Cádiz Bay tram-train: the first experience over Spanish conventional tracks

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ABSTRACT
Tram-train systems are an evolution of light rail in which the vehicle can run on the tram tracks that have been implemented specifically for the system, but it can enter, at a given point, into conventional railway tracks that have been implemented for and are used by conventional railway vehicles. In this way, urban light rail services can be extended further away from the city center, avoiding part of the cost of new infrastructure, and offering a seamless link between the urban center and the suburban areas.

The fact of running on different kinds of tracks, with different types of superstructure and geometric characteristics, as well as different standards in relation to safety and other subjects, makes the design of tram-train systems especially complex.

The aim of this paper is to describe some of the most important technological challenges for the implementation of Cádiz Bay tram-train. It is the first tram-train developed over Spanish conventional railway tracks belonging to ADIF (Administrador de Infraestructuras Ferroviarias, Administrator of Railway Infrastructures). Some of the main technological features of this tram-train are: 1,668 mm track-gauge, with the possibility of a future transformation to 1,435 mm; a partially low-floor tram-train vehicle, to cope with the two kinds of stations/stops (urban and railway ones); a tram-train wheel with wide flange, to match the conventional railway tracks, which leads to wide-grooved rails in the new urban stretches of the network; dual-voltage vehicle 3000-750 V dc; among other aspects that will be presented in the paper.

1 INTRODUCTION
As it is known, tram-train systems are an evolution of light rail in which the vehicle can run on the tram tracks that have been implemented specifically for the system, but it can enter, at a given point, into conventional railway tracks that have been implemented for and are used by conventional railway vehicles. In this way, light rail services can be extended further away from the city center, avoiding part of the cost of new infrastructure, and offering a seamless link between the urban center and the suburban areas.

The first tram-train system developed in the world was the one of Karlsruhe (Germany), which was opened on September 27th, 1992. Since then, several cities and countries have implemented or are planning the use of this solution, as it is the case, among others, of Saarbrücken, Nordhausen, Kassel and Heilbronn (Germany), Mulhouse, Bordeaux, Nantes and Strasbourg (France), Sheffield-Rotherham (United Kingdom) and Aarhus (Denmark).

The advantages, technological challenges, drawbacks or complexity for implementing tram-train systems have been deeply studied during the last two decades, and several papers have been published in relation to this subject, as [1 to 8].

The aim of this paper is to describe some of the most important technological challenges for the implementation of Cádiz Bay tram-train, which is planned to be partially inaugurated at the end of 2013. It is the first tram-train developed over Spanish conventional railway tracks belonging to ADIF (Administrador de Infraestructuras Ferroviarias, Administrator of Railway Infrastructures). ADIF is a state-owned Spanish company that manages the Spanish national railway network (the lines that have not been transferred to Regional Governments).

This project has been promoted and is managed by the Agencia de Obra Pública de la Junta de Andalucía, the regional company that manages public works in Andalucía, which belongs to the Consejería de Fomento y Vivienda de la Junta de Andalucía.

2 CÁDIZ BAY TRAM-TRAIN NETWORK

2.1 Infrastructure
The Cádiz Bay tram-train network is shown in Figure 1. It comprises two kinds of stretches:
- The new urban-suburban stretch (the blue line in the figure) from Chiclana city center to the link with the conventional railway line, running through San Fernando city center. This part of the line starts in the South with the Chiclana council stretch (2 km), in “La Hoya” industrial park, going northwards in parallel to N-340 road until the integration into the urban zone of Chiclana (Reyes Católicos and Alameda del Solano avenues), going out of the city through another industrial park zone.
- Then there is an interurban stretch between Chiclana and San Fernando (7 km).
It continues with the urban stretch of San Fernando (3.5 km), running through Real Street. It ends with the interurban stretch until the link located in La Ardila (1 km). The overall length of these tracks is 13.5 km. The foreseen total cost is around 225 M€ (280 M$) [9], which means an average cost of 16.67 M€/km (20.74 M$/km).

