Transport
An approach to mark-ups through capacity charges
Calvo and de Oña

ice | proceedings

Proceedings of the Institution of Civil Engineers

http://dx.doi.org/10.1680/tran.11.00050
Paper 1100050
Received 15/09/2011 Accepted 24/01/2012
Keywords: mathematical modelling/railway systems/transport planning

ice
Institution of Civil Engineers
publishing

An approach to mark-ups through capacity charges

1 **Francisco Calvo** PhD
Associate Professor, TRYSE Research Group, Department of Civil Engineering, University of Granada, Granada, Spain

2 **Juan de Oña** PhD
Associate Professor, TRYSE Research Group, Department of Civil Engineering, University of Granada, Granada, Spain


1


2

Charges related to rail infrastructure capacity in the European rail network show great diversity and are not sufficiently transparent. This paper develops a simple and transparent methodology that takes the main aspects related to rail infrastructure capacity into consideration to give an approximated value of the maximum capacity charge (initial mark-up). The method can be used (as a basic calculation tool) to develop a uniform (and thus, interoperable) charging system. According to the hypothesis formulated, the result of the method's application to typical railway services was from higher to lower initial mark-up: suburban trains, intercity trains, regional trains, express freight trains, conventional freight trains. After this preliminary valuation is reached, the railway undertakings' willingness to pay and the socioeconomic aspects of transport come into play for setting the definitive mark-ups, thereby establishing the final charging level.

Notation

CF_{ij}	capacity factor for section i–j
C_{ij}^{1}	demand component for section i–j
C_{ij}^{2}	quality component for section i–j
C_{ij}^{3}	consumption component for section i–j
n	number of trains running in the i–j section, as per the time band according to the current used capacity
$n_{\max}$	maximum number of trains running according to the practical capacity of line section i–j
P_{ij}	train priority in section i–j
t	the time a train takes to travel across section i–j
$t_{\min}$	the minimum time it takes to travel across the i–j section at the maximum speed allowed and with no intermediate stops

1. Introduction

The European Commission (EC) directive 2001/14 (EC, 2001) suggests setting the charging level for using rail infrastructure somewhere between a minimum related to the cost that is directly incurred as a result of operating a train service (mainly maintenance and renewal costs) and a maximum related to the total cost for providing the infrastructure (which would also include fixed costs such as investment costs). This implies that infrastructure charges should be set somewhere between the marginal cost and the average cost associated with each train. The level of charges between the two extremes can be established by levying surcharges (normally called mark-ups) on the marginal cost.

According to the directive, mark-ups should reflect railway undertakings' willingness to pay, which would lead to market-oriented charges. Moreover, mark-ups should also improve infrastructure managers' and railway undertakings' efficiency.

In this sense, rail infrastructure capacity management and the corresponding capacity charges could be used to set mark-ups. This could be a first approach to the market because the most sought-after train-paths tend to generate the highest profits, thereby increasing railway undertakings' willingness to pay.

Aside from market factors and scarcity costs, the directive also recommends that the level of charges should take into account certain considerations, such as the rail services' features (mainly passenger or freight), public transport factors (suburban and/or regional) and how competitive rail transport is compared with other modes of transport (transport of goods in the freight transport market, in particular).

2. State of the art

2.1 Capacity management in the European rail network

In implementing the directive, scarcity costs have usually been managed by creating different types of charges, depending on the country concerned.

