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ZARAGOZA: LRT FOR A NEW GENERATION

**SPECIAL
REVIEW**



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TRANVÍA DE ZARAGOZA

Already an industry award-winning project, in March 2013 Zaragoza completed Line 1 of its modern tramway. With the full service in operation, Neil Pulling reports from Spain and looks to the future.



Special review in association with

TRAMWAYS & URBAN TRANSIT &  **tranvía zaragoza**

▼ Parque Grande, Zaragoza's magnificent central park: Line 1 is at the western end between Emperador Carlos V and Romareda.



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A tramway serving modern needs in an ancient setting



▼ Wire-free operation has helped to preserve views of Zaragoza's emblematic Basilica de Nuestra Señora del Pilar.

By a window in Tranvía de Zaragoza's control centre lies a pitted length of rail. Unearthed during construction of the new system, it is a remnant of Spain's last traditional tramway network. Once a 17-line, metre-gauge operation, it closed in January 1976. The tram-free years up to the 19 April 2011 opening of Line 1's first section saw marked changes in Zaragoza, the capital of Aragon autonomous community.

Little over a decade separated the end of fascist rule in Spain and economic stimulus following entry to the European Union in

1986. Concurrent with a new high-speed rail link, Expo 2008 brought Zaragoza to a wider audience. The exhibition brought a landscaped riverside site, dramatic buildings and new bridges to the west. Yet the historic core still remains the biggest draw for visitors.

The name Zaragoza evolved from that of the city's founder, Emperor Caesar Augustus. Roman and Moorish artefacts remain, but the dominating structure is the immense Catedral-Basilica de Nuestra Señora del Pilar, built over 200 years up to 1872. Spain's boom years had encouraged urbanisation,

Zaragoza population figures

1981	571 855
1991	594 394
2001	614 905
2011	678 115
2012	701 887

**1981-2011 data from Spanish National Institute of Statistics, 2012 data courtesy of Ayuntamiento de Zaragoza - 'City Hall'*

with major cities like Zaragoza (the country's fifth-largest) rapidly building on previously undeveloped land.

More recent news from Spain has been dominated by severe unemployment driven by banking and construction industry failures, with Zaragoza not immune. However, its new tramway was conceived in a long-term Sustainable Mobility Plan begun in 2003, then looking to 2015. City Hall proposed increasing the reach of public transport – initially buses only – and operating it in controlled conditions. This envisaged tighter traffic regulation and restricting vehicle access in certain zones. The plan also featured light rail, considering up to three lines incorporating features to encourage more walking and cycling journeys.

About 310km (approx. 195 miles) from Barcelona and Madrid, Zaragoza is the principal stop between those cities for national carrier Renfe's AVE trains. The 1435mm-gauge high-speed line supplanted Iberian 1668mm-gauge for long distant services in 2008, bringing a transfer from Zaragoza-Portillo station to new dual-gauge Zaragoza-Delicias. More distant from the centre, Delicias' western location ruled out inclusion on the first tramline's north-south axis, favoured by City Hall as offering the greatest benefits for the investment.



▲ A relic of Spain's last first-generation tram network.



▲ On the Iberian gauge network and AVE Barcelona-Madrid high-speed line, Zaragoza-Delicias station is due to be at tramline 2's western end.

Rapid development and tight budgeting

In 2009 a 35-year contract to design, construct, commission and operate Line 1 was awarded to the Traza consortium. The specification, including partial operation without overhead supply, saw Traza in final competition with a consortium offering Alstom APS ground supply, similar to applications in Bordeaux and Angers. The motive power partner in Traza is Spanish company CAF. It is CAF's Rapid Charge Accumulator (ACR), Ni-MH batteries and energy recovery systems aboard Urbos 3 trams that now cover the wire-free requirement.

