Automatic gauge changing for freight. The OGI project

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Abstract

Having different gauges on a railway network is a difficult challenge for planners and operators. There are a set of tools that can be used to minimize the connection problems at gauge frontiers. For HS, the solution has come through automatic gauge changing trains. For freight there are other solutions working now such as static wheel changing at frontier and third rail, but each has its disadvantages and there is need for enhancing the array of tools at the disposal of the infrastructure planners and decision makers at the transport ministry.

The Spanish rail authorities have decided it is time to develop an automatic gauge changing technology for freight trains, and they have put forward a program that aims at having a certified variable gauge wheelset by the end of this year. ADIF awarded the consortium formed by the Spanish companies TRIA and AZVI a contract to develop and homologate two variable gauge wheelsets for wheel diameters of 920 mm and 760 mm, that mount on Y21 bogies in the case of the 920 mm wheel and on vehicles carriages in the case of the 760 mm wheel.

At this moment, the prototype train has done 20 thousand kilometres on the HS and conventional networks of the 250 thousand required for final approval. Previously, the wheelsets have passed bench tests and the gauge changing tests.

Keywords: track gauge, automatic gauge changing mechanism, changeover facilities, rail freight transport
1. **Introduction**

The decision of constructing the main Spanish railway network to a 1668 mm track gauge continues being today one of the major challenges for the railway operation in Spain. Both freight and passenger trains find significant difficulties when it comes to operating in two different track gauges, mainly from/to the border between France and Spain.

In the case of passenger trains, automatic gauge changing trains and changeover facilities have been highly developed due to the decision taken by the Spanish Government of using the standard 1435 mm track gauge in HSR network. The need of facing the challenge of the coexistence of two different track gauges in the main passenger network (HSR lines and conventional lines) gave priority to the stakeholders to find the solution to this problem.

However, as almost the whole new HSR lines are not designed for mixed use and freight traffic, the need to solve the gauge problem has been forgotten in time for the freight trains. This brings us today to the situation that Spain has one of the lowest percentage rate of rail freight modal share\(^1\) (both inland and international freight). This lack of competiveness of rail freight transport is due, among others, to the different track gauge and the fact of not having developed variable gauge systems for freight wagons.

The Spanish infrastructure manager ADIF, being aware of the problem, published a call for tenders in 2015 to develop an automatic gauge technology for freight trains. The state of the art and future benefits of this new technology will be analysed in this paper.

2. **State of the art**

2.1 **The different track gauge and existing solutions to the problem**

It is known that the challenge of different track gauges has existed since the first constructions of railway lines. The main problem of the break of gauge is that a train cannot pass from one track gauge to another and this implies, therefore, a railway border. We can find one of the best examples between the track gauge of the Spanish conventional network (1668 mm) and the track gauge of France and most European countries (1435 mm).

Different solutions have been implemented historically to solve this problem, to eliminate these railway borders, we could list the next types of solutions that are valid for freight trains:

a. Interchange of wagon axles ad wheels, as found in Cerbère/Hendaye borders
b. Transfer of goods, helped by large cranes that transfer the containers from one wagon to another, as found in Portbou/Irun borders
c. Using tracks of three or more rails so that it exists continuity for one of the track gauges, as found in some railway sections in Spain
d. Using automatic gauge changing trains (a solution yet not very extended for freight traffic)

The two first solutions (a and b) require big areas to place the necessary tracks, factories and cranes to carry out the interchange. Apart from that, these two solutions entail an inconvenient in terms of time-consuming process.

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\(^1\) European Court of Auditors (2016). Rail freight transport in the EU: still not on the right track.
The third rail (c) implies solutions of great technical and operational complexity, that affect the existent services in the modified line and requires a complete upgrade of signalling, catenary and operational systems.

The last solution (d) is very extended in passenger trains and services but it still has not been successfully developed in freight trains. One of the main reasons why it has not already been implemented in freight trains deals with the axle load and, more accurately, with the total weight of the train.

