Rail Capacity Management

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Rail has a key role to play in making transport more efficient and sustainable in the EU and elsewhere. However, increasing passenger and cargo volumes require investment in infrastructure, and also more efficient track capacity management. This issue of Network Industries Quarterly focuses on the capacity dimension of railway infrastructure, and in particular on how to increase capacity for both passenger and freight railway undertakings (RUs), as availability of reliable railway infrastructure capacity is a condition for the much-needed modal shift from road (and air) to rail. Needless to say, capacity management takes place in a situation of growing competition for track and it is necessary to ensure non-discriminatory treatment of competing RUs when it comes to track availability and usage. Somewhat paradoxically, this gives the infrastructure manager (IM) an important and more active role than was previously the case, and at the same time requires an independent regulator to not only supervise non-discrimination but also ensure that the IM stays within its legal mandate, not to mention the fact that capacity needs to be planned, financed and built well ahead of time.

In his contribution entitled *Regulating active infrastructure management in railways*, Juan Montero shows the growing importance of infrastructure managers in capacity management, and also the need to ensure that they act in the public interest.

Dariush Kowsar and Alain Quinet's paper on *Capacity Management as a cost-effective way to boost Rail Traffic in Europe* shows how a combination of careful planning and digitalisation can contribute to more efficient investment, improved network utilisation and overall lower costs of the available capacity.

Paolo Beria explores the relationship between *Track access charges and capacity management*. More precisely, he argues for including capacity pricing elements such as track access charges and illustrates this with the example of Italian high-speed railways.

Martin Aronsson addresses the issue of *Flexibility in the railway capacity allocation process* and argues for some slack in the capacity allocation planning process as capacity usage by train operating companies can never be fully planned ahead of time.

Matthias Finger
Publication Director

dossier

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Regulating Active Infrastructure Management in Railways

Juan Montero[1]

Various concurrent trends are driving infrastructure managers to assume a more active stance in capacity management. These trends include digitalisation, the need for efficiency in handling scarce capacity in complex systems and the specific requirements of different sectors. Railways serve as a notable example of this phenomenon. However, giving frequently monopolistic managers such an active role requires implementation of countervailing instruments. These instruments are necessary to safeguard the interests of the entire system and the public good, thus ensuring that active management serves the collective benefit rather than individual interests.

A trend of more active management of capacity can be identified in infrastructure. It can have various names: active management, dynamic management, dynamic pricing, etc. It can take the form of actively driving capacity demand, but also of actively managing capacity supply with various instruments: more pre-planning, a more dynamic capacity allocation process or more dynamic traffic management in real time. This is happening in various industries – dynamic pricing in road and electricity systems to manage demand, software-defined networking (SDN) in telecommunications networks, etc. – both in sectors in which traffic was previously barely managed (roads) and in sectors in which traffic was already actively managed (electricity), in which management instruments are being reinforced. The same trend can be identified in railways.

Digitalisation certainly plays an important role in active infrastructure management. Digitalisation provides infrastructure managers with more information as data is generated on the status of the infrastructure and real-time information on traffic flows (smart meters of all kinds). Predictive algorithms and artificial intelligence are able to predict demand with increasing accuracy. With more information, infrastructure managers are in a position to take a more active role, not merely waiting for traffic or planning it months in advance with a rigid allocation of capacity for a whole season but actively managing the dynamic allocation of capacity in order to optimise the load factor while avoiding congestion. In fact, our research in Montero and Finger (2021) shows that active infrastructure management is the main consequence of digitalisation in different kinds of infrastructure.

Active infrastructure management is also the result of a reaction to fragmentation created by regulatory reform in the EU. Liberalisation has multiplied the number of providers of infrastructure-based services: railway undertakings, electricity suppliers and so on. Vertical separation has further fragmented sectors as the role of the infrastructure manager has been unbundled from the role of service provision. This has been the case in railways (to a certain degree), electricity, gas, etc. The system has been enriched with further actors (ancillary service providers such as maintenance facilities, etc.). In some sectors specific traffic coordination mechanisms have been introduced (the EUROCONTROL Network Manager in air traffic management, transmission system operators in electricity). In other sectors, coordination of such complex fragmented systems has been left to market mechanisms and sometimes regulation (mostly access regulation): railways, postal services, telecoms, etc.

Railways are a very clear example of the lack of effective coordination after regulatory reform. Railways are very rigid systems traditionally characterised by heavy planning. Regulatory reform gave a somewhat passive role to the infrastructure manager, who would merely wait for capacity requests by competing railway undertakings, with no planning to optimise capacity but only reacting *ex post* to conflicting requests with request coordination and prioritising certain types of traffic in the case of congestion (with little guidance from legislation). Suboptimal results of this approach were identified at a very early stage (Stakie 1993).

1 Director, Florence School of Regulation – Transport Area

However, railways have reacted to fragmentation by creating new and sometimes unexpected coordination mechanisms beyond those in the regulatory framework. Let us recall some examples. 1) Timetable redesign is a process to preplan capacity allocation in an active form in order to optimise capacity and ensure an optimum allocation of capacity for coordinating different types of traffic and fully exploiting network effects (RNE & FTE 2023); 2) Preplanning temporary capacity restrictions (TCR); 3) Optimisation of capacity by Spanish Adif in the main high-speed corridors before assigning framework contracts in a tender (Montero & Ramos 2022); 4) In France, at an early stage in the capacity allocation process, packages of routes are prebuilt at regular intervals and priority for the use of these routes is given to PSO traffic (UIC 2022); 5) 'Station utilisation plans' in Italy (UIC 2022); 6) In the reform of the rail sector in the United Kingdom, one of the proposed lines of action was a more active role for the infrastructure manager (Shapps 2021).

It is possible to conclude that there is in the system an organic tendency to recreate missing coordination mechanisms. Coordination is necessary to improve efficiency in the use of scarce capacity. Coordination is necessary to provide all actors with certainty on the availability of capacity to meet their needs. Coordination is necessary to react to events impacting the available capacity.

Furthermore, it can be seen that most of the new coordination instruments rely on the leadership of the infrastructure manager. A more active infrastructure manager is in a position to act as system integrator in the rail system. This seems to be the party that is best positioned to coordinate the complex ecosystem created by the EU regulatory framework.