- The existing conventional railway track, belonging to the Sevilla-Cádiz railway line. The tram-train enters this line by means of the link located at La Ardila, which is shown in Figure 2. At this point the new stretch to San Fernando and Chiclana is linked to the railway line by means of a fly-over and new switches (that are not built yet in the figure). The tram-train runs on this conventional railway track to Cádiz, through 10.3 km. This stretch runs on surface in the first zone and then it is laid underground, from Ciudad de La Coruña Avenue to Cádiz railway station. The frequency of conventional railway services existing on this track is approximately of 1 hour from 5 am to 11 pm.

FIGURE 1 Cádiz Bay tram-train network.
The overall length of the network is 23.7 km, and it will have a total of 22 stops/stations, including 5 existing stations in the conventional railway stretch. The served population within a distance of up to 1000 m to the stops/stations is 233,483 inhabitants. The expected demand is 6.14 million passengers/year. The planned frequency for the tram-train services is 15 minutes.

2.2 Rolling stock

The service will be provided by means of 7 tram-train vehicles manufactured by the Spanish company CAF (Construcción y Auxiliar de Ferrocarriles). The total acquisition cost for them is 43.3 M€ (53.9 MS). This high value (6.19 M€/vehicle or 7.71 MS/vehicle) is due to the small amount of vehicles, whose design has had to be customized in every detail in order to fulfill compatibility conditions to run on conventional railway tracks as well as on the new urban stretches.

The vehicles are composed of three cars with a total length of 38,140 mm and a width of 2,650 mm. These vehicles have a maximum capacity of 299 passengers (84 seated), considering 6 passengers/m². The total weight of an empty vehicle is 67.79 tonnes.

The maximum speed will be 100 km/h on the conventional railway track, 70 km/h over the suburban stretches of the new line, and 20 km/h on the urban zones. The whole line, between both terminuses, will be covered in 28 minutes (with a very good commercial speed of around 50 km/h).

Acceleration values of the vehicle are as follows: maximum acceleration for the vehicle full of passengers (considering the extreme value of 8 passengers/m²): 1.06 m/s² for 0-40 km/h, 0.78 m/s² for 40-70 km/h and 0.50 m/s² for 70-100 km/h. The maximum deceleration with service brake and full vehicle (8 passengers/m²) is 1.10 m/s², while the emergency braking leads to 2.50 m/s² under the same conditions.

The main reference parameters for the layout of the new stretches of the track are:
- limit value for longitudinal gradients of unlimited length, 4.0%; for sustained longitudinal gradients with limited length of 750 m, 6.5%; for exceptional cases, 8.0%.
- minimum horizontal curve radius: 50 m.
- maximum superelevation 150 mm; recommended superelevation rate of change 2 mm/m; exceptional superelevation rate of change 3 mm/m.
2.3 Future extension plans

There is a future plan to extend the tram-train service to Puerto Real. This plan would entail the construction of a second bridge (named Puente de La Pepa) over the bay with tram-train superstructure. This line could be extended to Jerez de la Frontera providing its airport with a tram-train service. Nevertheless, it is difficult to think about the realization of this project in the near future, due to the severe crisis suffered by the Spanish economy.

3 CÁDIZ BAY TRAM-TRAIN TECHNICAL CHALLENGES

3.1 Track-gauge

There are several solutions for the case that the tram-train would have to run on existing urban and railway networks with different track-gauge, as can be seen in [3]. Nevertheless, when the tram-train system is going to be developed at the same time as the urban network (that is, building new tracks for its circulation in the urban zone), the recommended approach is to build the tram-train with the same track-gauge as the existing railway tracks. This is the best way to ensure an easy compatibility between the tram-train and the railway network in relation to this subject.

As the only existing tracks of Cádiz Bay tram-train were the ones belonging to the conventional railway network, the track-gauge of the new tracks has been selected as the same as the one in such conventional tracks. Thus, Cádiz Bay tram-train is being built with Spanish conventional track-gauge (1,668 mm, also known as Iberian track-gauge). This fact means that it is the first light rail (and tram-train) system with 1,668 mm track-gauge in Spain (and in the whole Western Europe), as all of the earlier Spanish light rail systems have been implemented with 1,000 or 1,435 mm track-gauge.

