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Maintenance. From asset management to direct cost calculation. A key issue for the future of the HS Railways System.

Jiménez, Pablo Lorenzo
Zamorano, Clara Isabel
Escobar, Adrián
Escobar, Jorge

European University Madrid[1]
Technical University of Madrid

Abstract

The separation between infrastructure managers and transport operations is one of the basic principles of European railway regulations. The relationship between railway undertakings and infrastructure managers is based, among other considerations, on the payment of a charge for the use of the infrastructure.

The recast of the first railway package (Directive 2012/34/EU) states that "the charges for the minimum access package and for access to infrastructure connecting service facilities shall be set at the cost that is directly incurred as a result of operating the train service" (Article 31.3). This is what is known as the direct cost principle, whereby the infrastructure manager will apply a charge so that, if an additional train passes, the charge paid by the latter will allow no losses to occur. The current formulation of the charge is based on different parameters, among which are the number of trains-km, speeds or train types.

To enable the establishment of these charges, infrastructure managers need to have a comprehensive understanding of all the elements that determine the cost of operating the infrastructure. Amongst them, maintenance costs caused by normal operation of train services might be considered.

The purpose of this presentation is to discuss a model that could be used to improve the implementation of the direct cost principle, in terms of maintenance costs. Firstly, the formulation of the fees is analysed, using the Spanish case as an example. A brief overview of railway maintenance and asset management is given below. Different studies are then considered on the relationship between tear and wear, as well as the costs of railway maintenance. Finally, a proposal is made for a new methodology.

Keywords: Directive Recast, Infrastructure charges, direct costs, asset management, maintenance

1 *Jiménez, Pablo Lorenzo. Civil Engineering Department European University Madrid. (corresponding author). Email: pablolorenzo.jimenez@universidadeuropea.es.*
Zamorano, Clara Isabel. Technical University of Madrid. Email: clara.zamorano@upm.es
Escobar, Adrián. Technical University of Madrid. Email: adrian.escobar.pastor@alumnos.upm.es

1. Introduction

Since the beginning of the 1990s, European railway legislation has sought to revitalize the sector by separating the functions of provision of transport services and infrastructure management. An essential aspect of this separation is to correctly regulate the relations between the two functions, ensuring equitable and non-discriminatory access for undertakings wishing to provide their services on railway infrastructure. Access to the infrastructure and services of the infrastructure manager must be paid by the levying of charges.

The regulation of these charges is a very important aspect of European railway legislation. Section 2 of Chapter IV of Directive 2012/34/EU (Recast) deals with fees and the principles to be followed in setting, applying and charging them. One of these principles, set in article 31.3, states that *"the charges for the minimum access package and for access to infrastructure connecting service facilities shall be set at the cost that is directly incurred as a result of operating the train service"*

The determination of the direct costs is a difficult aspect, since it is a matter of discerning which part of the costs incurred by the administrator in his activity is reportable to each circulation. One of the main costs is due to the maintenance of infrastructure, which is one of the fundamental functions of the managers, as set out in Article 7 of Directive 2012/34 / EU, as amended by Directive 2016 / 2370.

The Rail Sector Law (Law 38/2015) reflects the Recast Directive, and in fact, the PITVI 2012-2024 establishes three major action programs. One of them is the regulation, control and supervision program. Within this, one of the points is the modification of the system of charges, as a consequence of the application of the Recast, explicitly stating that *"for the Conventional network, the charge per use will be equivalent to the directly attributable cost to the operation of the rail service, and for the High-Speed network, whose objective will be the recovery of costs, the charge will include surcharges based on principles of efficiency, transparency and nondiscrimination"*.

This task is fundamental for the rail system. The rail system, in search of greater speeds in the transport of passengers, and of greater loads in the transport of goods, needs a high level of maintenance, to achieve a high-quality infrastructure. Therefore, for a correct pricing of the charges, it is essential to allocate to each circulation the cost that it entails within the maintenance.

The purpose of this paper is to analyse the methodology of direct costs, and how it can be used for the costs stemming from maintaining the railway infrastructure, and, more specifically, the platform and track. For this, first, we analyse the charges and fees, and the methodology of direct costs. Next, we deal with rail maintenance. Subsequently, the existing methodologies for the determination of the direct costs of railway maintenance are analysed. Finally, a proposal is made to improve these methodologies, based on the condition data of the different lines.