However, countervailing measures are necessary to supervise a more active infrastructure manager. Regardless of how organic this evolution might seem, and it certainly can deliver efficiencies, infrastructure managers mostly enjoy a monopolistic position to exploit rail infrastructure. Therefore, their emerging position as active managers of the system requires some countervailing measures to ensure all the interests in the system are taken into consideration and the general interest is protected.

The recent Commission proposal for a regulation on the use of railway infrastructure capacity (COM(2023) 443/2) works in both directions. On the one hand, it formalises and empowers infrastructure managers to take a more active role. On the other hand, it defines countervailing measures to control the new powers of infrastructure managers (Montero et al. 2023).

First, such active infrastructure management will only improve the system if it is undertaken in close collaboration with other stakeholders, responding to the needs of railway undertakings and service facility operators. The regulation proposed by the Commission envisages consulting stakeholders on strategic capacity planning (Article 13). A fundamental element in the new regulation is the so-called strategic capacity planning in the TEN-T core and extended network, which empowers infrastructure managers to adopt a capacity strategy, a capacity model and a capacity supply plan for a period of 5 years. Infrastructure managers need take into account in a balanced, fair and non-discriminatory manner all the types of rail transport services for which they are liable to receive requests for capacity. To ensure this, "Infrastructure managers shall consult all operational stakeholders" (Art. 13). These consultations are key in the new model.

Second, closer more active supervision by regulatory bodies seems necessary if a more active role of infrastructure managers is expected. National regulatory bodies are empowered not only to supervise and resolve disputes on the annual allocation of capacity, as in the past, and traffic management, but also to intervene in strategic capacity planning. According to the procedure in Article 56 of the recast directive (Directive 2012/34/UE), railway undertakings and other stakeholders are granted the right to appeal to the national regulatory body to review the capacity model and the capacity supply plan (Art. 63).

Third, performance regulation becomes even more important as monopolistic infrastructure managers become more active. The recast directive already required a performance scheme for each infrastructure manager (Art. 35 and Annex V). The European Network of Infrastructure Managers was even charged with identifying common principles and practices to monitor benchmarking of performance in a consistent manner (Art. 7f). However, there is room for improvement in the implementation of performance schemes.

The regulation proposed by the Commission promotes creating a performance review body in the form of a group of rail experts providing advice to the Commission to follow the issues initially defined in Annex VII. This model closely resembles the existing performance review body in the Single European Sky (Finger 2016).

Fourth, closer coordination of EU infrastructure managers is necessary to reinforce the Single European Railway Area so the different infrastructure managers work as a single system. Different options were available, including creating a European network manager following the EUROCONTROL model in aviation (Montero & Finger 2022). The model in the new regulation, however, seems to follow the less ambitious but still transformative path of reinforcing the role of the European Network of Infrastructure Managers (ENIM) which seems to be inspired by ENTSO-E, the European Network of Transmission System Operators for Electricity. However, it is envisaged that ENIM will appoint a network coordinator, an operational body to support its work (Arts. 58 and 59), which again resembles the appointment of EUROCONTROL as network manager in the Single European Sky, going beyond the association of infrastructure managers model.

This is a very fundamental step forward in the construction of the Single European Railway Area, as the previous instruments to coordinate national infrastructure managers proved too weak. Railways are still national systems with very little coordination. Cross-border services are poorly served and the competitiveness of rail services, particularly freight services, is seriously affected. This is probably the most relevant evolution ever in the creation of the Single European Railway Area. At the same time, it is the most relevant challenge in operational terms.

Just as the role of infrastructure managers at the national level is replicated by ENIM and the network coordinator at the EU level, the countervailing role of the national regulatory bodies is replicated at the EU level by the European Network of Rail Regulatory Bodies (ENRRB). There is experience of this model in other network industries, such as BEREC in telecommunications. Again, more active infrastructure management of the EU rail network requires more active supervision by a regulatory authority at the EU level.

In conclusion, railways in the EU are undergoing a profound transformation comparable in magnitude to the historic shifts seen with vertical separation and the introduction of competition. While the operational hurdles are significant, the potential efficiency gains justify the journey forward.

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Capacity Management as a Cost-Effective Way to Boost Rail Traffic in Europe

Dariush Kowsar and Alain Quinet[1]

Europe is a densely populated and urbanised region with a significant number of metropolitan areas and economic clusters. These specificities are conducive to the development of rail. It is no surprise that rail emerged in Europe in the nineteenth century and is still today an efficient mode of transport for both mass transit and long-distance traffic. However, due to bottlenecks, missing links and a lack of interoperability, all the potential for rail traffic has not yet emerged. Rail is still operated according to widely varying national processes and priorities. As a result, the share of rail passenger traffic is currently limited to 10% of journeys[2] in Europe, despite an extensive network of 200,000 km of lines[3].

There is today a broad consensus on developing rail traffic in Europe to decarbonise mobility, save energy and improve the quality of life in dense and congested areas.

To achieve a significant modal shift however, railway infrastructure must be able to absorb a strong increase in demand for metropolitan, regional, national and international passenger services, for long distance freight services and for the return of the once very extensive offer of night services. This article focuses on one specific challenge: improving network utilisation in Europe through capacity management. This involves improving the quality and reliability of railway capacity (routes) and minimising infrastructure-related costs.

Designing railway capacity is a significantly complex process. Railways are a guided mode, in which vehicles are bound to a linear infrastructure. With few notable exceptions, the lines of the network are widely utilised by different types of trains (freight, passenger) with different characteristics (e.g. speed, weight …) and different needs in terms of service. In such infrastructure the interaction between segments and the presence of nodes produces far-reaching network effects, which include cross-border and trans-European dimensions. Intensive work on the European infrastructure, which will undergo a cycle of renewal and upgrade in the coming years, connected to the TEN-T and TSI regulations among others, will add to the challenge of making additional and reliable capacity available.

As traffic volumes grow, both national and trans-European, the urgency to better structure capacity planning and capacity utilisation becomes apparent. This requires a thorough industrial process beginning ten or even twenty years ahead of train runs. In this process issues such as stable planning of work, related temporary capacity restrictions, traffic forecasts, the ability of the infrastructure to respond to applicant announced capacity needs, consultation, optimisation, conflict resolution and economic balancing by the infrastructure manager have to be taken into account. To catalyse the development of international traffic, in addition to national needs, processes and timelines must be harmonised effectively where relevant. In this context, the infrastructure manager is naturally the stakeholder which can guarantee ‘the best possible’ utilisation of the asset while finding a fair compromise between conflicting needs. Largely inspired by sector initiatives, the European Commission’s proposal for a regulation on the *use of railway infrastructure capacity in the single European area* is a step in this direction.