### 2.2 The axle load and the weight of the train - different automatic variable gauge systems for passenger trains and freight trains

The existent technology of automatic gauge changing mechanism for passenger trains entails to release the weight of the wheels to allow them to adapt the new position. That means that the weight of the train is not supported by the wheels during the change operation and it is the changeover platform that support the weight of the train while it passes through the changeover facility.

The axle load of most passenger automatic variable gauge trains in Spain is about 17-18 t/axle (e.g. Talgo 250 is 18 t/axle²). Consequently, the total weigh of a passenger train that passes through a variable gauge facility is about 250-280 tonnes for a simple train and no more of 500-600 tonnes for a multiple-unit train. These variable gauge passenger train weigh is much lower than the axle load of a freight train.

Nowadays freight rolling stock is designed for the standard 22.5 t/axle. This means, in the end, 25-32% increase compared with the previous passenger example of 17-18 t/axle. This variation and the fact that a 700m freight train could carry 1500-2000 tonnes or even more, depending on the track conditions, make it difficult to extend the current variable gauge technology to the freight trains.

To develop a variable gauge technology to higher axle load and heavier trains, the first objective is to be able to adapt the wheels to the new position without releasing the weight of the train from wheels. This entails a significant difference between the actual automatic variable gauge technology - valid for passenger trains - and the automatic variable gauge technology valid for freight trains.

### 2.3 The OGI project

The OGI project that is being developed by the consortium TRIA-AZVI will mean an important step in terms of a new concept for the freight operation rail services and also in the construction and gauge adaptation of new rail lines in Spain.

This project consists on the development of two new automatic variable gauge systems for freight trains and its certification according to the European standards. Both solutions are based on the OGI technology developed in the 70’s for which has been necessary an important labour of re-engineering to adapt it to the current time.

The two new variable gauge wheelsets are being certified for two different types of freight wagons and wheel diameters: 920 mm and 760 mm. The 920 mm wheel diameter is the one that mounts the standard bogie Y21 (valid for 1435-1668 mm gauge tracks) which is similar to the European standard bogie Y25 (just valid for 1435 mm gauge tracks). This type of bogie is the most extended all around Europe. The 760 mm wheel diameter is used in wagons for transport of cars.

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2 Corporate catalogue - TALGO
In the homologation process a wagon series Sgnss (4 axle wagon, 920 mm wheel, bogie Y21, for transport of containers) and a wagon series Laaers (2 axle half wagon, 760 mm wheel, for transport of cars) have been used.

One of the keys of this OGI wheelset refers to the fact that it is easily interchangeable. This means that it does not matter the series of wagon we are interested to equip with the OGI certified wheelset 920 mm or 760 mm.

2.3.1 The homologation process of the OGI variable gauge system

The homologation process for a variable gauge system is highly regulated in the EU and it also exists in Spain a great experience in the national variable gauge regulation due to its different 1668 mm track gauge.

The legislation followed in the OGI project has been the Spanish ETH (“Especificación Técnica de Material Rodante Ferroviario: vagones”). The certification plan was in accordance with ETH and not with TSI because “variable gauge system” was an open point at the moment the homologation process started.

The process to homologate a variable gauge system consists mainly on:

- The design review.

In the design review are analysed the functionality of the system including calculations of the components according to the EU standards (e.g. wheels or axles), the locking mechanism, the thermal effect of braking on the variable-gauge systems, the maintenance plan and the study of functional reliability RAMS.

- Laboratory tests - fatigue tests to validate the locking system.

