonment, though, was proposed from very maximalist positions. What was needed was to reclaim the squares for people and expel or bury the cars. In many of these, underground car parks were built, seeking an alternative space for vehicles that no one wanted to see, but everyone wanted to have close by.

Democratic attention to municipal management, though, immediately had to concern itself with budgets that would not stop growing. The new social and cultural services taken on by the local councils were draining an enormous amount of resources, so design solutions for all urban elements that saved maintenance costs, at least on paper, were welcome. It did not matter if much more needed to be invested, if certain recurrent costs could be saved, even if they were small.

The solutions proposed discouraged the facilitation of the public life which is characteristic of squares. They assaulted citizens' well-being, but they also worsened their urban ecological role. The few voices that warned of the increased run-off produced by the elimination of soil from the ground and their replacement by impermeable paved surfaces were ignored. Instead of permeating into the subsoil, rain water runs across the paved surface and needs to be collected in large drains to be discharged into the river. That extraordinarily increases the magnitude or seriousness of the spate flows and, with that, the risk of local flooding or overflowing due to lack of capacity in the collection system.

Desolation and severity

The few designers aware of the harshness of those designs or the disadvantages of the impermeable paved surfaces were marginalised by the modern trends to rigid geometry in what is built. At that time, many of them preferred extraordinarily precise solutions, true to what was on the drawing: stone or concrete was more stable than soil flooring and they gave their final appearance from the first day. Soil, on the other hand, was carried away by water and the trees took time to grow and never had the shapes and sizes intended for them.

Trees disappeared from the squares or were reduced to residual samples enclosed in flower beds or ridiculous tree pits, which were more ductile and controllable in the plays in shape of the design. The lawn, above all, was the great enemy: it consumed a lot of water and you had to water it often.

Design against lawns

The only really green space, for many people the most attractive in Madrid due to its dimensions and bareness, was the cover of the Canal de Isabel II tank in the street named Islas Filipinas. An initial intervention in 1985 partially opened the north-west side to the public, with the name of Parque de Santander, but left the great green space untouched. That space was later to be split up and trivialised by part of its area being converted into a golf practice range and a part into a collection of samples of paving, at the construction climax of 2008.

The examples are as numerous as the great variety of authors and perspectives from which the scarcity of trees has been criticised. In his article *Madrid seen from the Sierra*, Adrian Piera protests against the process: *In the new squares it appears that they have forgotten to plant trees. In remodelled squares they have systematically pulled up the ones there were, leaving them in a pathetic state of coldness and desolation*. He then points to examples

Correlative rejection of concrete



Green Canal Golf

of the Plaza de Chamberí, which everyone found pleasant and which has been remodelled unsuccessfully a couple of times, the Plaza Mayor, the Boulevards running from the street Colón to Rosales or those in the street named Velázquez, the little gardens on the Quevedo roundabout, the Plaza de Salamanca and the Plaza de Manuel Becerra, later called the Plaza de Roma. He ended by mentioning the problems of lack of security associated with *these deserted concrete spaces called squares*, mentioning AZCA and the Plaza de Dalí [194:373].

Never had a construction material been made into the target of all the critics in such a way. Concrete has had the unwonted capacity to draw all the attitudes against what was built. It is the word that best summarises the contempt for any concern for the environment which goes beyond the interests of the specialists who construct and the companies that promote what is built. This happens regardless of the fact that, even though it is the most common material, it is not usually used in squares or streets, where treated asphalt road surfaces or industrial floor tiles or stone slabs (there is a love of granite in Madrid) are certainly used, or in streets or roads where it was never successful.

Painful balance

The result of the primacy of the built up over plants was devastating and did not satisfy citizens. As Luis Fernández Galiano stated, *The squares of the 1980's, scenographies without representation, oscillate between historicist pastiche and the most extreme abstraction, between populist triviality and hard line avant garde: you had to choose between cloned replicas of classical colonnades and hermetic landscapes of concrete and metal[...] Hard and staggered, treeless, the pleasant squares were made unpleasant* [94:12].

Neither did the designers like them, as there had been little agreement on the main projects, the prestige of which lay more in the well-known name of their designers than in their intrinsic virtues. Several important, recently renovated squares were soon subject to successive remodelling. However, in spite of well called competitions and their impeccable panels of judges, the problem was always the same: different designs, but the same severe nature. In Madrid's harsh climate it was better to avoid them or go around them, seeking the shade or protection of the buildings at the sides.

This not only occurred in the capital, though, as the Comunidad de Madrid, always concerned with the power of the capital, gave priority to extending its action *not just to the whole metropolitan area or those areas near its periphery, but to the rest of Madrid's municipalities, including the smaller ones* [109:25]. Three hundred and twenty eight squares were studied and interventions took place in the great majority, giving undoubted improvement in all the town centres near Madrid. The result was better the smaller the dimension of the places where interventions took place, where the new abstraction did not achieve sufficient critical mass to impose its high-handed presence on the consolidated urban fabric.

Plaza de Colón

One of the first examples of this conceptual course of action was the design of the Plaza de Colón, called the Plaza de Descubrimiento, created after the demolition of the old Mint. The first thing was the construction of the car park, the top slab of which was designed to be able to plant trees on top of it. But the idea of building and placing all kinds of things on that space won out: the old statue of the discoverer, an auditorium, a café, an exhibition hall, a waterfall, diagonal parades to guide flows scarcely interested in possible routes and three enormous sculptures by Vaquero Turcios to remind you of Christopher Columbus's ships.

The work was poorly received, with some differences of opinion, as the newspaper El País showed on 15 May 1975, the day of its inauguration. Antonio Rumeu de Armas spoke of its *erudite rigour* and *expressive beauty*. José Luis Picardo found it *large and rambling*, like the Plaza de España. José A. Fernández Ordóñez spoke of an urban lack of emotional sensitivity and moral control and concluded: *It is just as well that Admiral Columbus, ashamed, has silently adopted the only dignified posture faced with such an indescribable spectacle: to turn his back on it*. Francisco Fernández Longoria entitled his *A load of blunders*. Antonio Fernández Alba wrote of *Imperial rhetoric*. To Leandro Silva it appeared to be *a complete example of coarseness and incoherence, an authentic synthesis of the criteria which have been dominating our urban landscape for several years*. For Santiago Amón it was simply a *freak*.

Then came some additions and changes, above all a flagpole, the highest in Madrid, with an enormous Spanish flag. And it started again. The waterfall was removed because it was noisy, Columbus moved back to the centre of the square, from

where he should never have moved, the parades changed several times, the whole roundabout at the junction of the streets named Goya and Génova with the Paseo de la Castellana was remodelled (see page 176). But not one new tree.

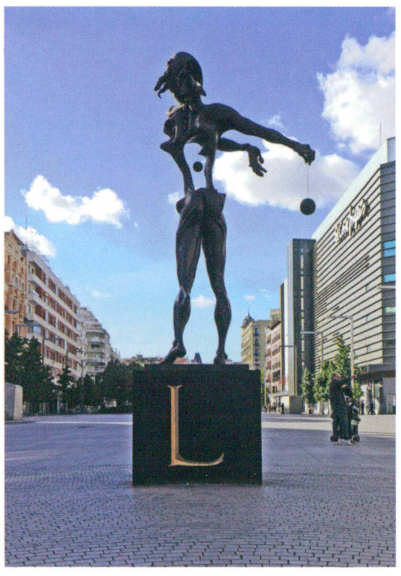
Later came more cases. The 1985 plan converted the old entry street to the Goya Bullring, demolished in 1945 and moved to Las Ventas, later converted to the Avenida de Felipe II, into a landscaped setting for walking on top of an underground car park, which came to be called the Plaza de Salvador Dalí [197].

Plaza de Salvador Dalí

To resolve the difficulties of planting vegetation on top of the underground space, the structure of the car park was over dimensioned to support containers of soil capable of housing species of a good size and horizontal extent. On a ground plan with the shape of an irregular trapezium and walls of variable heights, soil containers in the form of wedges were placed, with wooden benches placed against the highest walls. It has the inescapable children's parks and the sculptures which preside over it all, a dolmen and Dali's Homage to Newton, both from the previous intervention. The sculptor David Torres added an ancient olive tree, a fountain of books and cast iron slabs alternated in the granite paving [93:118].







Plaza de Salvador Dalí (Mangado & Torres, 2005)





Plaza de Santa Bárbara (Nieto & Sobejano, 2010)





However, some recent projects show a possible way out from the severity of squares lacking in vegetation, with solutions that add colours and geometric shapes to the presence of plants themselves. The Plaza de Santa Bárbara (Nieto & Sobejano, 2010) constitutes a tree-lined urban hall, with geometries inspired by the pentagons of the nearby Mercado de Barceló market to formalise kiosks, flower beds, pavements and green spaces [178:151].

Plaza de Santa Bárbara

The concentration of people in that relatively small space subjects the most highly designed elements of the square to enormous pressure from use. In spite of the robustness and hardness of the materials of the benches, kerbs and paving, the whole suffers from heavy wear which degrades the attractive and clean initial image.

Beyond the parks, squares and other spaces designed for the public to enjoy, many well constructed buildings and public works produce similar effects. Sometimes, some sparkling new buildings manage to transmit or irradiate their presence to the neighbourhoods where they are located.

A clear example is that of the extension to the Prado Museum and its effect on the neighbouring streets. Before the alterations, Juan Benet described it as the *Madrid's most harmonic and soothing neighbourhood[...] the most successful combination of monumental character, nature and neighbourliness. It is a neighbourhood so well designed for the arrival of spring that one day – in late March or early April – the air is saturated with an unmistakable aroma, the product of the combination of the Prado's myrtle and privet, the honeysuckle of the Academy, the whole of the Botanic Gardens, the Los Jerónimos hillock, the magnolias of the Murillo bower, an aroma I have never smelled anywhere else. It barely lasts two weeks* [43:19].

Presence of the Prado Museum at the back

Surely Benet would have appreciated the care taken by Moneo to choose the plants for the gardens at the back, where the main entrance to the building is located. The carefully laid out geometric strips of box incorporate rigour and sensitivity to the rear of the old museum and contribute to drawing its presence into the neighbourhood through its heady fragrance. It is not that the Museum invades the neighbourhood, but, by placing its entrance there, it actively joins it. It continues to belong to the Paseo del Prado, but it penetrates the neighbourhood and incorporates it in its sphere of influence.

Plaza de Barceló and market [aerial photo of the square in [178:142]



Barceló market and square

The project for the new Mercado Barceló (Nieto & Sobejano, 2009) too shapes an urban set of pieces of different scale and a programme that will notably transform a dense central area of Madrid[1]. Nieto & Sobejano's proposal defines new urban empty spaces that connect and relate the different volumes and uses anticipated that will need to coexist: market, shopping centre, sports centre, public library, car parks and open air spaces.

Of similar urban significance are the temporary facilities which continue market life during the construction of the definitive building. These are located on top of an underground car park and were drawn up as six bodies with pentagonal ground plans, of different heights and sizes to avoid the presence of an excessive volume with respect to the neighbouring streets [178:140], [16: 242].

Building *Edificio Mirador*

Another way of influencing the city is by standing out from the surroundings to appropriate them thanks to a design with greater presence. For example – regardless of its typological and construction interest, tested in the 1970's in a similar building in the La Défense area of Paris – the Edificio Mirador, meaning viewpoint building, was designed with reference to the new neighbourhood of Sanchinarro, with 12,000 homes, located to the north of Madrid, alongside the A-1 and between the M-30 and M-40.

It is located alongside the neighbourhood's central roundabout and concentrates all the area's suitability for building in its 21 floors[2]. Its stamp of identity is a large rectangular opening and the colour applied to its façades, the composition of which gives the idea of *Lego* bricks, combining up to eight types of different homes amassed in a vertical assembly. The opening acts as a local assembly room from where you can look out on the Sierra de Madrid mountains[3] [12: 92-93].

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[1] Credits for the Barceló Market: Architects: Fuensanta Nieto-Enrique Sobejano. Ownership: Madrid City Council. Project Architects: Alfredo Baladrón, Alexandra Sobra. Dates: Competition 1st Prize: 2007. Design: 2008. Construction: 2009. Construction Company: Acciona / Dragados Joint Venture. Location: Calle Barceló, Madrid.

[2] Edificio Mirador Credits: Architects: MVRDV (Winy Maas, Jacob van Rijs, Nathalie de Vries) & Blanca Lleó. Structure: Jesús Jiménez Cañas. Constructor: ACS. Client: Empresa Municipal de la Vivienda.

[3] Arquitectura Viva Monografías, 112 (2006):61.



Edificio Mirador (MVRDV & Blanca Lleó, 2005)

Richness of the urban fabric

Beyond any construction specifically designed for decoration or embellishment of the city, the layout of the streets themselves has a great influence on the way of living in the city and has strong links with its process of development. Initially this adheres to the morphology of the site, but it breaks away from this with the primacy of the flows for its citizens. The oldest streets located in the Arab quarter of the city and the Madrid of the Hapsburgs were not suitable for fluid movement of car traffic and have not been greatly modified. Those with straight layouts and those located outside of these areas underwent significant changes to accommodate transport flows. And those built ex novo from the late 19th century were already devised as traffic arteries, with boulevards and avenues abounding.

For their construction, the hillocks and watercourses appeared as privileged spaces in the uneven initial topography. The Plaza de España emerges where three valleys meet in a broad hollow. The stretch of the Gran Vía running towards it from Callao adapts itself to the route of a stream. The Calle Arenal occupies the course of a brook of the same name, from the Puerta del Sol to the Royal Palace, turning to the south to lead into the gully of the Calle Segovia. The Paseo de Recoletos and the Paseo del Prado follow the course of El Prado brook [110:46].

Operations at Sol and Gran Vía

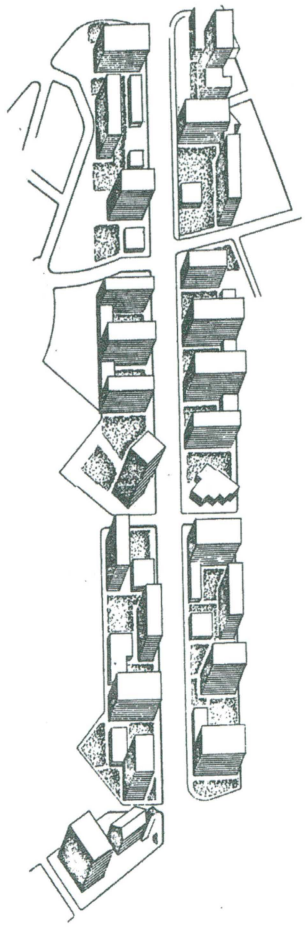
Later, streets and squares take on their own lives and set themselves even against the urban fabric, with a vision more of the city as a whole. The alterations to the Puerta del Sol and the opening of the Gran Vía were two large operations which have profound reflections on the character of the city. For De Amicis (1870), *the Puerta del Sol is a square with well-deserved fame, not so much due to its size and beauty as for the people, the hubbub and the variety of spectacles it offers at any time of day. It is not a square like the rest, but rather a mixture of meeting place, promenade, theatre, academy, garden, parade ground and market. From dawn until one in the morn-*





ing it is occupied by a throng, while another throng comes and goes along the streets that lead to the square and the carriages parade and intermix, with a hustle and bustle that comes to make you feel dizzy [226:155].

The Gran Vía contributes cosmopolitan airs in great contrast to the uses favoured by the narrowness of the Madrid of the Hapsburgs. For Hugh Thomas, *The new buildings built along the Gran Vía from 1911 (such as the Telefónica building, constructed at the end of the 1920's by Ignacio de Cárdenas and taller than any other church) conferred a certain South American air on the centre of the capital, as General Primo de Rivera gave to Spanish politics* [226:48].



Extension to the Calle General Mola

Railway green corridor

Extension to the Calle General Mola, volumetric study [3:110].

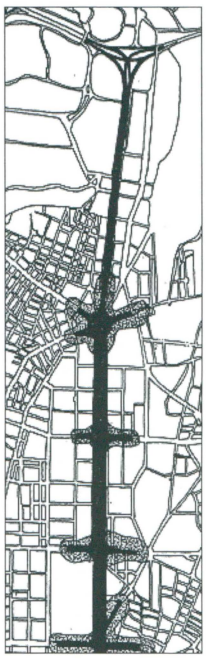
Another large operation that was postponed for many years and completed successfully in the early years of the 1970's was the connection of the street named General Mola – from the junction with the street López de Hoyos to the Plaza de Cataluña – with its own extension, built some time before in the Chamartín neighbourhood.

The connection formed part of the Plan for Complementary Accesses to Chamartín Station, drawn up by the Civil Engineer Enrique Pastor Pacheco and definitively approved in 1946. Its purpose was to feed the station's main entrance road, the Calle Pío XII, from the West. To do this, the Calle General Mola linked the ring roads to the Plaza de Cataluña, where it connected to the Calle de Velázquez along the Avenida Doctor Arce and was completed with the widening of and improvements to the streets named Segre, Cinca and Rodríguez Marín [3:109].

Its success was based on dedicating a large stretch to a series of institutional buildings, such as a church, a school, some offices of the Comunidad de Madrid and, above all, the Auditorio Nacional, linked through a small square to the municipal offices for the Chamartín district and to a landscaped area at its northern façade. The next buildings constructed on the two sides – the head offices for a bank, two large companies and several residential buildings – took advantage of the nobility bestowed by the width of the street with careful designs and noble materials, leading to a succession of good buildings which is rather rare in Madrid.

The alterations to the Suburban line connections gave an opportunity to completely rearrange a large area in the south of the city, in a great intervention known as the Pasillo Verde Ferroviario, or railway green corridor. The railway works consisted of expanding the lines from Príncipe Pío station to Atocha and laying them underground in a tunnel four kilometres long passing through the Arganzuela district. That made it possible to create a great tree-lined parade with big parks at its ends, linking the Parque del Oeste to the plant nurseries and the Parque de Tierno Galván.





Aerial view of the intervention zone

It also allowed the reuse of the old railway stations of Imperial, with a sports centre and a tertiary and residential area; Peñuelas, with another park, facilities and a residential/tertiary area; and Delicias, with a large space for extended development up to the Parque de Tierno Galván. The new line required the three new stations of Pirámides in the Plaza de Francisco; Delicias, at the junction with the Paseo de Delicias; and Méndez Álvaro, close to the new Bus Station and forming a new interchange [107:51].

Extension of the Paseo de la Castellana

A significant intervention which has still not been carried out is the extension to the Paseo de la Castellana. This is to be a new road which starts near the Plaza de Castilla and runs to the Colmenar Junction on the M-40, over land of which 63% belongs to ADIF, the railway infrastructure administration, and RENFE, the railway operator, 19% to the Government and 18% to private owners. It occupies 3,120,000 m^2 of land and 17,300 homes, 1,650,000 m^2 of tertiary uses – basically offices, although with commercial and accommodation uses too – and 550,000 m^2 of facilities are expected to be built on it.

Its main objectives are to extend the Paseo de la Castellana by 2.6 km, something that has not happened since the 1950's when it was extended by two kilometres from Nuevos Ministerios to the current Plaza de Castilla; and to remedy the urban wound produced by the railway facilities over more than five kilometres consolidated on either side of the tracks, integrating Chamartín station into the city and guaranteeing easy access to it.

This Project was selected for the 2010 Shanghai Universal Expo due to the great transformation it represents for Madrid and due to the application of the strictest criteria in mobility, energy and water.

Using the street on balconies

For many years the main enjoyment in the street in Madrid was adults walking and children playing. Fumes from fuel, lack of safety for children and the occupation of space by vehicles did great harm to the custom. Going out onto the street – day or night – was always a lifetime longing in Madrid. Although very small children no longer do so, for reasons of space and safety, youngsters and adults manage to spend a large part of their lives out of the house, at least when the weather is good.

The solution lies in the balconies, of all sorts and conditions, which represent a real institution in Madrid. The recent prohibition of smoking in public places has boosted occupation of balconies and many other new ones have emerged. To extend their use into the cold months, they have been equipped with awnings or roofs and side wind blocks, with butane heaters to warm the environment inside.

Personal mobility

The 1980's brought new attention to public in the street or walking in them. Mayor Tierno himself rejected the name for pedestrian as he consider it inappropriate and preferred to use passer-by. In the case of potential conflicts between cars and pedestrians, the mandate was to prioritise the comfort of the latter. It was not always like that, but the difference in attitude from the city of the 1960's was enormous. As the centre was restored, measures were taken to favour pedestrian mobility, with special attention paid to accessibility for people with reduced mobility.

Measures such as minimum crossing strips, longitudinal and transverse slopes, ramps, drops, protection of tree pits, islands in pedestrian crossings, stairs, handrails, car parking spaces, urban furniture, protection for works on public roads and signing were consistently applied in any urban action. This was, José A. Juncá summarised, to improve and recover the quality of the urban environment to *recover the old essence of the cities, that of providing satisfaction to its citizens, to increase its habitability* [137:24].

Conserving built heritage

In those years the posture towards built heritage changed radically too. Special attention was commonly applied to conserving the most valuable buildings, but *if unquestionable architectural pieces are defended, the possibility that the rest disappear is justified* [27:18]. That is, any catalogue makes it easier to conserve those included in it and to destroy those excluded. At the same time that *heritage was protected, significant demolition processes were mostly accepted* [27:22]. The alternative was to reformulate the concept of heritage, basing it on *each building, each urban area, each urban assembly having had a role, a function, a use which has contributed to forming and defining the character of a city*. Then the way they can continue to be useful to the city would give the interest in their conservation [27:32].