Defining upstream capacity processes and harmonising them will lead to a much-expected improvement in capacity utilisation. Three levers connected to network capacity must be taken into consideration:

Improving upstream processes and tools to be used in capacity planning and capacity utilisation.

Upgrading the network and digitalising it to respond to the challenges of the day. Consistent deployment of ERTMS is a key element in this.

1 SNCF Réseau

2 Railway innovation in the 21st century, The CER Essay series, 2024.

3 Eighth monitoring report on the development of the rail market under Article 15(4) of
Directive 2012/34/EU of the European Parliament and of the Council, September 2023.

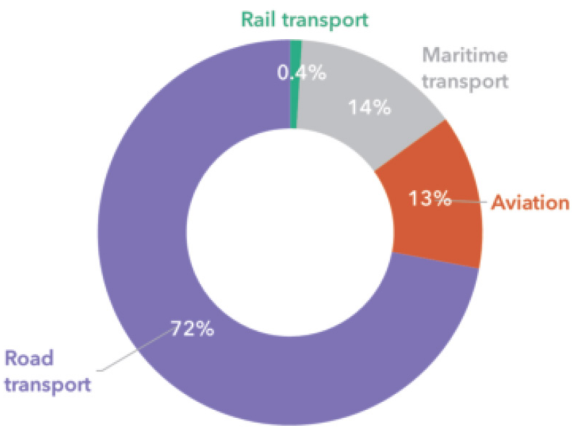
Developing criteria including methods for maximising the benefit to society and evaluating capacity options as an effective instrument for decision-making.

I. Stimulating railway traffic in the most cost-effective way

European transport policy is at a crossroads. The urgency to act both to mitigate the effects of unfolding climate change and to adapt the European economy and infrastructure have been acknowledged by the European Union and translated into a number of purposeful policies known as the 'Green Deal.'

Because transport in the Union accounts for 28.5%[4] of total greenhouse gas emissions, the sector needs to evolve.

Figure 1 - Greenhouse gas emissions from transport in Europe [5]



Railways, which account for only 0.4% of carbon emissions from transport in the European Union (Figure 1), in the coming years will need to absorb an expected growth in demand.

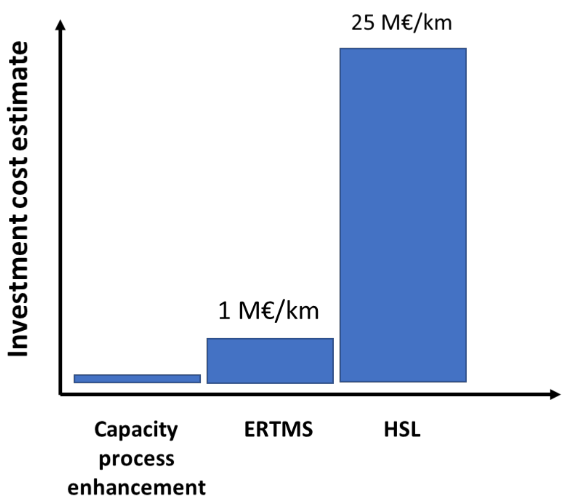
This growth can be achieved in various ways, notably:

- by further developing the physical infrastructure by completing missing links and creating new high-speed lines. This is, of course, the most effective way to increase capacity, but it is also the costliest path to follow. As an example, the investment needed for a high-speed line can be estimated at an average 25 M€/km in France.
- by further digitalising railways. Digitalisation is a less costly option compared to creating an entirely new line with, for example, investment in ERTMS estimated at an average 1 M€/km (Figure 2). However, the increase in capacity made possible by ERTMS, although potentially significant, is far lower than the capacity created by constructing new infrastructure. As an example, the most successful high-speed line in France, the Paris-Lyon link, brought a potential of 13 train routes an hour with its creation. The new ERTMS signalling system, which is being deployed, will allow an increase in capacity of roughly 25%, as the number of routes will pass from 13 to 16 an hour.

Figure 2 - The impact of ERTMS on Capacity

- by improving network utilisation with enhanced capacity management. While this may require adapting processes and further developing digital tools, it is likely that the total investment will be sensibly lower than for construction of new infrastructure or infrastructure digitalisation (Figure 3).

Figure 3 - The merit order of interventions to stimulate rail traffic



4 Agence européenne pour l'environnement, 2022.

5 Les propositions du Groupe SNCF pour le futur mandat de la Commission européenne et du Parlement européen, Jean Pierre Farandou, Janvier 2024.

It must be noted that none of the above-mentioned levers can alone bring railways to the required level of availability and performance. A combination of them is needed.

We here focus on network utilisation, and more specifically on railway infrastructure capacity.

Any approach to capacity must clearly involve guaranteeing the quality of service of railways compared to other modes of transport. In widely shared infrastructure, quality is a major challenge as demand increases: more routes, more reliable ones and routes better meeting the commercial needs of applicants are needed.

When capacity becomes scarce because of a multiplicity of characteristics and of a growing intensity of demand, the need to improve capacity *planning*, specifically in *upstream phases*, becomes ever more apparent.

II. Network utilisation: the challenge of defining infrastructure capacity.

While providing capacity is the core competence of a transport infrastructure manager, railway capacity is both a concept that is difficult to define and complex to construct. As UIC at one point stated, "*A unique, true definition of capacity is impossible.*"[6]

This statement may be challenged. *Theoretical capacity* can be defined as the number of trains running along a segment between two points in a given timeframe. Calculation of the *practically available capacity* is likely to require the definition of a timetable and of associated levels of service and take into account the 'individual' capacity of separate elements within the system, such as stations and nodes. A wide range of approaches and methods have been adopted to define railway capacity: *synthetic and analytical methods, asynchronous methods, synchronous methods (traffic simulation) etc.*[7]

However, the UIC definition well summarises the fact that railway capacity is the result of an interplay among an important number of factors, both physical and intangible, and that the outcome of this interplay is seldom unique. Most often, a range of different solutions are able to solve the equation, although invariably each comes with its own trade-offs.

III. Network effects and trade-offs

Railways are a guided transport mode, with wheeled vehicles bound by a linear infrastructure. Signalling systems help maintain trains at a safe and defined distance at all times in what can be considered a discrete system rather than a continuous one.