2. Charges and european directives. Direct costs

2.1 Concept of charges

Charges constitute an important part of the income of railway infrastructure managers. They cover the operating costs of the infrastructure manager, and, therefore, a high part of the price paid by the passenger for his ticket is intended for the levying of charges (Fernández Arévalo, 2013). Thus, charges are an important variable for the economic balance of the system.

Directive 1991/440 marked a milestone for European railways, changing totally their management. The main idea is the separation of the activities of infrastructure management and provision of transport services. The access rights to railway infrastructure must be granted in a uniform and non-discriminatory manner. The payment for this access shall be done with charges; the determination of these is further developed later different normative texts, among which the following can be found:

- Council Directive 95/19 / EC of 19 June 1995 on the allocation of railway infrastructure capacity and the charging of infrastructure fees
- Directive 2001/14/EC of the European Parliament and of the Council of 26 February 2001 on the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification.

In Spain, its development is done through the Rail Sector Law. The first law of such name, Law

39/2003, includes the concept of infrastructure charges in section IV of title V. Subsequently, in Law 38/2015 (second Rail Sector Law), the structure of the charges is modified, contemplating the payment of a charge for use of the railway lines, called Mode B. This charge is divided into two parts: a taxable base, to be determined by the infrastructure manager, and an additional, to be determined in the Law of General State Budgets[1]. Each year, the Network Statement, published by the Infrastructure Manager, sets out the general rules, deadlines, procedures and criteria that will govern the fees.

As indicated in the previous section, the European Union sets the principles to be followed by national regulations. A basic principle is that the infrastructure manager may only include in the calculation those costs for which it can objectively and rigorously demonstrate that they derive directly from the operation of the different services. This means that elements whose wear does not vary because of traffic, such as wear of track signs or interlockings, should not be included in the charge.

This is known as the principle of direct costs, whereby the infrastructure manager will use a charge so that, if an additional train passes, the amount paid will cause no loss in the system. The formulation currently used for the charges is based on different parameters, among which is the number of trains · km, speeds or types of train.

The Commission Implementing Regulation (EU) 2015/909 of 12 June 2015 for the calculation of the cost that is directly incurred of the cost that is directly incurred as a result of operating the train service sets out a number of ideas for infrastructure managers, or bodies responsible for the determination of charges, so they can calculate these direct costs, and thus determine which parameters should be used.

It should be noted that, according to Fernández Arévalo (2013), railway infrastructure is characterized by very low marginal costs, which means that a very low percentage of the total costs can be recovered with infrastructure charges. As Fernández Arévalo states, this can result in a lack of incentives for investment in new infrastructures to address capacity problems, as this would contribute to increase the manager's deficit. However, raising the charge above average costs can result in the expulsion of operators with lower market resources, reducing competition.

1 Law 3/2017, of June 27, of General State Budgets for the year 2017, which includes these aspects in articles 71 and 72.

2.2 Charges in Spain

The charges' structure currently used in Spain can be seen in the Network Statement 2017, last published by Adif and Adif AV. The charges are applied for the use of the lines, as well as the services rendered on them. Currently, there are the following modalities of rail charges and fees (Network Statement, 2017):

- Fees:
  - Safety Fee in Passenger Transport
  - Other Fees: to provide the necessary services for the granting of approvals, certifications, to issue titles to railway staff and grant Licenses or Safety Certificates

- Rail Tariffs:
  - Tariffs for using railway lines:
    - Access tariff: tariff for the intended use of the RFIG[2]. It depends on the type of line, and the estimated traffic volume, measured in km / trainyear.
    - Tariff for reserving capacity: levies the availability of the route requested. It depends on the time period, the type of line, and the type of service / train. It is measured in € / Train-km booked.
    - Tariff for running: it is similar to the previous one, but it governs effective use of the reserved capacity. It is measured in € / km-circled.
    - Traffic tariff: levy for the traffic produced on rail infrastructure. It is measured in € / 100 seats-km.
  - Tariffs for the use of stations and other railway facilities:
    - Tariff for using stations: it is applied to passengers using the rail transport service, depending on the distance covered and the station category in which the journey begins or ends. It is measured in € / passenger.
    - Tariffs for stabling and using platforms at stations: this tariff is calculated considering the period of train stabling, track change operations performed upon request of the operator and the category of the station. It is measured in € / Train.
    - Tariffs for passing through gauge changers: it is applied at every passing of a train by a gauge changer. It is measured in €/Train.
    - Tariffs for using sidings: they are set according to the type of lines at the station where used siding track belongs, to track occupancy time and type of service/ train. It is measured in € / Train.
    - Tariffs for providing services that require authorization to use public rail system: it is determined according to the area occupied. It is measured in € / m^2- month