Traza composition by partner core activity and share ownership:

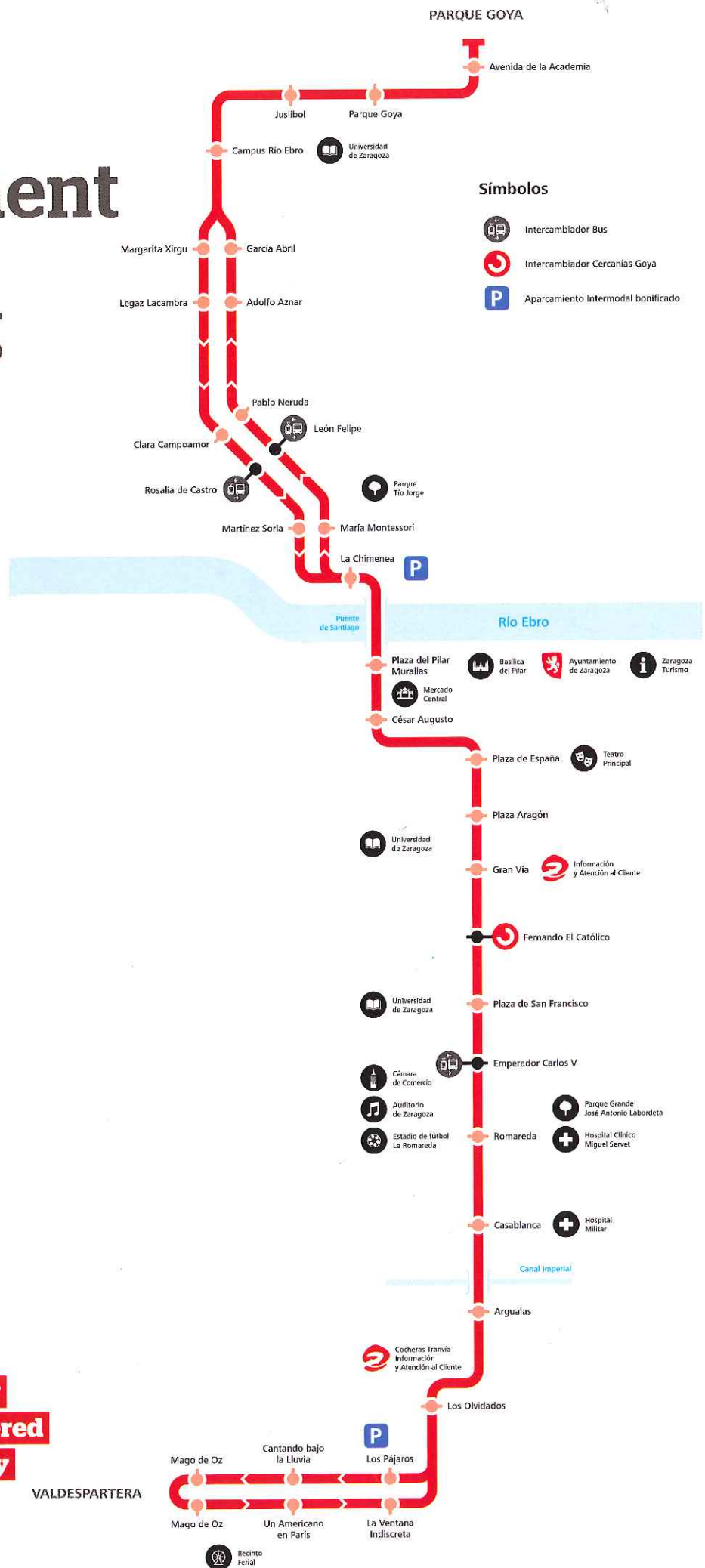
- › Tuzsa (Zaragoza bus operator) – 25%
- › CAF (rail equipment) – 25%
- › Ibercaja (financial sector) – 11.8%
- › Concessia (financial sector) – 5%
- › Acciona (construction) – 16.6%
- › FCC (construction) – 16.6%

Traza represents 80% of Tranvía de Zaragoza, the balance being Ayuntamiento de Zaragoza. The whole is classified as a Mixed Economy Company, in Spanish abbreviation SEM. The project investment was EUR355.7m, EUR45m lower than budgeted. About one-third had to be allocated to urban improvements not directly related to tramway expenditure such as cleaning, landscaping and installing paths and cycleways.

