

Alicante light rail: improving the use of existing railway lines

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ABSTRACT

The *TRAM Metropolitano de Alicante (TRAM)* is a unique metric (1,000 mm) gauge system that was born as the first Spanish tram-train, but later lost the tram-train characteristic of sharing the railway tracks with conventional trains due to the evolution of the network. Nevertheless, it still operates in a quasi-tram-train way, as the tram-train vehicle runs partly on railway tracks using the railway signaling system and other railway equipment.

This quasi-tram-train operation leads to some specific design issues that are explained in this paper. Additionally, the paper presents a thorough description of the Alicante network, its development, its construction and operational costs, its operation and its demand.

1 A BIT OF HISTORY

The city of Alicante had a network of urban and suburban streetcars from 1893 to 1969, when they were removed from operation following the then usual trend in Spanish cities of substituting streetcars with bus services.

On the other hand, the railway line from Alicante to Dénia was partially opened to operation during 1914, when the services between Alicante and Altea (around 50 km) were inaugurated. This stretch was extended to Dénia during 1915, reaching a total length of 93.235 km. The Alicante-Dénia line has a very complicated layout, due to the hilly topography of this zone, especially from Altea to Dénia, where there are important longitudinal gradients for a conventional railway (up to 30.70 ‰), 2.5 km in tunnel, 7 viaducts and 17 bridges over 8 m high [1].

Alicante-Dénia was a metric (1,000 mm) gauge line that was not electrified. It was constructed by a private company for moving freight at first, but later it was reoriented to passenger services [1]. During 1965, the FEVE state-owned company is created in Spain to manage metric gauge lines, including the Alicante-Dénia one [2]. But during 1987 this line goes on to depend on *Ferrocarrils de la Generalitat Valenciana (FGV)*, a new railway company owned by the Valencia Regional Government which manages the regional railways in this region [1]. The services on this line were operated with diesel trains, and their impact on mobility was low, although they had certain touristic potential due to the beauty of the route [1].

2 THE NEW ALICANTE NETWORK

Figure 1 shows the new Alicante network in operation nowadays. This network is known as the *TRAM Metropolitano de Alicante (TRAM)*.

2.1 Development of the new network

The development of this new network was made step by step. It started with a new demonstration light rail stretch of 657 m from Puerta del Mar to La Marina, in reserved right of way, which was opened for testing during 1999 (on tracks that were a harbor branch line from 1939 to 1961 [3]). This was followed by the opening of another demonstration stretch, 2,825 m long from La Marina to Albufereta, during the same year. In this case, it was a tram-train line where the light rail shared the way with conventional trains [1].

Once these demonstration lines proved to be a success, the construction of the network as a whole started in 2001, and it was opened to service in 2003 from Puerta del Mar to El Campello, using part of the railway tracks to Dénia [1].

In May 2007 the new stretch from La Isleta to Mercado was opened and, with it, light rail services reached Alicante city center through a new tunnel with two underground stations: Mercado and Marq. In June, another stretch of line 4 to Cabo de Huertas was opened, providing service to a beach zone by means of the Bombardier light rail vehicles. Finally, in July, line 1 was extended from Mercado to Creueta. To provide a fast service over this long route (around 32 km), Vossloh tram-train vehicles were selected. They can run on urban tracks like a light rail and they can also use railway tracks, reaching speeds up to 100 km/h. Transfer to line 9 could be made in Creueta station, in order to continue the journey to Dénia. [1].

During 2008, line 1 service was extended to Benidorm. This extension led to a change in the transfer point between lines 1 and 9, that was moved to Benidorm station from then on. During 2009 a



new extension of line 4 was opened, reaching the current length. Finally, in 2010 the new underground station of Luceros was opened to service, giving a better penetration of the network into the urban center [1]. Nowadays, the line is being extended in tunnel from Luceros to the central railway station of Alicante (300 m distance) in order to get a better service for transferring with other high capacity modes of the city.

The construction of the network has been financed by public investment.

2.2 Network description and network operation

Summarizing, the Alicante network is comprised of two different kinds of stretches.

- The first kind is composed of new light rail lines constructed in metric gauge during the last 13 years, which are used by new light rail and tram-train vehicles. The length of these new tracks is around 15 km. They are double track in the whole length except for the final loop of line 4 (a single track stretch of around 2.3 km). The new urban network comprises the whole line 4L, line 4 from Lucentum to the east, including the loop, and part of the lines 1 and 3.
- The second kind is the former Alicante-Dénia railway line of metric gauge and single track that is owned by FGV, the regional railways company. One part (51 of 97 km) of this line is operated in the traditional way, by regional trains that have been recently refurbished. The other part is operated in a tram-train way, that is, with tram-train vehicles. This part has been refurbished and electrified. Some stretches of the refurbished part have been converted to double track too.

In any case, strictly speaking, the Alicante system cannot be considered as a tram-train. Tram-train is defined as an adapted light rail system that can use urban tracks as well as railway tracks, sharing the latter with conventional trains [4]. In Alicante, the former railway tracks that are used by the “tram-train” vehicle are not used by conventional trains anymore, so this is not an actual tram-train. Nevertheless, as the operation over these zones continues to be made in a railway manner (using the railway signaling and equipment), it cannot be considered as “light-railization” of a line either. Indeed, the vehicle utilized to run over these stretches is not a conventional light rail, but a tram-train similar to those that would have been used if the shared running would exist. Under these circumstances, it can be said that the system is operated in a quasi-tram-train way (tram-train operation even though no conventional trains are sharing that track anymore).

On the other hand, in the previous phases of the operation of this system shared running did exist in the stretch between La Marina and La Albufereta. So, the TRAM was the first tram-train in operation in Spain, on metric gauge tracks.

Line 1 is always operated by 6 tram-train vehicles (4100 series) that can run up to 100 km/h, while line 3 is normally operated by light rail vehicles (3 vehicles plus 1 in peak hour) that can run up to 70 km/h, although sometimes line 3 is operated by tram-train vehicles too. Lines 4 and 4L are always operated by light rail vehicles (3 for line 4 and 1 for line 4L). Finally, the stretch from Benidorm to Dénia (line 9) is operated by conventional diesel trains (2500 series), as this part of the former railway line has not been refurbished and it is not electrified. There is a plan to refurbish this line as well, but it is not foreseen in the near future because it would be really complicated due to the hilly orography of this zone and the amount of bridges and existing structures that would need to be modified.

Tables 1 to 4 show the main characteristics of the lines and the operation regime. Electrified lines have the standard light rail electrification (750 V dc). Light rail operation regime means that the driver drives on sight, having to be able to stop the vehicle in visibility distance depending on the circumstances of the track and the signals. On the other hand, railway operation regime means that the driver is supported by the signaling and equipment of the railway system, and he/she has advanced information about the circumstances of the track ahead, having space between consecutive signals to stop the train if needed.