Nevertheless, track-gauge in Spain is a tricky issue nowadays. While the conventional network has, in general, the Iberian track-gauge (1,668 mm), the new high-speed railway lines have (and will continue being built) with standard track-gauge (1,435 mm). This fact has led to several track-gauge borders (places where the track-gauge changes) in several locations of the Spanish railway network, in addition to the existing borders in the link to the French (and European) network. Although Spain is, perhaps, the main power in relation to track-gauge interchangers’ technology, these borders are becoming an increasingly important problem for railway operations in Spain. So, the old idea of changing the track-gauge of the whole Spanish network has entered the fray again in the last years. Of course, changing the track-gauge once and for all would be extremely expensive, and would lead to operational inconveniences that have to be taken into account. In order to facilitate an eventual future track-gauge change, the renewals of the main lines are carried out, for about the last two decades, using polyvalent sleepers. These sleepers are specifically designed to allow the track-gauge change by only relocating the rails and the fastenings without replacing the sleepers of the track, in order to make this change easier, faster and cheaper.

The Sevilla-Cádiz railway line (which is going to be used by Cádiz Bay tram-train) is not an exception to this track-gauge problem. It has 1,668 mm track-gauge now, but the possibility of a track-gauge change in the short or mid-term future cannot be ruled out. This fact has led to a unique and complicated solution for Cádiz Bay tram-train: it is being implemented in Spanish track-gauge, but it has been designed considering the option of changing the track-gauge of the whole system to the standard value (1,435 mm) at a later time. In this way the tram-train operation is guaranteed even in the case that this gauge change finally would be realized in the Sevilla-Cádiz railway line.

This option of changing tram-train gauge in the future has implications in the design of several aspects of the system:

- The tram-train vehicle, as every equipment in the vicinity of or in contact with vehicle wheelsets, has to be designed to allow this change and to run properly for both gauge alternatives.
- The suburban stretches of new tram-train lines, which has been built with a conventional railway superstructure of Iberian track-gauge, but with polyvalent sleepers to allow the future track-gauge change, as can be seen in Figure 3.
  The track structure in this zone is composed of a minimum thickness of 30 cm of ballast, 25 cm of sub-ballast, polyvalent sleepers (type PR-01) and 54 E1 rail type.
- The urban stretches of new tram-train lines, which need to be prepared for track-gauge change. This change will be the most expensive operation, as tram-train urban lines have the
superstructure shown in Figure 3 (although with some variations in different areas of the line due to anti-vibration treatment).

As the figure presents, the track superstructure is composed of a concrete layer where the rails are fixed in the trough or “rail duct” by an elastomeric material. For changing the track-gauge, the covering material of the street (large stone slabs) will have to be removed, then the elastomer has to be eliminated as well (which will be a difficult operation), and then the rails can be relocated in the new position for the standard gauge. This sequence of work will lead, as can be supposed, to high costs of the track-gauge changing. In addition, the rails may remain permanently deformed as a result of this extraction, which can make them unusable (and so, new rails can have to be purchased).

On the other hand, the track-gauge change would lead to operational problems in the urban stretches, as the service will have to be interrupted or seriously limited, using only one of the tracks in a single-track mode in order to make the track-gauge change in the other one, making then the same process with the second parallel track.

**FIGURE 3** Track superstructure: a) new tram-train suburban stretches; b) new tram-train urban stretches.

*Courtesy of Sacyr Vallehermoso.*

Another option for solving the problem of the possible future track-gauge change of the conventional railway line could have been the use of an urban mixed-gauge track with three rails. This option was dismissed because of the impacts that the existence of six grooved rails would have had in the streets, especially considering the use of a wide-groove (see section 3.4). This impact would have been even worse for the case of turnouts and crossings.
3.2 Passenger access

One important issue in the implementation of a tram-train (or any other kind of transit) system is to guarantee a safe, quick and easy access to the vehicles for all sort of passengers, regardless the station or stop in which they enter the system. Nevertheless, for tram-train this is not a trivial issue due to differences in floor height and car width of urban light rail vehicles in relation to conventional trains. These differences lead to important dissimilarities in the design of railway stations and urban or light rail stops, mainly in the height of the platform and in its distance to the center of the track.