- *Access charges:* Access charges for network access rights are based on how long an infrastructure will be used (per year, per month). They are a fixed part of the fare in two-part charging regimes. Even so, in some countries, the price of these charges varies from one line to another, depending on traffic, the quality of the infrastructure and the type of service. Therefore, these kinds of access charges reflect scarcity costs on the one hand, and are used to raise recovery costs on higher-quality lines (upgraded lines, high-speed lines) on the other. France and Spain have these kinds of access charges (based on train path-km) somewhat related to capacity issues (Thompson, 2008).
- *Capacity charges:* These are variable charges related to the use of rail infrastructure capacity. They are additive charges in Spain (by way of the train-km parameter (ADIF, 2012)), Denmark (per train (Elm-Larsen, 2004)), France (per path-km (RFF, 2008)), Italy (per train-km (RFI, 2004)) and the United Kingdom (per train-mile (Network Rail, 2012)), and multiplicative surcharges that affect the basic charge in Germany (DB Netz, 2010) and Belgium (Infrabel, 2008). Specifically, capacity charges in France increase with a section's degree of utilisation (high, medium and low traffic) and with congestion, depending on the time of day. Lines are divided into sections and days into time periods (RFF, 2008). In Germany, too, lines are classified by categories according to their traffic levels. The basic price increases as traffic level increase and, moreover, a utilisation factor (equal to 1·20) is applied to very busy routes. Furthermore, in the train path pricing system (DB Netz, 2010) the basic charge is affected by a multiplicative surcharge that varies between 1 and 1·80 for passengers and between 1 and 1·65 for freight trains, depending on path quality. The Belgian pricing system (Infrabel, 2008) has a priority coefficient (multiplicative, affecting the unit price) that increases from 1 to 1·50 with path quality. Finally, the German and Belgian charging systems also use multiplicative surcharges to represent capacity consumption. In Belgium, multiplicative surcharges vary from 1 to 2·2 for freight trains and from 1 to 16·75 for passenger trains, depending on the discrepancy between train path and standard train path on the section of line (Infrabel, 2008). The German charging system applies a multiplicative surcharge (equal to 1·5) on slow trains to optimise capacity utilisation (DB Netz, 2010). In the Italian system, the variable part of the charge also takes inefficient use of capacity into consideration (RFI, 2004). Finally, in the United Kingdom, capacity charges vary to take into account the group of services (for franchised passenger services), the time of day (only for non-franchised passenger services), whether running is weekday or weekend and, in the case of freight services, a 10% discount that is applied to reflect their greater flexibility in pathing their services (Network Rail, 2012). Thus (and perhaps due to its franchise-based system), the UK capacity charges do not show clearly how (or even whether) issues such as priority and capacity consumption are taken into account (which could help to improve capacity utilisation), as do other charging systems like the Belgian one. In general, it can be said that capacity charges rise in value with the level of congestion (according to time band, line, and line section), infrastructure quality, type of service (passenger or freight), train speed, and quality of train path. Therefore, apart from scarcity cost considerations, operators' willingness to pay is also used to modulate the magnitude of capacity charges.
- *Station charges:* The charges for stops at stations in Spain, France, Austria and the Netherlands tend to increase with the category of the station and the length of the stop (Thompson, 2008). In the United Kingdom, the station charge depends also on the category of the station (it is even different for each station) and is used for funding capacity enhancements of the station; it is paid proportionally to the number of trains departing from the station (Network Rail, 2012). One unique case is Italy, where the charge levied is based on the time (minutes) a train stays in a node (congested areas and rail nodes (RFI, 2004)).
- *Performance-related charges:* Networks with traffic levels close to system capacity (e.g. in the United Kingdom) tend to set supplementary charges (Network Rail, 2012) for those who are responsible for delays (the railway undertaking or the infrastructure manager). Performance-related charges are generally based on how many minutes the delay lasted.
- Finally, there are penalties for failing to reserve capacity sufficiently in advance (Spain (ADIF, 2012)) and for cancellations of planned traffic (Germany (DB Netz, 2010)), which are also related to capacity management and consumption.

This reveals that the European rail network uses several very different charges (fixed, variable and penalties) and methods to process scarcity costs. This diversity does not help at all to achieve a uniform pricing system, and therefore hinders the process in terms of interoperability in the European railway network (Calvo and de Oña, 2005). Moreover, national charging systems are not transparent, and therefore it is not clear where the charges related to capacity come from. In general, it can be said that the cost increases with demand for line usage, but also with the quality of the infrastructure, path and service. All these aspects are related to a railway undertaking's willingness to pay. Capacity charges, therefore, can be used as an essential tool for setting mark-ups and modulating charging levels.

Taking into account the situation described above, this paper develops a simple and transparent methodology that takes the main aspects related to rail infrastructure capacity into consideration to give an approximated value of the maximum capacity charge (initial mark-up). The method can be used for a wide variety of railway services and traffic situations, so it can help (as a basic calculation tool) in developing a uniform charging system, and therefore contributing to interoperability in the European railway network. The proposed methodology has been developed taking into account the aforementioned starting situation and the aspects included below.

2.2 Scarcity costs and traffic management

The High Level Group on Infrastructure Charging (Expert Advisors to the High Level Group on Infrastructure Charging, 1999) defines railway line section link capacity as the maximum number of trains that can use the link, and highlights that this depends on several aspects: the number of tracks in a section (single track or a multiple track), average train speeds, geometry, signalling and traffic control systems, section lengths, and train length. The traffic mix also has a significant impact on a line's capacity. Thus, the carrying capacity diminishes when a line is used by trains travelling at very different speeds. For example, on a mixed-traffic line, freight trains will occupy sections for a longer time than passenger trains will, owing to their slower speed. The longer sections are occupied, the higher the capacity consumption will be.

Rail infrastructure capacity is limited. When the demand for infrastructure is close to its capacity threshold, congestion occurs, making the network less efficient and raising transport costs. When capacity is scarce and an additional operator uses rail infrastructure, it affects other operators in two ways.

1. Higher traffic volumes increase the risk of delays because network operation becomes more complex, the system is working at full capacity and any minor failure can collapse it. There is evidence (Turvey, 2002) that the more saturated an infrastructure is, the longer it takes for a system to revert to normal after an incident. This, in turn, makes delays longer.
2. Rail infrastructure capacity management is centralised (by way of traffic planning and traffic management). Even so, allocating a certain path to a given operator in the context of coincident demand generates an opportunity cost because it implies that the path was not allocated to any other operator, who might have generated a higher profit from it.

Therefore, although railway scarcity costs are not due to a network user's decision alone (since infrastructure managers have the final say in whether or not to allocate capacity to an operator), using a network does give rise to costs that should be included in the pricing system (delay-related costs plus the opportunity cost).