As derived from these tables, the average distance between stops/stations is 2,281 m for line 1; 1,126 m for line 3; 704 m for line 4; 588 m for line 4L; and 2,947 m for line 9.

Headway of service is half an hour in every line, except for rush hours in line 3, where it reaches 17 minutes, in line 4L, 20 minutes, and in line 9, where headway is one hour.

The commercial speeds of each line are the following: 36.01 km/h in line 1; 30.12 km/h in line 3; 18.08 km/h in line 4; 17.64 km/h in line 4L; and 44.2 km/h in line 9. Obviously, the higher values of commercial speed are achieved in the lines where an important part of the journey is made on conventional railway line. This is due to several reasons, among others: the higher distance between



stops/stations in these stretches; the relatively better layout of the tracks in the railway zone; the use of railway operation regime, with higher maximum speeds due to the advanced information about the circumstances of the track, and the long distance available for stopping the vehicle if needed.

The population of some of the cities and villages where the network has stops/stations are the following (2011 data from *Instituto Nacional de Estadística* - Spanish Statistics Institute-): 334,329 for Alicante; 27,345 for El Campello; 32,733 for La Vila Joiosa; 72,062 for Benidorm; 24,056 for Altea; 29,718 for Calpe; 13,536 for Benissa; 6,283 for Gata; and 44,726 for Dénia. These data are for year-round population but real population increases dramatically in the holiday season, reaching 400,000 in Benidorm.

The number of passengers moved in the network during 2011 was 6,132,716. The average value of passengers per day was 17,100 in 2011, with a maximum average value (average value of passenger per day for the best month, July) of 22,500. The worst average value (for January) was 12,900 passengers/day. The maximum number of passengers per day in 2011 was 43,600, on June 24th (the great day of Alicante; the main celebration of the year – Saint John). As can be seen, the best months for the network are the summer ones, due to the important increase of population in the area for recreational and beach activities, as well as to routes served, connecting with this kind of developments and spaces.

During June 2012, the total number of passengers was 653,437 and the demand on each line was as follows: 216,150 for line 1; 236,606 for line 3; 128,563 for line 4; and 72,118 for line 9 [5].

The punctuality of the network is higher than 95% [5].

2.3 Network track description and construction costs

Figure 2 shows several track cross-sections for urban new stretches.

As shown in Figure 2, new light rail tracks are composed of grooved rails (types Ri59 with 59 kg/m and Ph-37 with 65 kg/m) laid over a concrete slab, isolated by means of elastomeric profiles located around the rail with intermediate concrete blocks between them. This structure can be finished with asphalt, concrete or stone pavement.

Turf track structure is an exception to this scheme, in which flat-bottom rail (of 54 kg/m) is fastened to concrete prefabricated blocks that are embedded in a concrete slab by means of an elastomeric material (see Figure 2). The rails and fastening elements are isolated from the substrate by a fleece. The fleece covers the rail and continues between the gravel and the substrate in order to separate them and to avoid gravel contamination.

The refurbished railway tracks have the standard superstructure of ballasted track with mono block concrete sleepers and flat-bottom rail of 54 kg/m [3]. Nevertheless, some stretches are built with the Stedef concrete slab solution, shown in Figure 3, where the rail is fastened to concrete prefabricated sleepers (with concrete block and steel tie-bar). The concrete blocks of this sleeper are embedded in a concrete slab by means of an elastomeric material.

According to FGV data, the average cost of the new stretches of the line per meter of track and type of work were: 7,000 €/m (8,562.4 \$/m) for track superstructure; 1,000 €/m (1,223.2 \$/m) for track electrification; 1,000 €/m (1,223.2 \$/m) for signaling and communications; 1,500-3,000 €/m (1,834.8-3,669.6 \$/m) for street urbanization, with a high level of variation depending on the type of finishing and the extension of the area improved with the tracks; and 600 €/m (733.9 \$/m) for the pipe detour of affected services. The average cost of the platforms was 250 €/m² (305.8 \$/m²).

Nevertheless, the cost of the line 4 extension opened during year 2007 was much lower. This extension has an approximate length of 4.5 km, constructed in single track making a loop, and electrified. Its total cost was 26 million euros (31.80 M\$), and an average of 5.78 M€/km (7.07 M\$/km) of single track, which would be among the cheapest light rail lines developed in Spain [6].

2.4 Operational costs

Some operational costs of the Alicante network are the following, according to FGV data:

- Energy consumption: between 0.70 and 0.95 €/km (0.86-1.16 \$/km).
- Vehicle maintenance and workshop: 1.20-1.40 €/km (1.47-1.72 \$/km).
- Aerial contact line, electric facilities and substation maintenance: 0.75-0.90 €/km (0.92-1.10 \$/km).
- Signaling and communication facilities maintenance: 0.12-0.16 €/km (0.15-0.20 \$/km).
- Toll system maintenance (vending and validation machines in stations/stops and vehicles, access control to underground stations): 0.15-0.25 €/km (0.18-0.31 \$/km).



- Infrastructure and superstructure maintenance and additional costs (fire, water and plumbing facilities maintenance, water consumption, buildings and underground stations maintenance, elevators, ventilation facilities for tunnels, etc.): 1.00-1.50 €/km (1.22-1.83 \$/km).
- Cleaning: 0.15-0.30 €/km (0.18-0.37 \$/km).
- Control center: 0.30-0.40 €/km (0.37-0.49 \$/km).
- Circulation agents, supervisors, reviewers for stations: 3.00-5.00 €/km (3.67-6.12 \$/km). This is a very wide range due to the differences between underground and on surface stations and to the differences in railway and light rail operation regimes.

These values include neither the maintenance of the traffic lights regulation facilities nor the vegetation maintenance. On the other hand, they include neither the company structural costs (commercial, economical and human resources management), which are between 15 and 18%, nor the payment of infrastructure use taxes (taxes to be paid to the management public entity of the region for using the superstructure and installations that it provides, in order to cover the investment made).

2.5 Network future extension

The second line of the network has been built and is waiting for its opening to service. This second line connects Luceros with San Vicente del Raspeig, providing service to the University of Alicante. This line shares the tracks with lines 1, 3 and 4 from Luceros to Marq. The expected commercial speed is 21 km/h, with maximum speed of 50 km/h on surface and 70 km/h on tunnel and on interurban stretches. 14 new Bombardier light rail vehicles have been purchased for the operation of this line, with a total cost of 46 M€ (56.27M\$) plus taxes.

The first tendering procedure to operate this second line had no success, as the Regional Government had to cancel it due to the lack of budget because of the crisis. A new bid was published for public information in May 2012, in the figure of “competitive dialogue” and with new operation conditions, reducing the number of operated kilometers, in order to have enough funds for the needed subsidy.