The text above, by Álvarez Mora, was published in 1983, when the concept of landscape as an instrument for working in the city still had not taken shape. However, with the consecration of the cultural as the fundamental way of considering the character of the landscape in the first decade of the new millennium, the urban came to occupy a central place and the ideas contained in this text are entirely topical. According to this, the *variety of architectural types* (cathedral, humble houses, palaces, middle-class housing, factories…) takes on special significance in forming the city's character. Their value lies, precisely, in that *each of these types represents* something and, without considering it, you cannot understand the city, which is a complex phenomenon [27:36].

Monuments in Madrid

That attention was decisive in maintaining the urban landscape in its most structural constructed part and contrasts, in a way, with the frivolity demonstrated by the city in its handling of its monuments. Fountains, sculptures and all sorts of monumental embodiments were disassembled and moved to other places.

There is not space here to list or describe the many monuments placed, moved or disassembled throughout the city. There is no square, roundabout or public space without its corresponding monument, although, unfortunately, the general level is rather poor.

Plaza de Castilla monument

The design was presented for the first time on 21 October 2004 by Mayor Gallardón and the Chairman of Caja Madrid, Miguel Blesa, in one of the Plaza de Castilla towers, which was the company's head office at the time. Madrid had no works by Santiago Calatrava and this, for the Mayor, *was a painful wound* [53:30]

Construction work started in 2008, after making some adjustments to the initial design, basically related to the foundations, the movement of the pieces and to safety. The site selected is on top of an underpass, two Metro lines and several service galleries, which demanded a large metal tripod, weighing 150 tons supported on three piles of up to 26 m in depth. Erected at its centre was the tubular shaft of 2 m in diameter and 93 m in height (230 tons), to which were to be connected the movable bronze slats of 7.7 m in length with a square section of 0.14 m on the side and 5 mm thick (92 tons).

The bronze slats are covered in 24-carat gold leaf, fixed to the bronze using six layers of different products [53:82], in a delicate operation calling for technicians and experts who usually work on the restoration of Baroque altarpieces.

The sculpture moves with a simulated rotation that climbs up the shaft, achieved by a tilting oscillation of the slats in an inclined plane with respect to the axis, out of phase with the previous ones. The mechanism consists of three groups of 42 hydraulic devices, each arranged on three levels of the shaft and computer controlled, with which *the slats flow before our astonished eyes like a river of gold* [53:148].



The work was inaugurated on 23 December 2009, but the high operating and maintenance costs for the hydraulic mechanisms deterred the use of the slat movement. After a few days of Christmas, the sculpture stopped its rather peristaltic movements and is seen at passive rest.



Plaza de Castilla monument (Calatrava, 2009)
[photo under construction in [53:94, completed competing with the water tank in [53:135]

For Santiago Calatrava, *This column will hold up Madrid's sky […] I wanted to create a 21st century work with references not just to the 20th century, but also ancestral ones[…] It combines the verticality of masculinity itself and the delicacy and movement distinctive of femininity* [53:37]. The column *signals, with beauty and symbolic strength, an end to the development of Madrid in the 20th century, the artery of the Paseo de la Castellana and the starting point of the new perspective of Madrid for the 21st century, with its colossal collection of new skyscrapers* [53:113].

Character the built environment in Madrid

All the power of what has been built decisively impregnates the character of the city, with powerful arisses, but by no means easy to summarise. For the city's residents, describing Madrid's character is more a case of taking up an individual posture than an attempt to summarise the city in an overall expression. However, it is not difficult to describe a certain pattern in that subjectivity, charged with contradictory notes of affection and contempt. These peculiar citizens love their city, but they cannot recognise it without standing back from their own pronouncements.

The hispanicist Hugh Thomas collects abundant attempts by travellers from all ages to define the character of Madrid [226]. It offers a view of Madrid *that alternates jokes and contempt with affection and admiration, that a significant proportion of its current citizens would subscribe to, whether writers, councillors, criminals, shop assistants or road sweepers*, Casariego summarises in his review and he offers some of them[4]: Unamuno describes it as *a giant owl that sets out to go to sleep*. According to Richard Ford, a 19th century English traveller: *The more you know Madrid, the less you like it*. For Baroja, referring to the El Retiro park gardens: *The spectacle was exclusively about Madrid, a bit courtly, a bit provincial, elegant and, at the same time, very poor*. The Marquis de Custine, in the 19th century, did not hold back in defining it as *an almost African town*.

Chiaroscuro, affection and contempt

Lope de Vega, in a letter to his patron, the Duke of Sessa: *Madrid continues to be the same as when Vuesa Merced left it; the Prado, carriages, women, dust, executions, comedies, a great deal of fruit... and very little money*. Charles Bouffleur, official British doctor in the Peninsular War said that *the city is the most beautiful I have ever seen*. George

[4] Casariego, Nicolás; Antología de Madrid, by Hugh Thomas, Letras Libres, May 2005 | Tags: Books Article of opinion.

Borrow, another Englishman declared: *I have visited all the world's important capitals, but, as a whole, none has interested me as much as the city of Madrid.*

Juliet Adams, a 19th century French writer, commented: *This city so ugly and so loved by King Felipe II does not remind you at all of the inquisitor King. Here everything is happy, even the misery; here men like Don Quijote, Sancho Panza and César de Bazán are counted in their hundreds. Madrid society, perhaps in an unconscious way, is democratic, frank and sincere, in a way that is completely lacking in conceit and affectation*[5].

Manuel Azaña, on the other hand, boasted of knowing Madrid well and used to say that the *irritable nature of Madrid's residents is clear*. But he did not *attribute this ill temper to a defect of the race, but rather to the road surface*. And he believed that *if the road surface were more elastic, the courtiers would have better manners* [39:217].

Character, contrasts, permanence

The passing years do not appear to have altered the mixture. There is no risk of Madrid becoming a *generic city*, that category predicted by Koolhaas [179] [65] as the result of mass immigration and the globalisation of products and services in newly-made cities. Madrid continues to show strong features of character, although they are probably different to the folk labels managed by tourism.

This does not involve investigating whether Madrid continues to be an "authentic" city or not, whatever that term means in 2013. It means, rather, determining whether that name characterises the city now or not. And when the distinctive features of the authentic are examined one by one, it is not easy to find them in the active life projected towards the world by the city. However much the tourist or nostalgic classes aim to keep the classic stew, the "cocido", the traditional "chotis" dance, the "zarzuela" casserole or the figure of the working class "chulo" alive, it is difficult to attribute them any representative nature in the city's symbolic profile.

This is not a new position, as already in 1920 Azaña distanced himself: *I am not a "Madridist". "Madridism" is a crassness imported from the periphery. Years ago, a Catalan who sold paving stones to the City Council wanted to become a councillor and he called himself a "Madridist" on his election posters. It was an entrepreneur's idea. Some gambling houses made it theirs later* [39:215].

Image of capital status

More difficult to handle is the representative image that its status as the capital of Spain, of the Kingdom, of the Country or, simply the common name of "the capital" means. No matter how often it is repeated, Madrid's residents do not recognise themselves as subjects of any centralist position, like those alleged by the different outskirts that Madrid has lost its popular roots: as Carandell explains, the typical is a very different thing to the popular [60: 125]

The Court drew people from the widest social backgrounds, but it did not create a strong social, cultural and entrepreneurial fabric with its own life. Madrid had no university until the 19th century and its companies are from the day before yesterday. It has been no use to Madrid being the capital of Spain, because its inhabitants were unable to set up a community independent from central political power, with its own life and interests defended with tenacity and cohesion [221:10].

Manuel Azaña used to say that, *if no idea of Madrid exists, it is because the city has been the Court and not the capital. The function of a capital consists of establishing a radiant culture: Madrid does not do so. It is a frustrated capital, like the political idea to which it owes its rank. They named it as the federal capital of the Spains and instead of presiding over the integration of an empire, it did no more than record the sinking of fleets and the loss of kingdoms* [39:219].

The trace of the Court and immigration

Living together with the monarchy, the government and the country's central administration has left something of a mark on Madrid's citizens. Pérez Galdós summarises the effect of the Court and the people it attracted in a very graphic way: *This city, where the aristocracy, the middle classes and the common people alternate pacifically, is a real republic that the monarchs wear as a crown and set in its immense orbit, it contains examples of all classes of people.* [226:287].

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[5] Selection by Nicolás Casariego, see note above.

As Arturo Soria y Puig maintains, *Madrid… has behind it many centuries of idleness and administrative ineptitude, of chicanery and speculation*. But also, *The same Madrid that did not know how to take advantage as a city of the chance to become the Court, was the place where Cervantes published El Quijote, where Lope, Tirso de Molina and Calderón wrote, performed for the first time and fertilised universal theatre. Even modest nineteenth century Madrid, which was expanded and altered internally so timidly, was a city famous for the spark and charm of its citizens, who inspired so many authors of musical theatre and one-act comedies, and in the first third of our century was again an important cultural focus* [221:12].

Permanent state of works

Curiously, the enormous amount of works that have marked the city decisively do not appear in the balance. *Madrid is unmade because we have not thought much about it*, Azaña used to say [39:218]. For Madrid's residents, the works are a nuisance and it would be better if *Madrid were finished once and for all*. But that does not seem possible in Madrid or any other city with the slightest heartbeat. It is enough to visit New York now (2013) to see how its vitality strikes you after the infinite scaffolding and cranes scattered throughout the city.

In the last years of the construction boom, in the middle of the first decade of the new millennium, the M-30 remodelling works were added to the alterations to the Calle Serrano and the Atocha - Chamartín tunnel, together with several scattered works to alter and expand the Metro to make the city impassable. This was nothing new for a city habitually bogged down, but the people continued to complain.

Incessant otherness

Jean Luc Nancy understands works as something inseparable from the city: *The City has started with the building work and can live for nothing apart from it, see itself in it. The City constructs itself by deconstructing itself. On deconstructing itself, it takes itself apart to put itself together in another way, to gather together an incessant otherness, always transformable, always prolonged, always renewed. Building work brings the unceasingly metastable balance of urbanicity up to date. For that reason, it often lacks urbanity and is disagreeable, overwhelming with noise and dust, breaking edges, blocking ways and accesses, destroying routes, disappointing customs, moving neighbourhoods further away, without becoming neighbourhood* [173:17].

To a certain extent, Nancy continues, *a transport network will never be a finished product (as a property or a park can be), as it is impossible to grasp it as a whole from any point of view other than the ground plan on the drawing or on the surveyors' wall or announced in the stations. Its reality is deployed, not developed, over its route, discontinuous, mobile in unity which in its entirety is immobility* [173:20].

A great port city

In spite of the works or more probably thanks to them, no one feels like a stranger in this city. Rarely has the capital of a state been so welcoming, universal and diverse and at the same time so attractive and defining. Although we all complain, what has been built makes today's Madrid a good place to be or, with luck, to live that *invades us like a state of mind*.



Mayor Tierno used to say that *a long and arid path across the Castilian meseta ends in Madrid; "the last big village in La Mancha" it has been called. That is its part of New Castile, that weakens in the foothills of the central mountain range, where the path becomes a port and the city a great port city, where novelties and influences arrive from everywhere* [227:19].

Now not only do they arrive along the roads from the north, from the other side of that port, but also through Atocha and Barajas Airport, fundamental works for understanding Madrid as a place to arrive from where you do not need to leave. As Joaquín Sabina sang[6],

In the middle of the route between hell and heaven,
I get off at Atocha, I am staying in Madrid.

[6] Song: *Yo me bajo en Atocha*. Lyrics: Joaquín Sabina, Pancho Varona,1998.

"EXTENSION OF THE PASEO DE LA CASTELLANA" PROJECT

Luis Irastorza
Civil Engineer

The "Extension of the Paseo de la Castellana" Project covers the scope of the unconsolidated urban land with the aim of integrating Chamartín and Fuencarral by means of a global operation to rearrange its areas used by the railway and the creation of a new urban planning centrality in the Northern crown of the City of Madrid, based on an urban plot that provides the solution to the integration of its environment and to the growth of the city.

The Extension of the Paseo de la Castellana Project is the final episode in this process. Therefore, it looks to fulfil the dual aim of, on the one hand, extending and completing Madrid's best and most important street and, on the other, to do this by boosting its nature as the city's centrepiece: an attractor of the best qualified institutional and tertiary functions and, for that reason, a privileged space for innovation in architecture and in the construction technology needed to face the great challenge of constructing buildings with almost nil energy consumption.

The scale of this Project is similar to the large projects carried out in Western Europe, such as La Défense and Austerlitz in París and Broadgate and Canary Wharf in London, as can be seen in the following table:

	Madrid Castellana Extension	Paris La Défense	Paris Austerlitz	London Broadgate	London Canary Wharf
Area of scope (m^2 of land)	3,120,658	1,300,000	1,300,000	106,013	420,000
Profitable buildable area (m^2 built)	3,276,691	3,750,000	2,050,000	410,000	2,250,000
Buildability coeff. (m^2 built/m^2 land)	1.05	2.88	1.58	3.87	5.36
Use	Residential / Offices	Offices	Residential / Offices	Offices	Offices
Year construction started	2017	1958	1993	1987	1987
Year of Project completion	2030-2035	2005	2013	1992	2010
Management Model	Private Company	Public Company	Public Company	Private Company	Private Company

The Project has five main objectives: to extend the Paseo de la Castellana artery by 2.6 km; to remodel Chamartín station and its accesses; to reclaim a degraded area of the city; to remove the urban planning barrier created by the railway; and to integrate the new North, Fuencarral neighbourhoods and the Pilar neighbourhood with the Paseo de la Castellana in a centrality of tertiary uses and facilities.

Its scope is divided into two areas due to its crossing of the M-30: to the south around Chamartín Railway Station, with a large urban park with a centrality which makes it into its antechamber; to the north, from the M-30 to the M-40, between the Begoña neighbourhood, the town of Fuencarral and the railway yard, developed according to the linear structure of the extension to the Paseo de la Castellana.

The arrangement of the Extension to the Paseo de la Castellana has a urban planning focus which is innovative in many aspects. In land uses, almost one third of the total land area will be occupied by the road, with its main arteries being both the new Paseo de la Castellana, with its 83 metres of section, and the transverse east-west roads. This road network will provide service both to the people who live or work in the area (60%) and the through traffic with its origin or destination outside of it (40%). The area for use for public facilities totals 31 hectares and the system of green zones totals 55 hectares with a central park over the tracks of 13 hectares and small local parks to create more open spaces in the tract, eliminate the "bridging" character and promote an urban feeling.

The design has been set out in a three dimensional form, with the superposition of uses in different planes, overcoming the strict separation of uses and functions on a horizontal plane. Housing and offices intermix in the overall operation, so as not to set up separate or closed enclaves. The tertiary uses are concentrated in the taller buildings at the public transport nodes, where Metro and Suburban rail stations converge.

In turn, the types of housing are specified as differentiated solutions depending on the location. A more open and flexible arrangement has been designed around the Station. In the Extension to the Paseo de la Castellana and the perpendicular streets with restricted traffic, the creation of a residential face is fostered. The 3,276,691 m^2 of buildable area above grade for profitable use are located on the 548,074 m^2 of land that qualifies as residential. Similarly, on the 309,000 m^2 of land that qualifies for public facilities, up to 450,000 m^2 can be built. Residential use is specified as 17,300 homes, of which 3,900 (22.5%) will be subject to some form of social housing regime.

As this is the most significant urban planning project ever undertaken in Spain, and given its long timescale, it appears essential to apply the strictest sustainability criteria in terms of mobility, energy efficiency and water cycle optimisation to the Project.

As regards mobility, the proposed arrangement locates more than 70% of the population and employment at less than 300 m from a Metro or Suburban rail station and more than 95% at less than 500 m. These percentages are higher than those for Madrid's centralcore. On the other hand, the tertiary uses are located at the public transport nodes as they generate or attract more trips per built m^2 than residential use, so reducing trips in private vehicles. A dense 18 km network of cycle paths has also been designed, connecting the seven Metro and three Suburban rail stations. Furthermore, the road network incorporates greater traffic capacity than necessary for the population and employment to be located in the area, with forecast travel time savings of 10% in areas neighbouring the Project.



New Chamartín station and accesses

To optimise the energy efficiency of the buildings, the volumetric arrangement has been studied in great detail so that exposure to the sun throughout the year is the maximum possible. Energy optimisation of the buildings has also been studied to set the design criteria, the additional costs and the return on investment for buildings with almost nil energy consumption. A viability study was also carried out for a centralised heating and air conditioning system for the whole area, with provision of heating and cooling to the office buildings and only heating to residential buildings.

The optimisation of the water cycle is based on two actions: a) reduction in demand for drinking water by using regenerated municipal water, from waste water treatment plants, for use in lavatories in housing, in street cleaning and in irrigation of green zones; and b) the use of Sustainable Urban Drainage Systems (SuDS), such as permeable paving on pavements and cycle lanes, bioretention areas in tree pits and central reservations and detention tanks or infiltration pits inside the plots. All of this aims to reduce the peak flow before development, to avoid overloading existing drains which are already close to their maximum drainage capacity and considerably reduce the volumes of water treated in treatment plants.

Economic impact and job creation

The investment forecast for executing the Project totals €11,100 million, of which €4,300 million is for public infrastructure and the remaining €6,800 million for building. These sums are estimated in 2010 euros. The 2014 prices may be similar, though, as the inflation accumulated since 2010 is offset against the reduction in construction prices as a consequence of the drastic reduction in works contracted both at this time and forecast for the next 10 years. All of this is a consequence of the need for Public Authority budgetary consolidation and the foreseeable reduction in the construction of housing. In any case, the amounts are not updated with forecast future inflation, but rather expressed at constant value.

It will mean the creation of around 16,000 to 20,000 direct and indirect jobs over the 12 to 15 years anticipated for its execution. Of these jobs, around 50% correspond to infrastructures and the other 50% to building. Once the Project is complete, around 50,000 people will live in the area and some 88,000 jobs will be located there.

(Summary of text by Luis Irastorza).

MADRID-RÍO. FABRICATING AN ARTIFICIAL LANDSCAPE. THE GREEN NETWORK PROJECT ON THE BANKS OF THE RIVER MANZANARES

Ginés Garrido & Francisco Burgos
Architects

In the first half of the 20th century, the course of the river was canalized, when its banks were still practically free of buildings. After the Civil War, the control of flooding by building concrete and granite side walls and seven dams prompted rapid development of new neighbourhoods, leading to a very dense urban continuum that progressively knitted in the peripheral settlements south-east of the city.

Madrid's growth never faced the edges of the river as a nice place, but rather ignored them and defended itself against them. The differing topographic and social conditions of the two banks caused the urban fabric to approach its limits in different ways. At the right bank, from the 1950's, the buildings crowded together a short distance from the bank, leaving a narrow, rigid, linear strip free, running north to south. On the left bank, on the other hand, the historic city remained separate from the river, establishing a chain of spaces on the hillside that gently approached the base of the buildings.

The 1970's were a landmark for Madrid in the scope of the river as the western arc of the city's first ring road, the M-30 motorway, was built from the El Rey Bridge heading south, on both banks. This infrastructure formed a traffic distribution ring that avoided the urban centre and transformed mobility and the relationships between the neighbourhoods, especially between the central area and the periphery of Madrid.

With the construction of the motorway, the river was left constrained on both banks by the carriageways. In this way, any relationship the public had with the river area and the canalised course was left completely isolated, inaccessible and invisible. The motorway was an impenetrable, aggressive barrier, generating high levels of pollution. Likewise, the new infrastructure blocked up the footbridges built when the river was channelled and eliminated the historical connection between the gardens of the Campo del Moro and the Casa del Campo park.

Between 2003 and 2007, the tunnelling work was carried out to take the western arc of the M-30 underground in the area of the river. This made it possible to eliminate the traffic from the surface and release the over 50 hectares of land



Madrid-Río, general view

previously occupied by the carriageways. Added to this area were another nearly 100 hectares of separate stretches of underused land adjacent to the motorway.

After construction of the tunnels, an empty gash emerged, made up of a string of vacated spaces with the latent potential to become a link as an environmental corridor of almost 3,000 hectares within the municipal area, extending from El Pardo to Getafe and connecting three of the city's extremely important green areas: the Casa del Campo park, the Parque de la Arganzuela and the Parque del Manzanares Sur.

Therefore, the benefits obtained from running the motorway underground are not limited to improving certain aspects of urban mobility or even to the local restoration of neighbourhoods, rather it can in the near future acquire a grand dimension that will need to impact relationships between

the city and the territory, with its broadest meaning. The enormous importance to the city of the spaces released as a result of laying the M-30 underground led Madrid City Council to call an International Design Competition to devise and design the new free spaces around the river. The competition was won by an association of Madrid architecture studios (Burgos & Garrido, Porras & La Casta y Rubio & Álvarez-Sala). This group of teams, christened as *mrío arquitectos asociados,* in collaboration with the Dutch West8 office, proposed the solution for building an urban park of over 120 hectares to occupy the space released by the motorway tunnelling.

Summarily, the project strategy is based on the conviction that the city, the ultimate expression of artificial action, can be connected via the river to the territories north and south of Madrid, where the natural elements belonging to the water course still survive. The river becomes a door or link between the urban inside and the territory outside and continuity and permeability are established along its banks, which until now have been crushed by successive concentric rings, trampled down by the M-30, M-40, M-45, M-50…, ring roads resulting from applying mobility models from the mid-20th century to the traffic network.

The project has been devised as successive approaches or steps from which reflection on the field of play is applied to obtain a variety of responses or solutions, from territorial or strategic scope to the local or specific.

At a territorial scale, basic parameters have been established so that, in the medium term, the banks of the river can be regenerated over their whole length as real areas to integrate the landscape and human activity, with a contemporary understanding capable of overcoming the antagonism implicit in the urban-rural pairing.