Delays may be attributed to an operator (when a train breaks down, for instance) or to an infrastructure manager (as in the case of poorly maintained assets). Penalties for delays should be levied on those who cause them. Penalties could be based on an appraisal of the delay interval, which, in general, will depend on the type of service involved (passenger, freight, and so on). If the delays occur regularly, the negative effects may be much worse, leading to a loss of railway passengers and even to suspension of trains, in which case the scarcity cost would be much higher.

Rail congestion issues are not limited to cost since they are also related to the management of the available capacity. Normally, rail infrastructure capacity allocation is based on train paths. Capacity charges (scarcity cost-related track charges) can reflect path appraisal. Therefore, paths need to be clearly defined (with prices per section and timetables) and allocated by an independent body.

Finally, higher traffic levels require a more detailed division of networks into sections and timetables for optimal capacity utilisation.

2.3 Path appraisal: opportunity cost against social opportunity cost

According to Nash *et al.* (2004), optimal capacity charges should give operators adequate incentives to increase services only in those situations where the value of the services is at least equal to the costs they create, and to ensure that the service provided is the one that has the highest value.

In more detail, the study carried out at the University of Leeds Institute for Transport Studies (Nash *et al.*, 2004) proposes basing capacity charges on the social cost. To arrive at the social cost, first the capacity used by each train must be known, and then the opportunity cost must be estimated. The authors recognise the difficulties involved in these two stages. The social cost includes the costs and revenue from the allocation and utilisation of capacity (opportunity cost), and also the global effect of the external costs on the entire transport system. The two concepts are defined as follows.

- *Opportunity cost:* A path's opportunity cost is related to the economic benefit gained from using it. Thus, higher quality paths should be allocated to the operators who can obtain the highest profits from using them (taking the internal cost of operating the service and the profits obtained into consideration), since then a higher capacity charge can be levied. This way, the line operation scheme gives managers maximum revenue.
- *Social cost:* A path's social cost is based on the benefits the wider community obtains from using it. While the appraisal method is similar to the previous one, it also takes into consideration variations in a transport system's external costs owing to the diversion of traffic from other means of transport (normally roads), which is caused by the rail service requesting the path (Nash *et al.*, 2004). Therefore, this system can be used to obtain a maximum social benefit.

2.4 Traffic planned jointly by infrastructure manager and the railway undertaking

Appraising variations in external costs involves a number of difficulties, including the appraisal of initial external costs, study of transfers of demand, and appraisal of the external costs in the planned situation. Therefore, as a preliminary approach to appraising paths, only the opportunity costs will be considered at first.

Focusing on the opportunity cost, it may appear at first glance that auctioning would be the best way to appraise paths and set capacity charges, since it gives rise to two outcomes that solve the problem (Nilsson, 2002): capacity charges (by way of payment per path) and timetables (by way of path allocation). However, the use of auctioning as the only method may be inadvisable, because it could leave out of the market rail services that are economically unprofitable but socially beneficial (for instance, suburban trains). Moreover, a new entry into the market would change price allocation, and with it path and timetable allocation, thereby introducing an element of instability in timetables and the capacity charges.

Therefore, allowing managers to plan infrastructure use seems inevitable, as a first step (Expert Advisors to the High Level Group on Infrastructure Charging, 1999). After the preliminary approach is made (consisting in a pre-timetable and capacity charge benchmarks), knowing the railway undertakings' willingness to pay would be the next most efficient way of allocating a final value (Expert Advisors to the High Level Group on Infrastructure Charging, 1999). The willingness to pay could be known by way of negotiations or an auction. Either method would be a second step towards the final planning of infrastructure operation. To summarise, the stages for mixed infrastructure manager/railway undertakings planning could be as follows.

1. First, the operators state their timetable preferences (in general terms).
2. The infrastructure manager takes them into consideration to design a preliminary line operation plan that includes sets of paths (pre-timetable) and the related capacity charges (benchmark path prices).
3. The railway undertakings make a choice of provisional paths.
4. The infrastructure manager studies the information received during the pre-planning process.
5. Finally, the two parties negotiate the final path allocation and charges. This last stage could also be achieved by way of an auction, in which case a limited number of auctions throughout the year should be established, with sufficient time in advance to set timetables. In the case of passenger trains, for instance, there could be two auctions, one for the winter timetable and one for the summer timetable.

3. Using the capacity charges to set the charging level

The objective of this paper it to develop a simple and transparent methodology for a preliminary calculation of mark-ups by using the capacity charges as an additive surcharge and therefore establishing a benchmark price for paths in the preliminary infrastructure capacity planning process (step 2 above).

Thus, the proposal is an approach to capacity charges whereby the result of values of the extremes would give the maximum charging level variation allowed by directive 2001/14: a minimum charging level equal to the marginal costs and a maximum charging level equal to the total costs. To this end, mark-ups are defined and added over and above the marginal costs. Basically, the marginal costs have to do with track maintenance costs, and their value is around 20% of the total costs (Nash *et al.*, 2005).