In general, modern European urban rail systems do not accept the use of high-platform stops in the city environment, as they imply important problems of urban integration and higher space occupation. So, the problem of stop/station compatibility between tram-train and railway systems has to be solved either on the railway stations or in the vehicles.

The solution on the railway stations can be the implementation of new platforms, either parallel or in series to the existing ones (see [2]), in such a way that the new platforms have the appropriate geometry to fit the urban vehicle, leading to adequate values of horizontal gaps and vertical distances. Nevertheless, as the stations of the conventional railway line used by the Cádiz Bay tram-train are located underground, the option of implementing new platforms would be extremely expensive, so it was rejected.

Given this fact, the only remaining alternative is to solve the problem in the vehicle. This was the option adopted in the Cádiz Bay tram-train. To get an easy access from every kind of stop/station, the Cádiz vehicle is partially low-floor, with two double doors in each side of the vehicle located in its high-floor area, and another two in its low-floor zone (see Figure 4). So, the access height for stations in the railway stretches is 790 mm, while it is 380 mm for the rest of the stops. The usable door width is 1,300 mm and the height is 2,010 mm.

In any case, a passenger with disabilities needs to have the possibility to enter the vehicle through the low-floor area (corresponding to new urban and suburban stretches of the line), and leave it through the high-floor area (corresponding to existing conventional railway stretches of the line), or vice versa. As the vertical distance between both floor levels is too high, the option of an internal ramp in the vehicle would be a source of trouble, and this is the reason why the tram-train vehicle has been provided with an internal electric elevator, which is shown in Figure 5. This solution obviously has an impact in the vehicle capacity, as this zone of the vehicle (approximately 2 m²) cannot be occupied with standing passengers when the elevator is being used by a passenger with disabilities, which leads to a decrease in the maximum vehicle capacity of 12 passengers (considering 6 passengers/m²) over a total of 299. In any case, the use of an internal ramp would have had a similar or worse effect, as the ramp is not a comfortable zone for passengers to stand, and it would take more interior space in the vehicle.

![Figure 4 Scheme of the Cádiz tram-train vehicle. Courtesy of CAF (Construcción y Auxiliar de Ferrocarriles).](image_url)
FIGURE 5 Cádiz tram-train interior elevator. a) High-floor level; b) Intermediate position; c) Low-floor level; d & e) Control device.

Courtesy of CAF (Construcción y Auxiliar de Ferrocarriles).

On the other hand, the tram-train vehicle is narrower than conventional trains (2.65 m in comparison to 2.90 m). In order to avoid an excessive horizontal gap between the tram-train vehicle and the platform in conventional railway stations, the tram-train is provided with a retractable ramp that is unfolded before the doors open (see Figure 6).
3.3 Trucks

As shown in Figure 4, the vehicle has four trucks, three of them are power trucks (each one with a total weight of 6.26 tonnes), while the other is a carrying one (4.97 tonnes). The carrying truck is located under the intermediate car. There are six engines in the vehicle (two in each power truck), with a total power of 900 kW.

Primary suspension has rubber-metal springs, while secondary suspension has coil springs. The first and the last trucks of the vehicles are equipped with flange lubricator and sand-dispensers. The wheels are elastic and are mounted on wheelsets. The brake disks are mounted on the wheelsets and their size cannot be very large due to the need for an eventual change of track-gauge to 1,435 mm in the future.

3.4 Wheel-rail interface

As previously stated, the Cádiz tram-train vehicles will run on existing conventional railway tracks, as well as on new built urban and suburban light rail tracks. The new tram tracks have been provided with wide-grooved rails (type Ri Ph 37N), to allow the tram-train vehicle to use the same wheel profile as the conventional commuter trains (see Figure 7). The only difference is the wheel diameter, which is 640/580 mm for new/worn wheels of tram-train vehicles, in contrast to 890/790 mm for commuter trains.
FIGURE 7 Rail and wheel profile of Cádiz tram-train. a & b) Rail profile of the Cádiz tram track; c) Cádiz tram-train wheel profile.

Courtesy of CAF (Construcción y Auxiliar de Ferrocarriles) and Sacyr Vallehermoso.