At the metropolitan scale, the corridor extending along the river edges on its way through the city is being incorporated by means of the project and its concept as a great infrastructure. This forms part of GR 124 (Great Route as part of the European Network of Footpaths) which it will already be possible to walk, in 2011, over its whole length, from Manzanares el Real to Aranjuez.

At the urban scale, the project incorporates the river like a new double line of façades and arranges a connected set of green spaces that infiltrate the city; it establishes a new system of mobility and accessibility at ground level; it increases the urban integration and quality of neighbourhoods bordering the river; it protects and enhances historic heritage and detects areas of opportunity that, based on this new centrality, will be capable of generating potential changes to the whole city in the long term.

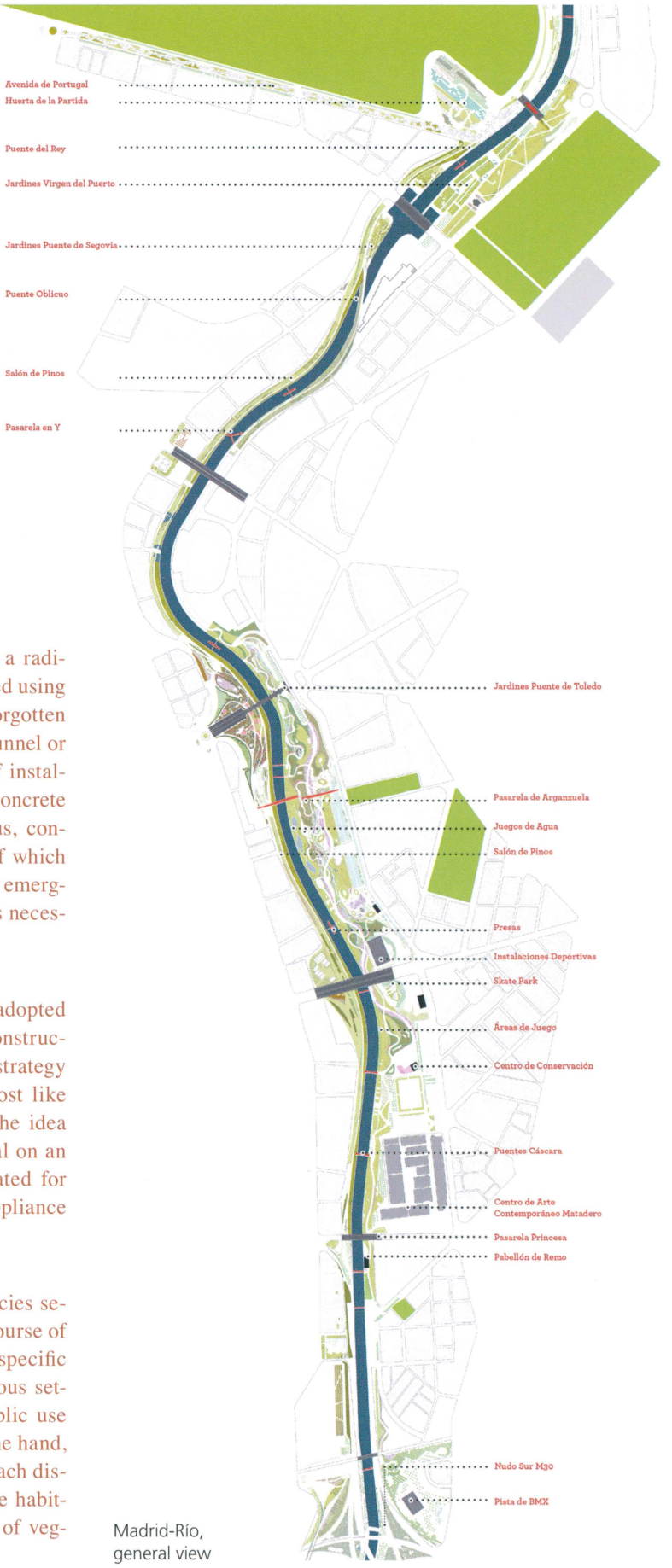


Madrid-Río, Avenida de Portugal ©ANA MULLER

At a local scale, the design is being executed as a radically artificial operation which is, though, embodied using eminently natural instruments. It should not be forgotten that the project is being implemented on top of a tunnel or rather on the roof of an extremely complex set of installations serving the underground road. This is a concrete building over six kilometres long, with enormous, conditioning easements and a topography the logic of which obeys only the construction of the infrastructure, emerging on the surface unexpectedly, with which it was necessary to negotiate.

On top of this underground building, the solution adopted has been based on using vegetation as the main construction material. The project establishes as a general strategy the idea of introducing a dense plant layer, almost like a forest in nature, wherever possible. As such, the idea is to manufacture a landscape with living material on an inert underground substrate modified and excavated for cars, on a construction expressing the ultimate appliance in itself.

The families, forms and associations of plant species selected come from extrapolating the study on the course of the river and its adaptation, in each case, to the specific urban environment. The arrangement of the various settings and their characterisation as places for public use has been applied by taking into account, on the one hand, the required functions and the needs detected in each district and, on the other hand, the capacity to shape habitable spaces, inherent in the organised groupings of vegetation of varying sizes.



Madrid-Río, general view



Madrid-Río, historic area

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The solution is embodied in three main landscaping units. Firstly, the Salón de Pinos, the green corridor running along the right bank of the river. This is the structure that gives continuity to the routes and reacts when it meets the existing bridges, leading to a variety of types of river bank gardens (under Toledo Bridge, at San Isidro Bridge, Toledo Bridge and Praga Bridge). Secondly, the definitive link between the historic centre (represented by the imposing image of the Royal Palace and the high rim of the city) and the Casa de Campo, the park of over 1,700 hectares. Included in this setting are the Avenida de Portugal, the Huerta de la Partida, the Explanada del Rey and the Virgen del Puerto gardens. Thirdly, the broad strip at the left bank where the Parque de la Arganzuela grouping is located, including the Matadero centre for creation of contemporary art, representing the single largest area of green space in the design.

In addition to these three large mutually coherent landscaping operations, the project puts forward 150 interventions of varying nature, outstanding among which is the system of bridges that give the watercourse a new level of permeability. Solutions have been developed over more than 20 bridges or footbridge, restoring the seven dams, recycling some existing bridges and creating new crossings, sometimes with a silent language and at others intentionally expressively. Like microsurgery, the project incorporates, link by link, a chain of formulas for integrating the river into the city and the city into the river. These are elements that will guarantee the contagion of the new values of the regenerated river banks to the nearby areas and neighbourhoods. Using this resonance effect, a succession of operations is anticipated to ensure renewal with great scope. From now on and irreversibly, a radical metamorphosis is being hatched, unprecedented for the city of Madrid.

Landscaping Units.
First landscaping unit: the Salón de Pinos

The linear superstructure of the Salón de Pinos is the element which organises the continuity of routes along the right bank of the river. It is built on top of the tunnels over practically their whole length and is an average of 30 metres wide. Over 9,000 individual pine trees of different species, of different sizes, shapes and groupings with a forestry plantation framework, have been planted on top of the slab covering the route of the cars. The individuals were selected basically in fields where there was a chance of extracting plants with natural morphologies (non-linear trunks, double trunks, inclined trunks, etc.). This gives a controlled extension of the pine groves of the mountains north of Madrid, appearing to extend to the confines of the city. These trees have been anchored to the tunnel slabs using steel cables and biodegradable clamps to promote stability and the horizontal growth of their roots on the package of soil available. This walkway, however, often meets structures of great urban or heritage value. Two symbolic examples of this intersection are the historic Segovia (1582) and Toledo (1732) Bridges. At these locations, the path reacts like a dwelling space by expanding its limits and offering a specific design, with deciduous bank side trees and alignments of hedges and stone benches. The activities built into the route are included using a language consistent with its forestry nature. A clear example of this procedure is offered by the set of children's playgrounds, which are designed specifically as a complete system of natural forms.

Second landscaping unit: the Monumental Setting

The connection between the historic centre and the La Latina neighbourhood to the Casa de Campo park was prohibited to pedestrians from of old. The new contact, now made possible by the cars disappearing underground, has been resolved by means of a variety of interventions which take on the monumental, panoramic nature of this area, where the elevated base of the Royal Palace (the primitive seed of the city's development) contacts the river. Various solutions were proposed to handle the context of the setting with extreme care: The "Explanada del Rey" is an open, paved esplanade with a large figurative pattern, acting as a great atrium before the Casa de Campo park. The Huerta de la Partida, which is an enclosed space where grids of different fruiting trees (pears, apples, mulberries, pomegranates, figs, walnuts, hazel nuts, etc.) have been planted, takes in an extraordinary viewpoint from the rim. The Avenida de Portugal, made into a boulevard surfaced with Portuguese paving and populated by four species of cherry trees *(Prunus avium, P. avium 'Plena', P. yedoensis y P. padus 'Watereii')*, allows you to take in their spectacular flowering, which lasts for over a month. Finally, the Virgen del Puerto gardens, on the other bank of the river, are structured by laying out flower beds oriented according to the main urban entities

Madrid-Río, Plataforma del Rey

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in the area: Segovia Bridge, El Rey Bridge, the Avenida de Portugal and the Puerta del Rey, which have been restored and resited according to the data available in historic maps of Madrid.

Plataforma del Rey

Outstanding in the monumental access linking Madrid's historic centre to the Casa de Campo, an old hunting ground, is the Plataforma del Rey, an open space of 14,000 m^2 and a face parallel to the river of a little less than 250 m in length, forming a stage capable of forming the venue for a variety of civic events (concerts, official celebrations, cultural activities, etc.) in a setting of extraordinary environmental quality, from where you can see the city's historic rim. This place is connected to the Salón de Pinos and forms a part of it, although due to the demands of its use, it is an area almost devoid of trees. The main element which organises the area is the paving which, very gently, adapts to a topography that covers all the elements emerging from the tunnels and makes them imperceptible. The small pieces of granite and basalt in this paving form a pattern leading down from the Avenida de Portugal and spreading over the ground surface at an increasing scale. This pattern links the platform to the paving projected in the avenue. In this way, the Platform is an element that naturally links important parts of the monumental setting occurring at this point, such as the El Rey Bridge, the Casa de Campo, the Avenida de Portugal and the Salón de Pinos.

Huerta de la Partida

This is a reclaimed space that housed one of the main junctions on the motorway in past decades. The proposal to regenerate this place includes: the construction of a garden wall, in places opaque and others permeable, which gives the place the character of a closed kitchen garden; the artificial modelling of the land, making the surface more regular and producing a single plane sloping gently towards the river; the planting of groups of fruit trees (pomegranates, mulberries, apples, pears, hazel nuts, almonds, figs, olives and walnuts) in grid squares with subtle variations in orientation; and a waterway that follows the course of the Meaques brook, now hidden in pipes.

Third landscaping unit: the Edge of the Water. Arganzuela and Matadero

On the left bank the city distances itself from the river. The most important example of the design on this bank is the new Parque de la Arganzuela, constructed on old communal grazing pasture. The Municipal Abattoir, or Matadero, was built in this setting, a noteworthy example of post-industrial architecture from the second decade of the 20th century. With the motorway laid underground, Madrid now has 33 hectares of free spaces available to it at this point, forming the biggest park in the project. This was devised as a large space from which the river has withdrawn, leaving its ancestral trace. It is organised by various interweaving lines like indentations where the water passed, leaving spaces for different uses between them. These notably longitudinal lines are paths of different types running across the space from north to south. One path is wider and flatter (the Fast Path), another more winding and with a variable slope (the Slow Path) and there is a paved strip with leafy margins (the Dry Brook) that provides the park with its central backbone. The construction of the space is set out as a large grove containing various landscapes, some of which are natural and others more highly constructed, made up of various species, heights, densities and textures. In this way, the park, devised as a remnant of the river basin, incorporates three botanical areas: Mediterranean forest, Atlantic forest and riverside foliage. The character of these internal landscapes is related to the longitudinal routes in the park, with trees following the paths and tracks, with thickets and woods that emerge on the topography. The wooded texture alternates with surfaces planted with aromatic species between the paths and the Dry Brook. Following the left bank of the river there is a wet green strip with a grass meadow sloping towards the water. A constellation of ornamental fountains and a group of three elliptical sheets of pure water introduce this element as a narrative material that relates the different associations of vegetation. Each fountain has a different visual and audible play and is surrounded by small slopes planted with fruit trees referring to the gardens of legend



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Madrid Río, Avenida de Portugal



Madrid Río, Avenida de Portugal

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or of paradise. The interwoven lines that structure the park allow the formation of places in which significant facilities have been installed for recreation for users of all ages. Included in this is the Once football pitch, two skating rinks and three large children's playground groups. The park also includes the Matadero assembly for the creation of contemporary art, as a significant cultural facility based there. Access is gained to the bays of the old abattoir complex, the restoration of which is almost complete, along the paths. The design of the routes allows the relationship of the Matadero and the park to be understood as a continuum between the river and the city.



Madrid-Río, historic area

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Credits:

Architects: Burgos & Garrido / Porras La Casta / Rubio & Álvarez-Sala / West 8. Team Manager: Ginés Garrido. Design Team: Francisco Burgos, Ginés Garrido, Fernando de Porras-Isla, Arantxa La Casta, Carlos Rubio, Adriaan Geuze, Edzo Bindels.

Collaborators: Team Coordinator: Javier Malo de Molina, architect.

Madrid Team: Samir Alaoui, Irene Álvarez de Miranda, Jaime Álvarez, Silvia Aydillo, Pierre Banchet, María Bandrés, Araceli Barrero, Carlos Carnicer, Rocío Caro, Almudena Carro, Sergio del Castillo, Alicia Colmenarejo, Isabel Cuellas, María Ángeles Fernández, Carlos Fernández, María Jesús Franco, Gabriela Galíndez, Elena Garicano, Eduardo González, Maya González, Miguel Ángel López-Mir, Raquel Lozano, Marina del Mármol, Agustín Martín, Rocío Martín, Raquel Marugán, Gemma Montánez, Eleucidio Moreno, Víctor Muñoz, Matías Nieto, Emilio Ontiveros, María Ortega, Ana Palancarejo, Susana Paz, Nerea del Pozo, Lucía Prado, Jonás Prieto, Eduardo Ruiz de Assín, Ramiro Sánchez, Marco de Simone, Emma Simonsson and Juan Tur.

Rotterdam Team: Christian Dobrick, Freek Boerwinkel, Karsten Buchholz, Lennart van Dijk, Juan Figueroa, Michael Gersbach, Magdalena González, Enrique Ibáñez, Joost Koningen, Sander Lap, Silvia Lupini, Perry Maas, Ricardo Minghini, Eva Recio, Marta Roy, Carlos Saldarriaga, Alexander Sverdlov, Mariana Siqueira and Shachar Zur.





ALTERATIONS TO RECOLETOS AND THE PASEO DEL PRADO

Juan Miguel Hernández de León
Handling of the main areas

The general criterion, simplified, for the whole intervention was to reclaim historic spaces for the city's new needs in an area with a particularly sensitive fabric, both due to its position and its dimensions or the cultural values it contains.

It is also necessary, urgent, to correct the confusion the urban scene currently suffers from the accumulation of small interventions, most of which could be considered as maintenance, the apparent insignificance of which evolves to become an operation requalifying the characteristics of the public space, made into a site where all the means – they do not deserve to be called criteria – for equipping the public road have been deposited one next to another with no apparent order.

The scope of the area, covering substantive and extensive parts with groups of residential housing, would have called for a thorough reflection on the habitability of the historic centre, if this had not already been done, to a great extent, by the Municipal Plan Office during the preparation of the currently valid new General Plan for Madrid. It was, then, easy to detect the master plans for this reflection and support them with actions inspired by the same principles, principles that can be summarised as respect for built heritage and the provision of facilities, of varying scales, that the area lacks, always as far as possible.

To achieve a more than notable reduction in the perceptive tumult we noted above, it was enough to clear the pavements of the now unnecessary strata and homogenize those needed with criteria of respect for the types and positions of those of value complemented by the ones that were necessary to make correct use of the city.

You could say that to understand an area like the one studied, now expressed with the clearness and power used here, it suffices to clean away the added discords, set its notable values, of all types, that already exist and give lustre to the quality of the architecture which currently configures it.

The need for and importance of the operation have been clear since the Madrid General Urban Development Plan referred to this area, specifying its perimeter through the public competition for a specific Special Plan, the initial conditions of which are laid down, in the municipal planning documents, in similar terms to those stated above.

Indeed, at an area of around 164 hectares, it runs along the north-south axis of the city, with extensions at the eastern and western edges, to complete a length of some 4.7 km. It contains numerous monumental buildings protected by both national and autonomous region Historic Heritage sector legislation, and a large part of the area – the Paseo del Prado from the Plaza de Cibeles Carlos V roundabout – has even been declared a Historic-Artistic Grouping with its own personality within the Historic-Artistic Grouping of the city of Madrid itself, inside which the whole area is located. The notable accumulation of museums influences the personality and vocation of the place in a defining way.

These circumstances and these general criteria guide all the interventions that will be described in detail but briefly below, using a geographic criterion, that is describing them by position from the north to the south with the range in each stretch that makes it possible to cover the whole intervention. A legend will be used for this which, in the attached images, allows you to compare the proposal with the current situation.

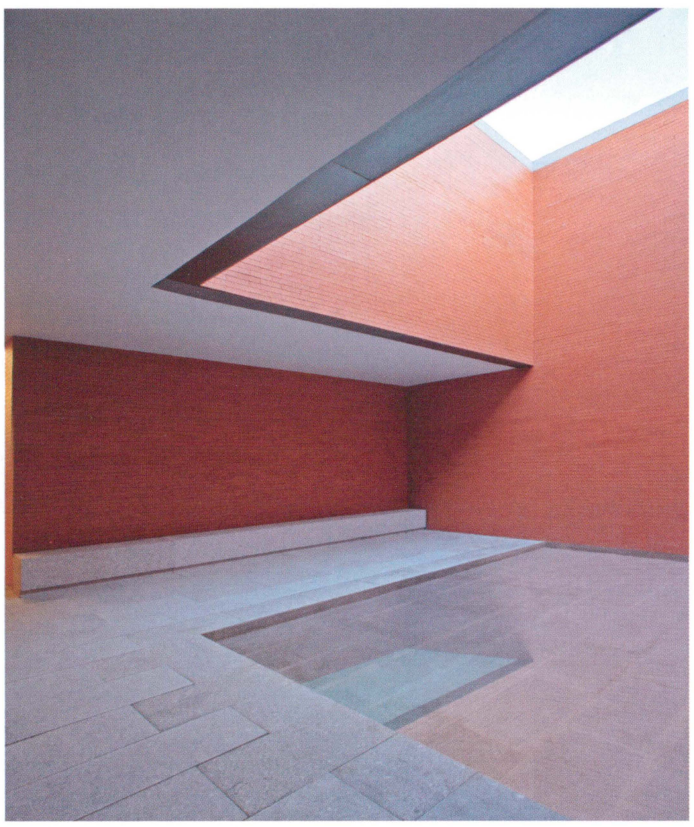
Plaza de Colón

The layout of the current Plaza de Colón is changed, returning its character to that of a roundabout, with traffic going around the monument to the discoverer, Christopher Columbus. This is returned to the place it occupied in 1892, when it was designed by Arturo Mélida as a support for the statue sculpted by Jerónimo Suñol. The pedestrian crossings are also resolved at ground level, so that the current underpass crossing the Paseo de la Castellana can be closed.

In order to bring to the surface the sunken Centro Cultural de la Villa, a municipal facility of notable significance that is undervalued in part due to its hidden position, the proposal is to position, approximately where one of the pavilions stood that used to flank the old Mint, the Casa de la Moneda, a built volume to connect, through an open portico, to another located at the other end of the square. This arrangement will give the square a façade, differentiating the area where people visit from the roundabout. Its final formalisation, which of course will need to be defined after a reflection on the architecture project, will also enable a remote view of Vaquero's sculptures if it satisfies the parameters indicated in the Special Plan.

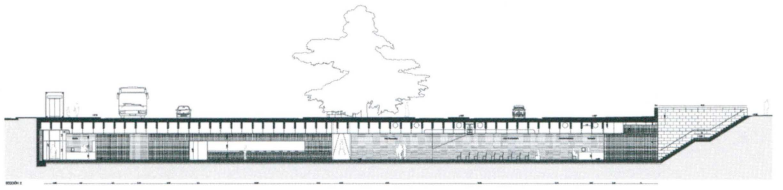
Access to the Cultural Centre will take place through an underground square at the level where pedestrian traffic currently passes under the existing waterfall.





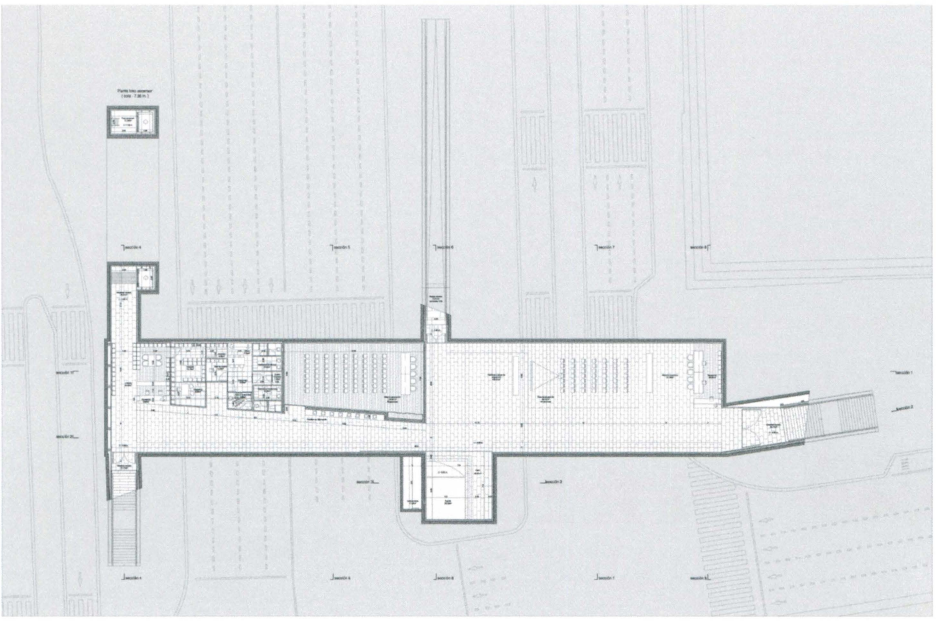
The square's gardens are corrected slightly to make them harmonise with the new facilities and the line of banana trees, removed from the west pavement of the Calle Serrano, is returned so as to serve as a backdrop to the sculptures and to generate a new scale for the square, giving the buildings in the expansion back their own. The whole intervention can be undertaken without making significant alterations to the existing facilities of the Cultural Centre.