Therefore, mark-ups constitute an additive surcharge. This surcharge is obtained (see Equation 1) by multiplying the difference between total costs and marginal costs by a product coefficient (hereinafter referred to as 'capacity factor') related to infrastructure capacity. Thus, the surcharge would be a 'capacity charge'. The capacity factor value should range between 0 and 1, so cost recovery will not be higher than the total costs. The mark-ups serve to increase the cost recovery, allowing infrastructure managers to recover at least part of the major costs for rail infrastructure provision – construction costs, upgrading and renewal costs, for instance.

1. $$\begin{aligned}\text{Maximum level of charges} &= \text{MC} + \text{Mark-up}\\ &= \text{MC} + (\text{TC} - \text{MC}) \times \text{CF}\end{aligned}$$

where MC is marginal cost, TC is total cost and CF is capacity factor, $0 \leqslant \text{CF} \leqslant 1$. According to this definition, the proposed method is compatible with and could help to implement a charging method based on activity-based costing, since the capacity factor can also be applied to the difference between the social marginal cost and the total cost, thereby obtaining the final charging level, as proposed in RailCalc (RailCalc, 2007).

4. Capacity factor: definition and values

The capacity factor of a line section between stations i and j would be obtained as the product of three components (see Equations 2 to 5), in a way that takes into account capacity, demand, congestion, quality of service and time interval during which the section concerned is used. This factor's maximum value is limited to 1, so the section's maximum level of charges is equal to the total costs

2. $$\text{CF}_{ij} = \min\left(\prod C_{ij}^{k};\ 1\right) \quad \text{with } k = 1,\ 2,\ 3$$

3. $$C_{ij}^{1} = (n/n_{\max})_{ij}$$

4. $$C_{ij}^2 = f(P_{ij})$$

5. $$C_{ij}^3 = (t/t_{\min})_{ij}$$

where

CF_{ij} = capacity factor for section i–j
C_{ij}^1 = demand component for section i–j
C_{ij}^2 = quality component for section i–j
C_{ij}^3 = consumption component for section i–j
n = number of trains running in the i–j section, as per the time band according to the current used capacity
$n_{\max}$ = maximum number of trains running according to the practical capacity of line section i–j. Practical capacity is the practical limit of a 'representative' volume of train traffic that can travel on a line with a reasonable degree of reliability. The 'representative' traffic reflects the actual train mix, priorities and so on, so the practical capacity is the capacity that can be provided under normal operating conditions (Abril *et al.*, 2008). It is usually around 60–75% of the theoretical capacity (Kraft, 1982). Theoretical capacity is the number of trains that could travel on a route during a specific time interval and under ideal conditions (homogeneous traffic, trains evenly spaced and running at the same speed etc.) (Abril *et al.*, 2008).
P_{ij} = train priority in section i–j
t = the time a train takes to travel across section i–j
$t_{\min}$ = the minimum time it takes to travel across the i–j section at the maximum speed allowed and with no intermediate stops.

The demand component (C_{ij}^1) (see Equation 3) takes into consideration the existing traffic in the i–j section during a given period of time in relationship to the maximum level of traffic the line can take (practical capacity). Therefore, this component shows both the degree of congestion and the level of path demand. Normally, a railway undertaking's willingness to pay increases with the degree of path demand, since the most highly demanded paths tend to bring in more profits. Therefore, higher levels of traffic imply higher demand and a higher demand component value (close to 1).

The demand component could be used to give economic signals to railway undertakings on higher path value and to tell infrastructure managers where to invest (enhanced capacity on the more heavily congested sections). Table 1 lists potential demand component values, together with their meaning.

This variation level of the demand component is within the limits of the GRACE case studies that show that scarce tracks in peak hours might be around 10 times more expensive than tracks in off-peak hours (GRACE, 2007).

The quality component (C_{ij}^2) (see Equation 4) uses path quality as an indicator of the quality of infrastructure provision. This component is based basically on a train's priority of movement with respect to other traffic (P). To simplify the problem with regard to this aspect, there could be two main contexts and a number of intermediate contexts, as follows.

- *Top priority:* In this case, path quality is at its highest. When the railway undertaking opts for these paths, it is given top priority in terms of operations management within the limitations of the railway infrastructure compared with other movements, even in the case of traffic disruptions. These paths allow a railway undertaking to travel along the most direct and/or highest-quality line between i and j (if alternative routes exist) and with priority over all other trains (without being passed or shunted so that another train can pass). These features increase path value, particularly when there is scarce capacity, and therefore the charging level can be increased (in this case, by way of a higher quality component). This increase is in keeping with the railway undertakings' willingness to pay, which increases with service quality and path value. Therefore, it also contributes towards

Variation range	Demand component (C_{ij}^1)		
	Less than 0·60	From 0·60 to 0·75	From 0·75 to 1·00
Meaning	Little used section or time band. No congestion problem Minor value paths	Section with a medium level of traffic Intermediate value paths	Congested section or highly demanded time band Demand is nearly as high as capacity Higher-value paths
Examples	Conventional freight train	Regional train Intermodal freight train	Long-distance fast train Suburban trains