The laboratory tests have consisted on the determination of the fatigue strength of a variablegauge running gear. In our case, the bench consisted on a rotational bending test where they were applied dynamic and static forces at a speed of 50km/h. The 10 million of cycles where divided in 3 stages, in accordance with the next table:

| Table 1. Phases, cycles and forces of the variable gauge system laboratory test |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Phase | Number of cycles | Vertical force [kN] | Transverse force [kN] |
|       |                 | Static | Dynamic | Static | Dynamic | Static | Dynamic |
| I     | 6·10^6          | P      | ± 0,5 P at 4 Hz | 0      | ± 0,3 P at 2 Hz |
| II    | 2·10^6          | P      | ± 0,6 P at 4 Hz | 0      | ± 0,36 P at 2 Hz |
| III   | 2·10^6          | P      | ± 0,7 P at 4 Hz | 0      | ± 0,42 P at 2 Hz |

* Prepresents the static axle load corresponding to the maximum payload
* Frequencies reflected is for a 50 km/h speed.
• On-track tests

It is mandatory to test at least four different variable gauge wheelsets for the on-track and inservice tests which means that two-axle wagons are not admitted. In the OGI project, as we have seen before, a bogie Y-21 Sgns wagon series was equipped with four 920 mm wheelsets and a Laaers wagon series (composed by two half-wagons) was equipped with four 760 mm wheelsets.

On-track tests consisted in 500 automatic gauge changeover processes run without inspection at the nominal passage speed and under the intended operational conditions. In the end of these tests the locking system had to be checked in terms of back-to-back dimensions, forces during automatic gauge changeover process and measurements of wear of components. These tests are called “on-track” tests in the ETH regulation. Once these “on-track” tests were successfully finished, “in-service” tests were allowed to be performed.

• In-service tests to validate the system in operational and real conditions

In-service tests may cover the following distances in three different phases:

- Phase I: 50,000 km in 1668 mm or in 1435 mm track gauge. No automatic gauge changeover processes are allowed in this phase.
- Phase II: 50,000 km in both 1435 mm and 1668 mm track gauges (at least a 20% of this distance may be covered in any of the track gauges). In this phase 50 automatic gauge changeover processes will be performed.
- Phase III: 150,000 km in both 1435 mm and 1668 mm track gauges (not less than 25% of this distance will be covered in any of the track gauges).

If results of phase III are positive, the technical approval will be extended to the variable gauge system. However, it exists a phase IV of 400,000 km or 4 years have passed since the start of in-service tests. By the end of this phase IV, the technical approval of the system may be extended without any limitations.

2.3.2 The OGI changeover facility

The changeover facility consists of a platform whose components may be classified in three different groups:

<table>
<thead>
<tr>
<th>Group</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundations</td>
<td>• Structural concrete</td>
</tr>
<tr>
<td></td>
<td>• Steel anchor plates</td>
</tr>
<tr>
<td></td>
<td>• Plastic pods (for rail screws)</td>
</tr>
<tr>
<td>Track and guided components</td>
<td>• Base plates</td>
</tr>
<tr>
<td></td>
<td>• Rails</td>
</tr>
<tr>
<td></td>
<td>• Check-rails</td>
</tr>
<tr>
<td></td>
<td>• Check-rails bearings</td>
</tr>
<tr>
<td>Unlocking system</td>
<td>• Unlocking central bearings</td>
</tr>
</tbody>
</table>
The total length of the OGI changeover facility is about 33 metres. The reason why it is required such a large length deals with the automatic gauge changeover operation. In passenger variable gauge trains the length of the platform changeover facility is usually between 14-15 meters because the changeover process is done in just one step for both right and left wheels. Wheels change simultaneously to its new position and new track gauge.

In the case of the OGI operation changeover facility, the process is carried out in two steps. The first step is the changeover operation of one wheel of the wheelset and the second step is the changeover operation of the other wheel that belongs to the same wheelset. Due to this operation, the exerted axial forces to the axle is minimized, what brings more stability to the process.

3. Experimental analysis

3.1 European Rail freight Corridors - the problem of the different track gauge in Spain

Regulation (EU) 913/2010, adopted by the European Parliament and the Council of Europe, enacted the “establishment of international rail corridors for a European rail network for competitive freight, with the overall purpose of increasing international rail freight attractiveness and efficiency”.