Centro Colón





Recoletos-Prado remodelling model

Paseo de Recoletos

The existing entrances to the car park are arranged above the eastern side band of the longitudinal garden, using the width so gained to expand the pavements with this orientation and the occupations of the public street by municipal concessions to commercial establishments along the western boulevard are also arranged. The latter action was applied in general throughout the scope of the intervention. The aim of this, apart from reclaiming space for pedestrians, is to minimise the impact of the existing actions.

In this order of things, in the final preparation of the Special Plan, an alternative will be proposed to the current urban furniture, the heterogeneity of which, but above all, the quantity of which – a quantity obtained more due to an accumulation of alternative solutions and different to the functional problem which due to real needs – generates perceptive "noise" inappropriate to the quality of the spaces they supposedly serve.

An analogous regularising treatment is intended with the pavements, reducing them to two main types: Soil flooring for the new park zones – large continuous pedestrian surfaces – and granite in slabs for traffic like on pavements – the pavements themselves and those at the edge of the aforementioned parks. The historic pavements, generally associated with the monuments aligned along the routes and the landscaped zones with these characteristics are, naturally, respected, adding some new ones too.

A cultural use, which has still not been defined, has been put forward for the old Palace of the Marquis of Salamanca, so incorporating a container of very appreciable architectural values to the offer already present in the area.

These same criteria of simplification, both of furniture and road surfacing, are intended, equally to that described for concessions of public land to private traders, to extend to the whole area of the intervention, as will be described.

By means of the appropriate signing, but also the appropriate roadway layout, it is intended to prevent the passage of through traffic in area delimited by the streets named Alcalá, Serrano, Villanueva and the Plaza de la Independencia and the Paseo de Recoletos, reserving it solely for residents.

Plaza de Cibeles

Simplifications in the road traffic routes confirm the vocation as a roundabout of the Plaza de Cibeles, currently disturbed by turning spaces, bus shelters and various obstacles to circulation around the fountain.

To return both its scale and its relationship with its immediate surroundings to the latter, the pedestal of the sculptural group is removed and it is supported at ground level again.

Salón del Prado

All the road traffic, in both directions, is diverted along the western edge of the Paseo de Recoletos, the old Calle de Trajineros, recreating a large part of the space that was the promenade of the Salón del Prado.

The reduction in road capacity also allows the western pavement to be widened to 7 m at its narrowest part.

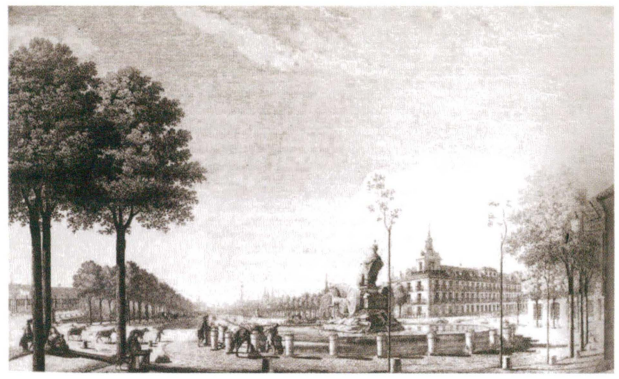
In order to make the connection between the Museo Thyssen Borsnemiza and this revived Salón and slow road traffic speed, there is an extended pedestrian crossing, at pavement level and using the general pedestrian route materials, facing the current entrance, as there will be too for the extension now being built.

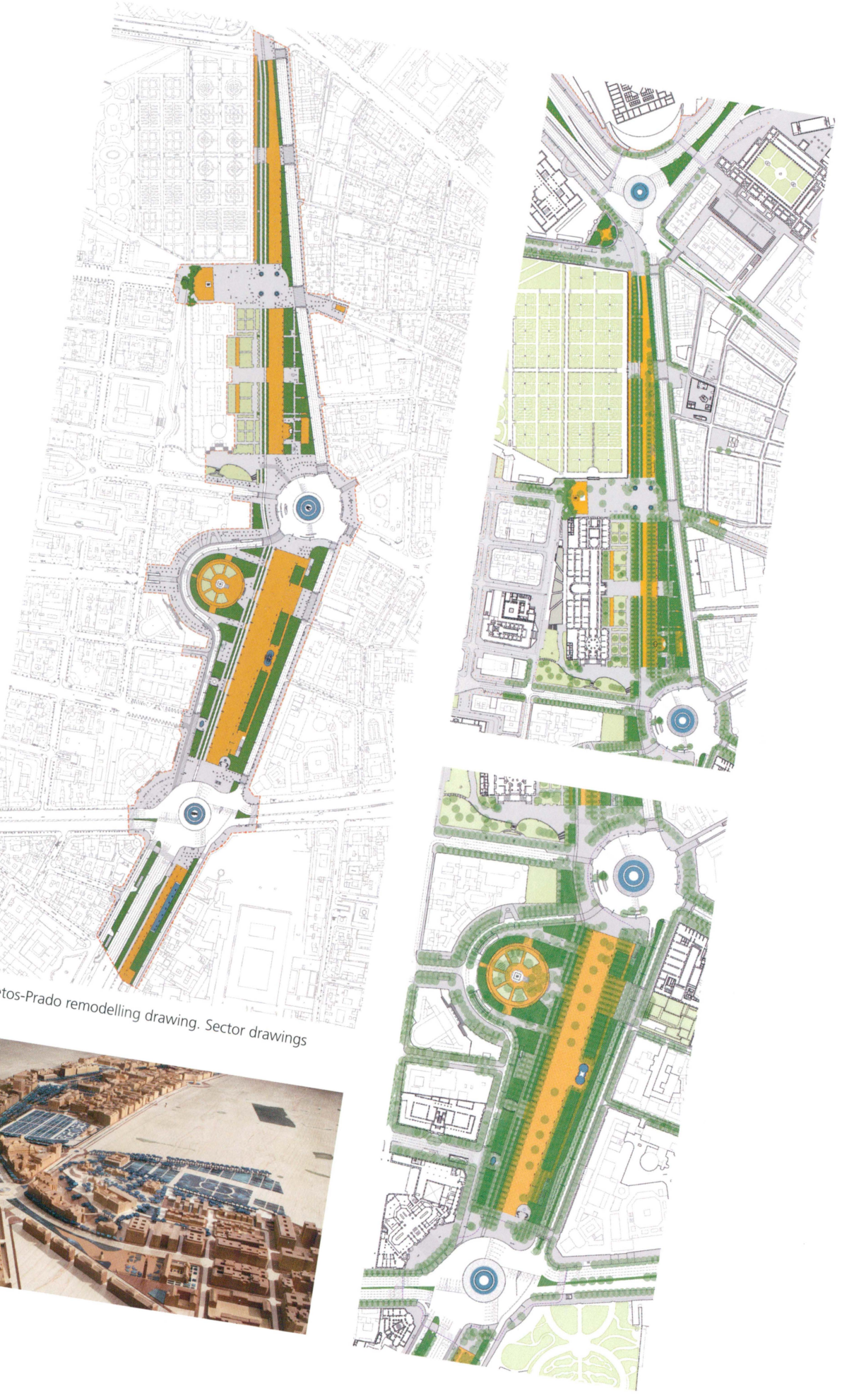
This is the area where the simplification considered necessary in road surfaces and urban furniture will best be appreciated, given that the whole surface of the Salón will be covered with soil flooring, surrounding the fountain of Apollo, and only the edges, under the lines of trees will be paved with granite pavements. This pavement will cross the street with road traffic until it connects, as stated, with the pavement on the other side.

An urban promenade of these proportions needs to be appropriately furnished to make staying there and walking pleasant. It was before with folding chairs to rent, complementing the existing stone benches, served by passing water sellers. It would be desirable to recover a versatile, useful element like the chairs as a public service, with or without renting, but it would be a rather impractical romanticism to suggest the awarding of municipal tenders for the posts of street sellers of barley water or tiger nut milk to serve the area, so the installation of appropriate catering premises has been considered, through municipal concessions, offering services as they have been doing on other stretches of this long route.

The scale also allows more sheltered areas to be set aside, on the eastern edge, to allow enclosures to appear, in quiet places with respect to pedestrian traffic in the area, delimited by fences that give a degree of privacy covering the needs of longer stays to make that possible there.

To remove non-municipal collective transport vehicles from the street, the volume of which pollutes, when it does not to-





Recoletos-Prado remodelling drawing. Sector drawings

tally obscure, a large portion of the urban views in the area, a tourist bus park is created under the street surrounding the Plaza de la Lealtad. This parking area is aimed and being made, more precisely, into a bus station equipped with those services which enable it to be the start of a tourist visit, on foot, to the area's museums.

Indeed, by arranging tourist visits, with a little effort, so that the buses wait at the station while their passengers make the visits to their destination museums, the removal from one of the most aggressive elements, particularly when stopped, from the street in the public area served will have been achieved.

Plaza de Neptuno

In a similar way to the intervention in the Plaza de Cibeles, the operation of this square as a roundabout will be promoted by simplifying routes for road traffic, by making the current disjointed edges geometrically regular and removing the petrol station located at its southern edge.

The god of the sea will be given back his position, at square level, to leave him in the same relative position as his distant companion the goddess of the earth, with a similar protective ring paved with granite flagstones.

Paseo del Prado

The solution proposed for the previous stretch is extended by channelling all the road traffic to western lane of the Paseo so as to generate a broad pedestrian promenade in front of the Museo del Prado, the Plaza de Murillo and the Royal Botanical Gardens.

The whole zone lying between the street named Alfonso XII, the Plaza de la Lealtad, Paseo del Prado, the Carlos V roundabout and the Paseo de la Infanta Isabel will be treated as restricted for road traffic, by executing appropriate road surfaces accessible only to residents, so as to give precedence to pedestrian connection, without interferences, to all the buildings making up the new Museo del Prado and boosting permeability towards the area of Retiro from the whole area.

In front of the southern gate to the Museo del Prado, it is proposed to move the statue of Murillo to the eastern end of the square to reveal the relationship between this side door to the Museum and the main entrance to the Botanical Gardens.

The intention is to recover, over its whole length, the continuous bench placed with its back to the iron railings that close the façade of the Botanical Gardens on the Paseo del Prado and which has now been lost, perhaps buried, at the southern end, closest to the Carlos V roundabout. This recovery, with the necessary agreement in the various levels between the base of this closure and the level of the soil flooring, will generate a longitudinal place for people to stop with benches facing the one mentioned before belonging to the Botanical Gardens.

Also proposed is to make the Cuesta de Claudio Moyano completely pedestrianised, redistributing the secondhand booksellers' stalls in a dual line in the centre, so that the walls of the Royal Botanical Gardens are left free along with cultural use of the old Ministry of Development building, now the Ministry of Agriculture.

Within the Royal Botanical Gardens, the proposal is to replace the built up area at the corner of the streets named Alfonso XII and Claudio Moyano with a building backing onto the side dividing walls of the houses with their façades on Alfonso XII respectively, so eliminating two of the most glaring negative impacts on this exceptional space.

The new building will have specific uses, to be defined, for service to the Botanical Gardens themselves, compensating for the loss of area that will undoubtedly occur by moving the functions currently performed in the building to be demolished to any of those proposed as cultural containers at the nearby Cerro de San Blas. This transfer would also provide added value to the operation planned for the Cerro with the presence there of a scientific institution like the Royal Botanical Gardens.

The layout for road traffic in a straight line, correcting the current situation, parallel to the façades, makes it possible to gradually widen the pavement so as to produce natural channelling of circulations towards the Centro de Arte Reina Sofía.

The natural route between the historic centre and the Paseo del Prado is along the Calle de las Huertas, crossing and ordering the neighbourhood known as the Barrio de las Letras. This street is the only one in the neighbourhood offering a view of an exit at the end, with the attractive background of the groves of the Paseo and, above them, those in the Retiro park. This involves supporting this communication by integrating the Plaza de Platerías Martínez, by means of a pedestrian crossing, like the one described for the Museo Thyssen, with the actions in the Paseo del Prado, extending the paved area under Cuatro Fuentes to the Plaza de Murillo.

The project also includes proposals for the Carlos V roundabout, the Paseo de la Infanta Isabel and the Paseo de la Reina Cristina, the Cerro de San Blas, where the generating idea of reclaiming the "Hill of the Sciences" for the Retiro park, by demolishing the parasitic buildings that have grown up around the historic buildings, is conserved.

Credits: Architects: Álvaro Siza Vieira, Director; Juan Miguel Hernández León, Carlos de Riaño Lozano, José Miguel Rueda , Fernando de Terán Troyano. Coordination: Prointec, César Cañedo-Argüelles, Ramón del Cuvillo, Civil Engineers; José Ignacio Gómez Cuesta, Architect. Collaborators: Patricia Hernández Tejada, Miguel Ángel Sánchez Rico, Architects, Emilio Sánchez Horneros, Architecture student. Traffic and Mobility: Consultrans, Jorge Hernando, Juan Samos, Daniel Fernández, Civil Engineers. Landscaping and Gardening: Carmen Añón Feliú. Landscaping: Ana Luengo Añon, Architect; Antonio Prieto, Forestry Engineer. History and Archaeology: Pedro Navascués Palacio, Art Historian; Martín Almagro Gorbea, Archaeologist. Urban Environment: Javier Ortega Vidal, Gloria Álcazar Albajar, Architects; José Sandoval Martín, Draughtsman; Procesos Constructivos, SL.

MADRID 1985-2012. FROM URBAN DEVELOPMENT WITH AUSTERITY TO WITH EXPLOSIVE GROWTH

Josefina Gómez Mendoza
Universidad Autónoma de Madrid, Real Academia de la Historia and Real Academia de Ingeniería

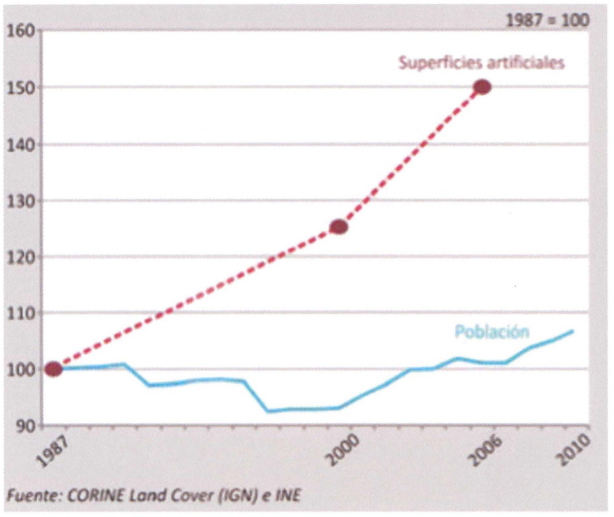
From the urban development of austerity of the PGOUM of 1985 to Urban Development Plans (PAUs)

Aware of the loss of population from the municipality, the PGOUM (Madrid General Plan for Urban Development) of 1985, conceived at the end of the long oil crisis, opted for moderating physical expansion, limiting building to consolidated areas and it focused what was called the "cosido" or sewing of the city, enhancing and finishing off the periphery inside the fourth ring road (the M-40). Buffered by the most prestigious urban development literature of the time (Campos Venuti, the author of the relationship of urban development with austerity, Bernardo Secchi, Manuel de Solà-Morales, etc.), the recovery of the existing city rather than extending, the regeneration of urban fabric, the restraint of private vehicles and consequently the construction of routes for traffic was defended. In addition, as the City Council was held by leftist parties and those executing the Plan were architects and other professionals closely allied to the neighbourhood movements that had developed in the post-Franco period and the transition to democracy, rights to the city and to housing, the need to rebalance the existing city, putting a brake on outsourcing in the centre and protecting and reclaiming built heritage had been raised since the Preview of 1982. The instruments brought into play were urban development agreements which made it possible to stop some processes and reinterpret others.

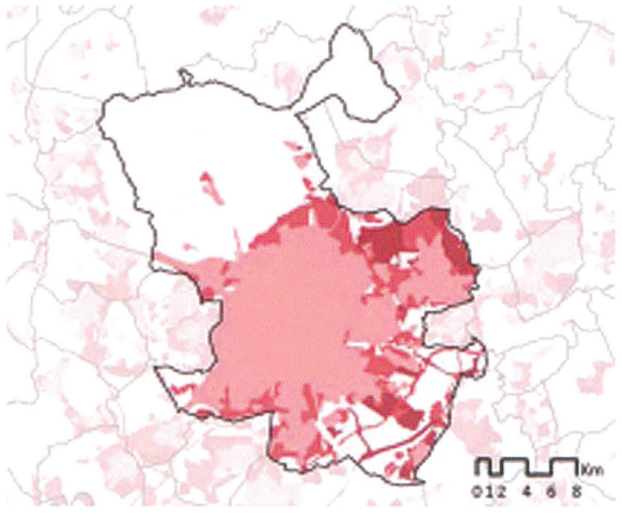
There were two big problems with the 1985 PGOUM: the fact that it lacked a regional or at least metropolitan framework, but above all that when it was to be applied, an expansive phase had begun, leading to the imbalance noted above. So, as its leading lights have said, the 1985 Plan had more doctrinal than practical success.

The following years witnessed a passionate debate on the way of reducing the repercussion of land prices on the price of housing. A particularly important moment occurred when, in 1994, the Competition Court issued a report advocating deregulation. Its chairman of the time had said shortly before that: "Something is wrong when the market price of land in Madrid is three times higher than in New York".

The thesis that to ease the housing shortage it was necessary to increase the offer of developed land had won out since the beginning of the last decade of the previous century. The 1991 Municipal Strategy aspired to fill the edge "spaces", hence the City Council proceeded to change to developable status land that had been planned developable land until then: these were the Urban Development Plans for Montecarmelo, Las Tablas, San Chinarro, Carabanchel, Vallecas and Arroyo del Fresno (Figure 3). These six developments occupied 2,261 hectares on which it was intended to build 72,750 homes. The objective was to avoid the population moving towards the metropolitan rings and to invigorate the property market to kick-start the economy. The municipal grouping of the PSOE political party and some independents appealed against the change of land use and, after many ups and downs, the Supreme Court condemn the decision and requested its correction.



Evolution of population and 1987-2010 and of artificial surfaces 1987-2005



Artificial surface evolution. 1987-2010 Corine Land Cover. (light pink 1987, darker pink 2000 and wine-red 2006)

Source: Corine Land Cover and preparation *Ciudades &Capitales+100*. Statistical information for Spanish cities.



Las Tablas Urban Development Plan, Madrid



Homes at Montecarmelo, Madrid

Explosive growth: Urban Development Plans and Development Areas in the 1997 PGOUM

In 1997, the 1991 expansion strategy was concluded and extended with the approval of the new PGOUM and its doctrinal foundations were set. In the commentary of the Plan it says specifically that the cause of the high price of land "is the scarcity the plan itself determines by qualifying an insufficient amount as land suitable for urban development". It also advocates complying with competition rules and criticises the profusion of regulations and a degree of "canonisation" of the previous Plan. Due to this, the need to classify the whole municipal area was raised, consequently increasing the supply of residential land capable of counteracting speculation. The scale of the changes in land use was also justified by the idea of conveniently starting up a system of compensation to guarantee not only this, but the connection of infrastructures to the general systems.

As stated, the 1997 Plan exacerbated the strategy of the urban development of expansion, establishing mass occupation of land which was previously non-developable protected which, also on this occasion, it changed to developable. Not only did this cover the Urban Development Plans, but it also proposed other enormous residential developments, 5,055 hectares for the building of 122,613 homes in eight developments, being: Valdebebas, the Barajas expansion, Los Cerros, El Cañaveral, Los Ahijones, Los Berrocales, La Atayuela and Valdecarros (Spain's largest urban development operation at 2,000 hectares with provision for 48,000 homes). In total, between the Urban Development Plans and Development Areas, this meant acting on a total of 8,000 hectares – of which approximately one third was in the Urban Development Plans – which was equivalent to a new city of 200,000 inhabitants.

As can be seen, all the developments lay between the M-40 and M-50 and were based around radial roads 2, 3 and 5, started in 1999. Some more major strategies and other singular ones were raised. Among the former was the new centrality of the East with actions of considerable scope: the Barajas extension, the Olympic ring based on the M-40, the Valdebebas Casa de Campo park, etc. The intention with the new Barajas airport terminal was to drop an anchor to keep the airport in the municipal area and promote the appearance of an airport, logistics and business town. This was the context in which the overambitious terminal T4, at over one million square metres and delivered in its entirety to Iberia as the national airline, a decision which meant linking the infrastructure to the company's development, with the hazards which are now beginning to materialise.