Source: Own source, based on Kraft (1982) and UIC (2004)

Table 1. Demand component variation range, meaning and examples

market-oriented charging systems. Normally, these paths are used by long-distance fast trains.
- *Low priority:* In this case, the paths adapt to the line's operation programme so the infrastructure manager can optimise capacity utilisation. Therefore, these paths are more able to adjust to infrastructure managers' constraints than to railway undertaking constraints. If a railway undertaking chooses a low-priority path, its train will have no priority over other trains, so the railway undertaking must be flexible in its capacity request. In this case, path quality is minimal, so the charging level should also be minimal. These paths could be in demand for freight trains, for instance.
- *Standard priority:* In this case, path quality is medium, and trains have medium priority compared with the top- and low-priority paths. They could be in demand for regional trains and fast freight trains, for instance.

Priority appraisal should take into account that available capacity utilisation can increase if a railway undertaking allows other trains to pass theirs or show a certain degree of flexibility in a path allocated to them, in comparison with the one they requested. Since lower priority and higher flexibility enable infrastructure managers to optimise their resources and the railway undertaking gets a lower-quality path, the quality component should decrease when priority is low and flexibility increases.

A high demand level and an important traffic mix will require a broader variety of paths, so railway undertakings can choose the path that will bring them higher returns and the infrastructure manager can adjust prices to different market sectors.

Table 2 shows a series of quality component values, with their meaning and examples of the trains that would typically request each level. To show priority-related path values numerically, the highest quality component value (1) could be assigned to the top priority paths, and the value could be gradually reduced from there until it is down to the low-priority path, with as many intermediate values as priority levels (and therefore, time flexibility levels) as desired. For instance, if five levels are considered, the quality component would be 1·0, 0·8, 0·6, 0·4 and 0·2 (Table 2).

Consumption component (C_{ij}^3) (see Equation 5) takes into account capacity consumption by the train when it runs from *i* to *j*. The charging level increases with capacity consumption (capacity consumption diminishes when a train's speed increases, along with its acceleration and braking capacity, and increases with the number of stops and their duration), thereby providing an incentive for railway undertakings to use infrastructure efficiently. In other words, capacity consumption increases with the length of time a train occupies a given section of track. Accordingly, the consumption component is defined as the quotient between the time it takes for a given train to cross it (according to its technical specifications and programmed stops) and the minimum amount of time in which it could be crossed (at the maximum speed allowed and with no commercial stops). Therefore, the consumption component takes into account traffic mix (by considering train specifications and service features) and infrastructure characteristics. Line capacity is an infrastructure manager's own resource. Therefore, the more the resource is used, the more revenue the manager should receive, which justifies an increase in the charging level (through a higher consumption component as capacity consumption increases). Table 3 summarises this approach.

To sum up, Table 4 shows that, despite their simplicity, the variables and formulation chosen for the capacity factor allow a wide range of factors and constraints related to the activity of infrastructure managers and railway undertakings to be taken into consideration. This contributes to relating the capacity factor to market and infrastructure features and the operator's characteristics.

5. Examples of calculations for train types

Some examples of the capacity factor for a variety of railway services and situations are calculated. The following assumptions have been considered for standard railway services, from those with the highest priority to the lowest.

- *Intercity trains:* Long-distance fast trains are presumed to

Variation range	Quality component (C_{ij}^2)		
	0·2	Intermediate values	1
Meaning	Lowest priority Minor-value paths	Standard priority Intermediate-value paths	Top priority Higher-value paths
Examples	Conventional freight train	Suburban trains Regional train Intermodal freight train	Long-distance fast train

Table 2. Quality component variation range, meaning and examples

Variation range	Consumption component (C_{ij}^{3})	
	1	⩾1
Meaning	Fast train with no stops Maximum capacity utilisation	Slow train and/or more stops Intermediate-capacity utilisation High-capacity utilisation
Examples	Long-distance fast train Off-peak periods	Local trains Regional train Intermodal freight train Freight train

Note: Considering that there is a lot of surplus capacity during the off-peak period, it would be illogical to penalise trains for travelling slower than the maximum speed. Therefore, in such cases, their consumption component is restricted to 1.

Table 3. Consumption component variation range, meaning and examples

Variable or component	Factor or constraint that shows or has a relationship with. . .	Variation of the variable or component with regard to the factor or constraint
n	Market competition	+
n_{max}	Line capacity (infrastructure quality)	+
t	Train speed	−
t	Acceleration and braking rates	−
t	Station stop interval	+
t_{min}	Infrastructure quality	−
$C^1 = (n/n_{max})$	Congestion	+
$C^1 = (n/n_{max})$	Path value	+
$C^2 = f(P)$	Path quality (priority)	+
$C^3 = (t/t_{min})$	Capacity consumption	+

Note: +, the variable or component increases as the constraint increases; −, the variable or component diminishes as the constraint increases

Table 4. Aspects taken into account with the capacity factor

travel during a high demand period (arrival to the city in peak hour). The section is nearly congested during peak hours, with traffic supposed to be at 90% of its practical capacity. Intercity trains are supposed to travel with no intermediate stops in the i–j section and at the maximum speed allowed.