3 SOME CONSEQUENCES OF THE QUASI-TRAM-TRAIN OPERATION

As previously stated, the TRAM is operated in a quasi-tram-train way, as the tram-train vehicles do not share the way with diesel trains nowadays, but there are some parts of the network on which the tram-train operates in a railway way and others on which it behaves as a light rail. Some particularities of the system, derived from this quasi-tram-train operation, are going to be explained in this section.

3.1 Passenger access

As mentioned in Section 2.2, the services in the Alicante network are provided by three different kinds of vehicles: 11 units of light rail standard vehicles from Bombardier; 9 units of tram-train vehicles from Vossloh; and 6 units of refurbished diesel trains.

One problem derived from the use of these three kinds of vehicles is that the vehicle carbody width is not the same in all of them: light rail is 2,400 mm wide, while tram-train vehicles are 2,550 mm wide (very similar to diesel trains 2,570 mm). The differences in vehicle width between light rail and tram-train vehicles have made it necessary to use a retractable ramp in light rail ones, shown in Figure 4, which is automatically unfolded in the stations/stops where light rails share the platform with tram-trains.

On the other hand, the access height to the vehicle is quite similar for light rail and tram-train vehicles, which means that minor modifications have to be made to guarantee a level access from the shared platforms. In fact, the theoretical access height to the Alicante light rail vehicles is 315 mm, while the one for tram-train vehicles is 360 mm. The Alicante light rail vehicles are provided with a supplement in the suspension in such a way that their access height rises to 340 mm, which gets very similar to the actual (not theoretical) tram-train access height (340-350 mm).

Nevertheless, access height of diesel trains is much higher than the one for tram-trains (1,050 mm). To make it possible for both kinds of vehicles to share the same platform, the following changes have been made in the stations they share: in the first place, the platform height is lowered from the former height adapted to level access for diesel trains to the new height adapted to level access for tram-trains; then, a provisional structure like the one shown in Figure 4 is mounted in the station. This structure is mounted over the lowered platform in such a way that the structure’s floor height allows the level



boarding to diesel trains. The rest of the platform stays with the low height needed for level boarding to tram-trains. This structure is provisional so it can be easily mounted and dismantled when needed. That was necessary because the shared stations have changed during the evolution of the network, being at a first stage the Creueta station and changing to Benidorm later. This dual-height loading platform is only needed in Benidorm station nowadays, which is the only one now utilized by diesel cars and light rail vehicles for interchange between lines 1 and 9.

3.2 Alicante tram-train vehicle characteristics and performance

Table 5 shows a comparison of the main characteristics and performance of the Alicante tram-train, the Vossloh standard light rail vehicle, and the Bombardier light rail utilized in Alicante.

Figure 5 shows a comparison between the trucks of the Vossloh tram-train and the Bombardier light rail vehicles for Alicante.

One of the big dissimilarities between light rail and tram-train vehicles is the kind of trucks (and sometime wheelsets) utilized in them. Modern light rail vehicles are usually 100% low-floor, which leads to the need of using truck structures quite different from the conventional rail vehicles. In turn, tram-train vehicles are normally provided with standard truck structures, which leads to partially low-floor schemes (60% in the case of Alicante), in order to allow the location of these trucks under the high-floor zone of the vehicle. These trucks make the vehicle more stable and allow, combined with the railway signaling systems, maximum speeds of 100 km/h (higher than the 70 km/h usual for light rail). On the other hand, due to the differences between suspensions in light rail and tram-train vehicles, the latter ones are usually more comfortable for passengers because of their better ability to reduce the vibrations transmitted to the carbody.

3.3 Wheel and rail profile

As the urban vehicles have to run on refurbished railway tracks as well as on new built light rail tracks, these latter ones have been provided with grooved rails with a wide flange way, allowing the urban vehicles to use the standard railway wheel profile with a wide flange (see Figure 6), instead of the standard light rail solution of narrow flange. Therefore, urban tracks have been built, as mentioned previously, with the Ph-37 and Ri-59 rail profiles.

3.4 Alicante tram-train vehicle lights

To allow the tram-train vehicle to run on the conventional railway tracks with railway operation, it has been provided with the standard lights for conventional trains, in addition to those needed for running on urban tracks. Figure 7 shows a comparison between the vehicle lights in the standard Vossloh light rail vehicle and the Alicante tram-train vehicle lights.

Figure 8 shows the comparison between the exterior lights of Bombardier light rail and the Vossloh tram-train, both in operation in Alicante.

4 CONCLUSIONS

This paper presents the Alicante network, composed of different kinds of tracks and different types of vehicles: former refurbished conventional railway tracks used by light rail and tram-train vehicles; new light rail tracks utilized by tram-train and light rail vehicles; as well as standard conventional railway tracks served by diesel trains.

The paper shows the main characteristics of the network and the vehicles which make this system a unique solution in the world. Additionally, interesting data about demand, as well as about construction and operational costs are provided in the paper. Summarizing, this paper presents a thorough description of the Alicante solution.

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Table 1: “Network characteristics. Lines 1 and 3. Courtesy of *FGV*”.

Table 2: “Network characteristics. Line 4. Courtesy of *FGV*”.

Table 3: “Network characteristics. Line 4L. Courtesy of *FGV*”.

Table 4: “Network characteristics. Line 9. Courtesy of *FGV*”.

Table 5: “Vossloh tram-train characteristics and performance, in comparison to standard Vossloh and Bombardier light rail. Courtesy of *Vossloh* and *Bombardier*”.

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Figure 1: “Alicante network. a) Schematic plan; b) Network integration in the Alicante region (excluding line 9). Courtesy of *FGV*”.

Figure 2: “Cross-sections of new light rail track: a) New light rail track with embedded rail and concrete finishing; b) New light rail track with embedded rail and asphalt finishing; c) Detail of embedded rail; d) New light rail track with turf finishing in straight layout; e) Detail of 54 kg/m rail for turf track. Courtesy of *FGV*”.

Figure 3: “Cross-sections of refurbished railway tracks using Stedef concrete slab solution. Courtesy of *FGV*”.

Figure 4: “Passenger access issues: a) Retractable ramp of light rail vehicle being deployed in workshop; b) Provisional structure for level boarding in shared platforms between tram-trains and diesel trains”.

Figure 5: “Alicante vehicles trucks: a) Bombardier light rail; b) Vossloh tram-train”.

Figure 6: “Wheel profile of Alicante tram-train vehicles. Courtesy of *Vossloh*”.

Figure 7: “Comparison between the vehicle lights in the standard Vossloh light rail vehicle and the Alicante tram-train. Courtesy of *Vossloh*”.

Figure 8: “Exterior lights of Alicante vehicles: a) Bombardier light rail; b) Vossloh tram-train”.