On this occasion it could not be said that the plan was behind the times: the 1997 PGOUM came into force coinciding with what has come to be called the "prodigious decade" in property development and the Spanish economy, coinciding, in short, with the climax of the property bubble. But it can be said to have confused the nature of the expansion and misjudged its capacity to last. At the end of 2012, construction in the Urban Development Plans was not complete; it had scarcely begun in the new neighbourhoods for development, except Valdebebas. The large operations too were practically all interrupted, some put in question. The promised new "Casa de Campo" of the East of around 800 hectares was cut back by 300 hectares to build offices,



Urgent Action Programmes and other developments.
Source: Madrid City Council

Urban Development Plan: 1. Arroyo del Fresno, 2. Montecarmelo, 3. Las Tablas, 4. Sanchinarro, 5. Carabanchel expansion, 6. Vallecas expansion

Other developments: 7. Valdevevas, 8. Barajas expansion, 9. El Cañaveral, 10. Los Cerros, 11. Los Ahijones, 12. Los Berrocales, 13. La Atalayuela, 14. Valdecarros



El Restón urban development, 2nd phase, Madrid



El Cantizal urban development, Madrid

housing and the Real Madrid Sporting City. The new City of Justice, near these facilities, where twelve buildings had been planned, was paralysed in 2007 with one single building erected and incomplete.

In addition, the Supreme Court ruling of 28 September 2012 upholding the previous appeal for annulment, represents one more brake on the actions concerned: siding with those who had appealed against the removal of protected land status and the subsequent changes of use to urban land. It is particularly serious for the East Madrid Strategy, with partial plans approved, compensation boards set up, urban development projects also approved and construction permits granted, as is the case in Valdebebas. Although the City Council has stated that this is a technicality, it will not be able to proceed as it did in 2007, by limiting itself for arguing that it affected land without value and therefore developable, it needs to make the in-depth adjustments necessary.

A Plan revision which is still too vague

Madrid is in the phase of reviewing the Plan. A Draft of it was presented in 2012 and the Preview is soon to be revealed. These contain a diagnosis which is already considered almost final and strategic and urban development proposals which are clear still not definitive. One of the reasons for this revision is the need to adapt the PGOUM to the new regulatory framework, Madrid's regional land law of 2001, which is very expansive, and the 2008 national land law, which is much more restrictive. Additionally too, the chance has been taken to reflect on the general planning. It is considered that the legislation governing it has conceived of it excessively as an urban growth plan, failing to take into account its capability for intervening in and transforming the existing city; it is also considered that the general plans have suffered from too much structural rigidity, from limited capacity for adapting to economic and social changes, as well as showing excessive compartmentalisation by sector.

For a situation as uncertain, delicate and demanding as the current one, the diagnosis document in the Draft is, in my opinion, too long-winded and very non-specific. It is acknowledged that the 1997 Plan contained a strategy for expansion that approached the limit of capacity. Also accepted is the fact that Madrid exhausting its capacity to generate land has brought as a consequence an excess of land which is developable and in the urban development phase, which has, in fact, become a hindrance. The possibility of restricting it has not been ruled out.

Compared to the model of urban development for expansion, the Revision opts for "urban development by changing land use", for focusing on initiatives in the consolidated city, for stopping unlimited growth and restoring



Las Rozas urban development, Madrid

and regenerating the "compact, complex" city. After the lunacies committed in forecasting, in construction and in urban design, even the Mediterranean city model is invoked, which in general would have worked sustainably. About time. The reorientation anticipated is undoubtedly essential, but it is too timid, generic and vague, in spite of the seriousness and urgency of the situation. The need appears to be not so much to fill pages with well-intentioned, but also rather empty, language on urban positioning, city of opportunities, sustainability, social and territorial cohesion, quality of life, etc., but rather to really propose, discuss and agree what needs to be done and how, in short, a document not just of good specialists, but rather expert, political and civic agreements. A committed plan: it is not enough to criticise the previous one and foresee a less rigid scenario, a "game grid" for setting the rules and conceiving of the different possible moves. As well as the general criteria of regeneration and restoration, it needs to be studied piece by piece to propose appropriate, discriminating solutions.

The recent history of Madrid's urban planning is a good example of the need for a good general plan and, at the same time, how easy it is to fall victim to deficiencies. It also reveals the level to which many actions, including strategic and structural decisions, have been taken on the margins of the Plan, outside the Plan or even against the Plan. Suffice it to say that the Parque Lineal del Manzanares was hinted at in the 1985 Plan, while Madrid-Río was not in the 1997 version. Neither was the extension to the Paseo de la Castellana over Renfe land. Not to mention actions that today represent a crisis of considerable proportions: the underutilization of Barajas terminal T4, as a consequence of the fall in tourism and the crisis in Iberia, which has exclusive use of it; or very particularly that the public accounts have had to accept the losses accumulated by Madrid's radial motorways, together with the AP-41 to Toledo and the M-12 to Barajas, all resulting from delusions of grandeur (and, incidentally, a central concept of the territory).

Accurate diagnoses and categorical responses are now required. Because this is called for in a Madrid territory constructed in parts, in large pieces and, therefore, with physical and social fragmentation; with large wastes of space; where mobility has increased because housing has moved away and according to an irresponsible road infrastructure policy; where the environment is being damaged at an increasing rate and an increasing amount of fossil fuels are consumed as a consequence of the urban explosion; finally, a territory where the costs of facilities and services rise ever higher and become more difficult to maintain.

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8 | Implementations





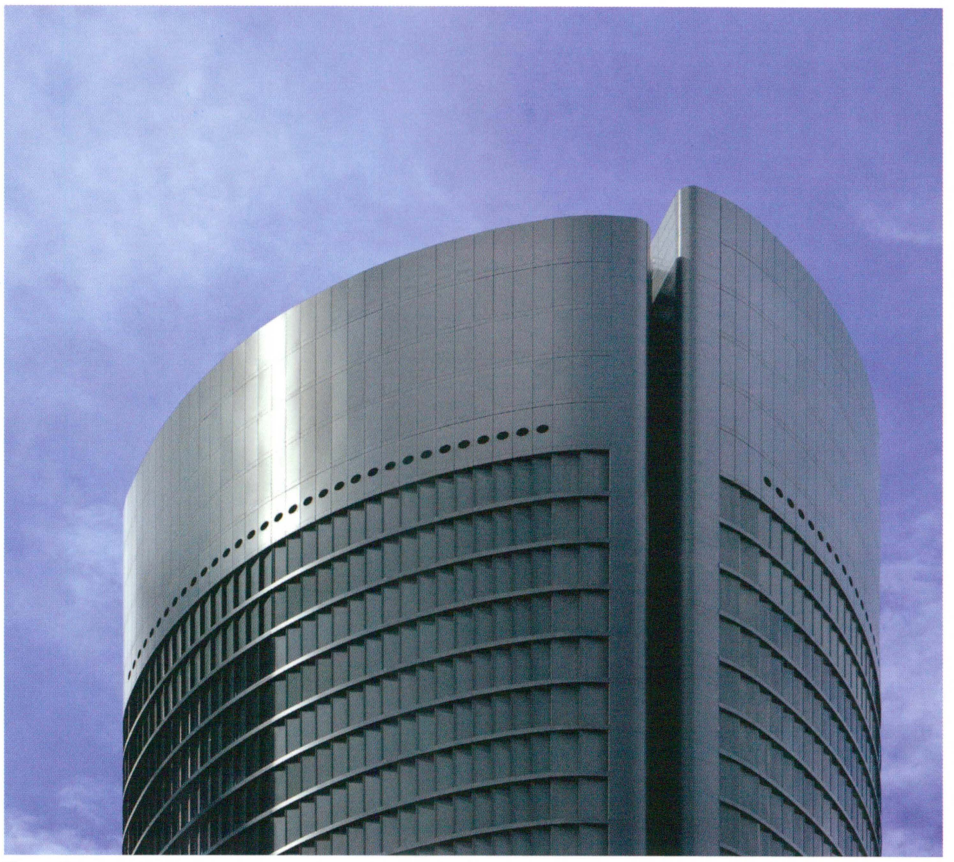
Rockódromo Arena. 2005



O'Donnell maternity hospital



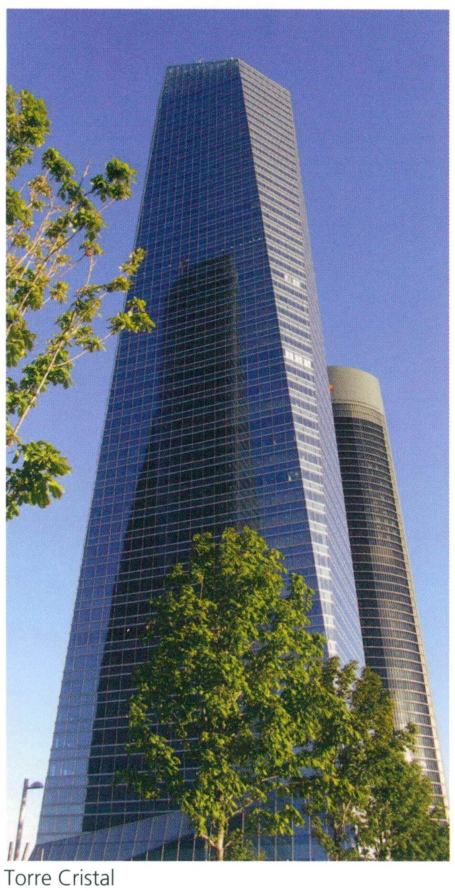
Community of Madrid Emergency Centre



Torre Sacyr



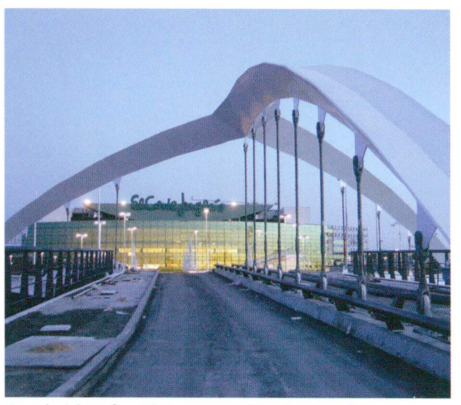
Conditioning of the streets Federico Rubio and Hortaleza



Torre Cristal



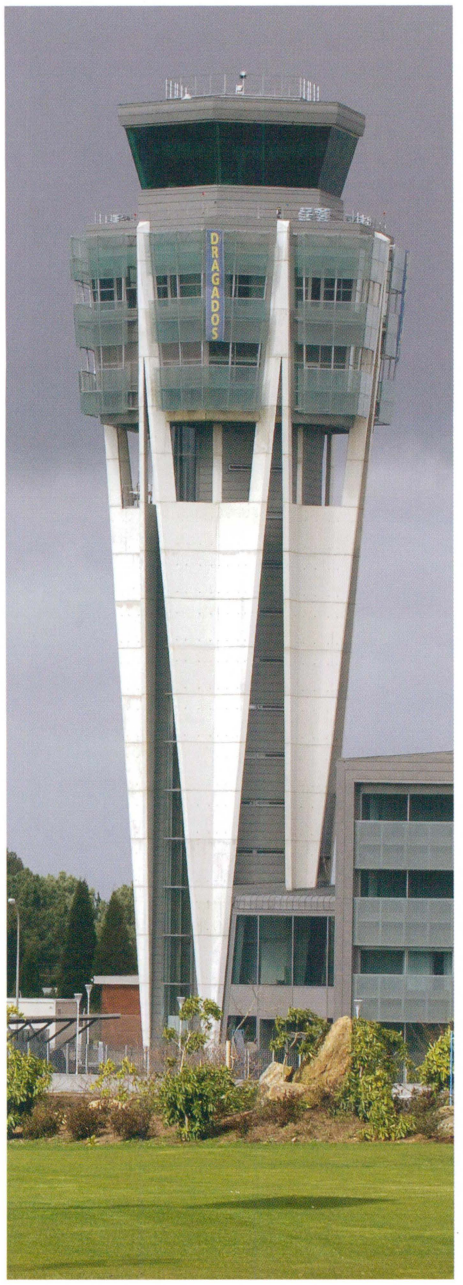
Third Runway at Barajas



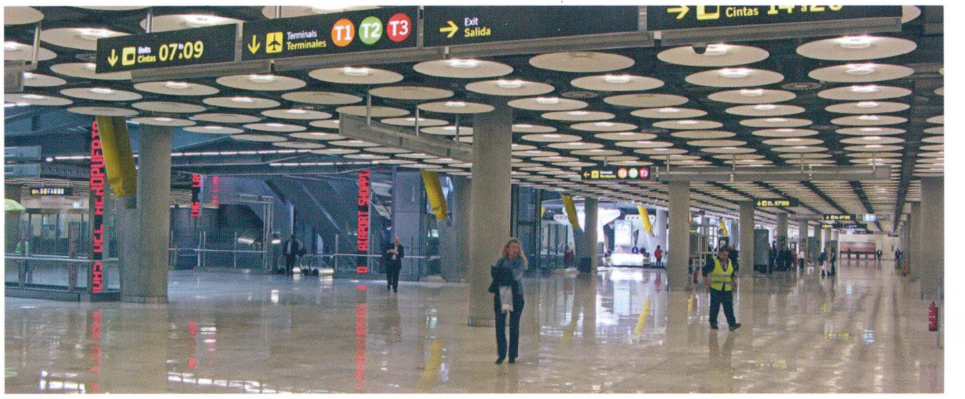
Footbridge for El Corte Inglés de Sanchinarro. Crossing 2



Torre Bankia



AENA control tower



Barajas Airport terminal T4



Santiago Bernabeu stadium, opened in 1949 (photograph from 1994)



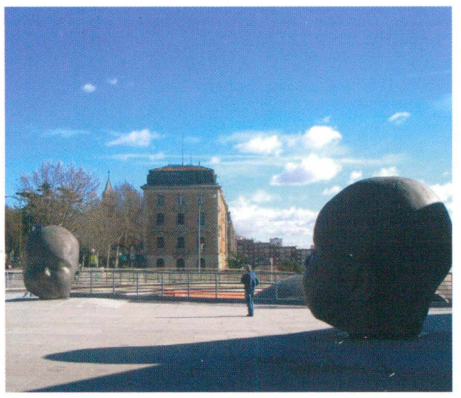
Recinto Canillejas stores. 2010



Coperlim warehouse



Atocha station expansion. 2010



Atocha station expansion,Phase 1. 2010



Sierra de Guadalupe interchange at Vallecas



Nuestra Señora del Recuerdo car park. 2009



El Pardo junction footbridge, M-30 and M-40



Velázquez car park



Viaducts on the M-40, La Zarzuela junction. 1997



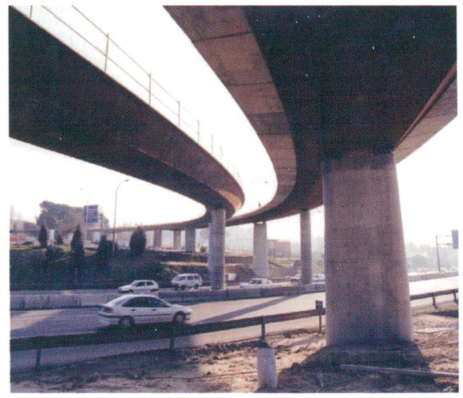
Museo del Prado extension



Corazón de María car park



Corazón de María car park



Puerta de Hierro junction, Madrid. 2000



M-40 highway



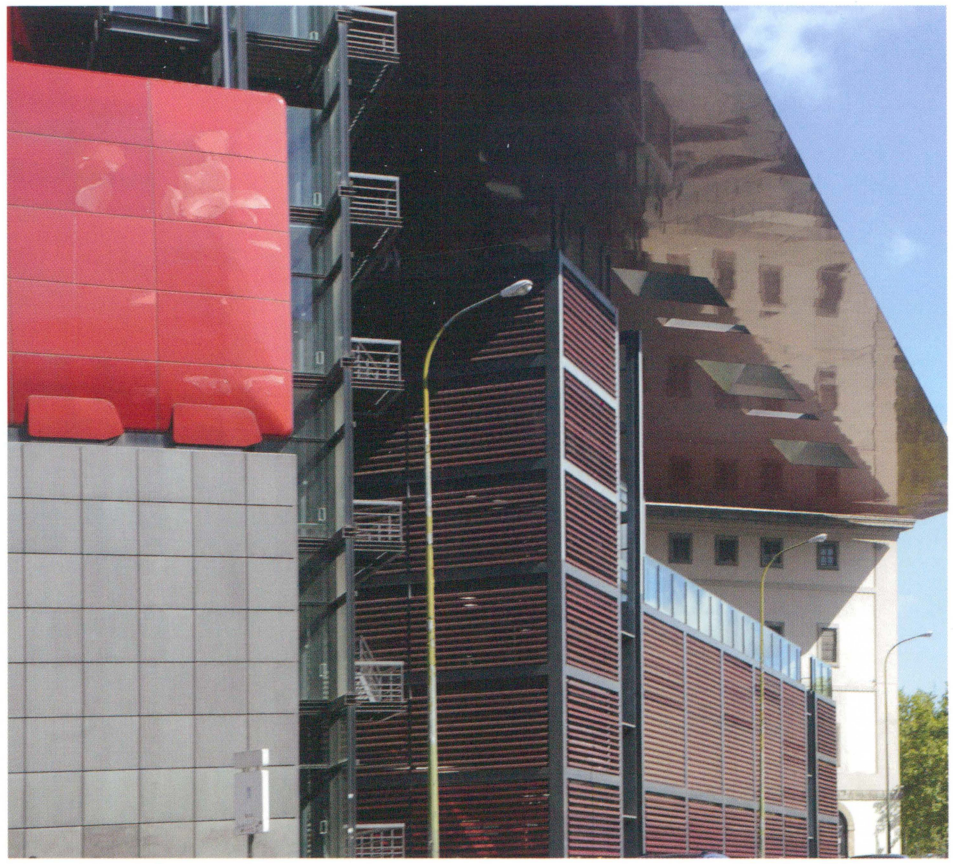
Plaza de España car park



Calle Basauri car park



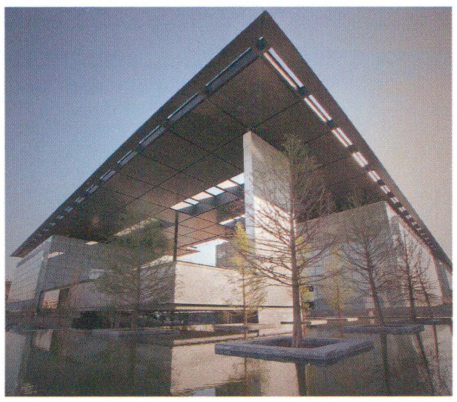
Arganzuela II footbridge. 2010



Museo Reina Sofía expansion



Miguel de Unamuno underground car park. 2007



Telefónica Telecomunications City



Showgrounds



Banco de Crédito Local



M-40 highway


Serrano high-speed rail tunnel. 2010


M-40, Madrid. 1994


Vallecas Community Library


University Library in the Calle San Agustín



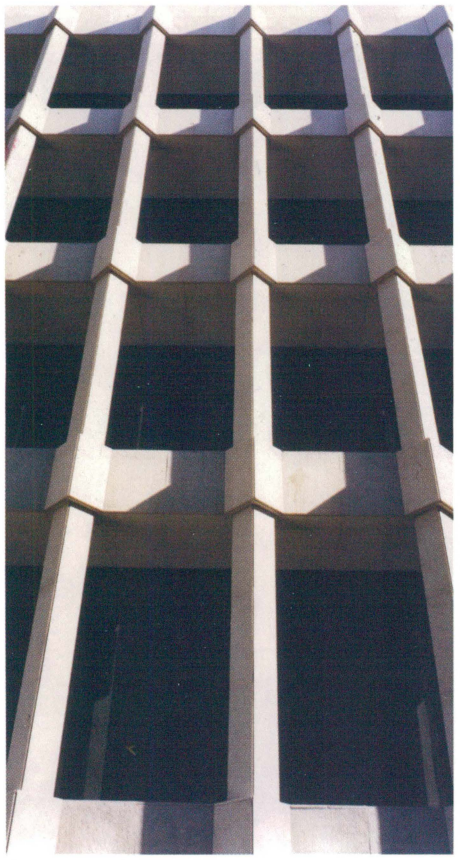
Madrid City Council - Latina Municipal Council


Special Technical Sciences, Universidad de San Pablo CEU


Metrovacesa Office Building


Community Libraries


Banco de Crédito Local



Banco Urquijo



Madrid Regional Library (old El Águila factory)



Avenida de Córdoba [conditioning]



Guadarrama Tunnel, Southern Mouth. 2005



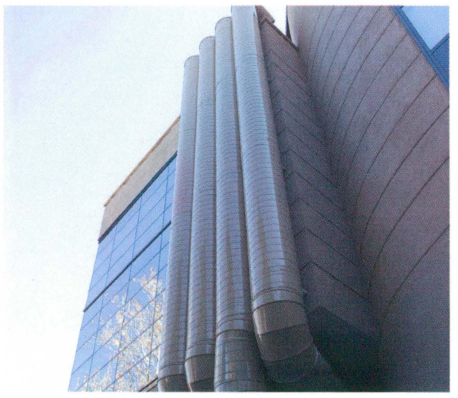
Usera Welfare Centre



Madrid Casino [Restoration]