- *Suburban trains:* These are presumed to travel at peak hours. The suburban trains attain a moderate average speed and make stops at all intermediate stations, so the assumption is that they travel along the i–j section at a commercial speed that is 50% slower than the maximum allowed speed.
- *Regional trains:* These are presumed to travel during a normal period. Traffic is supposed to reach 60% of a section's practical capacity during the normal period. Regional trains' top speed and number of stops are supposed to be somewhere between the number of stops and the speed of intercity trains and suburban trains. Therefore, the travel time allocated to them is 25% longer than the minimum time.
- *Express freight trains (e.g. intermodal freight trains):* These are presumed to travel during a normal period. Express freight trains are supposed to have a higher speed than conventional freight trains and a lower speed than regional trains, but because they make no stops in the section i–j, the same travel time as for regional trains is assigned to these trains.
- *Freight trains:* Conventional freight trains are considered to travel mostly during valley periods (with the section at 20% of its capacity). Owing to their moderate speed, they are presumed to take 75% longer than the fastest train to travel along the section.

Table 5 gives numerical values of the demand, quality and consumption components according the assumptions considered. It also shows the capacity factor calculation for each standard railway service.

Rail service	Demand component	Quality component	Consumption component	$\prod C_{kij}$	Capacity factor
Intercity train	0·90	1·00	1·00	0·90	0·90
Suburban train	0·90	0·80	1·50	1·08	1·00
Regional train	0·60	0·60	1·25	0·45	0·45
Intermodal freight train	0·60	0·40	1·25	0·30	0·30
Conventional freight train	0·20	0·20	1·00	0·04	0·04

Table 5. Calculation of the capacity factor for several railway services

In Table 5 it is found that, for suburban trains, the product of three components is a value higher than 1, which shows the huge magnitude in costs these trains generate when capacity is scarce. Using Equation 2, the capacity factor is restricted to 1, to prevent cost levies from being higher than the total cost. Furthermore, according to Table 3, the consumption component for conventional freight trains is restricted to 1.

Figure 1 shows the capacity factor for the various railway services, according to the assumptions considered. In Equation 1, the capacity factor is defined as the maximum value of the multiplicative coefficient that is to be applied to the difference between the marginal cost and the total cost to obtain the maximum capacity charge. As Figure 1 shows, the maximum initial capacity charge values (following the assumptions considered in these examples) would be for suburban trains, followed by intercity trains, regional trains, intermodal freight trains and, lastly, conventional freight trains. If this initial capacity charge is considered as an approximation to the path value, the maximum mark-up in the pre-planning of traffic on the line would be for local and intercity trains, and the lowest for conventional freight trains.

Next, adding the maximum capacity charge value to the marginal cost gives the maximum charging level for each railway service, as shown in Equation 1.

The final mark-up for profitable transport services can be found by offering operators pre-scheduled paths based on the price range calculated as explained above. Next, the end mark-up can be set according to the railway undertakings' willingness to pay (by way of negotiations or tendering).

On the other hand, discounts would need to be applied to unprofitable public transport services (namely, suburban and regional transport) and the services required to ensure the efficiency of transport systems as a whole (namely, freight services), which cannot pay the capacity charges arrived at using the capacity factor. The discounts should be calculated according to the savings in external costs (accidents, avoided road congestion, pollution and so on) and the accessibility guaranteed by the railway compared with other less efficient modes of transport (Calvo *et al.*, 2007). Discounts should be refunded by the public administrations to the infrastructure manager, as payment for its main resource (the capacity consumed). The process is outlined in Figure 2.

6. Conclusion

This paper proposes a method whereby capacity charges that comply with EC directive 2001/14 are used to calculate an approach to mark-ups on the basic price charged for rail infrastructure use. The method is based on a product coefficient called