Once final approval came in July 2009, the project was delivered rapidly, in places sufficiently ahead of schedule to allow earlier openings. From the start of construction, only 21 months elapsed when public service began over the southern section on 19 April 2011. This had been preceded by two months of simulated operations, initially without passengers and then with selected groups who reported their experiences and recommendations to inform fine-tuning of the service.

During civil works there were 1700 people engaged in the project. Preparing the public for the presence of trams were teams of staff and volunteers at special events and by the lineside, backed by a media campaign advising of the tramway's use, benefits and potential hazards.

“Upon final approval in July 2009, the project was delivered rapidly, in places sufficiently ahead of schedule to allow earlier openings.”





Line 1: Phased opening and room for further expansion

Line 1 connects many of Zaragoza's main traffic generators. The authority specifically wanted to link the city centre to two large, still-developing areas, Valdespartera in the south-west and Parque Goya in the north. Between these points were incorporated other locations that would gain substantially from the service.

Much of Line 1 is fairly level, consistent with the city centre site. Towards the northern and southern ends, tracks follow a pronounced rise, curving up the two slopes. At the top of the inclines, except for underpasses of major roads, gradients are gentler onwards to the termini. Line 1 uses grooved rail and occupies reserved space alongside or in the middle of roads, mixing grassed and paved surfaces. Stops are variously island or side platform layouts at pavement level. There is a high incidence of controlled crossings by roads and paths, averaging 13 per kilometre.

To limit intersections causing delay, the authority installed a live data traffic management system that anticipates arrival of trams at given points and sets priorities accordingly. The end-to-end scheduled journey time is 40 minutes, approximating



▲ TOP: The north side of the uni-directional loop at Valdespartera, Line 1's southern end.

▲ ABOVE: Urbos 3 3040 climbs towards Parque Goya near the University of Zaragoza's Rio Ebro campus.

to an average 20km/h (12mph). Tranvía de Zaragoza identifies an 8% energy saving due to trams running under the traffic system.

The dates of section openings demonstrate the project's rapid implementation. For an added perspective (at the time of publication) it is instructive to view internet street and satellite images of Line 1's course. In places showing no track or only initial groundwork, some outer zones appear as building sites or unbroken ground. In spite of financial and employment problems, today much of the track is lined with buildings that are delivering very high loadings on the tramway.

Mago de Oz - Gran Via (April 2011)

The first phase opened throughout between city centre Gran Via and still-developing Valdespartera. Trams do not reverse due to a turn between the stops forming the southern terminus. There is a double loop to provide extra holding space for trams, important during the service for a fairground forming part of the annual ten days of Zaragoza's main celebration, Fiestas del Pilar.

The layout allows for westward expansion to serve neighbouring Arcosur, the case for which is already being made by its residents. Mindful of scarce resources and aware of the expansion rationale, they claim that a longer Line 1 would attract heavier patronage – and yield better value – than Line 2.

As in many planned developments, street names follow a theme. Here 'the Seventh Art' (cinema) has some bequeathed improbable tram stop names. There are two called Mago de Oz (The Wizard of Oz), one either side of the curves transforming the outbound track to city-bound. With locals versed in mystic distinctions and operators identifying stops by number, duplication is not problematic.

Following one-way traffic flows, the tracks are divided eastwards to an Alfred Hitchcock-inspired double-bill of Los Pájaros (The Birds) and La Ventana Indiscreta (Rear Window) which has a subsidised park-and-ride site. Still

separate although closer, the tracks run more tightly bounded by buildings along Paseo los Olvidados, a name honouring Luis Buñuel who had strong Zaragoza connections.

Descending past Valdespartera depot, the tramway joins a long-established roadway north-east towards the centre, initially between the Vía Ibérica carriageways. Near Casablanca (not a film reference, it relates to a once-prominent white house) the line crosses the Aragon Imperial Canal, an 18th Century irrigation and transport artery of great importance to Zaragoza. Romareda stop sees regular heavy demand due to being in front of a large general hospital. Directly opposite, Real Zaragoza football stadium adds less frequent but more concentrated loadings. The line now sheds its suburban surroundings.