It should be noted that the railway charges cited in the Network Statement correspond to the concepts form Law 39/2003 (previous Rail Sector Law), and have not been developed in accordance with Law 38/2015 (current Rail Sector Law). However, in the preamble of Law 38/2015, it is stated the new structure of the charges is simpler, and it is intended to stimulate the traffic better than the previous one. The charges for access are abolished,

2 *RFIG: Rail Network of General Interest. A definition can be found at Adif's Network Statement.*

as they constituted a barrier to the entry of new operators to the market. Besides, new criteria for the classification of lines are implemented

The tariff structure for the use of facilities is also modified. The classification criteria for passenger transport stations are modified and expanded to take into account the economic capacity of associated services to determine the amount of the fee.

As a conclusion, neither in the current structure of charges, nor in the one to come, costs stemming from infrastructure maintenance are directly considered. In the current structure, the tariff for running would cover maintenance costs, as well as other variable costs due to the passage of trains.

3. Rail maintenance and asset management

3.1 Main railway maintenance activities

Spanish national standard UNE-EN 13306: 2011 defines maintenance as *"the combination of all technical, administrative and management actions during the life cycle of an element, intended to preserve or return it to a state in which it can perform the function required"* (UNE-EN 13306:2011).

In any element, we can distinguish two main types of maintenance, according to the occurrence of failures: preventive maintenance, when maintenance aims to avoid failure, and corrective maintenance, which is done when the failure has already occurred. The standard defines them as follows:

- Preventive maintenance: *"maintenance that is performed at predetermined intervals or according to established criteria, and is intended to reduce the probability of failure or degradation of the functioning of an element"*.
- Corrective maintenance: *"maintenance that is performed after the recognition of a fault and that is destined to put an element in a state in which it can perform a required function"*. That is to say, it is the one destined to correct or to repair the defects already produced, with potential harm to the service.

Preventive maintenance operations aim to minimize the likelihood of a failure in the elements, due to operating risks, and the higher cost that corrective maintenance entails. Within preventive maintenance, we can distinguish predetermined maintenance, which is performed according to established time intervals or operating units, and condition based maintenance, where the condition of the element is monitored or inspected to determine the actions to be undertaken.

In railway infrastructure, the different elements that integrate it have different associated maintenance methodologies. In the track, preventive maintenance operations that are carried out are based on the previous knowledge of the state of the elements, and, therefore, it is mainly a condition based maintenance.

To determine the state of the track, different systems are used. The status of track elements can be checked, or geometric quality of the track can be analysed. For this purpose, different types of inspections can be used: walking tours on the infrastructure, cabin rides with specialized staff, or train measurements, where we can distinguish several types: geometric, dynamic, ultrasonic for the condition of the rails, etc.

The geometric quality of the track measures the deviations between the theoretical track and the real track with a series of parameters. The definition of these parameters, and the

methodology for measuring them, is defined in the standard UNE-EN 13.848.

The parameters used to determine the geometric quality of the track are the following: gauge irregularities, longitudinal and cross level irregularities, alignment irregularities and twist irregularities.

3.2 Asset Management

A basic tool for managing railway infrastructures is the asset management policy they follow. Efficient management results in an increase in the life cycle of the different elements, besides of a reduction in the costs associated with that life cycle. This type of management should foresee maintenance needs, to cover them before they limit circulation or pose any risk. Therefore, in order to optimize maintenance, it is necessary to have tools that allow to anticipate the needs.