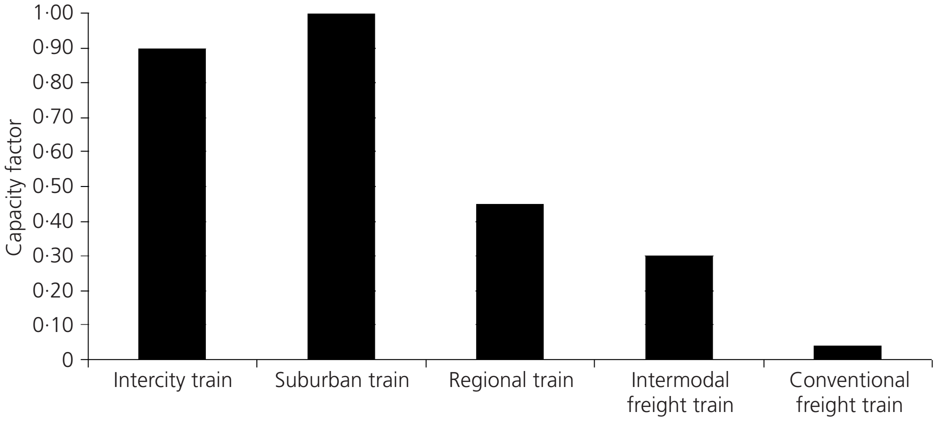

Figure 1. Capacity factor for several railway services

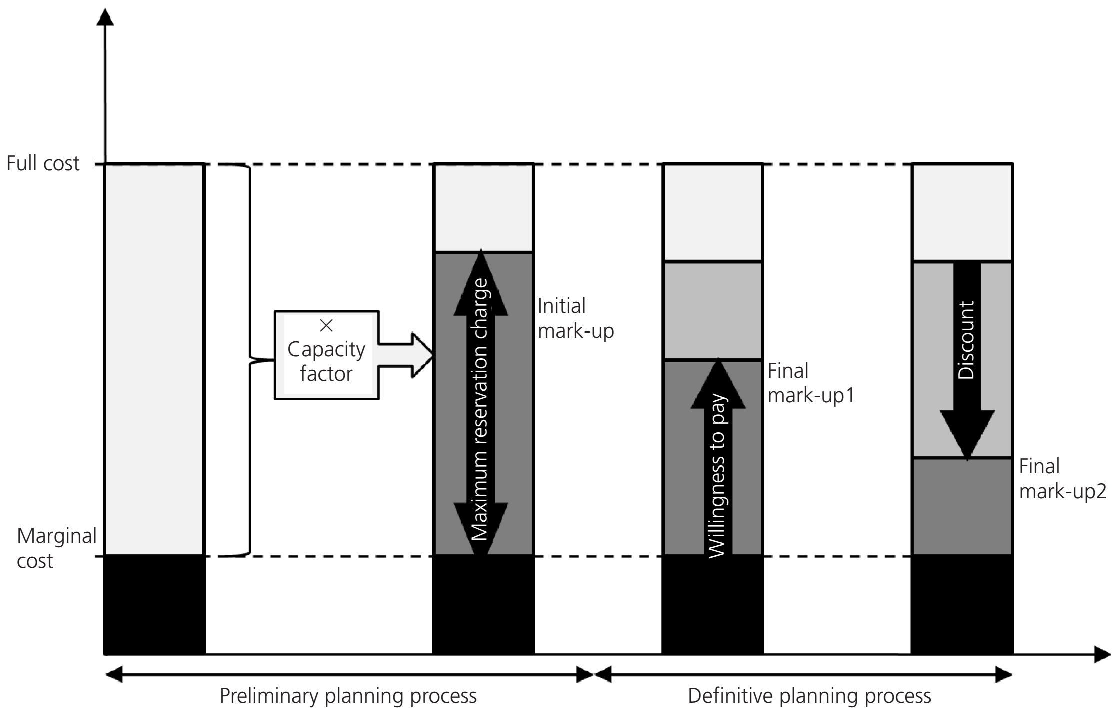

Figure 2. Mark-ups and capacity charge calculation using the capacity factor

the capacity factor that depends on demand for line utilisation, path quality and capacity consumption.

The capacity factor ranges between 0 and 1. Applied to the difference between total cost and the marginal cost, it gives the maximum capacity charge value. Thus, the final mark-up will be somewhere between 0 and the maximum capacity charge. Because the capacity factor establishes the highest starting price, it can also be used to decide a path's maximum value when designing a preliminary plan for line operation.

According to the assumptions considered for typical train services, the maximum capacity charge value (which can be identified with the maximum mark-up) would be for suburban trains, followed by intercity trains, regional trains, express freight trains (e.g. intermodal freight trains) and, lastly, conventional freight trains.

The proposed method gives an approximation to the maximum mark-up. Next, operators' current willingness to pay needs to be known (by way of tendering and negotiation) before these benchmark values can be used to set the definitive mark-ups, as well as other considerations such as social factors (regional and suburban public transport constraints) and the efficiency of the transport system as a whole (for freight traffic, in particular).

The proposed charging system develops a simple and transparent methodology for the calculation of the mark-ups in the pre-planning of traffic on the line and thereby establishing a benchmark price for paths in the preliminary infrastructure capacity planning process. The methodology takes the main aspects related to rail infrastructure capacity into consideration to give and approximated value of the maximum capacity charge (initial mark-up). The method can be used for a wide variety of railway services and traffic situations, so it can help (as a basic calculation tool) in developing a uniform charging system, thereby contributing to interoperability in the European railway network.

Finally, the suggested method contributes to a market-oriented charging system by providing an easy and transparent way to establish a relationship between capacity charges (and, therefore, mark-ups) and issues such as the demand for infrastructure utilisation, the quality of infrastructure provisioning services and railway undertakings' efficiency.

REFERENCES

Abril M, Barber F, Ingolotti L *et al.* (2008) An assessment of railway capacity. *Transportation Research Part E* **44(5)**: 774–806.