With some exceptions such as dedicated high-speed lines, the same set of lines is used by different kinds of trains (passenger, freight, short or long distance, national or international) with different characteristics when it comes to speed, weight, expected performance and stops. This allows for scope externalities, but the ordering of their movement on a line needs to be carefully constructed.

These elements (distancing, different uses) represent a first set of 'constraints' on theoretical capacity and impose a first set of trade-offs.

It is important to consider, beyond individual segments, the overall network effect. A segment on which capacity is planned is naturally part of an interconnected and wider physical network. The design of a route on one segment can influence routes on distant segments. In addition, train travel needs to offer final services that may require intermediate connections, including cross-border ones, to complete a journey.

Beyond these, *nodes* are a fundamental part of a network. They are where the interactions among lines materialise, possibly generating bottleneck effects. While preparing the recent successful opening of the high-speed rail market in Spain, ADIF, the infrastructure manager, carefully worked on the issue of nodes and of turnaround times in terminals.[8]

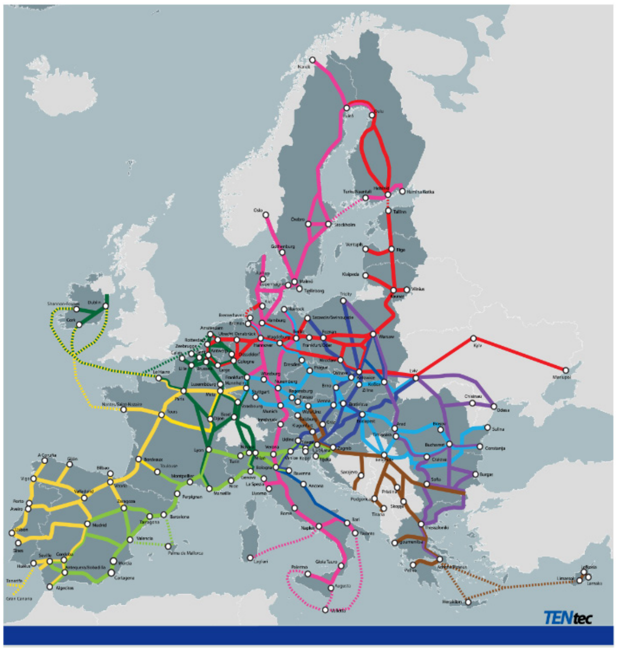
Finally, as international transport increases driven by the strengthening of the single European market area's economy and by political ambition, the effects of interactions, not only among the lines of national networks but also among different and cross border networks, grow and need to be fully taken into account.

6 UIC, Capacity (UIC code 406). 2004, International Union of Railways (UIC); Paris, France.

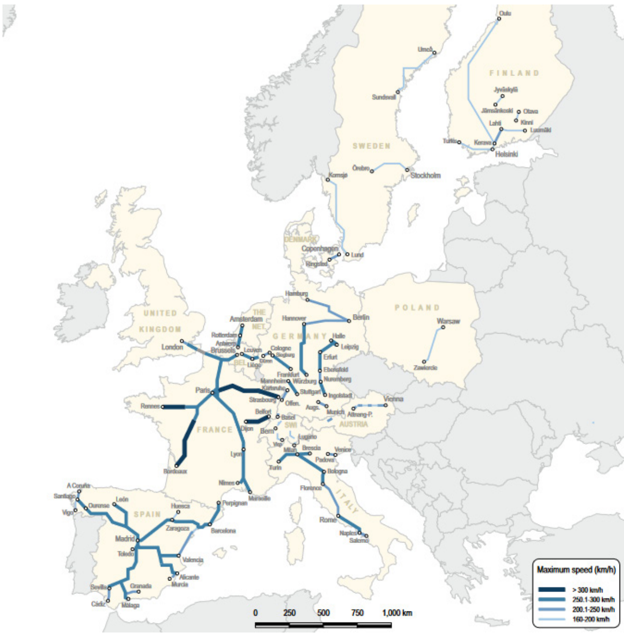
7 Rotoli, F., Navajas Cawood, E. and Soria, A., Capacity assessment of railway infrastructure: Tools, methodologies and policy relevance in the EU context; EUR 27835 EN; doi:10.2791/03775.

8 New rules for better rail capacity management, ADIF, Florence School of Regulation, September 29th 2023.

Figure 4 - The TEN-T network and the European high-speed network



The European TEN-T Network[9]



The European High-Speed Network[10]

IV. Constructing capacity in Europe as a full industrial process

It is therefore easy to conclude that constructing, optimising, allocating and utilising railway capacity is a key process. It is an industrial process that leads to a product that is contractual, binding and enforceable, and invariably leaves many stakeholders complaining.

It is a process:

- that involves cycles starting far ahead of train run;
- in which interoperability and international harmonisation must be taken into account early on;
- in which wide stakeholder consultation must take place at every stage, with final customers, railway undertakings, political and administrative authorities, industry and suppliers.

In France, this process starts roughly 20 years ahead of trains running[11] and relies – in later and more operational capacity-associated stages – on newly developed digital tools (Figure 5).

In its implementation phase, it leads to a preconstructed catalogue widely based on announcements of capacity needs.

Figure 5

V. The socio-economic conflict resolution criteria

In this complex industrial process, the infrastructure manager is naturally the stakeholder which can guarantee 'the best possible' utilisation of the asset while finding a compromise between conflicting needs.

9 Source: TEN-TEC, Directorate-General for Mobility and Transport.

10 Source: Atlas High Speed Rail 2022, UIC.

11 In France, Mobility Scenarios and the Target Network Strategy are looked into as of Y-20, while the 'Emerging Operating Plans,' known as PEE, give an outlook 10 years ahead of trains running, and a first estimate of potential bottlenecks in the infrastructure.

Eventually, such compromises must result in striking a balance between conflicting needs and preserving the economic models of the different stakeholders. When conflicts cannot be solved through consultation, specific rules may be introduced to support arbitration.

Conflict arbitration can be performed by the infrastructure manager using purely financial criteria. One of the difficulties in this simple objective approach is a systemic bias in favour of passenger traffic, as track access charges are higher for passenger trains than for freight trains. For this reason, allocation rules tend to rely on socioeconomic rather than financial priority criteria to resolve conflicts in capacity allocation. This method allows taking into account the relative benefits of each type of traffic to society at large (time saving, carbon emissions etc.) rather than to the financial situation of the infrastructure manager. This approach has been implemented in Sweden since 2011. It is used by Trafikverket throughout the capacity construction process, from long-term capacity structuring (up to 20 years) to hourly construction. The method involves evaluating the consequences of excluding traffic for end users and assessing the cost to society of alternatives in the case of conflict.