Upon opening in April 2012, sub-surface Zaragoza-Goya became the most central of the city's stations. Being near Fernando El Católico tram stop, it remains the only heavy rail interchange, mainly for local trains. The approach to Gran Via features a wide shaded walkway between the tracks and roads.

Gran Via - Plaza de España (October 2012)

This 800m section introduced the project's distinguishing technical feature, wire-free operation. Initially to Plaza de España and later for a total of approximately 2km (1.25 miles) to La Chimenea, trams operate north of Gran Via with pantograph down using stored energy. Originally it was planned to open Line 1's second phase in its entirety, although short sections were added earlier than scheduled.

Gran Via retains the turn-back crossover used when it was a terminus and is the site of the main information centre. Road traffic has been reduced by 35% on this main commercial thoroughfare, but it remains busy with buses and cars either side of the tramway. Just north of its stop, Plaza de

España is marked by a fountain overlooked by tall buildings in assorted styles. The paired tracks curve west beyond the fountain into Calle del Coso (El Coso).

Plaza de España - Plaza del Pilar Murallas (December 2012)

This section presently serves as a controlled experiment in urban management. It exemplifies the case for removing or severely restricting road traffic in favour of pedestrians and environmentally sensitive public transport.

El Coso follows most of the outer line of the old Roman Wall around the historic centre, its western arm now effectively pedestrianised. It remains vibrant with walkers, trams and cyclists. In contrast, heading east on El Coso from Plaza de España presents a different experience. In spite of buildings being more set back from the roadway than on the western arm, it is dominated by traffic noise and grime, with pedestrians clustered at crossing points.

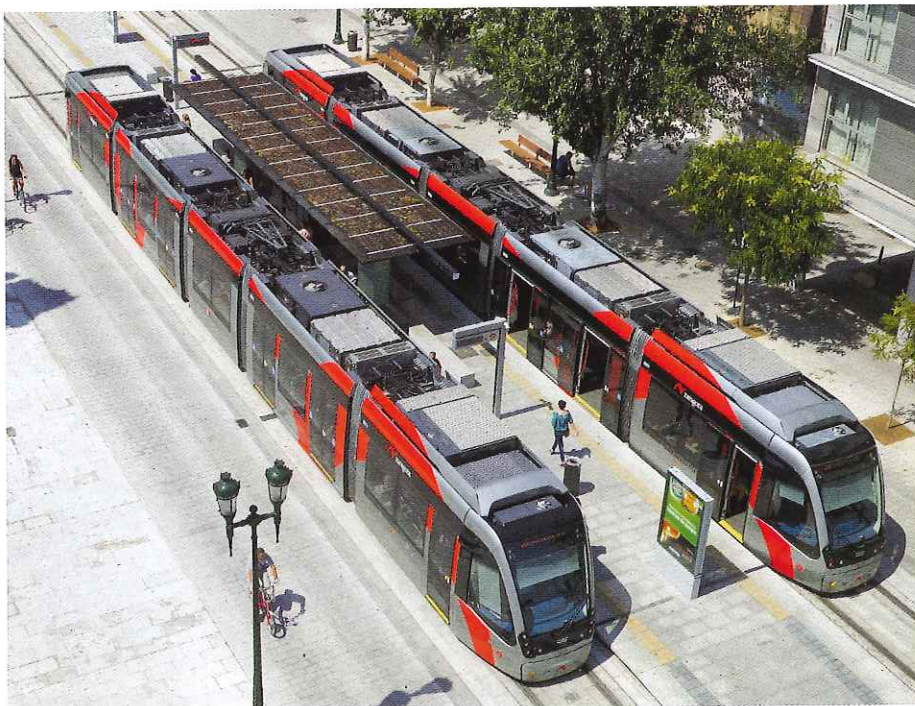
Line 1 curves from El Coso north into Avenida César Augusto. Limited clearance led to restrictions for road vehicles either side of the track, including access to an underground car park. Perhaps counter-intuitively, blurring of roadway and pavement distinctions seemingly forces careful movement by all moving within this space. Between César Augusto and Plaza del Pilar Murallas stops is perhaps the most attractive of the project's urban settings.