ADIF (Administrador de Infraestructuras Ferroviarias) (2012) *Network Statement 2011 Update*. ADIF, Madrid, Spain. See http://www.adif.es/es_ES/conoceradif/doc/CA_DRed_Capitulo_6.pdf (accessed 22/06/2012).

Calvo F and de Oña J (2005) Opening of the European railroad network: a lost opportunity for European Unification. *Transportation Research Record* **1916**: 8–19.

Calvo FJ, de Oña J and Nash A (2007) Proposed infrastructure pricing methodology for mixed-use rail networks. *Transportation Research Record* **1995**: 9–16.

DB Netz (2010) *The Train Path Pricing System of DB Netz AG*. DB Netz AG, Berlin, Germany. See http://fahrweg.dbnetze.com/site/dbnetz/en/product/train__path/prices/brochure/train__path__pricing__brochure.html (accessed 22/06/2012)

EC (European Commission) (2001) 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. *Official Journal of the European Communities* L075. See http://eur-iex.europe.eu/LexUriServ/LexUriserv.do?uri=CELEX:32001L0014:en:HTML (accessed 16/07/2012).

Expert Advisors to the High Level Group on Infrastructure Charging (1999) *Calculating Transport Congestion and Scarcity Costs*. Final Report of the Expert Advisors to the High Level Group on Infrastructure Charging (Working Group 2). See http://ec.europa.eu/transport/infrastructure/doc/congestion-cost.pdf (accessed 22/06/2012).

Elm-Larsen K (2004) *Development of Infrastructure Charges for the Liberalised Railways*. National Rail Authority, Denmark. See http://internationaltransportforum.org/IntOrg/ecmt/railways/pdf/04ElmLarsen.pdf (accessed 22/06/2012)

GRACE (2007) *GRACE – Generalisation of Research on Accounts and Cost Estimation-Deliverable 5: Monitoring Pricing Policy Using Transport Accounts. Version 1.0*. European Commission. See http://www.grace-eu.org/public/D5%20Final%20080607.pdf (accessed 22/06/2012).

RailCalc (2007) *RailCalc. Calculation of Charges for the Use of Railway Infrastructure*. See http://ec.europa.eu/transport/rail/legislation/doc/railcalc_discussion_paper_final.pdf (accessed 16/07/2012).

Infrabel (2008) *Network Statement 2009 & 2010. Annex 33: Charge-unit prices and values of the parameters linked to the Trainetwork Statememt 2008*. See http://ecms.b-holding.be/DMS/ds/en/6997129 (accessed 16/07/2012).

Thompson L (2008) *Charges for the Use of Rail Infrastructure*. International Transport Forum – OECD, Paris, France. See http://www.internationaltransportforum.org/Pub/pdf/08RailCharges.pdf (accessed 22/06/2012).

Kraft ER (1982) Jam capacity of single track rail lines. *Proceedings of the 23rd Annual Meeting of the Transportation Research Forum*, New Orleans, LA, USA, pp. 461–471.

Nash C, Coulthard S and Matthews B (2004) Rail track charges in Great Britain – the issue of charging for capacity. *Transport Policy* **11(4)**: 315–327.

Nash C, Matthews B and Thompson L (2005) *Charges for the Use of Infrastructure in ECMT (European Conference of Ministers of Transport) Railways*. See http://Inweb90.worldbank.org/ECA/Transport.nsf/ECADocByUnid/ZCF8BE276F63A37D85256FB20043A05D?Opendocument (accessed 16/07/2012).

Nilsson JE (2002) Towards a welfare enhancing process to manage railway infrastructure access. *Transportation Research Part A* **36**: 419–436.

Network Rail (2012) *The 2012 Network Statement*. Network Rail, London, UK. See http://www.networkrail.co.uk/aspx/3645.aspx.

RFF (Réseau Ferré de France) (2008) *National Rail Network Statement 2010 timetable*. RFF, Paris, France. See http://rff-document-de-reference.eu/en (accessed 22/06/2012)

RFI (Rete Ferroviaria Italiana) (2004) *Italy: Charging system on the Network Managed by RFI*. RFI, Roma, Italy. See http://www.internationaltransportforum.org/IntOrg/ecmt/railways/pdf/Rome04ITA.pdf (accessed 22/06/2012).

Turvey R (2002) Infrastructure access pricing and lumpy investments. *Utilities Policy* **9(4)**: 207–218.

UIC (International Union of Railways) (2004) *UIC Leaflet 406 R, Capacity*. UIC, Paris, France.

WHAT DO YOU THINK?

To discuss this paper, please email up to 500 words to the editor at journals@ice.org.uk. Your contribution will be forwarded to the author(s) for a reply and, if considered appropriate by the editorial panel, will be published as a discussion in a future issue of the journal.

Proceedings journals rely entirely on contributions sent in by civil engineering professionals, academics and students. Papers should be 2000–5000 words long (briefing papers should be 1000–2000 words long), with adequate illustrations and references. You can submit your paper online via www.icevirtuallibrary.com/content/journals, where you will also find detailed author guidelines.