In the case of a capacity conflict on a network, alternatives can take different forms:

- Extending the time slot, resulting in longer travel times for clients.
- Shifting the time slot, resulting in a change of arrival time for clients.
- Cancelling the time slot, requiring clients to switch to other rail services.

The costs incurred by society and by final consumers of transport services can be quantified by employing socioeconomic methods and concepts, such as the value of time or frequency, commonly used in cost-benefit analysis.

VI. Beyond national borders, the single European rail

The European Green Deal aims to multiply rail freight twofold and high-speed rail passenger transport threefold by 2050.[12] As a result, one of the challenges in the coming years will be increasing cross-border traffic, which carries a strong potential for modal shift. At the same time, the European railway network will continue to undergo a major cycle of renewals and upgrades. The combination of a high level of European ambition and the need for extensive work poses a formidable challenge and creates a need to harmonise cross-border route construction.

The European Commission has published a proposal for a regulation on capacity. It is currently going through the relevant legislative process. This proposal for a regulation on capacity seems to hit specific targets:

- It acknowledges the need to structure upstream capacity planning phases to optimise utilisation and to stabilise the offer, giving proper long-term visibility to applicants willing to engage or invest in rail transport;
- It supports the need for IMs to build such upstream phases based on the declared or foreseen needs of applicants.

Furthermore, the proposal relies on management by infrastructure managers as a community. A core process can only be designed by the entities in the system that have the competences, which can bear the risks and exploit the opportunities associated with a network catering to contrasting but legitimate needs.

However, it is important to remain 'realistic' about the expectations the regulation proposal creates. Better upstream processes are a necessary but not sufficient condition to reach the aims of the Green Deal. The Commission has assessed the additional capacity made possible by improvement and harmonisation of capacity planning processes at between 4% and 6%.

In a system in which capacity availability will have been increased using the levers mentioned above, it is likely that diversity of demand, and its sheer volume, will still result in a need for trade-offs.

When capacity may still be scarce (e.g. in peak hours, in specific nodes, temporarily during intensive renewal work ….) and when conflict-solving consultation among stakeholders does not result in a solution, specific criteria may need to be defined and applied. As mentioned earlier, these may rely on the principle of maximising the benefits to the community as a whole and take the form of socio-economic criteria.

12 Doubling rail freight, measured in ton/km, compared to 2015 and tripling high speed passenger traffic, measured in passenger kilometres, with high-speed rolling stock traveling at more than 200 km/h, compared to 2015.

VII. Conclusion

Improving the overall process leading to capacity construction and allocation is key. Its aim is to help optimise and maximise utilisation of the existing network while offering a quality of service in line with all levels of market demand. Harmonisation of relevant capacity processes at the international level is an additional and important step for the railway industry to respond to the increasing demand for cross-border journeys.

Improving and harmonising capacity-connected processes and tools is one lever. Beyond this, the European network needs to be renewed, digitalised and upgraded. Deployment of ERTMS, with its potential to enhance interoperability and increase capacity, will prove a key lever.

Eventually, even in a system in which capacity availability will have been increased with the above-mentioned levers, it is likely that the diversity of needs will result in a need for trade-offs.

The interplay eventually leading to the construction of a timetable includes a political dimension: reducing greenhouse gas emissions by developing long-distance transport of freight by rail; reducing congestion in urban areas with a shift from private cars to trains; and improving speed so as to offer travel times competitive with air travel. These ambitions necessarily result in a need for choices and trade-offs at every stage.

Train Access Charges and Capacity Management

Paolo Beria[1]

Introduction

We are used to considering pricing as one of the tools available to manage the capacity of a service in the case of excessive demand, although it is politically difficult to apply. Road pricing is used to reduce excessive demand for congested roads through the imposition of a surcharge, as opposed to more conventional but intrinsically inefficient bans. In this case, pricing has to do with the concept of externality. However, capacity pricing can also be applied for other purposes, for example to extract willingness to pay and increase the margin for the producer. For example, this is the case of airline 'fast track' options.

When we move to rail transport, capacity pricing becomes even more complicated because it overlaps with infrastructure managers' cost covering under natural monopoly conditions. Moreover, one must consider *what is priced*, an externality, compensation for an extra cost or simply the quality and scarcity of a route.

In this contribution I explore the inclusion of capacity pricing principles in train access charges (TACs). The following section briefly overviews pricing principles in Europe, followed by a discussion of *what is priced*, on which depends the viability and effectiveness of the measure. Finally, I conclude with a relevant case, namely the Italian TAC system and management of the saturated HS backbone.

Overview of rail pricing principles in Europe

The panorama of European track access charges is quite varied although they all originate from a common normative framework: Directive 91/440/EC, on the separation between infrastructure managers (IMs) and railway undertakings (RUs), and Directive 2012/34/EU, also known as the Recast, governing rail-charging systems.

Directive 91/440/EC conceives access charging as a way to recover infrastructure costs, but also to incentivise the optimal use and provision of infrastructure (IRG-Rail, 2020), for example using less damaging rolling stock or to manage scarce capacity. The minimum TAC *must* cover the direct costs caused by the single train (and thus depending on energy, weight etc.), but a broader definition allows covering all eligible costs, including amortisation of investments, with markups (Figure 1). Needless to say, the access charges must be net of the subsidies that the IM receives from the state or local authorities to support its functions and investments.

The TAC applied, therefore, is a result of a complex equilibrium among various factors:

- the direct costs, depending on the train and the route;
- the presence of mark-ups, reflecting the *ability to pay* of the train or specific aims;
- the inclusion or not of IM investments, both functional and upgrades (e.g. amortisation of new lines);
- the traffic: the more a network is utilised, the lower the unit charge;
- the size of subsidies: the more the subsidies, the lower the unit charge.

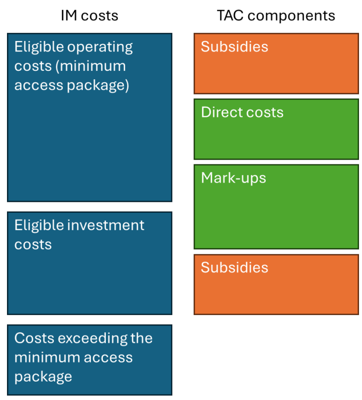


Figure 1. Schematisation of Directive 2012/34/EU pricing principles.