A list of 9 corridors are included in the Regulation, and Spain has 2 Core Network Corridors established by the Trans-European transport Networks (TEN-T): the Mediterranean Corridor (nº6) and the Atlantic Corridor (nº4).

One of the main challenges of both Corridors are the different track gauges between all the European countries integrated in the Corridors that feature the 1435 mm standard UIC gauge, and Spain, where coexist the 1435 mm track gauge (used on high-speed lines) and the 1668 mm iberian gauge used on the conventional main network (freight transport lines).

As reflects the Implementation Plan of the Mediterranean Corridor RFC 6, “the lack of standard gauge in most of the Spanish sections of RFC6, prevents from dispatching international direct rail freight trains, and forces to car load changing manoeuvres, which penalizes rail transportation”.

Several projects have been proposed in order to provide the standard gauge to Spain to the conventional lines. Projects such as the third rail and establishing new standard UIC gauge lines try to solve the different gauge issue. In this sense, the global projects of “The implementation of the standard track gauge between Castellbisball (Barcelona) and Almeria” and the “Bobadilla - Villaverde Bajo - Implementation of UIC track gauge” are the greatest challenges faced by the Spanish infrastructure manager ADIF and the Transport Ministry to achieve this purpose.

3.2 The intended purpose of having a freight automatic variable gauge system

3.2.1 Track gauge migration in railway networks

In Spain, the migration to the standard UIC gauge 1435 mm is a priority for the core European network. The final report of the study on the Mediterranean TEN-T corridor reflects that the rail share of the freight flows in the corridor’s market today is about 14,6% and that implementing the Corridor, the rail share will grow from 14,6% to a 27,1% by 2030. This shows the strong potential for international rail traffic development on the Mediterranean Corridor.

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3 RFC 6 - Mediterranean Corridor Implementation Plan TT 2015/2016
4 Mediterranean Core Network Corridor Study. EU. Dec 2014
especially in Spain. Furthermore, it is said in the report that “implementing the Corridor could potentially shift about 33-41 million tons per year from road to rail (about 2,3-3 million trucks/equivalent)”. The variable gauge system will permit the gradual adoption of the standard 1435 mm gauge in conventional lines in Spain. The idea to extend the standard gauge to the conventional lines requires a transition between the actual 1668 mm track gauge and de final 1435 mm track gauge. To achieve this objective it is necessary to implement the automatic variable gauge technology both in passenger trains and in freight trains to avoid services to be affected during the implementation.

This forecast data for different scenarios of the Rail Freight Corridor implementation means that disposing the standard UIC gauge in Spain will permit to promote freight traffic from/to Europe and that OGI project is one of the keys to achieve this objective.

### 3.2.2 Interoperability

Having a variable gauge system for freight trains will also promote the interoperability of rail networks of different track gauges in Europe. The European railway network is integrated by the different national networks with different track gauges. We find the most important breaks of gauge in the 1668-1435 mm track gauge border and the 1435-1520 mm track gauge border. The freight automatic variable gauge system will permit to improve the conditions for the transport of goods by rail between the different track gauge national networks in Europe. Furthermore, as the track gauge problem is not only found in Europe, this new interoperable system could also be implemented in other border sections such as the China-Russia border for freight trains from Europe to China. The new trans-Eurasian rail freight services are growing very fast in the latest years and several break of gauge are found in their routes. A variable gauge system, such as the OGI system, will permit to reduce the transit time in the border sections.

### 3.2.3 New rail network planning tool

The development of this R&D project will provide the infrastructure planners and decision makers a new tool for the railroad and service planning.

The new freight automatic variable gauge system in Spain would permit, as an example, that freight trains run in both the conventional 1668 mm track gauge network and the 1435 mm HS track gauge network. This would mean a new concept of rail freight traffic in Spain and a good opportunity to develop a new mode of transport where freight trains could benefit from the existent HS network.

### 3.3 Examples of the possible OGI system implementation in Spain and long-term impacts

In this section, two possible scenarios will be analyzed where freight variable gauge system services could be implemented in Spain and its long-term impacts: the Mediterranean Corridor in the Vandellós-Castellon section and the Pajares Pass.