In 2010, the UIC issued a guideline document for the application of asset management policies (available in Adif, 2011). This document explains briefly the steps to follow for the implementation of the system. Some aspects to watch are the definition of an asset strategy, and the data that will feed it, which is the asset information. The basic data that should be available for each asset include the following:

- Instalation date
- State
- Failure history and performance / security impact
- Maintenance and renewal history and plans
- Maintenance and renovation unit costs

These data are introduced in LCC (Life Cycle Cost) tools, which aim to optimize maintenance and renewal decisions, providing a forecast of all activities to be carried out annually.

3.3 Maintenance costs

The costs associated to the maintenance are necessary to feed the LCC tools. Obviously, knowing these costs correctly will allow us to fine-tune the optimization process and obtain a correct forecast.

On the subject of costs, it is worth noting that more than 50% of the maintenance costs due to traffic are allocated to track, according to Larsson & Gunnarsson (2001), in their analysis of the Swedish network.

It is clear that an improvement in the procedures followed in maintenance, seeking a better knowledge of the infrastructure, and the prognosis of the problems that will occur, should result in a saving in the costs incurred, and therefore in the canons passed. This is in line with Article 30.1 of Directive 2012/34/EU, which states that "managers shall be encouraged to reduce the costs of making infrastructure available and the amount of access".

4. Methodologies for estimating direct costs

The levying of charges and the principle of direct costs have led to a need for research in order to develop a methodology to calculate these direct costs, for each type of traffic.

4.1 Previous experiences

Before presenting these methods, let's take a brief look at the development of this problem. The first country to establish a separation between operation and infrastructure management was Sweden in 1988, when it separated its former state railway authority into two parts:

Statens Järnvägar (service operation), and Banverket (infrastructure management)[3]. For this reason, it is not surprising that the first investigation in this field was made in that country. Subsequently, the number of studies has expanded, covering other networks, such as Wheat and Smith (2008) for the English network. All approaches until 2015 follow the so-called econometric model; in 2015, Smith et al. present a model in which the damage caused in the infrastructure by different types of vehicles is analysed.

4.2 Methodologies

In order to assess correctly the amount of the fee, it is necessary to develop a methodology to determine what expenses are incurred. The problem is therefore to establish a link between the damage generated by a train, and the cost this entails for infrastructure. For this, we can use different models, for which we will need to have a series of inputs that can come from different types of analysis.

Wheat and Smith (2008) identify three different methodologies for determining directly incurred costs: top-down approach, bottom-up approach, and cost allocation method. These methodologies are explained in the following sections.

4.2.1 Econometric approach

The econometric approach, also called "top-down", is the determination of a global cost function for the maintenance of infrastructure. In this perspective, the concept of direct costs corresponds to the marginal cost, that is to say, to the increase of cost that is produced in the maintenance when one train runs over it. To obtain this, a global cost function must be established, which is done by statistical methods. Once this function is generated, the average cost of maintenance caused by the passage of a train can be approximated as the marginal cost, which is equivalent to that derived from the cost with respect to the number of trains running. This method has been the most used to the date.

4.2.2 Engineering approach

The engineering approach, also called "bottom-up", is based on the application of any method that allows to determine the concrete damages caused by a train and the subsequent maintenance needs. By valuing the cost of these, the cost to pay for each circulation can be calculated.

Different types of trains will produce different types of wear on the infrastructure. For example, the damage caused by a high-speed train will not be the same as by a freight train with a high axle load. Therefore, in this approach, the damages produced by each type of train are determined.

3 Subsequently, there have been more changes in the organization of the Swedish railways. Statens Järnvägar has been separated into seven companies, of which four have been sold. The provision of passenger services (SJ AB) and goods (Green Cargo) remains public. In terms of infrastructure management, the inspection functions (Järnvägsstyrelsen) have been separated from those of administration, which in turn has merged with the Trafikverket. The maintenance of the infrastructure is the responsibility of a subsidiary company, Infranord.

Within their analyses, Smith et al. (2016), and Smith et al. (2017) use these methods to determine the damage produced by each type of train traveling through the study sections.

4.2.3 Cost allocation

The cost allocation method can be defined as a hybrid between both methods (Nielsen et al., 2016). Smith et al. (2016), and Smith et al. (2017) employ hybrid methods, with both economics and engineering analysis. These studies start from the idea that it is difficult to implement methods that, by means of a single step, econometric or engineer, is useful to determine the correspondence between costs and damages. For this reason, it is necessary to use methods with both econometric and engineering approaches.