Metro station, Línea 11. 1997



Offices in the Calle María de Molina, Madrid



Madrid-Villanueva de la Cañada Connection



M-45 Highway



Footbridges at Entrevías



Palacio Fontagu



El Pardo junction footbridge, M-30 and M-40



Edificio Mirador. 2005



La Zarzuela Hippoddrome restoration



M-45 Highway



AP-6 motorway. Guadarrama tunnel. 2007



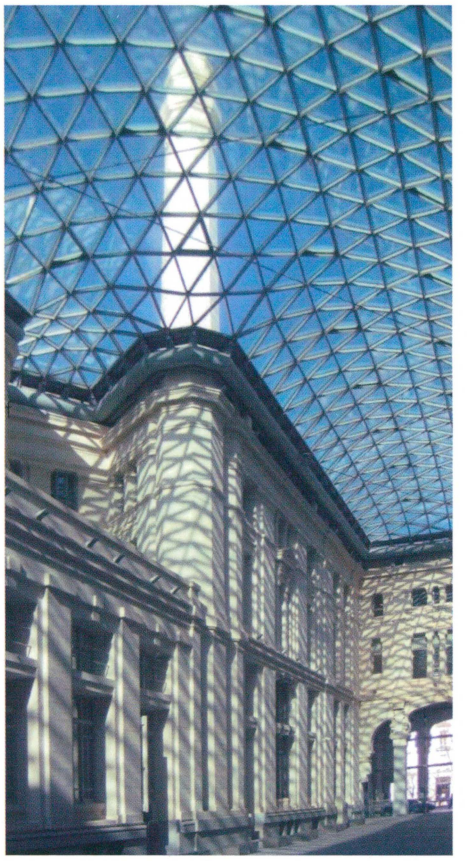
Community of Madrid Health Care Agency



R-2 Radial Motorway (Madrid-Guadalajara)



Teatros del Canal



Palacio de Comunicaciones



Remodelling of the Palacio de Comunicaciones



M-50 Connection to the Toledo Highway



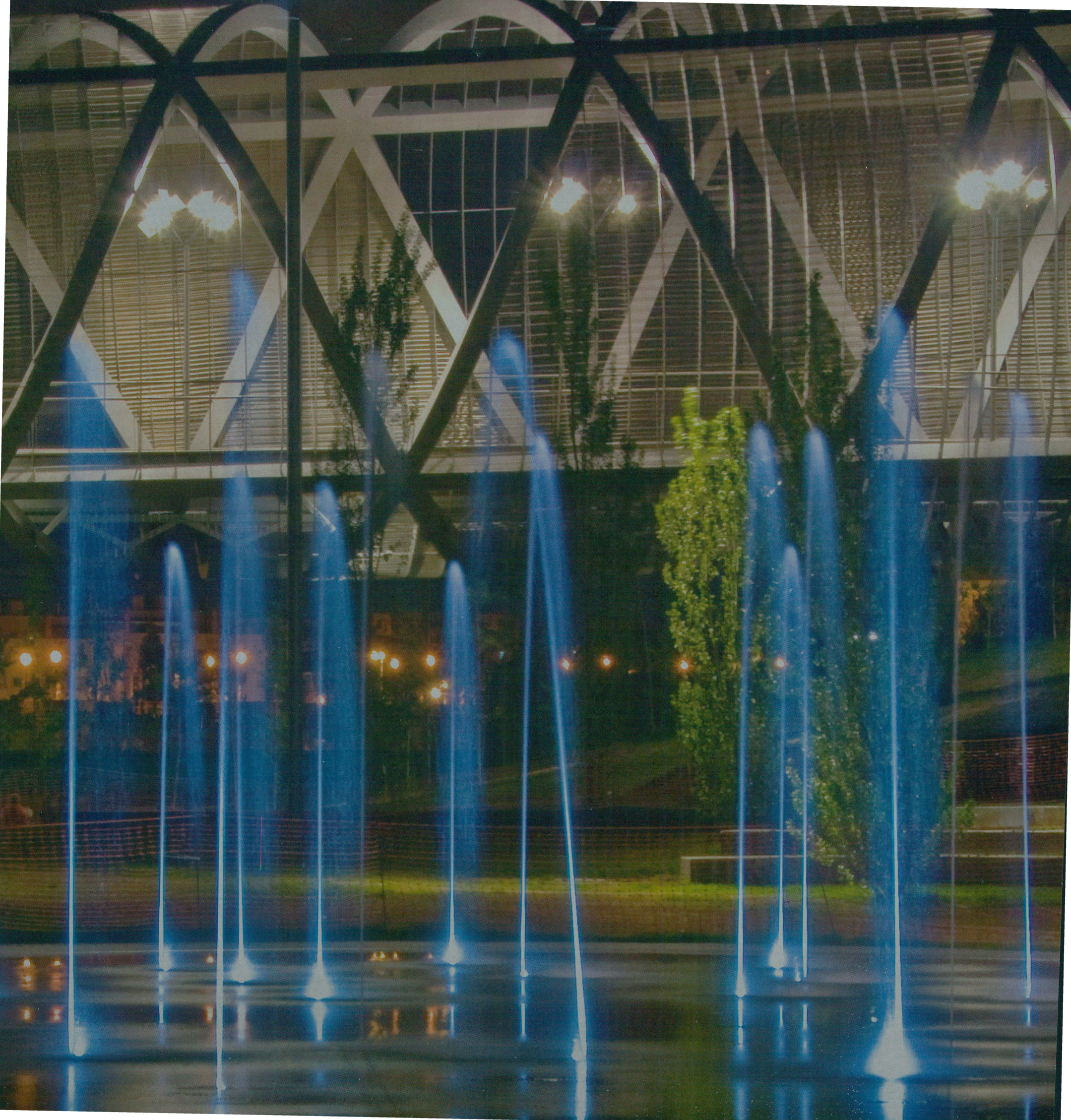
Camino Fuente de la Mora Offices



Underpasses on the Calle de Ríos Rosas. 1998



EMT Depot, Avenida de los Poblados



9 | References and Indices

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Appendix

APPENDIX. DESCRIPTION OF M-30 REMODELLING WORKS

A. Junctions in the Eastern Arc of the M-30

The M-30 project tackled the continuous traffic jams that built up on the whole eastern arc, from the junction called La Paloma in the north to the junction of the M-30 with the N-III Valencia Highway in the south[1]. Naturally, in all these works action was also taken on the drainage, which had become too small as in the western zone (see page 129). This work on the drains and the drainage system represented €8.6 million in the works at O'Donnell and €50.4 million at the connection to the Valencia Highway.

The new access and junction of the Avenida de la Ilustración with the M-607 Colmenar Road tackles one of the problems not resolved by the completion to the north of the M-30. The decision taken in the 1980's was to place roundabouts with traffic lights on the Avenida de la Ilustración, with the crossing from east to west along three arteries: the Avenida de la Ilustración, the "beach road" (Avenida Cardenal Herrera Oria) and the Sinesio Delgado artery. The triple crossing did not adequately resolve the traffic, with constant traffic jams at the traffic lights on the Avenida de la Ilustración and safety problems due to its tight curve in the only tunnel of Pío XII and with Avenida Cardenal Herrera Oria being too distant. In 2003, 70,000 vehicles per day passed along the Avenida de la Ilustración, while 251.000 passed through the southern junction. Additionally, the junction of the Avenida de la Ilustración with the rest of the M-30 was reduced to one lane at the eastern end, where it was made with a viaduct, and to two lanes at the western end[2] [3].

The remodelling of the link between the M-30 (La Paloma junction) and Calle Pío XII and the Avenida de Burgos tackles the weaving that used to take place between vehicles from the southbound M-30 accessing the Avenida de Burgos, Chamartín station and the Paseo de la Castellana and those coming from the Avenida de Pío XII to the northbound M-30 and the Avenida de San Luis. The completion of the Avenida de Pío XII by means of an overpass crossing the M-30, together with the mouths of the Chamartín station tunnel, led to the stretch between the Avenida de Burgos and the fork to the exit to the M-30 being a fast road for access to the M-30 itself, depriving this road of the image and urban use as a street[4].

To improve mobility from the M-30 to the Pío XII tunnels along the service road, the dangerous weaving was eliminated by building an underpass, of the pergola type, with a span of 77 m. To improve connections with the Avenida de San Luis and the Calle Arturo Soria in the Calle Serrano Galvache, two roundabouts were built to distribute local traffic. Under the intersection of the Avenida de Pío XII and the Avenida de Burgos, two tunnels were built in the M-30 direction of 405 m in length and in the Paseo de la Castellana direction of 219 m extending the Chamartín tunnels. The M-30 is connected directly in this way to the Paseo de la Castellana, the Calle Sinesio Delgado and the distributor ring under the four new towers, in addition to reducing traffic at the intersection of the Avenida de Burgos and the Avenida de Pío XII, which now runs to a new roundabout that allows all route options. These tunnels have entry and exit branches connecting them to the adjacent streets. The completion of the Avenida de Pío XII was executed by building an underpass of 50 m in length, enabling the road to be made two way again and reducing vehicles' journey distance[5].

The new Costa Rica junction connects the M-30 to the streets named Costa Rica; Alfonso XIII, Federico Salmón, Arturo Soria and Gran Vía de Hortaleza, with a direct connection to the Paseo de la Castellana at Cuzco and to the M-30 through the new long Sor Angela de la Cruz - Marqués de Viana tunnel. An underpass 190 m long was built for the remodelling under the Plaza de José María Soler with two three-lane carriageways separated by a central reservation enabling traffic to enter and leave the street Costa Rica from and to the M-30, both in the northbound and southbound directions. The project was completed with the rearrangement of the Plaza de José María Soler as a complete landscaped roundabout and the construction of a landscaped boulevard of 685 m^2 in the central zone of the Calle de Costa Rica[6].

The M-30 junction with the Avenida de América/A-2 produced traffic hold ups in turning to the left from the A-2 (Zaragoza) towards the M-30 (southbound), affecting traffic on the Madrid-bound carriageway of the A-2. The hold ups were made worse by the weaving stretch where it joined the lateral part of the M-30 with the exit from the latter towards the A-2 (Zaragoza).

The type of junction was modified in the project, with more direct movements, eliminating the weaving at the same time. The previous arrangement was a cloverleaf that caused hold ups and numerous accidents due to the weaving of various traffic flows in such a short distance. The most important action was the elimination of two looping branches – from the southbound M-30 to the A-2 towards Madrid and from the northbound M-30 to the A-2 towards Zaragoza – and their replacement by a direct branch and one as a circle respectively. These are two new infrastructures with a layout in plan view designed so that the main alignments have the maximum possible radius with the space available, allowing a greater flow of vehicles.

---

[1] The majority of the preliminary plans were also prepared by the specialists at Madrid City Council, led by Fernando Catalá, such that the construction projects were made with the appropriate modifications.

[2] The works were awarded to OHL and the project and control to Prointec. The Works Director was the Civil Engineer Luis Caneda.

[3] Caneda, L "Connection of the Avenida de la Ilustración to the M-30". In: [38] Ayuntamiento de Madrid; AA VV; 2007. Madrid M-30. *Un proyecto de transformación urbana*. Turner, Madrid.38:288].

[4] The remodelling works on the La Paloma junction were led by the Civil Engineers Juan de las Heras and Mercedes Jack Páramo.

[5] The works were led by the Civil Engineers Juan Antonio de las Heras Azcona and Mercedes Jack Páramo. The works were awarded to CORSÁN-CORVIAM, the project to AYESA and technical support to INOCSA.

[6] The works were awarded to the Sando-Ploder Joint Venture. The Works Director was Juan Antonio de las Heras. The project was awarded to Proser and technical support to INOCSA.



The new connecting branch from the side lane of the northbound M-30 to the A-2 in the Zaragoza direction is shared with movement to the A-2 towards Madrid and has two lanes. One of the two, the right-hand side, runs towards the Avenida de América in the Madrid direction and the left-hand lane is the branch in the Zaragoza direction. The other main action is the arrangement of a direct movement for traffic coming from the southbound M-30 heading for the A-2 towards Madrid and the elimination of the previously existing loop. These interventions are complemented by the elimination of the weaving movements which previously occurred in carriageway leading out of Madrid on the A-2, between movements towards the Avenida de América-Calle de Agastia and the M-30 southbound to the A-2 towards Zaragoza. To avoid this, the right hand lane of the three on the A-2 motorway has been segregated to lead to the Calle de Agastia. On the other hand, a new exit has been opened from the street named Arturo Soria to the A-2 via the street named Gregorio Benítez, complementing the existing one from the street Emilio Vargas. Of the four initial loops, only two remain[7].

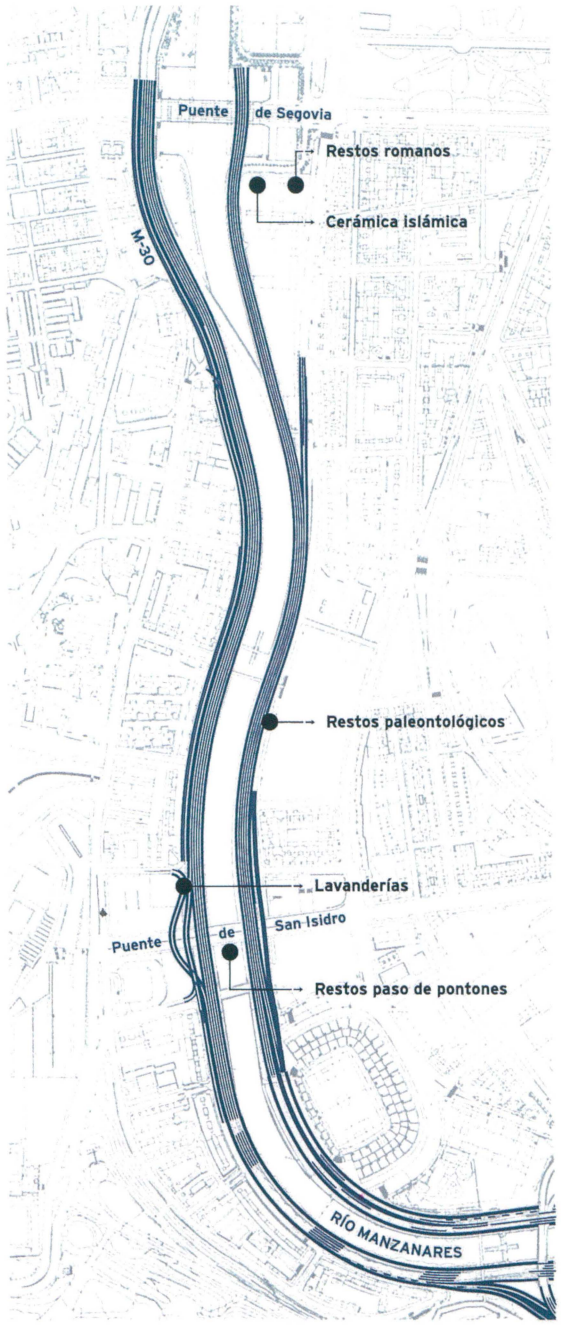
The links from the M-30 junction at the street named O'Donnell had serious deficiencies as regards functionality and safety. A total of 348,107 vehicles circulated per day, with 60,980 dangerous weaving manoeuvres and significant hold ups. The junction failed to resolve connectivity from the La Elipa neighbourhood to the M-30 south and had deficiencies in connecting the Avenida Alcalde Sáinz de Baranda to the southbound M-30. The barrier effect of the M-30 was particularly severe at this point. The initial connection between the M-30 and the M-23 (previously the N-100) was made using a full cloverleaf junction, with eight branches, to which two direct branches connecting the eastbound M-23 to the southbound M-30 and the northbound M-30 have been added. Two of the three weaving manoeuvres have been eliminated from the junction and the third for the Calle O'Donnell has been improved by increasing its length. Movement from the artery Calle de Alcalde Sáinz de Baranda-Avenida del Marqués de Corbera to the southbound M-30 has been incorporated This did not exist before.

To do all this, four structures were built; an overpass over the M-30 connecting the M-23 towards Madrid to the southbound M-30 and three underpasses. One of the latter is a continuation of the overpass linking the M-23 towards Madrid to the southbound M-30; another dual one connects the Calle Alcalde Sáinz de Baranda-Avenida del Marqués de Corbera to the southbound M-30 under the branch connecting the southbound M-30 to the Calle O'Donnell; and the third is an exit from the M-30 towards the centre of the capital under the Calle O'Donnell artery[8].

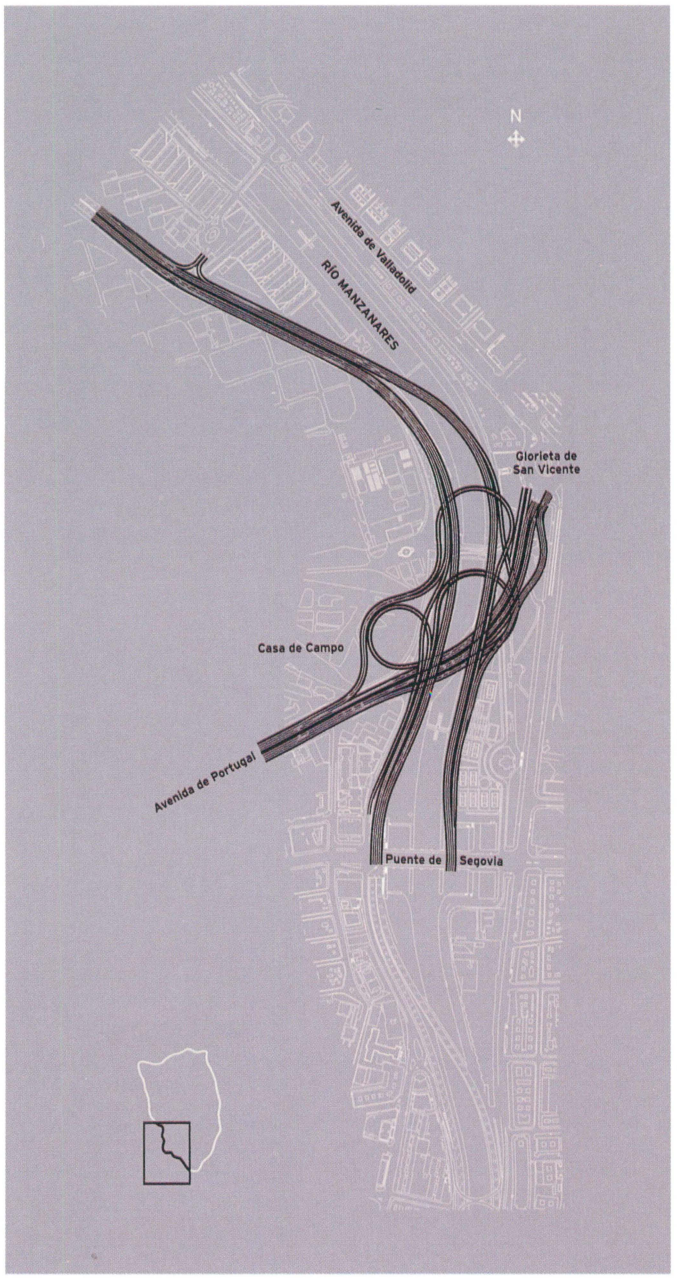
The new tunnel under the street named O'Donnell to the street named Alcalá makes it possible to channel traffic leaving Madrid on one of its most important roads. Its entrance is located at the beginning of the street, specifically at the corner of the Calle de Alcalá opposite Retiro park. It runs underground along the Calle O'Donnell and has its

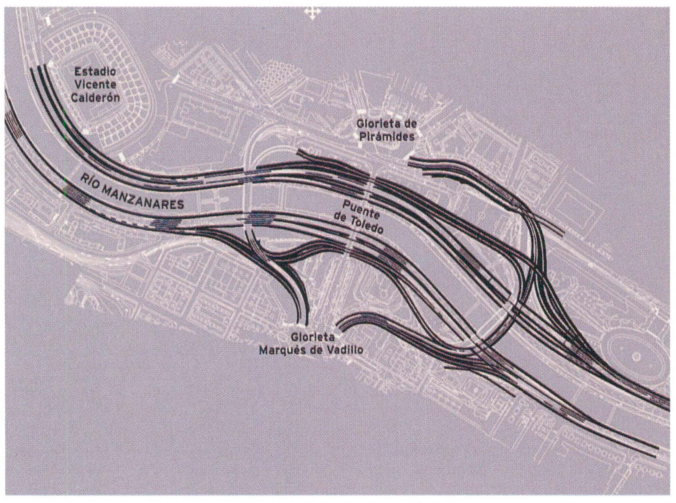
[7] The Director of Works was Juan Antonio de las Heras, the works were awarded to Aldesa, the project to Vigiconsult and technical support to Proser.