UIC (International Union of Railways) Leaflet 510-2 [10] states the minimum value of wheel flange height according to wheel diameter. For wheel diameters between 330 and 630 mm the minimum flange height is 32 mm, while for diameters from 630 to 760 mm a value between 30 and 32 mm is recommended (being 30 mm preferable). As Cádiz tram-train wheel flange height (29 mm) does not fulfill the recommendation, detailed studies and tests have been carried out about the running performance over the turnouts and crossings of conventional railway tracks.

3.5 Structural strength

The Cádiz tram-train vehicle has been designed to withstand a compressive force in buffers of 600 kN, which is the usual value for tram-train systems. This value is lower than the one required in the last version of the European Standard EN 12663-1:2010 [11] for P-II type conventional railway vehicles (passenger cars and fixed units). The tram-train type of vehicle is not covered within this standard, and
this is why this 600 kN value had to be established by the agreement of the certification group (see point 4 in this paper), by considering the experience of other European tram-trains, as well as the results of simulations and risk analysis.

Indeed, when the tram-train vehicle runs on conventional railway tracks, sharing the network with conventional trains, the same level of safety as if the tram-train vehicle had been provided with a buffer resistance of 1500 kN must be guaranteed. For complying with this condition, simulations have been performed with the crash scenarios established in the European Standard EN 15227:2008 [12], for both the real tram-train vehicle and a theoretical vehicle similar to the real one but with a buffer resistance of 1500 kN. The results of these simulations have shown that the deformation of the real vehicle will be larger than for the theoretical one, although the decelerations will be lower. In any case, every obtained value fulfills the limits established in the European Standard EN 15227:2008.

3.6 Traction power supply

Spanish conventional railway lines, when electrified, have a traction power supply of 3000 V dc, while the usual value for light rail systems is 750 V dc (which has been the one selected for urban and interurban stretches of Cádiz Bay tram-train). In order to allow the vehicle to use both kinds of lines, it has been designed as a dual-voltage one, having the ability to run under both power supply voltages (3000-750 V dc). This dual-voltage approach is the most usual solution for European tram-train systems, although different types of traction power supply are present in the railway lines of each country (1500 V dc, 3000 V dc, 15000 V ac, 25000 V ac, among other values).

Appropriate transition zones between the two types of traction power supply have to be provided, in which the change is made automatically by the vehicle, while the driver only has to open the circuit-breaker. These transition zones are provided with a downwards slope in the direction of travel, in such a way that even in the case that the vehicle has to stop in this zone, it will move in this direction once the brake is not applied.

On the other hand, the vertical contact force applied by the pantograph to the catenary is different for conventional trains than for light rail vehicles, being 100 10 N for the former and around 80 N for the latter. Anyway, as using 100 N is not a problem for urban and suburban lines in Cádiz, this contact force has been used as the unique one for the Cádiz tram-train vehicle.

3.7 Crossing with conventional trains running over adjacent track

Another technological challenge for the tram-train vehicle, arising from the compatibility to run on both kinds of networks, is the requirement of withstanding the efforts caused by the crossing with other vehicles, which may run at speeds up to 160 km/h on adjacent tracks.

Simulations have been made for the crossing of the tram-train vehicle with the most unfavorable locomotive that will share the railway lines with the tram-train vehicles. During these simulations, the pressure levels over the vehicles have been determined in order to establish their influence on the vehicle’s behavior, on doors and windows behavior, as well as on passengers comfort.

Some modifications have had to be introduced into the initial door design in order to avoid problems when crossing with the most unfavorable locomotive at such speeds.

3.8 Additional coupling elements for rescuing

The coupling elements of the tram-train vehicle have had to be adapted in order to guarantee that it can be rescued by any kind of train that may run on the railway track (not only by another tram-train, but also by a locomotive or by another passenger vehicle). This fact is necessary in order to avoid severe interference in the railway line operation in case of a tram-train failure.

The coupler has been subjected to the standard approval process for railway and light rail systems. It is equipped with anti-climber devices and with a height adapter for rescuing by conventional railway vehicles.
3.9 Signaling and communication systems

The tram-train vehicle has to be able to recognize and activate the signaling of any type of track on which it will run. On the other hand, it is necessary that the control center can always contact the vehicle, whatever the point of the network in which it is located.