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Given all these degrees of freedom, the resulting European picture is extremely mixed (Figure 2). The highest average charges for passenger trains are found in France, followed by Spain and the UK, all ranging between 1.5 and 2 times the continental average. The reason for such high charges lies in the inclusion of a larger part of the investments and related financial costs in the boundary of eligible costs, and also in excessive network or inefficiency (Crozet, 2018). At the bottom of the ranking, we have Central and Eastern European countries, but also the Nordic ones, the latter due to high subsidisation and the former group also to lower costs. In the middle are Central and Western countries (Germany, Italy, Austria etc.) with more balanced levels of subsidies and high traffic density. In some cases, the average TAC is far from that applied to specific train categories subject to different mark-ups. So, for example, in France market-driven trains (mainly HS ones) pay more than 3 times more than public service obligation (PSO) trains, while in Spain this difference is irrelevant.

TACs, overall, are designed to cover a state-defined[2] share of the costs of the network. However, the level they are set at can pursue other aims, including capacity management, as will be discussed in the following section.

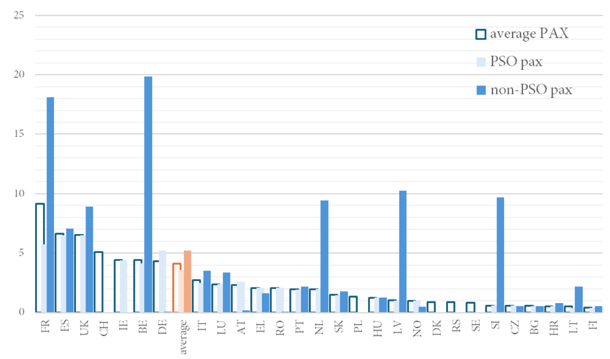

Figure 2. Average TAC for passengers services paid by Rus (excluding subsidies). Source: IRG_rail, 2023

What is (or should) be priced by TACs?

If we exclude highway concessions, when a road is priced the aim is generally to reduce an externality that is an uncompensated cost generated by the users. The fact that prices do not correctly reflect social costs causes excessive use of the infrastructure and a degradation of its speed, which is a welfare loss.

2 Explicitly, but sometimes implicitly defined by the subsidies available.

In rail, the relatively simple inverse relationship between flow and speed does not hold. Typically, the problem is not an excess of trains per se but that they run at different speeds, which reduces, sometimes dramatically, the number of available routes. A line used by trains with regular speed allows more trains/hour and reduces delays. In the long run, a well-structured timetable may even prevent the need for expensive line upgrades.

The causes of such 'heterotachy' (speed differences) are various. A common one is the use of different rolling stock (old vs. new, slow vs. high acceleration, cargo vs. passengers etc.). In addition, the timetable principles may have a role. Regular ('takt') timetables intrinsically maximise capacity, while services too concentrated around peak hours go in the opposite direction. In addition, train services are intrinsically different. On mainlines regional trains calling at many stations must share the track with long-distance or even high-speed trains, not to mention cargo. What is 'bad' from the point of view of the timetable and capacity is good for customers' needs.

If we aim to use TACs as a form of capacity pricing, we must first clearly define the actual aim:

cost covering: the charge compensates the capacity reduction due to the use of that particular route, which translates into fewer trains/km and consequently higher average costs;

optimisation: to induce the RU not to ask for a socially sub-optimal path, not to use inadequate rolling stock or to use a non-saturated line, etc.

quality: the charge is a markup to cover full costs, proportional to the *ability to pay* of the train;

internalisation: the charge is collected and used to compensate other RUs that obtain sub-optimal solutions due to the route (for example with discounts);

selection: the charge aims to exclude trains with lower *ability to pay* when the capacity is not sufficient to cater for demand.

According to the aim, the form and size of the pricing can be very different. For example, if the aim is to correctly cover costs (point a), the TAC would be proportional to the capacity reduction caused by a single route.[3] Instead, if the

3 An example may help. If a line can host 100 trains/day and costs 1M€ (average 1000€/train), a single slot reducing capacity to 90 trains/day should be priced according to the capacity consumed: 10% of total costs vs. 1% of the other slots.

aim is to induce a RU to use a secondary line instead of the mainline (point e), the charge will primarily depend on the difference in revenues and costs of the RU on the two alternate paths, not of the network. In conclusion, there is not *one single charge*, but the charge depends on its capacity-related aim and the possible aims are many and heterogeneous.

A final element to consider is how much pricing is an incisive tool to achieve the capacity management aims, in absolute terms and with respect to other approaches, such as one based on *command-and-control* principles, grandfathered rights, catalogues, auctions, etc. There are two factors to consider: the proportion of the TAC of the RU's total costs and the available alternatives. When TACs are low, the effect of pricing is probably limited, and also in cases where there are no alternatives (for example routes) that the RU can choose to respond to pricing. In countries where TACs are high and account for a significant share of operating expenses, such as France and Spain, the effect of a discount or of a surcharge can be greater.

In the next section I discuss in more detail the case of Italy, where part of the HS line has reached its capacity and implementing capacity charging has recently been suggested by the Regulation Authority (Annex A to regulation ART/11/2023).

The Italian case

Italy is considered one of the most interesting cases of rail liberalisation, as it is the country where head-on competition in the HS market segment has been most pervasive. The entry of Italo/NTV in 2012 and the energetic response of the incumbent Trenitalia have reduced prices (Beria et al., 2022), increased demand and created a network that now covers most of the country's mainlines and is not limited to HS ones. However, the most distinctive characteristic of the Italian case is probably the *focus of competition*: not prices or product innovation but frequency and capacity (Beria et al., 2023). The two players, in fact, are engaged in a sort of 'frequency war' (as opposed to a 'price war' as observed in Czechia (Tomeš et al, 2016)), which today consists in having trains connecting Milan and Rome every 10' or less all day long and Venice/Verona and Rome nearly as often. The consequence of this frequency war is that the central Florence-Rome section of the HS Turin-Naples line, where trains from Milan/Turin, Venice and Verona overlap and share the tracks with some PSO trains, is saturated.