Much is in parallel with the old central market building, an institution that the city was keen to bolster with improved surroundings and tram access. A length of Roman Wall and Zuda Tower, a remnant of a Moorish palace, mark the line's approach to Plaza del Pilar Murallas stop and the Ebro riverside.

Plaza del Pilar Murallas - Avenida de la Academia (March 2013)

Line 1 was completed with this long addition that took the tramway north of the Ebro over the existing Puente de Santiago. Still carrying road traffic, the tramway occupies the bridge's western side. Near Aragon broadcasting studios is La Chimenea stop, also the second park-and-ride site. Named after the chimney on landscaped former industrial ground, La Chimenea marks the return of overhead power, which continues to the northern terminus. Five pairs of stops and a return loop punctuate this second stretch of widely separated tracks. Much of the intervening space is given over to a succession of modern retail developments, the outer edges being more residential.

Tracks are again paired when Line 1 passes beneath the E-90 motorway and through a university and sports area before climbing past the second depot to Parque Goya. From the stop bearing the district name, the city appears distant and low in the Ebro valley. Another road underpass and curve brings Line 1 to Avenida de la Academia terminus, next to a large hospital and school. Unlike Mago de Oz, trams reverse at the platforms. Track continues well beyond, with crossovers either side of the island platform to allow for holding extra trams and increase flexibility when operating special timetables.



▲ Plaza del Pilar Murallas: Planting the roof of tram stops is one of many environmental measures.



▲ TOP: Immediately south of the historic centre, focus of city traffic Plaza de España has seen a significant reduction in motor vehicle movements since Line 1 opened.

▲ ABOVE: Set between a major hospital and the main football stadium, Romareda is one of Line 1's busiest stops.

▼ BELOW: A showpiece of city centre improvement, Calle Del Coso will become shared with Line 2.



ALEJANDRO MORENO - GENERAL MANAGER



Alejandro Moreno is General Manager of Tranvía de Zaragoza. With an engineering and business administration background, before joining the organisation his experience included main line and urban transit project management with CAF. Mr Moreno identifies three key criteria

required by City Hall for tramway projects:

- ▶ **Meeting social needs** - exemplified by connecting population concentrations and minimising access barriers.
- ▶ **Giving distinct, measurable environmental improvements** - such as emissions reductions and increased public transport use.
- ▶ **Economic sustainability** - notably high loadings at realistic fares; facilities to encourage walking or cycling.

By July 2013 the tramway had carried over 30m passengers, attained 99% reliability and was registering very high customer satisfaction scores by industry norms. Even before bus route restructuring due in the following month to create a 'fish-bone' configuration around the Line 1 spine, trams were carrying around 90% of the 2014 target of 100 000 passengers per day.

Speaking of the project's effect on the centre of the city to date, Mr Moreno says: "The priority is now the pedestrian, not the private vehicle. There has been a 12% carbon emissions reduction in the centre. Coso - it used to be an accident black-spot - is a notable improvement."

With good reason, judging by the popular uptake of the service, local demands for expansion and the attention accorded by the international transport industry, he is clear about the outcomes to date: "Zaragoza Tram has been a success in economic, social, technological and environmental sustainability. It is making a great contribution to Zaragoza's new culture of mobility."

Preparing for Line 2

Despite the economic conditions, Zaragoza is pushing forward with the Line 2 project. The first line's success, popular support for expansion and City Hall backing have added momentum to creating an east-west tram axis.