#### 3.3.1 Example 1: The Mediterranean Corridor in the Vandellós-Castellón section

In the current year 2017, the Ministry of Public Works and Transport has decided that the Castellón - Vandellós section will be migrated to the standard gauge⁵. This decision implies a big effort between the operators (Renfe and the private companies) in terms of adaptation.

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⁵ Ministerio de Fomento press release (02/06/2017)
of its current rolling stock material, along with the rail infrastructure manager ADIF and its implementation plan.

The most important issues during and after the implementation of the Castellon-Vandellós section in standard 1435 mm uic gauge are:

a. The continuity for the long-distance passenger rail services in standard gauge
b. The continuity for the medium-distance and regional passenger rail services in standard gauge
c. The continuity for freight rail services in standard gauge

Due to the non liberalisation of the rail passenger market in Spain, both a) and b) issues may be tackled by the incumbent operator Renfe. On the other hand, as rail freight services are liberated from 2007, it is not an easy task to solve the third issue c) as many stakeholders are now involved.

Furthermore, the continuity for the passenger long-distance trains is also assured at a significant proportion. This is because most long-distance Renfe services in the Barcelona-Valencia corridor are already provided by automatic variable gauge trains. However, regional services and freight services may be analysed more carefully.

In the next Table 3 the operational services are presented in the Castellón-Vandellos section.

<table>
<thead>
<tr>
<th>N.</th>
<th>Section</th>
<th>Daily Medium/long-distance passenger services</th>
<th>Daily freight trains from Monday to Friday (average)</th>
<th>Daily Long-distance passenger services</th>
<th>Total services/day</th>
<th>km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Vandellós - L’Aldea/Amposta/Tortosa</td>
<td>32 (16/direction)</td>
<td>12 (6/direction)</td>
<td>28 (14/direction)</td>
<td>72 (36/direction)</td>
<td>37</td>
</tr>
<tr>
<td>1.2</td>
<td>L’Aldea/Amposta/Tortosa - Castellón</td>
<td>8 (4/direction)</td>
<td>12 (6/direction)</td>
<td>28 (14/direction)</td>
<td>48 (24/direction)</td>
<td>116</td>
</tr>
</tbody>
</table>

As we have said before, long-distance passenger services are already provided by automatic variable gauge trains (both Renfe series 130 and 121). Thus, there would not be impediments to give continuity to the 28 long-distance services showed in Table 4.

In reference to the medium-distance/regional passenger services we find two subsections with large differences in terms of the total amount of services. On the one hand, in the Vandellós-Tortosa we find 32 regional services; on the other hand, in the Tortosa-Castellón we just find 8 regional and medium-distance services. It exists such a difference of services between these subsections because Tortosa is the last stop of the medium-distance R16 line which connects Barcelona and Tortosa. In these two cases, a migration in the existent rolling stock material will be mandatory to allow services in standard track gauge. It is noteworthy to say that it already exists some Renfe series such as the S449 that already has the standard gauge “preinstalled” in the coach.
For these S449 trains the adaptation to the new 1435 mm track gauge will be easier and cost-effective.

To achieve the continuity of the 12 daily freight services in the standard gauge scenario and/or during the implementation plan, there is a need for an automatic variable gauge freight system, that is to say, the OGI project.

The OGI system will permit the migration from the 1668 mm track gauge to standard 1435 mm track gauge by implementing the variable gauge technology in those wagons that run in the rail section that is being migrated from one gauge to another. Moreover, changeover facilities should be installed in the borders of the section that is being migrated, so that traffic could be running during the migration process.

This variable gauge system permits to replace in wagons the fixed wheelset for the OGI variable gauge wheelset without much difficulties. Thanks for this “interchangeable” feature, the issue of finding different typology and series of wagon running in the Castellon - Vandellós section (or any other) is almost solved.