There are not many solutions and they are not simple: building more tracks, forcing PSO trains onto a much slower line or trying to optimise the available capacity, for example by forcing or convincing the two competitors to use double-composition or double-decker trains. This last solution, which is broadly used in France and Germany, is just apparently simple: apart from technical issues, the two opponents are engaged in a strategic game where no one is willing to give up frequency because of the competition, even if double composition trains would theoretically be cost-effective.

The current TAC scheme (for 2016-2021 but extended until 2023 due to the COVID crisis) consists in two components of the minimum access package. Part A prices the direct costs and depends on train characteristics and infrastructure consumption. Part B is the mark-up to guarantee full cost coverage and depends on a classification of trains in terms of their presumed *ability to pay*. The segment priced more is the 'Open Access Premium' that includes all market-driven trains at least partially using lines classified as HS, in contrast to 'Open Access Basic,' which includes fully conventional market-driven trains. Other groups are PSO trains, national and regional ones and cargo, all of which have significantly lower Part B charges. Each group is further divided into sub-groups, again responding to different expected *abilities to pay*.

In the previous scheme, which was active between 2001 and 2017, capacity issues were only marginally present and they aimed at disincentivising heterotachy with a coefficient, surcharging trains whose route was excessively different from the other routes in the timetable. This surcharge can be classified as type b) of the previous list: disincentivising inefficient timetables.

The new pricing for the period 2024-2028 is currently being defined and is ruled by regulation ART/11/2023, which explicitly requires externalities (Part C) to be priced in addition to the *efficient total costs* fully covered by Part A and Part B. The Part C is the sum of five different components:

C1: scarcity pricing on specific lines and periods

C2: environmental costs

C3: incentive to equip trains with the ETCS signalling system

C4: discount for local authorities that finance infrastructure upgrades

C5 (-): compensation for suboptimal travel time during route allocation.

C1 and C5 are the components related to capacity. C1 has been introduced in response to the capacity shortage on the HS lines but it can be applied anywhere in the network that is *declared to be saturated or with limited capacity*. C1 will be applied experimentally in 2024 and officially applied from 2025. It explicitly aims to induce RUs' to behave more efficiently and is not a 'fine' for inefficient use of capacity. Application of it is now limited to the saturated part of the HS network and excludes the urban nodes, where it is impossible to define an 'optimal speed' due to the coexistence of different train categories.

The C1 surcharge is based on the difference between the optimal line speed and the actual speed requested by the RU. All routes exceeding the optimal travel time and a tolerance threshold (e.g. 15.5 minutes from Orte to Settebagni on the Florence-Rome line) are overpriced by a share of the TAC of the routes inhibited by the irregular one. The amounts of C1 for the first experimental year on the four sections to which it is applied are reported in Table 1.

Table 1. Amount of the C1 component experimentally applied in 2024. Values in the draft regulation, not yet confirmed (RFI, 2023).

Section	Optimal speed	Length of the section	C1 = *f*(speed difference)
1°Biv.Orte Sud - BV/PC Settebagni	250 km/h	48 km	13-26€/km
PM Rovezzano - 1°B.Valdarno N.	250 km/h	18 km	27-54€/km
1°B.Valdarno N. - Bivio Orte Sud	250 km/h	170 km	5.7-11.4 €/km
Milano Rogoredo - Bivio/PC Meleg	250 km/h	14 km	18-36 €/km

The other TAC component is C5. Unlike C1, C5 is a negative toll, i.e. it compensates RUs for an excessive speed reduction imposed by the IM for various reasons, including regularity buffers in defining the route. The proposed compensation is 6 €/minute exceeding the optimal path time and it is aimed at compensating the extra costs for crews.

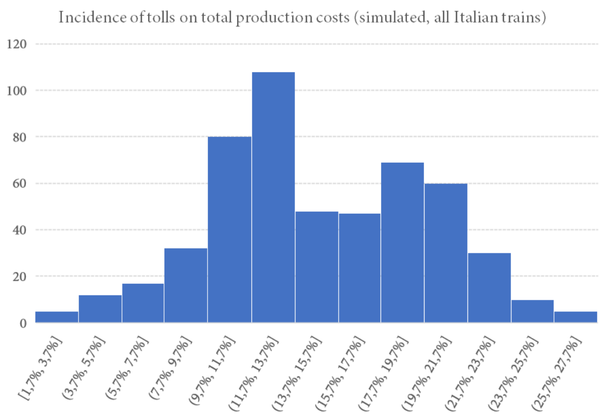

Figure 3. Weight of TAC (Part A and Part B) on estimated operating costs including energy. The observations are the number of lines with similar routes. Source: Beria (2023).

An important element is the effective ability of the C1 surcharge to shift or reduce the demand for routes on congested lines. Figure 3 shows the share of TACs (in the previous regulatory period) in estimated total operating costs, including energy for all Italian passenger services. The amount and distribution of the new TACs is not yet known in detail (the pricing is currently under consultation), but if they remain in the range of the previous ones, their weight will be around 20-25% for HS trains and 10-15% for PSO trains.

For example, for a Venice-Rome route hypothetically operated at 180 km/h, a speed lower than the optimal one on the HS Florence-Rome section, the C1 would come to 2025 €/train (the lower bound of the range). This surcharge represents an additional 16-18% cost with respect to current cost estimates (OPEX excluding TAC about 17-20€/km), or more if operated with cheaper rolling stock. A regional train, the lower speed of which would occupy more fast routes, would pay more than 4000 €/train. It is hard to say if these amounts are actually able to induce companies to change rolling stock or route requests, but the surcharge is far from negligible and it adds to the costs of slower trains. For this reason, it is likely that they may be effective in inducing more frugal requests and limiting the problem of capacity saturation.

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On Flexibility in the Railway Capacity Allocation Process

Martin Aronsson[1]

Railway infrastructure is expensive and it takes a long time to build. The railway system is also inherently rigid compared to most other transport modes. Trains are planned in great detail and long in advance. Over the years in most of Europe even more detailed planning and earlier planning has been the trend, under the assumption that more details and earlier planning should be more precise, thus ensuring better quality and efficiency, although at the same time increasing the workload.

Other industry sectors have had different development trends. Less is produced internally, production cycles and production series become shorter and standardisation sets in along with shorter lead times between 'selling' and 'delivering.' In this way, fewer monetary resources are tied up in stores and in semi-finished products, thus freeing up resources compared to previously. The time between order and delivery is also decreasing. 'Lean' is such a methodology. It employs just-in-time production but also emphasises continual improvements to lessen 'waste,' i.e. non-value adding time spent by production resources.