TABLE 1 Network characteristics. Lines 1 and 3.
Courtesy of FGV.

| Stop/ Station | Distance (m) | Surface / Underground | Electrified /Diesel | Operation regime | Max. Speed* | Ramp (av./max., ‰) | Min. radius (m) | Travel time L1 (min.) | Line |
|--------------------|-----------------|--------------------------|------------------------|---------------------|----------------|--------------------------|-----------------------|--------------------------------|---------|
| Luceros | | Underground | Electrified | Railway | 100/70 | 18.32/ 40.00 | 85 | | 1, 3, 4 |
| Mercado | 610 | Underground | Electrified | Railway | 100/70 | | | 2 | 1, 3, 4 |
| MARQ | 846 | Underground | Electrified | Railway | 100/70 | | | 3 | 1, 3, 4 |
| Sangueta | 842 | Surface | Electrified | Light rail | 50 | 8.12/ 48.00 | 52 | 3 | 1, 3, 4 |
| La Isleta | 2182 | Surface | Electrified | Railway | 100/70 | | | 4 | 1, 3, 4 |
| Albufereta | 582 | Surface | Electrified | Railway | 100/70 | | | 2 | 3, 4 |
| Lucentum | 529 | Surface | Electrified | Railway | 100/70 | | | | 1, 3, 4 |
| Condomina | 1003 | Surface | Electrified | Railway | 100/70 | | | 15 | 3 |
| Campo de Golf | 524 | Surface | Electrified | Railway | 100/70 | | | | 3 |
| Costa Blanca | 1198 | Surface | Electrified | Light rail | 50 | | | | 3 |
| Carrabiners | 1128 | Surface | Electrified | Light rail | 50 | | | | 3 |
| Muchavista | 936 | Surface | Electrified | Light rail | 50 | | | | 3 |
| Les Llances | 939 | Surface | Electrified | Light rail | 50 | | | | 3 |
| Fabrquer | 835 | Surface | Electrified | Railway | 100/70 | | | | 3 |
| Salesians | 586 | Surface | Electrified | Railway | 100/70 | | | | 3 |
| Pla Barraques | 592 | Surface | Electrified | Railway | 100/70 | | | | 3 |
| El Campello | 726 | Surface | Electrified | Light rail | 50 | | | | 1, 3 |
| Poble Espanyol | 1683 | Surface | Electrified | Railway | 100/70 | | | 10.47/ 21.00 | 117 |
| Amerador | 1043 | Surface | Electrified | Railway | 100/70 | 1 | | | |
| Coveta Fumà | 1000 | Surface | Electrified | Railway | 100/70 | 1 | | | |
| Cala Piteres | 1252 | Surface | Electrified | Railway | 100/70 | 1 | | | |
| Venta Lanuza | 4613 | Surface | Electrified | Railway | 100/70 | 1 | | | |
| Paradís | 6350 | Surface | Electrified | Railway | 100 | 9 | 1 | | |
| La Vila Joiosa | 2184 | Surface | Electrified | Railway | 100 | 3 | 1 | | |
| Creueta | 683 | Surface | Electrified | Light rail | 50 | 2 | 1 | | |
| Costera- Pastor | 1098 | Surface | Electrified | Light rail | 50 | 7.98/ 35.00 | 150 | 3 | 1 |
| Hospital Vila | 3003 | Surface | Electrified | Railway | 100 | | | 5 | 1 |
| Hiper Finestrat | 2382 | Surface | Electrified | Railway | 100 | | | 2 | 1 |
| Terra Mítica | 1645 | Surface | Electrified | Railway | 100 | | | 3 | 1 |
| Benidorm | 2215 | Surface | Electrified | Railway | 100 | | | 3 | 1, 9 |

* Where maximum speed of 100/70 km/h is specified, it means that the tram-train vehicle can run up to 100 km/h in that stretch, while the light rail vehicle can reach only 70 km/h due to the vehicle limitations.

TABLE 2 Network characteristics. Line 4.
Courtesy of FGV.

| Stop/ Station | Distance (m) | Surface / Underground | Electrified /Diesel | Operation regime | Max. Speed | Ramp (av./max., ‰) | Min. radius (m) | Travel time (min.) | Line |
|---------------------|-----------------|--------------------------|------------------------|---------------------|---------------|--------------------------|-----------------------|--------------------------|----------------|
| Luceros | | Underground | Electrified | Railway | 70 | 18.32/ 40.00 | 85 | | 1, 3, 4 |
| Mercado | 610 | Underground | Electrified | Railway | 70 | | | 2 | 1, 3, 4 |
| MARQ | 846 | Underground | Electrified | Railway | 70 | | | 2 | 1, 3, 4 |
| Sangueta | 842 | Surface | Electrified | Light rail | 50 | 10.10/ 20.00 | 52 | 3 | 1, 3, 4, 4L |
| La Isleta | 2182 | Surface | Electrified | Railway | 70 | | | 4 | 1, 3, 4 |
| Albufereta | 582 | Surface | Electrified | Railway | 70 | | | 1 | 3, 4 |
| Lucentum | 529 | Surface | Electrified | Light rail | 50 | 14.96/ 55.00 | 30 | 2 | 1, 3, 4 |
| Miriam Blasco | 305 | Surface | Electrified | Light rail | 50 | | | 1 | 4 |
| Sergio Cardell | 538 | Surface | Electrified | Light rail | 50 | | | 2 | 4 |
| Tridente | 774 | Surface | Electrified | Light rail | 50 | | | 2 | 4 |
| Avenida Naciones | 418 | Surface | Electrified | Light rail | 50 | | | 1 | 4 |
| Cabo Huertas | 450 | Surface | Electrified | Light rail | 50 | | | 2 | 4 |
| Avenida Benidorm | 527 | Surface | Electrified | Light rail | 50 | | | 1 | 4 |
| Londres | 538 | Surface | Electrified | Light rail | 50 | | | 2 | 4 |
| La Coruña | 608 | Surface | Electrified | Light rail | 50 | | | 2 | 4 |

TABLE 3 Network characteristics. Line 4L.
Courtesy of FGV.