It should be noted that, in these methods, the amount paid for maintenance in previous years, is considered to be produced by the different sources of damages. This has a problem, as it implicitly assumes the hypothesis that it covers the maintenance needs of the period. It is normal that, in situations of budget shortages, a certain maintenance deficit is generated, which in turn causes losses of the patrimonial value of the infrastructures.

5. Proposal for a new methodology

As it has been stated the models developed for the moment may have an econometric approach, an engineering approach, or a combination of both. The general idea from this methodology proposal is that it would be advisable to integrate asset management systems with charges calculation. This proposal, based on asset management systems, could be classified as a mixed proposal, as seen in the previous section, as it encompasses an engineering and economics approach.

Beginning with an initial estimate of maintenance costs based on the experience of infrastructure managers, the continuous use of these systems over several years would allow these costs to be fine-tuned until a good correlation between the forecast and the actual cost incurred is found.

To do this, the data of train measurements and asset management systems would be used to determine the condition of the track and the maintenance needs generated between two successive passes of the measurement trains. The steps would be:

1. The measurement data would allow to evaluate the damages that have occurred between t two successive passes. To do this, the asset management strategy should define what would be the minimum frequency of passing for the measurement trains.

2. The asset management system uses these data, and cross-matches them with data on expected traffic, age of elements, etc., to generate an estimate of the annual maintenance costs, as well as the replacement rates. Here, it is important to consider that we must separate the costs associated with the elements that present a wear and tear on the traffic (susceptible, therefore, of a direct cost), of those that do not have wear associated with traffic directly.

3. A fundamental aspect is to make a division of the infrastructure in homogeneous sections depending on its characteristics and traffic, to obtain comparable data

that can be extrapolated. The analyses to separate the sections by homogeneous types must consider the following parameters: type of infrastructure, type of track weaponry, climatology, layout in plan and elevation, etc.

These data would be cross-matched with data of traffic to obtain an estimation of costs by train and characteristics of the same in each specific section, producing a system of equations with as many equations as sections, and as many unknowns as types of trains, and characteristics of traffic. This would be easier in High Speed tracks, as the rolling stock would be more homogeneous.

From our point of view, this method would present the following advantages:

1. Starting from actual damage to the track, not from simulations, whose results would need to be calibrated.

2. With many track sections, a good amount of different cases would be available.

3. For different levels of track quality, the accumulated damages can be assessed, making possible to extrapolate in other cases with a different initial quality of the track.

4. It would be possible to calculate the real cost per type of train for each section of track.

5. This methodology, consisting of integrating the cost model with the asset management model, has the challenge of gathering data from both the financial department and the asset management department.

6. Conclusions

The integration of European Directives leads infrastructure managers to the use of the methodology of direct costs for the assessment of charges. One of the main costs incurred by railway infrastructure managers is maintenance and part of it is directly attributable to railway operation. Therefore, it must be reflected in the calculation of the tariffs. However, the cost of maintenance resulting from the passage of a train is not easily assessed. Therefore, different approaches have been developed, such as the econometric one, where a generalized cost function is determined to obtain the marginal cost, or the engineering approach, based on dynamic simulations, in which a correspondence is made between the behaviour of the trains and the damages produced on the track.

It should be noted that the methodology of direct costs has several limitations:

- Tracks with lesser quality, and thus, with grater maintenance needs, will have higher marginal costs. However, the major maintenance needs may be due to non-trafficdependent factors:
    - By the presence of worse layouts, with more curves and steeper slopes.
    - Greater deterioration of elements. The higher the wear, the higher the wear rate, and the higher maintenance requirements. Tracks in worse state are likely to cause greater damage to trains, due to the presence of defects which

influence the dynamic behaviour of trains, and therefore, on their elements, such as wheels (producing, for example, flat wheels). Thus, tracks in worse condition, which are going to cause greater damage on the trains, would have higher charges, which is a contradiction.

- The wear of the elements is considered completely attributable to the passage of trains, and does not consider the influence of time.

In this paper, an idea of a methodological proposal for the calculation of infrastructure maintenance direct costs has been posed, based on the use of asset management tools. This proposal, correctly calibrated, would allow a realistic approximation to the costs directly incurred by the passage of a train.

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