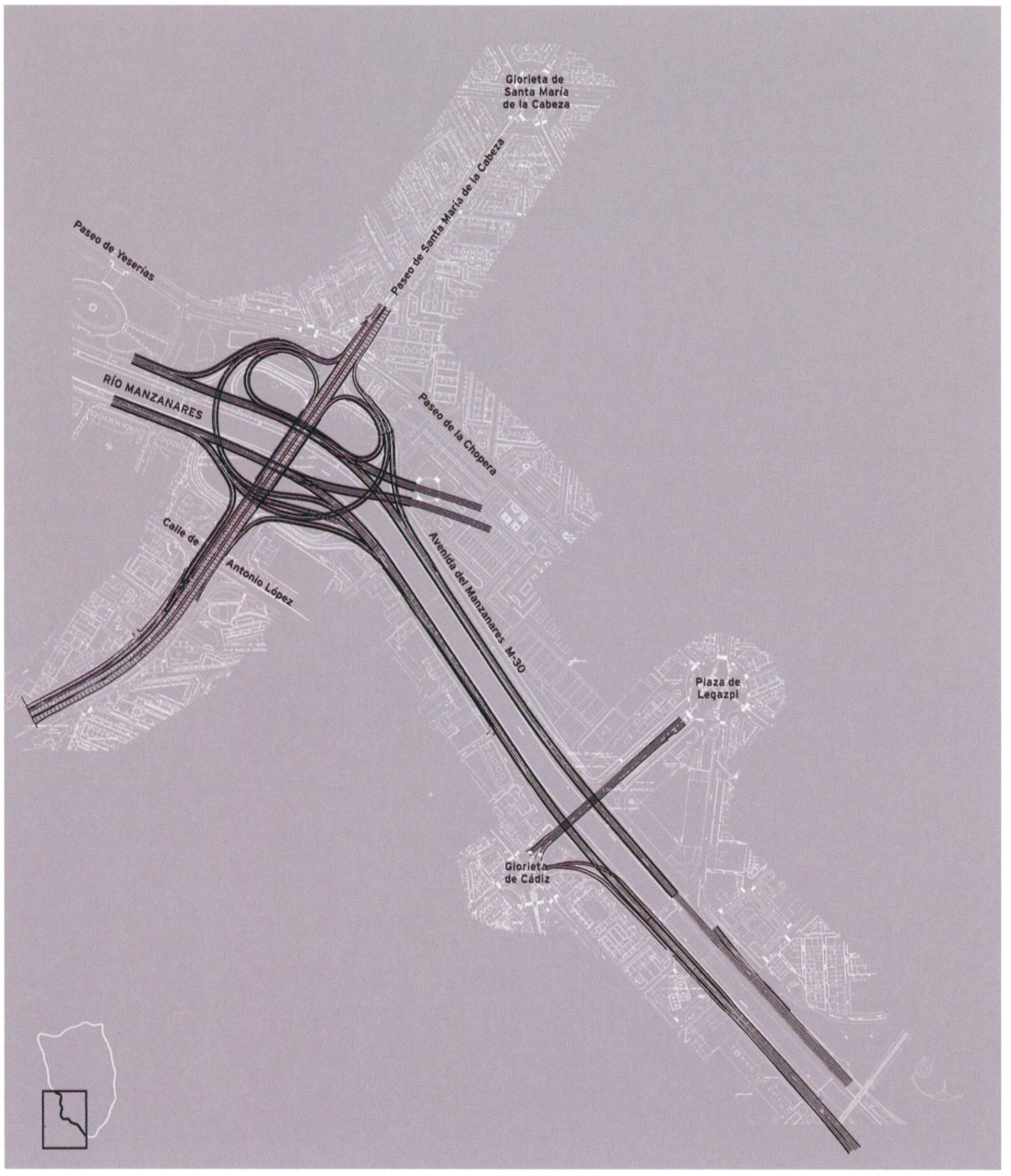
[8] The works were led by the Civil Engineers Juan Antonio de las Heras and Mercedes Jack Páramo. The works were awarded to Ortiz, the project to Esteyco and technical support to Proser.


Puente de Segovia
Restos romanos
Cerámica islámica
M-30
Restos paleontológicos
Lavanderías
Puente de San Isidro
Restos paso de pontones
RÍO MANZANARES


M-30
RÍO MANZANARES
Casa de Campo
Palacio Real
Avenida de Portugal
Escala 1:20.000
Estadio Vicente Calderón
Glorieta de Pirámides
Parque de San Isidro
Calle de Antonio López
Paseo de Santa María de la Cabeza
Plaza de Legazpi
Glorieta de Cádiz
M-30

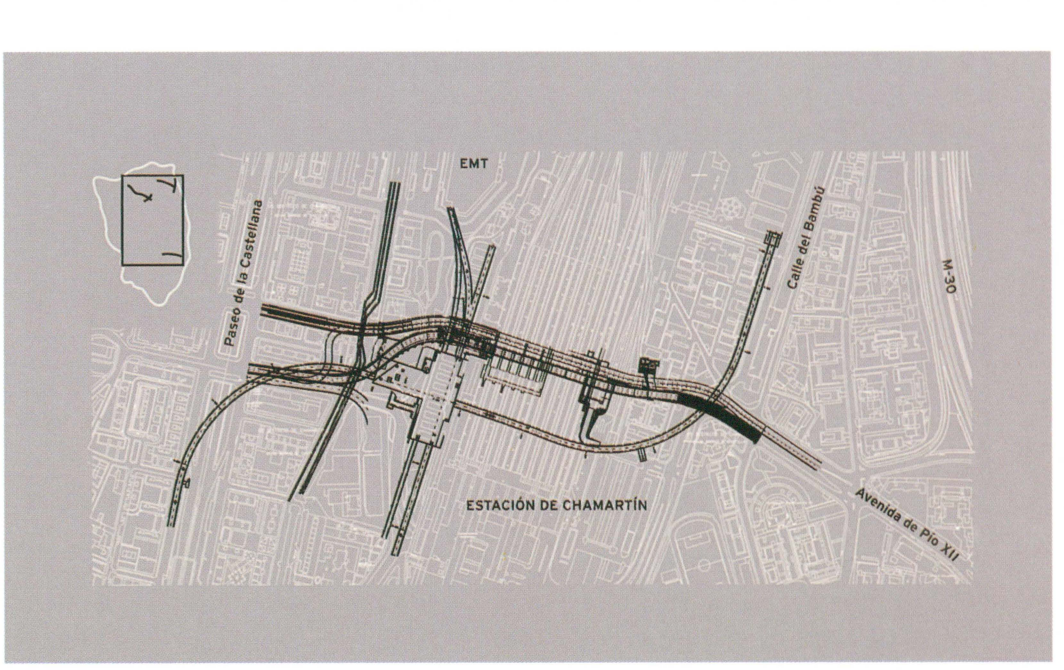

N
Avenida de Valladolid
RÍO MANZANARES
Glorieta de San Vicente
Casa de Campo
Avenida de Portugal
Puente de Segovia


Estadio Vicente Calderón
Glorieta de Pirámides
RÍO MANZANARES
Puente de Toledo
Glorieta Marqués de Vadillo


Glorieta de Santa María de la Cabeza
Paseo de Yeserías
Paseo de Santa María de la Cabeza
RÍO MANZANARES
Paseo de la Chopera
Calle de Antonio López
Avenida del Manzanares M-30
Plaza de Legazpi
Glorieta de Cádiz


N
Escala 1:20.000
Paseo de la Castellana
M-30
Avenida de Pío XII
Plaza de Castilla


N
Escala 1:20.000
Calle de Sinesio Delgado
Plaza de Castilla
Calle Sor Ángela de la Cruz


EMT
Paseo de la Castellana
Calle del Bambú
M-30
ESTACIÓN DE CHAMARTÍN
Avenida de Pío XII


Av. del Ventisquero de la Condesa
Herrera Oria
Avenida del Cardenal
Avenida de la Ilustración
M-30
Avenida de Monforte de Lemos

exit between the Calle Doctor Esquerdo and the M-30. It is 1,443 m in length, of which 1,241 m are roofed with two 3.50-m wide lanes and direct exits both to the M-30 and the M-23, which connects to the M-40. By using it you avoid six junctions at ground level in the Calle O'Donnell, outstanding among which are the streets named Narváez and Menéndez Pelayo due to their high traffic density. The removal from street level of the around 35,000 vehicles per day that use the tunnel has also made it possible to rearrange the street O'Donnell, creating a new 1,050-m long cycle lane as part of the cycle route between Retiro park and the green cycling ring[9].

The junction between the M-30 and the N-III Valencia Highway attempted to eliminate the constant traffic jams in connections entering or exiting between one and the other. Two tunnels were built for this. The first, 795 m long, from the northbound M-30 exiting to the N-III passes under the trunk road and comes out onto the N-III towards Valencia. The second is the tunnel for entry to Madrid, at 1,301 m long, starting at the edge of the N-III and passing under the M-30 trunk road, forking into two single lane branches of which one goes to the southern junction and the Avenida Ciudad de Barcelona at ground level and the other enters the southern bypass tunnel.

The two tunnels were built in the usual way, with screens, top slab and another intermediate slab shoring up the screens. The work, with traffic passing at all times, was already complicated to organise, but it became even more complicated when I decided to locate the working shaft for the Herrenknecht tunnel boring machine precisely in that area, which was to build the tunnel towards the river from there. In spite of that, the works were built perfectly and on time[10].

Two new branches were also built for the Moratalaz exit, one along the street named Arroyo Fontarrón, through a false tunnel towards the planned tunnel running from the A-3 to the southbound M-30, and the other, replacing the old connection from the Moratalaz neighbourhood to the northbound M-30 via the street located alongside the Hogar Ferroviario housing scheme along the street Ramón Areces[11].

B. Connections East-West of Madrid

The Cuatro Caminos tunnel works included the demolition of the overpass at the roundabout and its replacement by a tunnel. The tunnel is made up of twin shafts built using the Belgian method, with the side walls built first, as in the German method. The central side wall is common to the two tunnels, as the photograph shows. The tunnels are 320 m long and pass right under Metro Line 1 and the curved branch of Line 2 for entry to the Cuatro Caminos depot and Line 6 runs underneath it with its great cavern station. The tunnel was built in 13 months and went into service on 1 April 2005[12].

The connection of the street named Ventisquero de la Condesa to the M-40 was planned when that stretch of the M-40 was built in the early 1990's, with an underpass for a future junction with the aforementioned street, which had almost no buildings at the time. The junction became really necessary in 2002, although the start of the work was greatly delayed due to the serious problem of rehousing all the marginal population which had built a shanty town in the area and it was only possible to sign the variation certificate on 19 April 2004. The works had to cross under the two railway lines running from Pitis towards Fuencarral and Chamartín, and the crossing was made using two jacked boxes[13].

The M-40 junction at the Sanchinarro urban development plan consisted of completing the M-40 -Sanchinarro development junction at the junction which also connects to the Radial 2 road by building the two lacking overpasses and adapting the access roads.

The new Pío XII tunnel under Chamartín station was a world record for a jacked box with its 150 metres in length. It crossed under the Chamartín railway yard with the trains running at all times and created no obstacle to traffic whatsoever.

The old Pío XII tunnel that provided service from the avenue of the same name to the Paseo de la Castellana was not big enough to carry the traffic in the area and above all to meet the needs forecast according to the new urban developments. Additionally, its layout in plan and elevation was very dangerous due to the tight curve in it and that is why the objectives of this large project were to improve the road safety of the current tunnel and improve and increase its capacity and functionality. The bends in the existing two-way Pío XII tunnel, due to going around some buildings, made it exceedingly dangerous and hence it was decided to build a second tunnel, to the south of the first and running noticeably parallel. It was also decided to extend it at one end to the M-30 and at the other to the Avenida de Monforte de Lemos, once it had crossed the Paseo de la Castellana at a third level under an underpass, at a length of 1,360 m.

The southern tunnel is a completely new construction. It also has two lanes in one direction for west-east movements and also passes under the Paseo de la Castellana, under the arteries of Canal Alto and del Atazar and under the enormous Chamartín station railway yard. The two tunnels have three 3.33-m wide lanes and 0.5 m hard shoulders and 0.75 m pavements on each side of the carriageway. The works started in December 2004 and were completed in March 2007[14].

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[9] The works director was the Civil Engineer Ricardo Castro Canseco. The works were awarded to Comsa and technical support to Eptisa.

[10] The works director was the Civil Engineer Ignacio Arjona.

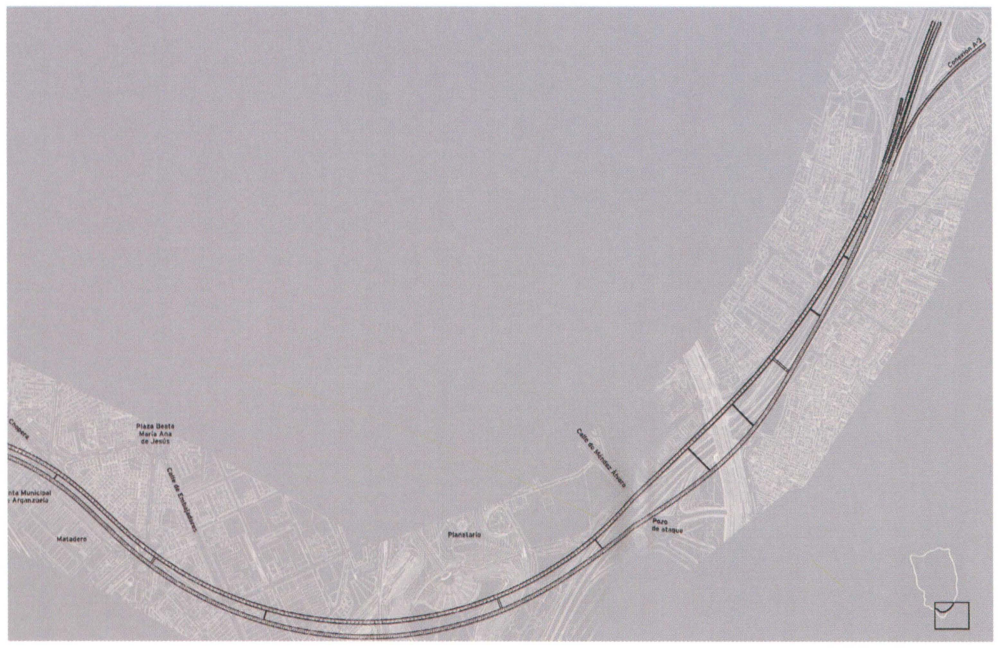
[11] The Works Directors were, as in the rest of the Eastern Arc, the Civil Engineers Juan de las Heras and Mercedes Jack. The works were awarded to SACYR and technical support to TYPSA-ASURINSA.

[12] The works were led by the Civil engineers Félix Ajates Martínez and Filemón Fernández Rodríguez and executed by an FCC-ACS Joint Venture.

[13] The works were awarded to FCC and were built by the team of Avelino Acero and Ricardo Gil, who had carried out the extensions to the Metro.

[14] The Works Directors were the Civil Engineers Francisco Javier Rodríguez Bernardo and Javier Maestro Aznar. The works were awarded to OHL and the Works Manager was the Civil Engineer Alonso Becerril Oriol. Technical Support was awarded to the Incoydesa-Ingeniería Básica Joint Venture.





The distributor ring under the four towers of the old Real Madrid Sporting City enable the four towers to be connected to the Paseo de la Castellana, the Avenida de Monforte de Lemos and, above all, permits an east-west connection, connecting the axis of the Pio XII tunnel under the Paseo de la Castellana to the street Sinesio Delgado and therefore to the N-VI and M-30 roads. The works started in July 2005 and were completed in March 2007[15].

The tunnel connecting the Avenida de la Ilustración and the street Ventisquero de la Condesa gives direct access to the M-40 and the areas of Mirasierra, Montecarmelo and Arroyo del Fresno with the accesses to the Barrio del Pilar neighbourhood in south Fuencarral. The connection had been broken by the Avenida de Herrera Oria or "beach road". The new tunnel is made up of two one-way tunnels, each with two 3.50-m lanes, with hard shoulders of 0.75 m and pavements of 0.50 m on both sides. The layout enables all possible route options and it has a total length of 1,454 m, with access ramps of 1,429 m[16].

The Sor Ángela de la Cruz - Marqués de Viana tunnel connects Cuzco and the Tetuán district, reaching the M-30 via the new Avenida del Camino de los Pinos with a total length of 1,850 m. The tunnel has a total length of 1,350 m, which with the access ramps totals 1,590 m. It starts at the junction between the streets Infanta Mercedes and Bravo Murillo, crosses Bravo Murillo by going under Tetuán station on Metro Line 1 with very little clearance and continues under the street Marqués de Viana. It ends in the Calle Villaamil after crossing under the Paseo de la Dirección. It has two lanes in each direction in two independent shafts. As in all the works on the M-30, these works were completed with many improvements on the streets affected and an underground car park with 196 spaces was built in the street Sor Ángela de la Cruz[17].

The Marqués de Viana tunnel needed a direct, simple connection to the M-30 and M-40, but the north-west corner of the M-30 where it needed to reach it via the street Los Pinos only had two lanes and its capacity was very limited.

The remodelling of the M-30 service road in the north-western zone and widening to three lanes at the north-west junction tackle the serious deficiencies existing in the north-west zone of the M-30. At the Mariano Salvador Maella roundabout and up to the junction with the M-40 there were three lanes in each direction – one of these in each direction was used for connection to the M-40 – while the M-30 had two lanes in each direction in the area where it crosses over the El Pardo road. Connections between the M-30 itself and the adjacent neighbours were scarce and deficient. For this area of Madrid, the M-30 constituted a frontier and had become obsolete with the forecast increases in traffic after the actions executed in the northern area of the city. The exit from the M-30 to the M-40 and the Avenida de Cardenal Herrera Oria took place via a single lane, which caused large build ups in traffic.

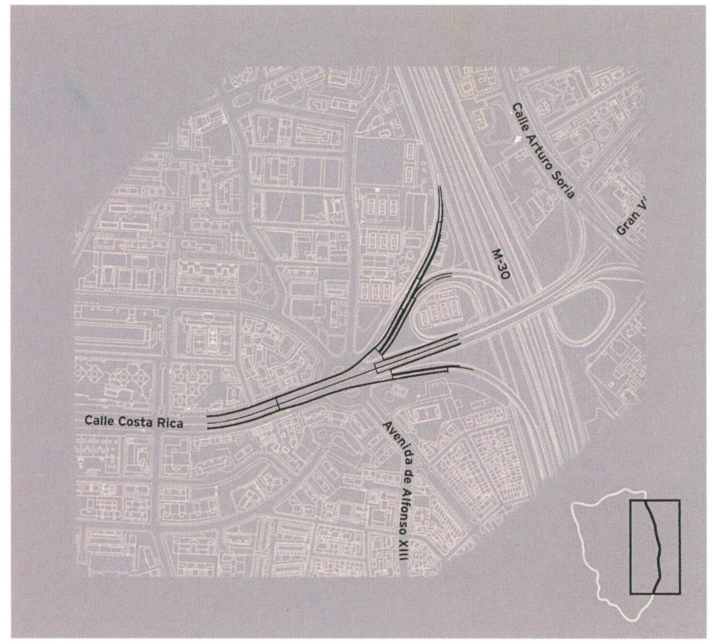
To resolve these problems, the M-30 was widened with the addition of one more lane in each direction from the Mariano Salvador Maella roundabout to the crossing over the El Pardo road, so as to maintain a minimum of three lanes on the whole M-30. Parallel service roads were also built or improved to improve connections between neighbourhoods and all the possible route options were enabled at the Nueva

[15] Designed by Professor Juan Fisac at Ingeniería Básica, it was awarded to OHL.

[16] The Civil Engineer Moisés Escolá Triolao led the works with Aquilino Gutiérrez Cornejo. The project was awarded to Intecsa-Inarsa. The works were awarded to Corsán-Corviam.

[17] The Works Director was the Civil Engineer Ricardo Castro with Filemón Fernández and Felicísimo Ajates. The works were awarded to Sacyr and technical support to Intecsa-Inarsa.





Zelanda roundabout for connection to the M-30. The widening of the carriageway under the Nueva Zelanda and Francisco Bayéu roundabouts was carried out using a pile screen wall behind the existing abutments, on which the widening of the covering slab was supported, to then demolish the old abutment and widen the carriageways. As additional works, the exit towards the M-40 from each carriageway was widened to two lanes and a false tunnel was built in the area of the street named Doctor Ramón Castroviejo, covering the M-30 over a length of 200 m. Two large footbridges were built on top of this, with the intention of reducing the barrier effect here too[18].

The connecting tunnels between the street named Embajadores and the M-40 are complicated works[19] to resolve the area's problems. It used only to be possible to join the M-30 from the Calle Embajadores heading south and from the M-30 to this street only if heading in the east-south direction, which greatly limited the connection options for the Arganzuela district and saturated the accesses via Legazpi and Méndez Álvaro to be able to make the rest of the connections. The Sur bus station had both an entry and an exit at Méndez Álvaro, so this bus traffic was added to the private vehicles obliged to pass through this area for the reason stated above. This commonly caused heavy congestion at the two roundabouts linking Méndez Álvaro - Avenida de Entrevías to the M-30, due to the needs for space and weaving required by passing heavy vehicles.

Additionally, around the southern junction on the M-30 and in both directions, there was a series of exits and entries to the main trunk road that generated weaving that was undesirable for both safety and functional reasons Especially significant in this in the east-south direction was the entry from Méndez Álvaro, with a give way junction and the exits to the M-40 bypass, the Avenida de Andalucía and the street Embajadores, and in the west-north direction the entry from the Avenida de Andalucía and the M-40 and the exit towards Méndez Álvaro - Avenida de Entrevías - Vallecas.

To resolve the access problems for the Arganzuela district, a dual action was planned. On the one hand was the construction of a tunnel with entries and exits in the street Embajadores and the Avenida del Planetario and the M-30-M-40 bypass, permitting direct connection from the district to the A-4 and all M-40 directions through the Súper Sur junction, without going via the M-30. This tunnel was executed by means of screen walls over the majority of its route, except for a central stretch of 240 m which, so as not to interfere with the Abroñigal drains and the M-30, was executed using the Belgian method. On the other hand, two branches of the main trunk are included in the direction of the A-3 from the M-30, connecting the southern part of the street Embajadores. This enables all the options between the M-30 and Embajadores, including access to the Parque Lineal del Manzanares, completed with the inclusion of a new branch connecting the city centre direction of the A-4 northern bypass to the street Embajadores, with which the M-40 is also connected directly to the park.

To avoid saturation of bus traffic around the Sur bus station, bus routes were designed so that the buses do not interact with private vehicle traffic. An entry and exit tunnel was built, just for buses, leading to the Avenida del Planetario where, after a short stretch at street level, now in shared traffic, it connects to the tunnel described above. The result of this is that the majority of the bus routes starting or stopping at the Sur bus station do not need to

[18] The works director was the Civil Engineer Luis J. Caneda. The works were awarded to OHL and the project to Eptisa.
[19] Awarded to Intecsa-Inarsa.

go via the M-30, so the pressure is relieved both from it and its accesses to the radial highways and they go directly to the M-40.