3.3.2 Example 2: The Pajares bypass section

The project of the new Madrid-León-Asturias mixed traffic high-speed line includes the construction of a new bypass in the Pajares Pass in the section León - Asturias, between La Robla (León) and Pola de Lena (Asturias).

This bypass aims to eliminate the main bottleneck in railway communications between Asturias and the rest of Spain (except the communities of Cantabria and País Vasco). Nearly 2/3 of all the railway freight traffic from/to Asturias run through the current Pajares line with strong limitations to capacity due to the existing 83km single track, the curves with low values of radius and the steep gradients.

The new 49.7 km bypass (30 km less distance than the actual track) includes two single 25-km tunnels that will permit to reduce the transit time, and consequently increase the frequency of both freight and passenger trains.

By adopting the standard track gauge in this section, the same issues would be found in relation with the continuity of the actual traffics, as we have seen in the previous Castellón - Vandellós example:

a. The continuity for the actual long-distance passenger rail services in standard gauge
b. The continuity for the actual medium-distance and regional passenger rail services in standard gauge
c. The continuity for the actual freight rail services in standard gauge

The following table shows the actual railway services in the section Oviedo-León:
Table 5. Operational services in the Oviedo - Leon section.

Source: Adif (freight operations), Renfe (passenger operations)

<table>
<thead>
<tr>
<th>N.</th>
<th>Section</th>
<th>Daily Mediumdistance/ regional passenger services</th>
<th>Daily freight trains from Monday to Friday (average)</th>
<th>Daily Longdistance passenger services</th>
<th>Total services/day</th>
<th>km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Oviedo - Pola de Lena</td>
<td>76 (38/direction)</td>
<td>42 (21/direction)</td>
<td>8 (4/direction)</td>
<td>126 (63/direction)</td>
<td>31</td>
</tr>
<tr>
<td>1.2</td>
<td>Pola de Lena - Puente Los Fierros</td>
<td>22 (11/direction)</td>
<td>42 (21/direction)</td>
<td>8 (4/direction)</td>
<td>72 (36/direction)</td>
<td>12</td>
</tr>
<tr>
<td>1.3</td>
<td>Puente Los Fierros - La Robla</td>
<td>8 (4/direction)</td>
<td>42 (21/direction)</td>
<td>8 (4/direction)</td>
<td>58 (29/direction)</td>
<td>71</td>
</tr>
<tr>
<td>1.4</td>
<td>La Robla - León</td>
<td>4 (2/direction)</td>
<td>42 (21/direction)</td>
<td>8 (4/direction)</td>
<td>54 (27/direction)</td>
<td>26</td>
</tr>
</tbody>
</table>

Total length 140

The three issues could be solved in the same way that in the Castellón-Vandellós section. The actual long-distance passenger services run under automatic variable gauge systems. Therefore, the first a) issue may be easily solved by constructing a new changeover facility in the end of the new 1435 mm track gauge section.

In the case of the medium-distance and regional passenger rail services we find the main challenge between Oviedo and Pola de Lena and also between Pola de Lena and Puente Los Fierros. These regional services and freight services may be analysed carefully.

For freight services, considering that freight traffic moves from its current running section through Pajares Pass to the new double-tunnel track section in 1435 mm track gauge, the new tool of the automatic variable gauge system would permit to give continuity to these trains.

4. Conclusions

The main conclusions that can be drawn from this paper are listed below:

- To solve the existent connection problems due to the different track gauge in Spain, there is a need to have an automatic gauge changing technology to be implemented in freight wagons. This solution already exists in passenger trains, but it is of the utmost importance to develop it in freight trains.

- An automatic variable gauge system, such as the OGI system, will permit to increase in Spain the percentage of rail freight services from/to Europe. This will entail a change in the modal share to the rail mode, in the search of more sustainable mobility and transport.

- The new automatic variable freight system R&D project will provide the infrastructure planners and decision makers a new tool for the railroad planning. This new tool would permit to enhance the interoperability between different track gauge networks.
5. References

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6. Acknowledgements

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