The Cádiz tram-train is provided with a train to wayside communication system, as well as GSM-R (Global System for Mobile Communications - Railway). GSM-R is the European standard for railway communications, which is used in every high-speed line in Spain, and is being extended to the rest of the lines. This system makes it possible to know the location of the vehicle at any moment, providing accurate and fast information to the operator and to users.

On the other hand the tram-train vehicle has also digital ASFA (Anuncio de Señales y Frenado Automático, that is, Signal Announcement and Automatic Braking system), which is the current signaling system in the conventional railway track used by the Cádiz Bay tram-train. In addition, it has SAE (Sistema de Ayuda a la Explotación, that is, Operation Support System), which is the usual equipment for light rail in Spain.

Furthermore these vehicles are equipped with event register, fire detection system, passenger-counter device, and CCTV (closed circuit television) with two interior cameras per car, two rear-view cameras per cabin, two front-view cameras and a 10.4 inches screen for each driver seat.

The vehicle’s cabin is shown in Figure 8.

Finally, the exterior lighting of the vehicle has to comply with railway and urban standards.

4 CERTIFICATION PROCESS

The fact that the tram-train vehicle needs to run not only on conventional railway tracks, but also on tram tracks, makes it impossible to fulfill every requirement established in the certification standards mandatory for operation over Spanish conventional railway tracks (these standards are stated in [13]). This circumstance has imposed the need for establishing a working group and a commission that have studied every breach of the standards, justifying its reason and guaranteeing that they do not result in additional operational or safety problems for the conventional railway network. This commission is composed by members of: ADIF (Administrador de Infraestructuras Ferroviarias), the entity responsible for managing the national railway network in Spain; General Directorate of Railways, the office in charge of railways in the Spanish Public Works Ministry; Renfe Operadora, the main railway operator in Spain, up to date, state-owned company; Agencia de Obra Pública de la Junta de Andalucía, the public works agency of the Regional Government of Andalucía, region in which the Cádiz Bay tram-train is developed;
CAF, the manufacturer of the vehicles; CETREN, a certification company recognized by the Spanish government and the European Union; and Ineco-Tifsa, one of the main railway engineering consultancies in Spain.

5 CONCLUSIONS

The main characteristics of the Cádiz Bay tram-train system have been shown in this paper, emphasizing the technological challenges that the need for compatibility with conventional railway tracks and with urban and interurban light rail tracks imposes on this system.

Once again, as in previous tram-train systems implemented in other countries, these technological challenges have proven to be solvable with the combination of an adequate configuration of the new tracks and a smart and thorough design of the vehicle. Some of the main technological features of this tram-train are: a 1,668 mm track-gauge, with the possibility of a future change to 1,435 mm; a partially low-floor tram-train vehicle, to suit the two kinds of stations/stops (urban and railway ones); a tram-train wheel with wide flange, to fit the conventional railway tracks, which leads to wide-grooved rails in the new urban stretches of the network; compressive strength in buffers of 600 kN, which being lower than the value required for type II conventional railway vehicles, has led to the need to prove the same level of safety by means of simulations; and a dual-voltage vehicle (3000-750 V dc).

The fact that the tram-train vehicle needs to run not only on conventional railway tracks, but also on tram tracks, makes it impossible to fulfill every requirement established in the certification standards mandatory for operation over Spanish conventional railway tracks. This circumstance has imposed the need for establishing a working group and a commission that have studied every breach of the standards, justifying its reason and guaranteeing that they do not imply additional operational or safety problems for the conventional railway network.

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REFERENCES


8. Griffin, T., Light rail transit sharing the Railtrack system, Proceedings of the Institution of Civil Engineers - Transport, 2, 1996, pp. 98-103. ISSN: 0965-092X.
11. CEN (European Committee for Standardization), EN 12663-1:2010: Railway applications. Structural requirements of railway vehicle bodies. Part I: Locomotives and passenger rolling stock (and alternative method for freight wagons), CEN, Brussels, 2010