For a better understanding of the southern junction and its solutions, the two directions of travel are differentiated.

West - North direction There is a stretch with weaving problems where the Avenida de Andalucía and the Southern junction - Superior junction bypass join the main M-30 trunk road in a short space, followed a little after by the exit to Méndez Álvaro - Avenida de Entrevías. The solution for this stretch consists of creating a collector road parallel to the main trunk road which the two entries (Avenida de Andalucía and the Bypass) lead into and which joins the main trunk road with its own lane which does not lead to weaving, and in turn, has a direct exit to the roundabout connecting to Méndez Álvaro - Avenida de Entrevías.

East - South direction In the stretch lying between Méndez Álvaro and the Southern junction, the M-30 has four lanes, with access to the right-hand lane having a "give way" sign. For this reason, the solution consists of providing the main trunk road with a fifth lane meaning that the road joining has its own lane, so eliminating the "give way" and the problems of adapting speeds this leads to.

If the reduction in traffic joining at this point due to the aforementioned direct connection with the A-4 and M-40 is added to this, a significant decrease is obtained in the number of vehicles which, having joined the right-hand lane, need to cross four lanes in a limited space to take the Bypass to the A-4 and M-40. Of the aforementioned actions, there are the following final tunnel length measurements:

Tunnel lengths

Between screen walls	m
Single lane tunnel	843
Two lane tunnel	722
Joint 2+2 lane tunnel	360
Two-way tunnel	270
Single lane ramp	490
Two lane ramp	245
Two-way ramp	155
Belgian method	**m**
Two lane tunnel	480

Two complicated tunnels have been constructed, one for the connection of the Calle Embajadores and the Avenida del Planetario to the M-40 and the other to connect the Sur bus station to the Avenida del Planetario for bus traffic alone.

The tunnel connecting the street Embajadores to the M-40 is made up in practice of an entrance tunnel and another exit tunnel with respect to the centre of the city, although there stretches with joint section from the structural point of view. The exit onto the street Embajadores takes place at two different points so that traffic at street level can move towards the Calle del Molino without cross traffic coming from the tunnel wanting to go towards Embajadores-Delicias. A point determining the layout in elevation was the crossing under the Abroñigal drains and the M-30, making it necessary to take the grade over 20 m under ground level, leading to slopes of 7.5%. From the point of view of the cross section, two lane tunnels were considered for the main movements, reduced to only one lane in movements connecting to the Avenida del Planetario, as well as the branches that fork to exit to a single lane in the Calle Embajadores.

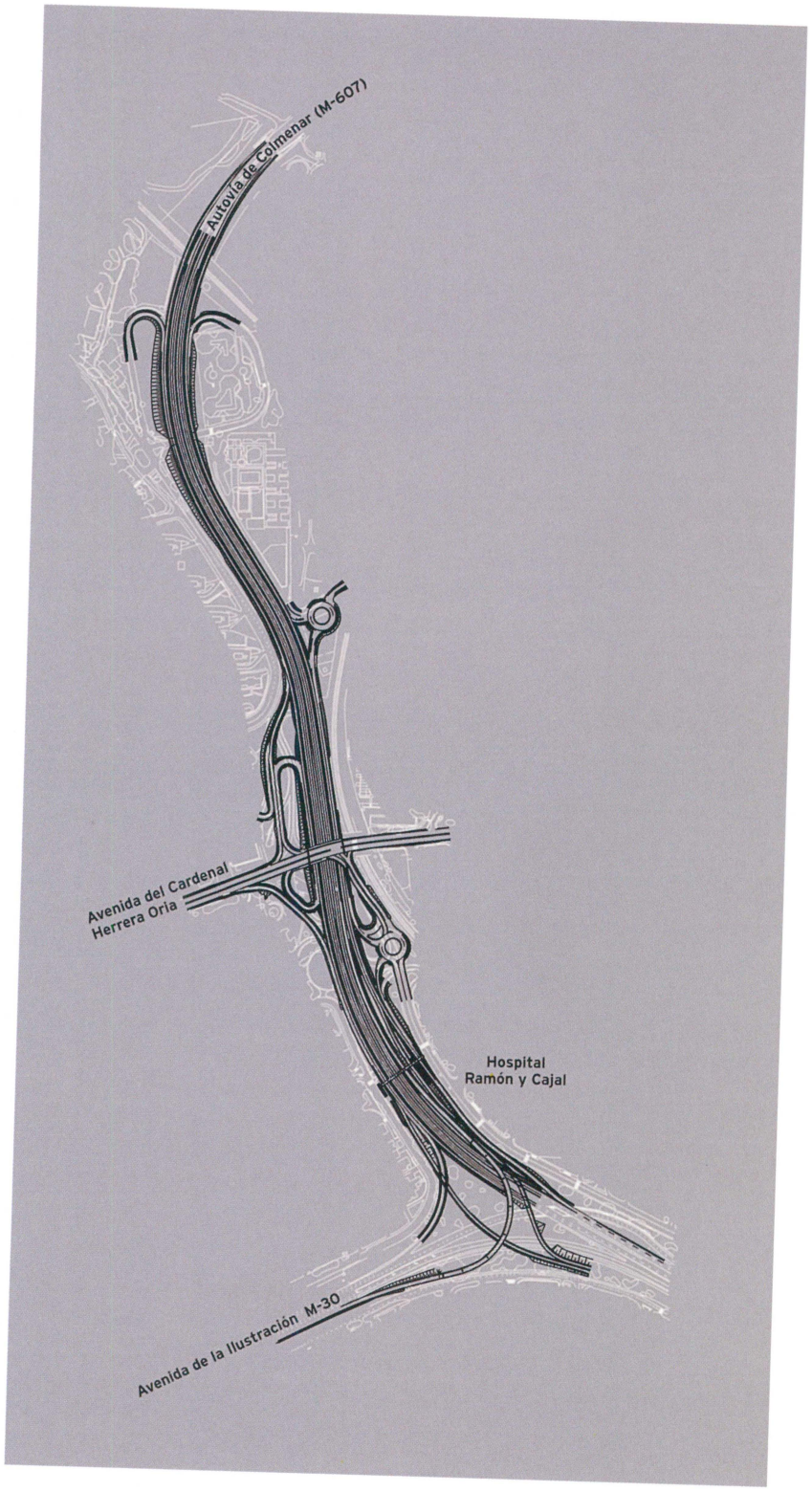
The tunnel connecting the Avenida del Planetario to the Sur bus station serves only buses, with one lane in each direction and the entrance and exit ramps located laterally. The longitudinal route of this tunnel was conditioned by it passing under the drain in the street Méndez Álvaro and the exit ramp from the bus station towards the M-30.

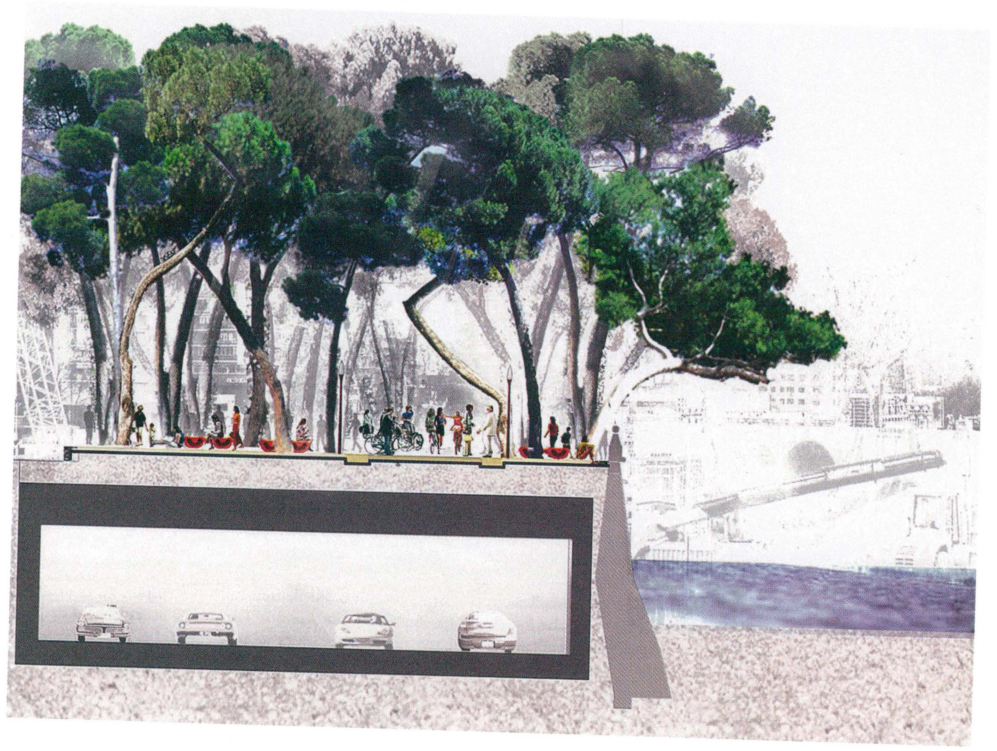
The works basically consist of the following three points:

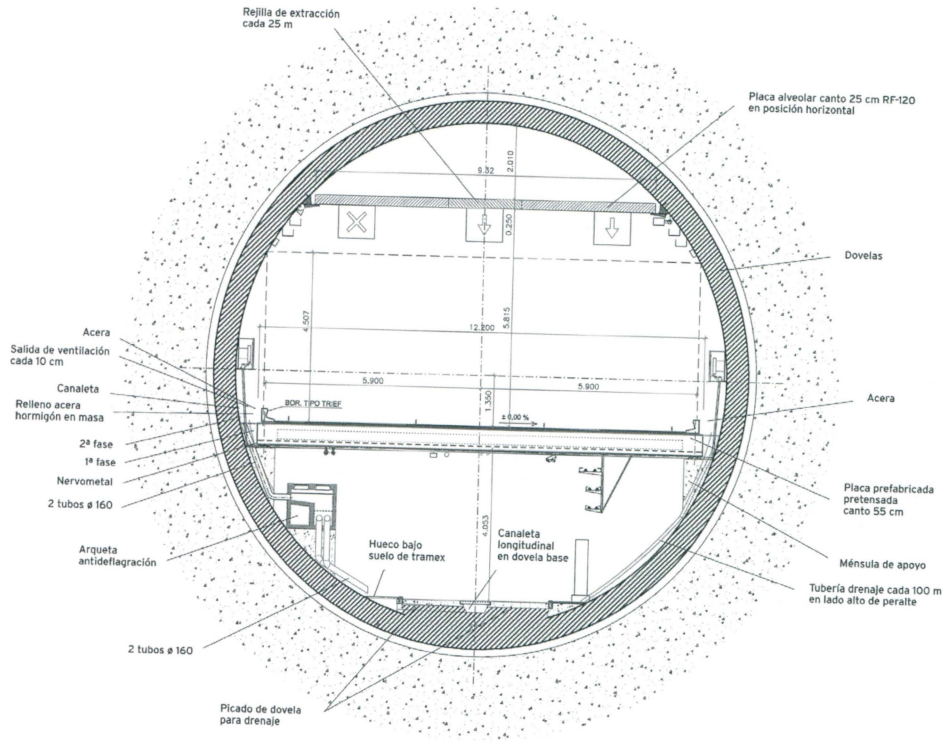
1. The two parallel two lane tunnels in the north-south direction, the entrances to and exits from which are located, on the one hand, in the Calle de Embajadores (one before and one after the Plaza de Italia and the Paseo del Molino) and the Avenida del Planetario; and on the other hand, at the Súper Sur junction, connecting the street Embajadores directly to the A-4 and with all options for the M-40, without needed to go via the M-30.
2. The complete remodelling of the Southern junction with the construction of five ground level structures that eliminate weaving from the outside lane of the M-30 and resolve the connections from the southbound Calle de Embajadores to the M-30. At the same time, these connections also give improved accessibility to and from the Parque Lineal del Manzanares. At the internal side of the roadway, the current "give way" from Méndez Álvaro has been eliminated and a lane to itself built in its place for joining the M-30 trunk road.
3. To resolve traffic build ups, a tunnel was built for use exclusively by buses, connecting the Sur bus station directly to the Avenida del Planetario. This solution makes it possible to link this tunnel to the system of tunnels described in the first point, taking the heavy traffic load off the urban area and sending it directly to the M-40 and the Súper Sur junction.

The total length of the project is 16,663 m, with a total length of tunnels of 3,848 m[20].

[20] The management team was made up of Juan de las Heras con Javier Nájera, Luis Caneda and Sergio Barral. The works were awarded to Dragados and were constructed by Pablo Quirós with his deputy being Julio Gracián. Technical Support was awarded to the Euroestudios-Eptisa Joint Venture.


Autovía de Colmenar (M-607)
Avenida del Cardenal Herrera Oria
Hospital Ramón y Cajal
Avenida de la Ilustración M-30




Rejilla de extracción cada 25 m
Placa alveolar canto 25 cm RF-120 en posición horizontal
Dovelas
Acera
Salida de ventilación cada 10 cm
Canaleta
Relleno acera hormigón en masa
2ª fase
1ª fase
Nervometal
2 tubos ø 160
Arqueta antideflagración
2 tubos ø 160
Picado de dovela para drenaje
Hueco bajo suelo de tramex
Canaleta longitudinal en dovela base
Acera
Placa prefabricada pretensada canto 55 cm
Ménsula de apoyo
Tubería drenaje cada 100 m en lado alto de peralte
9.32
2.010
0.250
4.507
12.200
5.815
5.900
5.900
1.350
BOR. TIPO TRIEF
± 0,00 %
0.053

D. Duplication of the Southern Link: the enormous Southern Bypass tunnels

Southern Bypass Tunnels

	PROJECT	Amount, €M	Start	End
1	Southern bypass. N-III tunnel north - Santa María de la Cabeza. Left carriageway	331	27/09/2004	27/03/2007
2	Southern bypass. N-III tunnel south - Santa María de la Cabeza. Right carriageway	410	27/09/2004	27/03/2007
	TOTAL	**741**		

In 2003, the traffic the M-30 supported, 251,000 vehicles per day, exceeded the road's capacity for practically the whole day and made it one of the busiest stretches of any of Spain's roads. Other problems with the M-30 in that area were the numerous and complicated junctions and the many places where the traffic needed to weave. For all these reasons, it was decided to double the M-30's capacity in that southern area, which it was decided to achieve with two tunnels of three lanes each. These tunnels were called the M-30 southern bypass. The tunnels start in the Praga Bridge over the river, as seen before, and ends at the M-30 where it connects to the N-III Valencia road and has a direct connection with the latter.

Its construction makes it possible to separate the medium and long distance traffic at the Southern Junction, reducing traffic intensity by more than 30%. East-west journeys are reduced to 4 minutes from the 30-40 minutes they used to take at rush hour, representing significant savings in journey time and fuel consumption, as well as a reduction of over 50% in the accident rate. Before construction of the bypass, pollutants from vehicle exhaust pipes were emitted freely to the atmosphere with no type of retention or purification. The bypass improves air quality, as the filtration stations retain over 85% of the particles of over 1 micron in size emitted by the vehicles and purification of harmful gases is carried out by means of gas purification stations using activated carbon technology.

For three lanes of 3.5 m in width, hard shoulders of 0.50 m on each side and 0.5 m pavements, there is a horizontal width of 12.50 m and headroom of 4.5 m to enable lorries to pass, an internal diameter of 13.45 m was obtained. This made it necessary for me to think about the need to design with manufacturers of very large tunnel boring machines, as with segments at least 50 cm thick, we were talking of excavations of around 15 m in diameter. So it was, and in the end I had to think of designing the two biggest tunnel boring machines in the world, with an excavation diameter of 15.2 m. Circular cross sections are excellent for tunnels for water, but very poor for transport tunnels because you lose a lot of useful section. It was possible, though, to employ the unused volumes above and below for ventilation and extraction of gases from the vehicles and as an emergency gallery in case of accident. In fact, a twin track Metro line fits perfectly into the lower part of those tunnels.

Once it was decided that the bypass would be made in twin tunnel, we started work at the end of 2003 in two areas. The first was the safety study, for which it was decided the systems with the highest authority in the matter, which was the Madrid Fire Brigade. The necessary meetings were held with Eugenio Amores and Carlos Arribas to design the safety systems and those for evacuation in case of accident or fire. A railway tunnel has no fire problems, but each car carries 50 or more kilograms of inflammable material on board. The two items of data the fire brigade's specialists considered most important were set with them. These were the distance between the passages connecting the two tunnels and the distance between the carriageway accesses for each tunnel to the lower gallery, as well as the evacuation protocols.

The second matter was more critical; the design of the tunnel boring machines, i.e. their basic technical characteristics: cutter head torque and total thrust, as well as the other important details of the machines. A few years earlier, Mitsubishi had designed the big EPB tunnel boring machines for the tunnel under Tokyo Bay, at 14.4 metres, and Herrenknecht had built the TBM for the third Elba tunnel, at 12.8 metres, which then went on to make the Lefortovo tunnel in Moscow, although this was a slurry shield machine, not EPB. There was, though, really no experience in the world with these diameters of 15 metres. After the analyses seen in the previous chapter and after numerous meetings and discussions with the manufacturers and with the engineers from Dragados (Álvaro Fernández Cota, who had made Madrid's Green Corridor tunnel and very many tunnels in its Metro expansions), FCC (Avelino Acero, Ricardo Gil and Alberto Enciso with Carlos Cebamanos), Necso (Antonio Moreno, Santiago Serrano) and Ferrovial (Joaquín Torres), I set the torque at 12,000 mt and thrust at 30,000 t. The rest of the details, such as tail injection, were agreed without problems. The engineers mentioned above were undoubtedly the world's best tunnel construction team, because what they had built between 1995 and 2003 had never been matched in costs, timescales or safety of the works.

One of the tunnel boring machines was built in Austria and the other in Japan. The Herrenknecht placed its first ring on 23 November 2005 and the Mitsubishi on 3 April 2006. The 5-month delay was due to delays in fabricating some simple boilermaking parts in Asturias in Spain. The Herrenknecht completed its last ring, number 1,763, on 11 July 2006 and in those 231 days it built 3,526 metres of tunnel, having been stopped for 24 days for various reasons, including 6 for Christmas. Its maximum was 18 rings in one day, on 25 May 2006. The Mitsubishi completed its last ring, number 1,829, on 29 October 2006 and

in those 210 days its 3,658 metres of tunnel, going slightly faster than the Herrenknecht despite having been stopped for 29 days. Its maximum was 23 rings in one day, on 9 October 2006, although it did 20 on 26 September and 22 on 4 October.

Both machines had excellent performance, to the point that some authors doubted them and in one book on tunnels they are marked with exclamation marks. With the provincialism now common in Spanish engineering, when they see these extraordinary performances, in other Spanish cities they say the usual now, that Madrid's ground is very good. But the reader should reread Chapter 9 of my notes on the construction of the Madrid Metro and the huge and serious collapses and accidents that happened when things were not done right.

The rest of the southern bypass project had no problems, there were just some ventilation structures equivalent to Metro stations, but without their serious finish problems.

The tunnels for interconnection were made using the Belgian method, removing the necessary segments in each shaft. As the works were the responsibility of and managed by the previously mentioned great engineers from the construction companies, who had already built a hundred kilometres of large Metro tunnels all over Madrid, there would be no serious problems with the works. So that when the machines had settled into their rhythm, I could dedicate myself to a more serious problem, which was completing the river works on time, something everyone, including the City Council itself – except the Mayor and I – considered impossible.

The works for the left-hand carriageway of the southern tunnel were awarded to the NECSO-Ferrovial Joint Venture. The works for the right-hand carriageway of the southern tunnel were awarded to the Dragados-FCC Joint Venture.

Also included in the M-30 project were two small actions affecting Madrid's traffic. These are as follows:

Other infrastructures for improving traffic in Madrid

	PROJECT	Amount, €M	Start	End
1	Connection of the Montecarmelo urban development plan to the Calle Costa Brava	1.9	16/07/2004	16/01/2005
2	Widening of the bus only lane between the Moncloa transport interchange and the Puerta Hierro junction	1.5	02/08/2005	16/09/2005
TOTAL		**3.4**		

M-30 Tunnels

Works	Tunnel	Meters	
Avenida Portugal	N. trunk	1,500	3,000
	S. trunk	1,500	
San Vicente Junction	Int. trunk	1,400	7,500
	Ext. trunk	1,800	
	Branches	4,300	
San Vicente-San Isidro Brg S. Isidro	Int. trunk	1,420	4,022
	Ext. trunk	1,474	
	Int. branches	442	
	Ext. branches	686	
Pte. San Isidro Brg-Praga Brg Praga	Int. trunk	2,375	10,693
	Ext. trunk	2,305	
	Int. branches	2,867	
	Ext. branches	3,146	
Praga Brg-S. junct.	Int. trunk	1,822	8,360
	Ext. trunk	1,774	
	Int. tunnel A	584	
	Ext. tunnel A	600	
	Branch 1	680	
	Branch 2	660	
	Branch 3	460	
	Branch 4	360	
	Branch 5	340	
	Branch 6	280	
	Branch 7	300	
	Branch 8	300	
	Branch 9	200	
Sth. bypass tunnel, North		4,000	8,000
Sth. bypass tunnel, South		4,000	
Valencia	Branch 1	700	1,900
	Branch 2	1,200	
Total M-30 River tunnels			43,475
O´Donnell		1,220	
Pío XII		1,500	
Ventisquero		1,950	
NII junction		1,100	
Costa Rica junction		400	
Azquilla		1,200	
Sor Angela		1,300	
Embajadores		3,200	
Total non-river			**11,870**
Total tunnels			**55,345**

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