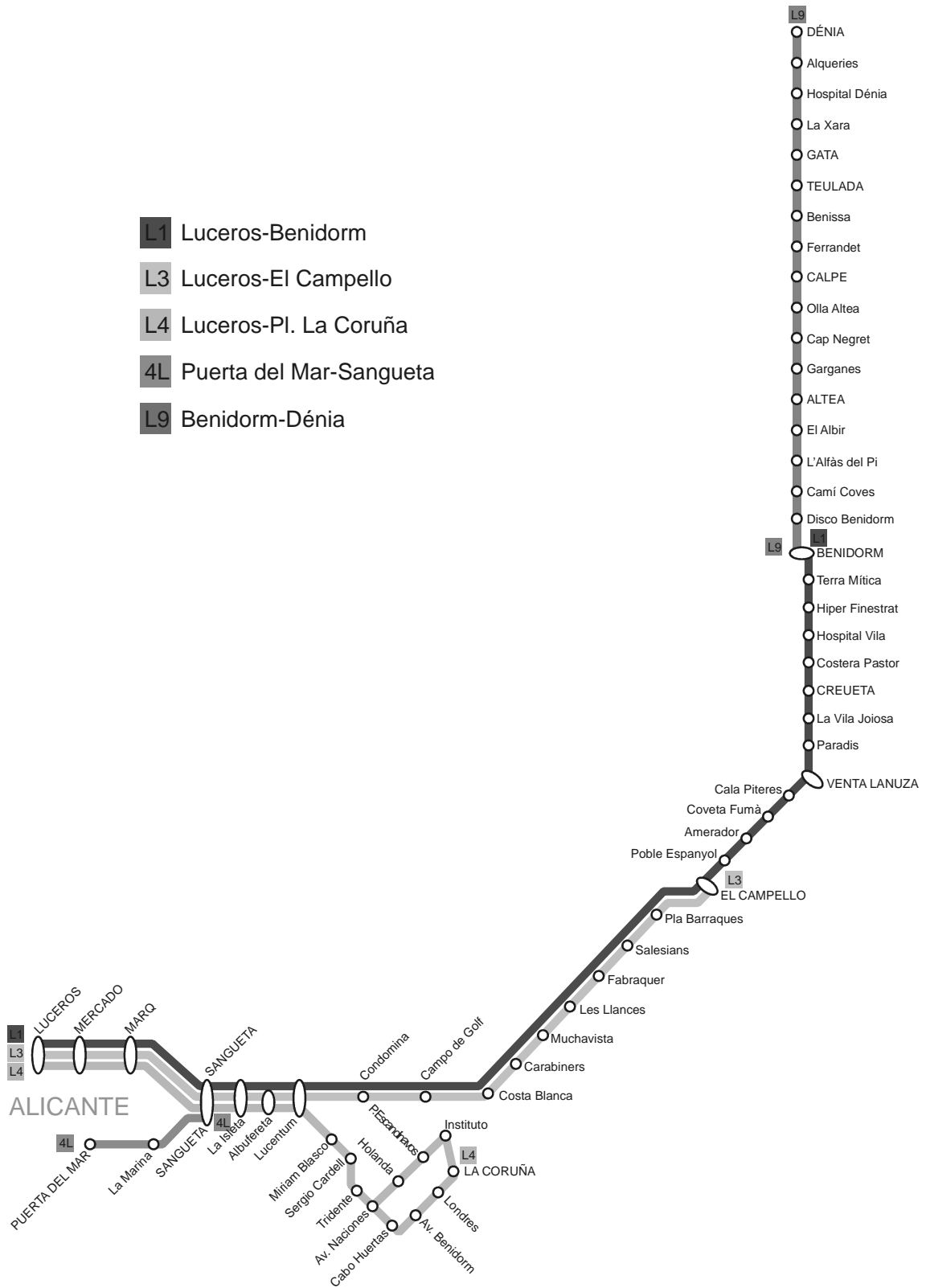
| Stop/ Station | Distance (m) | Surface / Underground | Electrified /Diesel | Operation regime | Max. Speed | Ramp (av./max., ‰) | Min. radius (m) | Travel time (min.) | Line |
|-------------------|-----------------|--------------------------|------------------------|---------------------|---------------|--------------------------|-----------------------|--------------------------|----------------|
| Puerta del Mar | | Surface | Electrified | Light rail | 70 | 3.92/ 40.00 | 100 | | 4L |
| La Marina | 660 | Surface | Electrified | Light rail | 70 | | | 2 | 4L |
| Sangueta | 516 | Surface | Electrified | Light rail | 70 | | | 3 | 1, 3, 4, 4L |

TABLE 4 Network characteristics. Line 9.
Courtesy of FGV.

| Stop/ Station | Distance (m) | Surface / Underground | Electrified /Diesel | Operation regime | Max. Speed | Ramp (av./max., ‰) | Min. radius (m) | Travel time (min.) | Line |
|-------------------|-----------------|--------------------------|------------------------|---------------------|---------------|----------------------------|-----------------------|--------------------------|------|
| Disco Benidorm | 1471 | Surface | Diesel | Railway | 80 | Not available/ 30.70 | 105 | | 9 |
| Camí Coves | 1608 | Surface | Diesel | Railway | 80 | | | 2 | 9 |
| L'Alfàs del Pi | 1352 | Surface | Diesel | Railway | 80 | | | 3 | 9 |
| Ventorrillo | 2150 | Surface | Diesel | Railway | 80 | | | 2 | 9 |
| Altea | 2697 | Surface | Diesel | Railway | 80 | | | 5 | 9 |
| Garganes | 899 | Surface | Diesel | Railway | 80 | | | 3 | 9 |
| Cap Negret | 1015 | Surface | Diesel | Railway | 80 | | | 2 | 9 |
| Olla Altea | 1385 | Surface | Diesel | Railway | 80 | | | 5 | 9 |
| Calpe | 7474 | Surface | Diesel | Railway | 80 | | | - | 9 |
| Ferrandet | 2355 | Surface | Diesel | Railway | 80 | | | 3 | 9 |
| Benissa | 8100 | Surface | Diesel | Railway | 80 | | | 10 | 9 |
| Teulada | 2575 | Surface | Diesel | Railway | 80 | | | 5 | 9 |
| Gata | 6772 | Surface | Diesel | Railway | 80 | | | 9 | 9 |
| La Xara | 6052 | Surface | Diesel | Railway | 80 | | | 7 | 9 |
| Hospital Dénia | 3101 | Surface | Diesel | Railway | 80 | | | 3 | 9 |
| Alqueries | 533 | Surface | Diesel | Railway | 80 | | | 1 | 9 |
| Dénia | 1292 | Surface | Diesel | Railway | 80 | | | 3 | 9 |

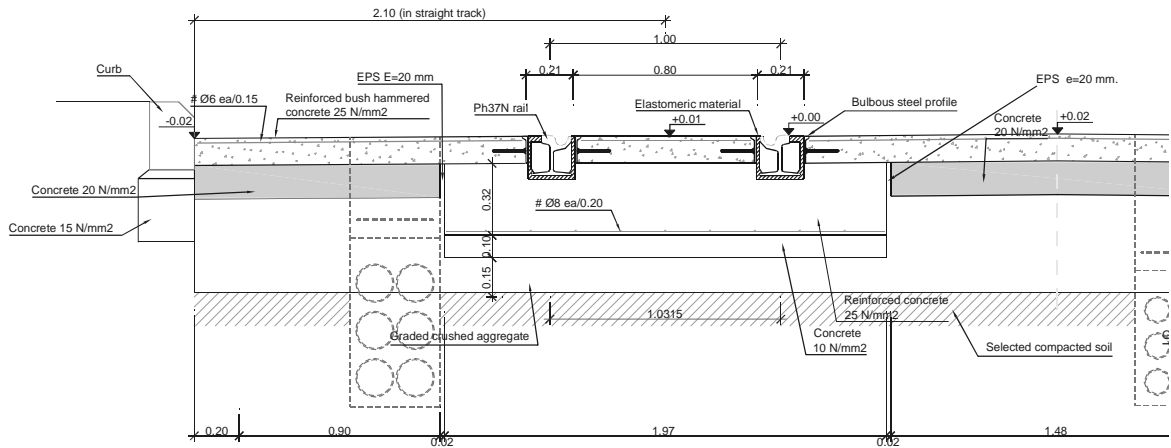
TABLE 5 Vossloh tram-train characteristics and performance, in comparison to standard Vossloh and Bombardier light rail.*Courtesy of Vossloh and Bombardier.*