Preliminary studies for the approximately 7km (4.4 mile) route with 16 or 17 stops indicate a cost of EUR179.5-185.3m. Opinions are being sought on which of three alternative routes should be adopted at the eastern end. The western part will incorporate Zaragoza-Delicias station and will join Line 1 where El Coso meets Avenida César Augusto, track-sharing for 300m over the existing wire-free section to Plaza de España. Competition controls mean that Line 2 could pass to a body other than Trasa and lead to different equipment and systems, a condition similar to Nottingham's tramway expansion project.

After previous expectations of an imminent start following Line 1's completion, City Hall now wants Line 2 ready for construction immediately after the 2016 local elections, with an expected two-year construction period.

Depots, maintenance and

▼ 3070 climbs past the storage sidings at Valdespartera depot.



Having two maintenance and storage depots to serve 12.8km (eight miles) of tramline and handle 21 trams may seem extravagant. The explanation for this however partly lies in the authority wanting to continue devoting street space to major public events – effectively creating a blockade – yet still maintaining public transport. This requires independent operations running either side of the closed zone for prolonged periods. The decision to provide two depots will additionally allow for fleet expansion, including for a second line.

With access by a very short connection from revenue tracks, Valdespartera depot is between Argualas and Los Olividados. The level site was created by cutting into rising ground, a feature emphasised by the change of track level curving around the southern perimeter on the line's steepest gradient. There is stabling for 18 trams plus space for maintenance. It provides engineering support that extends to a painting booth, allowing for most repairs to be handled within the premises.

Valdespartera is also the headquarters of Tranvía Zaragoza and the location of the

control centre. Normal operations require two duty controllers, each supervising six main screens to monitor functions such as power supply, tram location, traffic flow and movements within both depots. Supervision of stops along the line includes two-way communication with passengers and controllers can remotely operate the ticket machines if problems are encountered by users.

Parque Goya depot near Juslibol stop is principally a storage facility and for light maintenance. Less hemmed in than Valdespartera, it can accommodate 21 trams,



▲ General Manager Alejandro Moreno (left) hosts a visit by managers of Poland's Kraków tramway on 11 July.



▲ Inspection tracks at Valdespartera depot. There is stabling for 18 trams and it is the main maintenance facility for the system.

trams

with the possibility of adding five more spaces in the compound. Trams are washed every two days and both depots have washing plants with an 80% water recycling rate, the loss being largely due to evaporation in the hot climate.

The fleet

Traza partner CAF originated as an iron works in Beasain in Spain's Basque Country, extending to tram building in Zaragoza during the late 19th Century. Following mainly domestic sales of LRVs, CAF is now enjoying international market success with major contract awards in the UK, Sweden, USA, Taiwan, Hungary and to home-supply dominated France and Germany.

Zaragoza's fleet of 21 bi-directional *Urbos 3* trams (numbered 3010-3210) were constructed at CAF's Zaragoza factory, the first delivered to Valdespartera in October 2010 and the last in November 2012. The first digit derives from *Urbos 3*, with the next two plus a zero being the complete vehicle, as shown on the tram ends. Each section is also prominently numbered inside and out. For example, 3210 comprises motored driving ends 3211 and 3215, suspended open-plan cars 3212 and 3214, with the centre car with non-powered bogie and pantograph being 3213.

Passenger capacity is 204, with 52 seated and the tilting seats can easily be removed to improve passenger circulation, as when handling crowds during the Fiestas service. Audio and on-screen information is supplemented by illuminated diagrams showing the current route position.

Zaragoza's *Urbos 3* is 32.3m long and 2.65m wide. The ultracapacitors for short-term energy storage are mounted in the roof of the vehicles' driving ends. The tram could run for 5km (just over three miles) without external supply after a full charge, being easily able to cover Zaragoza's wire-free area. However, to give a wide margin during supply failure or blockage, there is also an *en route* re-charging system. Electricity travels via a short pickup

▼ To position trams for recharging at wire-free stops, drivers stop with their shoulder aligned with black inlays in the platform.



▲ Parque Goya in the north of Zaragoza was the second depot to open.



▲ Two duty controllers monitor the entire length of Line 1.