| | Bombardier light rail for Alicante | Vossloh standard light rail | Vossloh tram-train for Alicante |
|---|--|--|---------------------------------|
| Maximum speed (km/h) | 70 | 70 | 100 |
| Acceleration (m/s ²) | 1.20 | 1.20 | 1.20 |
| Service braking deceleration (m/s ²) | 1.20 | 1.20 | 1.20 |
| Emergency braking deceleration (m/s ²) | 2.60 | 2.80 | 2.60 |
| Maximum longitudinal gradient | 6% | 8% | 6% |
| Traction power | 4·105 kW | 4·105 kW | 6·140 kW |
| Length (m) | 32 | 28 – 35 | 37 |
| Height with folded pantograph (m) | 3.500 | 3.450 | 3.480 |
| Car body width (m) | 2.40 | 2.30 / 2.40 / 2.65 | 2.55 |
| Floor height (mm) | - | 360 / 450 | 375 / 900 (60% low-floor) |
| Access height (mm) | 315 | 315 | 360 |
| Access doors by side | 4 double (2,052 mm · 1,305 mm) 2 simple (2,052 mm · 800 mm) | 4 double (2,000 mm · 1,300 mm) 2 simple (2,000 mm · 800 mm) | 4 double (2,000 mm · 1,240 mm) |
| Wheel diameter (new / worn, mm) | 570 / 510 | 600 / 520 | 720 / 660 |
| Track gauge (mm) | 1,000 | 1,000 / 1,435 | 1,000 |
| Minimum curve radius (m) | 25 | 17-18 | 30 |
| Minimum vertical radius, Kv (m) | 500 | - | 1,200 |
| Empty vehicle weight (tare, kg) | 41,600 | 41,500 | 55,500 |
| Full vehicle weight with 4 pass/m ² (kg) | 55,000 | 55,000 | 69,000 |
| Crashworthiness | According to EN-15227 [7] | According to EN-15227 [7] | 600 kN |
| Primary suspension | Rubber-metal springs | Rubber-metal springs | Rubber-metal springs |
| Secondary suspension | Coil springs | Coil springs | Pneumatic suspension |

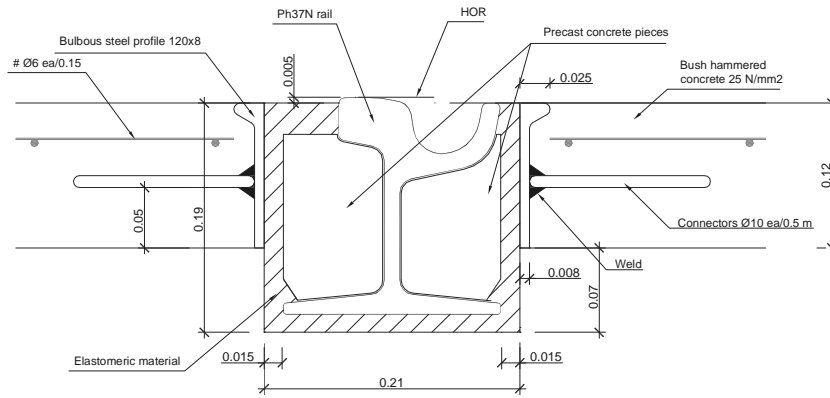
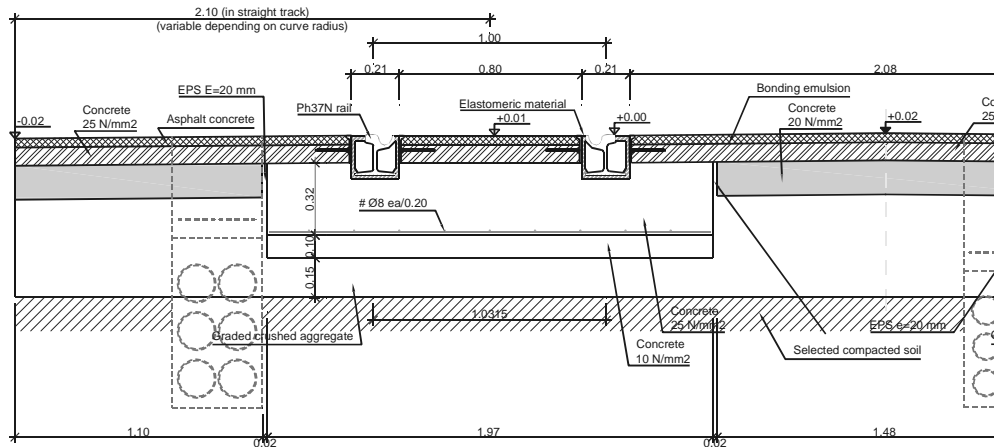


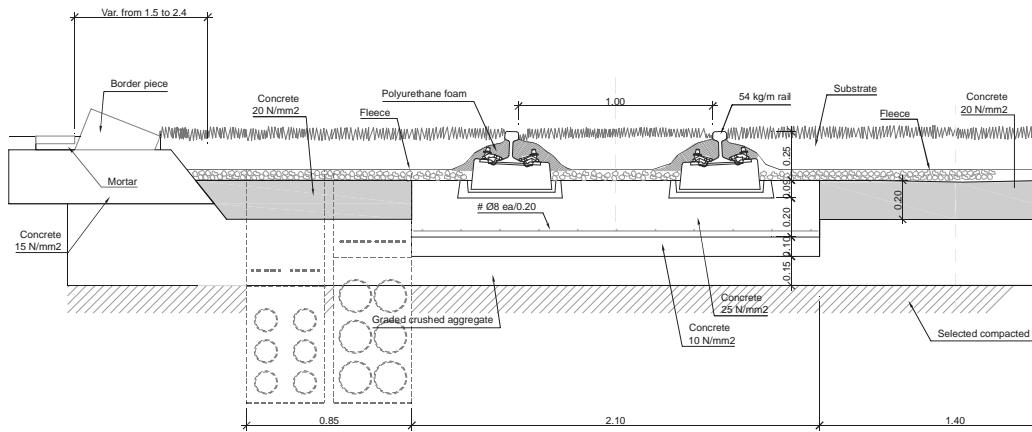


**FIGURE 1 Alicante network. a) Schematic plan; b) Network integration in the Alicante region (excluding line 9).
Courtesy of FGV.**



NOTE:
Bulbous steel profile will be located in crossings and in rights of way shared with buses





LONGITUDINAL SECTION A-B

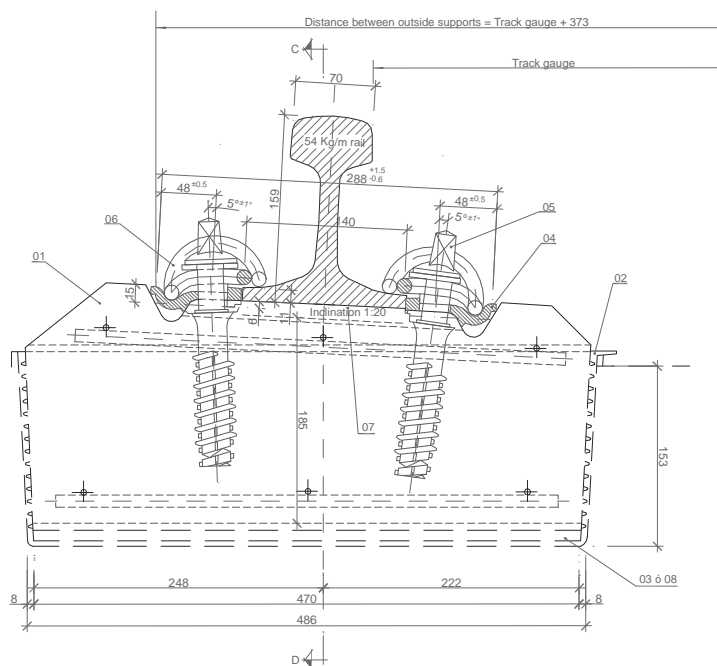


FIGURE 2 Cross-sections of new light rail track: a) New light rail track with embedded rail and concrete finishing; b) New light rail track with embedded rail and asphalt finishing; c) Detail of embedded rail; d) New light rail track with turf finishing in straight layout; e) Detail of 54 kg/m rail for turf track.

Courtesy of FGV.

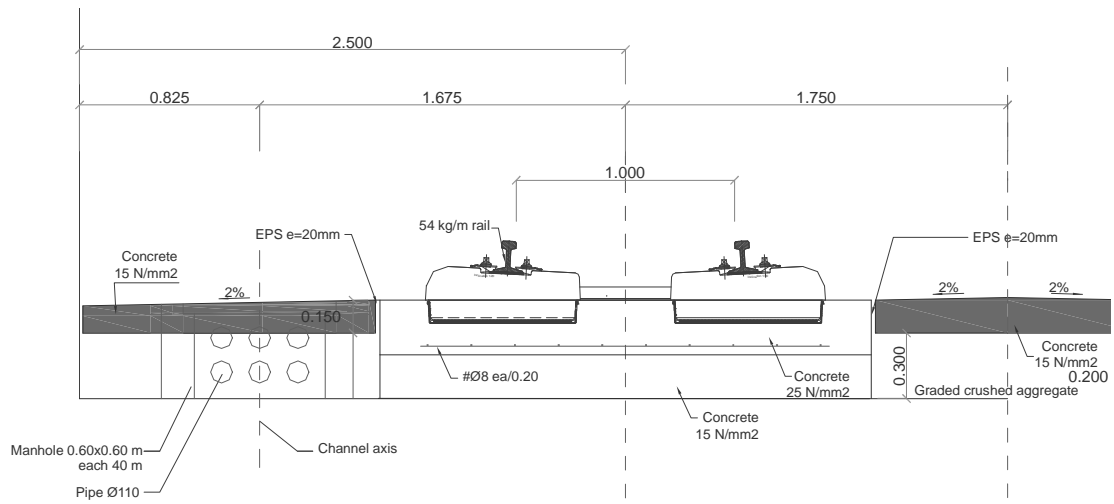


FIGURE 3 Cross-sections of refurbished railway tracks using Stedef concrete slab solution.
 Courtesy of FGV.



FIGURE 4 Passenger access issues: a) Retractable ramp of light rail vehicle being deployed in workshop; b) Provisional structure for level boarding in shared platforms between tram-trains and diesel trains.

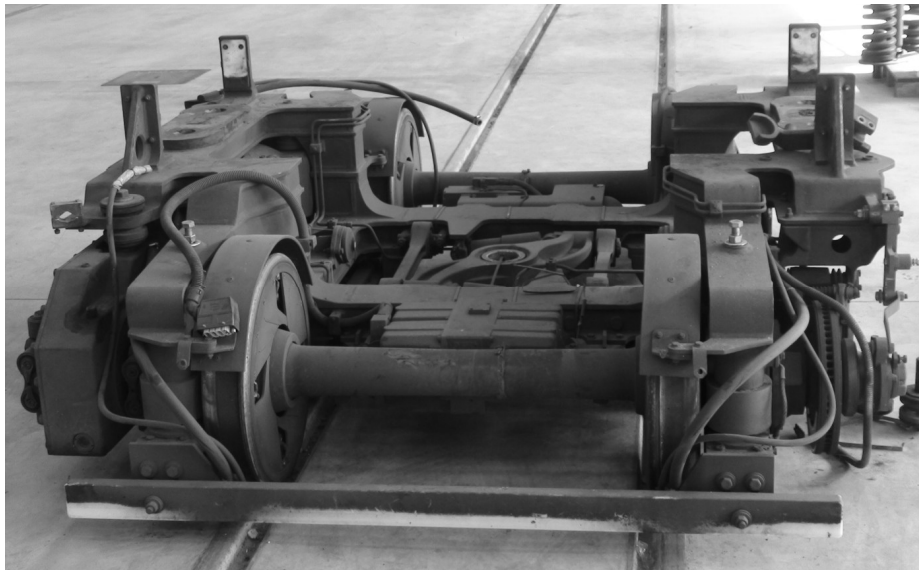


FIGURE 5 Alicante vehicles trucks: a) Bombardier light rail; b) Vossloh tram-train.