TRANVÍA DE ZARAGOZA: KEY FACTS

- › **Authority:** Ayuntamiento de Zaragoza
(www.zaragoza.es)
- › **Operator:** Los Tranvías de Zaragoza
(www.tranviasdezaragoza.es)
- › **Opened:** 19 April 2011
- › **Gauge:** 1435 mm
- › **Power:** 750V dc overhead supply + onboard energy storage
- › **Lines:** 1
- › **Route length:** 12.8 km (8 miles)
- › **Stops:** 25 (inc. 8 pairs on two one-way sections)
- › **Depots:** 2
- › **Fleet:** 21 CAF Urbos 3, overhead supply and ACR surface-based charging
- › **Max. speed:** 70km/h (43mph)
- › **Weekday operation:** 05.00-00.00
(24 hours in Fiestas)
- › **Peak frequency:** 5 minutes
- › **Lowest frequency:** 20 minutes

▲ ABOVE: 130 *bizi* hire points and 1 300 cycles form part of Zaragoza's mobility plan.

➤ RIGHT: The charging strip located in anticipation of running paired trams: this is Plaza de España.

➤ FAR RIGHT: Extending flaps give a virtually unbroken level between trams and platforms.

lowered beneath the centre-car that engages with a ground-based charging strip during the normal dwell-time at stops Gran Vía to La Chimenea inclusive. With snow, ice and extreme cold rare in the southern Spanish climate, the installation is not weather-prone.

Certified with the highest grade, Safety Integrity Level (SIL) 4, this fully-automatic system employs technology developed for automatic metros, with coded communication between ground and vehicle-based equipment to energise and deactivate the charging strip. The tram configuration relates to the position of the two ground-based charging strips per stop. This anticipates paired trams for increasing capacity, as opposed to adding extra sections. To correctly position the tram, drivers align themselves with a line of local black stone inlaid in the platforms.

Vehicle couplings are concealed behind nose visors and there have been successful tests with paired trams. Regular passenger operation in this manner would require extra stock: 2020 is the provisional expectation for multiple operation becoming the norm. Sixteen trams are currently required for a five-minute peak frequency. For nine days in October 2012 a 24-hour service, mainly at 5-7 minute frequencies, was run during Fiestas del Pilar. A similar provision is anticipated for 2013.

All trams are externally finished in silver and black, overlain with a tapering curved red band as used in city marketing. Wooden seat facings are from sustainable timber supplies. As with the city generally, graffiti and other vandalism does not appear to be a problem. There are separate air conditioning systems for the driver cabs and the passenger compartment, the latter soon warming up



in the extreme summer heat when doors open. All four double-doors and two singles each side are opened on uni-directional sections where platforms are installed on both sides of the track. Early collaborations with organisations representing those with disabilities brought bright contrasting colours for hand-holds, braille text on controls and ticket machines, adoption of Verdana text (recommended for clarity) and tactile strips at stops and crossings.

There are four wheelchair spaces per tram and 16 reserved seats for those with reduced mobility.

¿Ha Valido? Debe validar - Travelling legally on the tramway

All passengers above four years of age must already hold a ticket/card with value when boarding and validate immediately on entry. Illuminated readers and other reminders confront those entering trams. Onboard machines do not sell tickets and are for re-charging cards.

Comparing data from doorway-mounted passenger counters with validations can



be used to target revenue protection staff at times and locations most prone to fare evasion. A EUR50 penalty applies for those travelling without a valid fare, reduced if paid early. Fares are the same as city buses and there is cross-mode, multi-operator ticketing. As well as servicing the stored value system, multi-lingual machines at stops sell EUR1.35 one-hour single journey tickets allowing transfers, plus other permutations for discounted rates and multiple purchase. However, about 90% of passengers use cards.

There is no day fare, although the tourist Zaragoza Card incorporates some public transport use. The well-used *bizi* cycle subscription/hire scheme is within the ticketing system. **TRAVI**

Thanks in the preparation of this special review are due to Alejandro Moreno and Marcos Español of Tranvía de Zaragoza. All images taken by Neil Pulling, July 2013, unless otherwise stated.