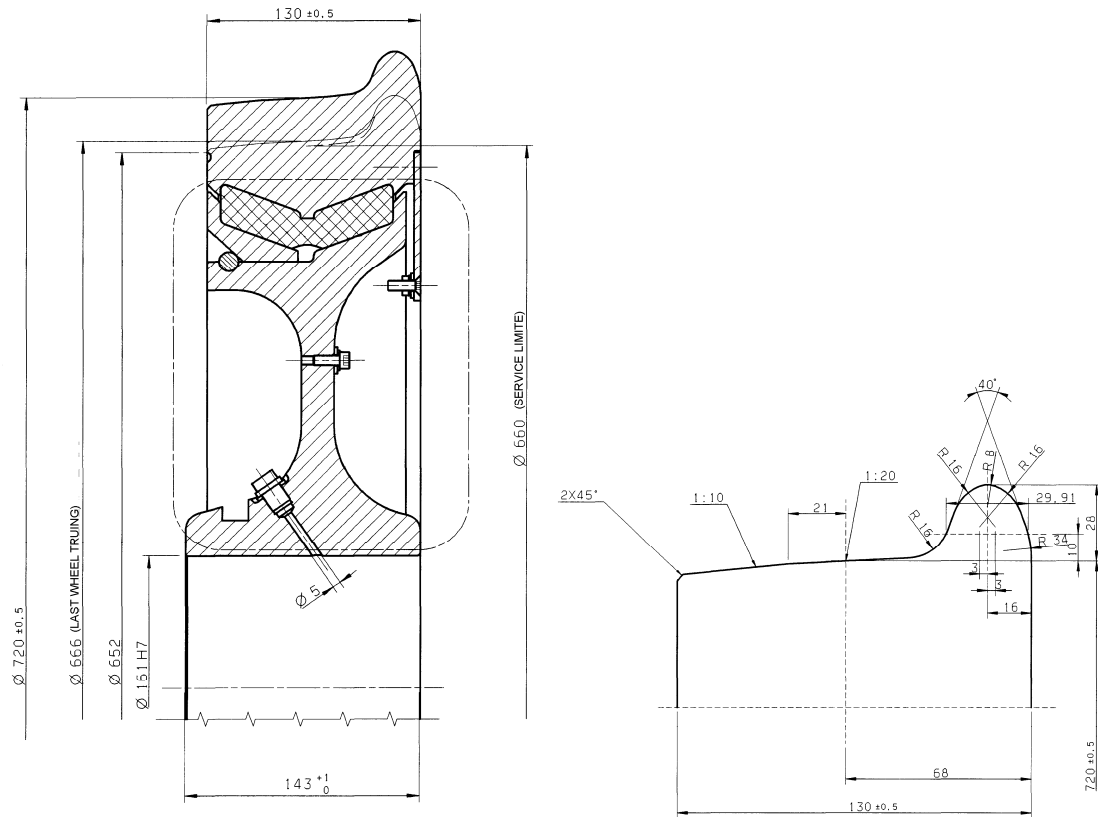
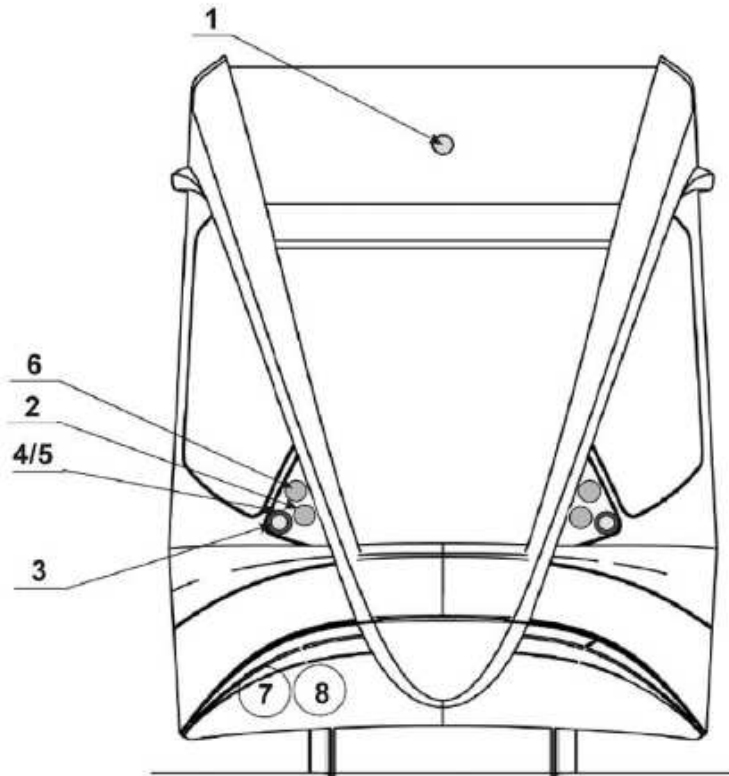
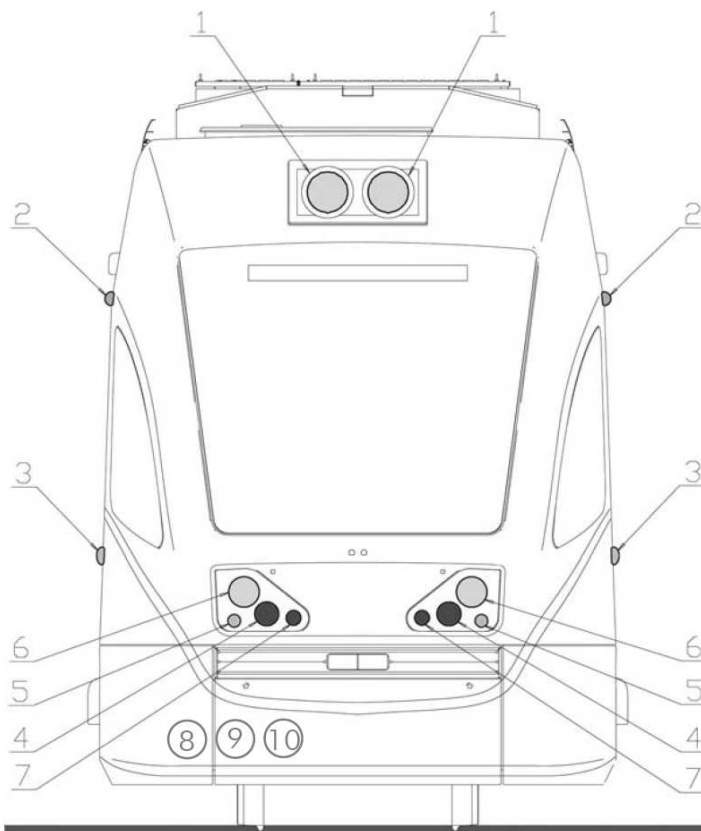


FIGURE 6 Wheel profile of Alicante tram-train vehicles.
 Courtesy of Vossloh.



LIGHT RAIL LIGHTS

- 1: Top headlight (low and high beam)
- 2: Headlights (low and high beam)
- 3: Front turn signals
- 4: Rear sidelights
- 5: Braking lights
- 6: Sidelights
- 7: Bell
- 8: Horn



TRAM-TRAIN LIGHTS

- 1: Reduced/normal beams
- 2: ATP (Automatic Train Protection) disconnected
- 3: Turn signals
- 4: Sidelights
- 5: Turn signals
- 6: Headlights (low and high beam)
- 7: Braking lights
- 8: Bell
- 9: Short horn
- 10: Long horn

FIGURE 7 Comparison between the vehicle lights in the standard Vossloh light rail vehicle and the Alicante tram-train.

Courtesy of Vossloh.



FIGURE 8 Exterior lights of Alicante vehicles: a) Bombardier light rail; b) Vossloh tram-train.