What would a 'Lean' approach in the railway industry look like, and particularly in the capacity allocation process? How can capacity allocation and the methods it uses be designed to increase flexibility, both in the planning process itself and also to improve service delivery as the daily timetable is executed? It is important here to stress that flexibility does not mean being sloppy; flexibility is to be understood as having *planned ability* to adjust as underlying facts and assumptions change.

'Lean' teaches us that we have to work with the things that can be improved, not the ones that are already best practice and competitive. Therefore, for the railway transport industry it is not the environmental impact that is of major concern. Most railway transport is already environmentally friendly. It is rigidness that must be addressed, and in particular the long lead times in planning. The annual timetable has to be developed incrementally as more requirements are known, but not too long in advance as the assumptions that the plan depends on may then change. Compared to other industry sectors the railway sector is late in adopting ideas from 'Lean' methodology, but when doing so it is important to not lose the advantages it already has.

At RISE we have conducted research aimed at improving flexibility in the capacity allocation process (see, e.g., Forsgren et.al., 2013; Gestrelius et. al., 2015; Gestrelius, 2022). Our research depends on a number of observations, some of the more important of which are presented below.

The first observation is that this industry sector is one of the few that 'promise' a plan rather than to deliver a result. Each year the annual timetable is fixed, down to the second at all timetable points (geographical points in the network). These points are far more than just the ones where there are commercial activities like passengers entering or leaving the train or freight wagons being (de)coupled. All the other *production* timetable points are also fixed, leaving no room for adjustments if the outer world changes and the assumptions made a year earlier no longer hold.

By shifting the focus from the detailed schedule, the timetable, to what is instead to be *delivered*, a first level of flexibility can be achieved. Do not 'promise' a plan; 'promise' to deliver on time where it matters. What is important for railway transport customers is almost always to depart from the origin and to arrive at the destination, not all the intermediate production timetable points. Compare this with a customer ordering something from a manufacturing company. He is concerned with the delivery of the product, not all the intermediate times and production plans. The contract accordingly specifies the quality of the product and the time of delivery. Our research over more than 15 years in Sweden has proven that there is much capacity that can be freed up by changing the focus from offering a detailed production plan to important delivery points and times. It is these places and times that are to be contracted. The production points between the contracted timetable points are thus free to continually optimise the production as the rest of the world changes, both planned changes, e.g.

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cancelled or added train routes and maintenance, and also weather conditions. Incrementally optimising the working timetable increases both capacity utilisation and punctuality. We call this *incremental allocation*.

The second observation concerns the difference between measuring capacity utilisation and measuring productivity. Resource utilisation measures the time a resource is allocated to a task while productivity measures the amount of work that gets done in that allocated time. It is important to distinguish between the two. The UIC-406 method essentially measures productivity. Given a detailed schedule, a 'compression' of the schedule is made while still retaining the train orders in the schedule. This is essentially the same as the critical path method used in project planning and one of the first computational methods for optimising a schedule. The amount of free space that appears at the end of the compressed result compared with the starting state measures how tight the schedule is. This does not, however, capture the available planning space as the train orders are retained. Essentially capacity allocation determines the productivity in that it determines the train orders in the schedule. To measure capacity *utilisation*, i.e. how well the infrastructure is utilised, we need another way to measure. In our research at RISE we have proposed using the area of the traditional Marey chart that the train route occupies. The utilisation is then the relation between the sum of all the areas covered by the train routes and the total area for a determined period of time, typically an hour, measured in, e.g., kilometre-hours. This measure does not depend on the different train orders and it tells us how many of the available production units are utilised in value-adding production. Hence the area covered in a Marey chart is a better measure in advance planning of the capacity allocation process while the UIC-406 method may be used to measure the productivity, planned or delivered, of a concrete schema.

When trains have different speeds and/or are on single-track lines in different directions, areas in the space-time diagram are 'lost', i.e. not used for value-adding production of railway services. See Figure 1. This corresponds to setup times in manufacturing, something planned to be able to manufacture different products on the same machine. Since nothing is manufactured during the setup time, it is not value adding and so the amount of it should be minimised. Therefore, it is important to set aside enough setup time in the utilisation plan, but not more than needed, to later enable detailed scheduling of traffic with different performances.

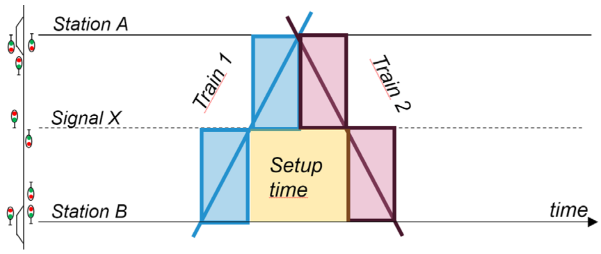

Figure 1 Setup time between train 1 and train 2, i.e. the capacity (time) spent to handle the change in direction between train 1 and train 2 on line segment B-X.

The third observation concerns workload and the quality of the schedule. This can be compared with the just-in-time concept in 'Lean' methodology in which semi-finished products arrive just before manufacturing, thus lessening the amount stored in front of the machine. In planning processes this corresponds to the number of decisions made during the process and the level of detail that these decisions involve. While deciding can be beneficial to get firm continuation of work processes, it can be devastating if the assumptions that planning decisions depend on are not realised, i.e. the decision was made on false assumptions. See Figure 2. If many decisions depend on a previous decision depending on a false assumption, many decisions will have to be 'unwound.'

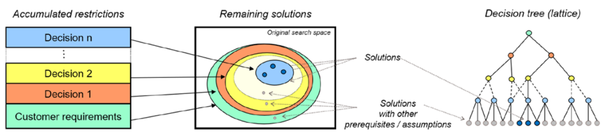

Figure 2 Decisions and remaining solutions to a planning problem. To decide is to gradually create a plan but also to discard alternative plans. It is therefore important to make informed decisions, not speculative ones.

As society is moving faster and faster, the lead time between deciding and acting is shrinking for the railway transport industry, not least with internet and the possibilities it allows to make late decisions. Waste in the planning process is when replanning occurs, as previous decisions have proven to be incorrect and must be changed. This should be avoided as much as possible. Replanning also takes time, time which may not exist late in the allocation process. The result may therefore be inefficient and with all the production timetable points being fixed there is less resilience. Passengers and freight forwarders, on the other hand, expect the railway system to be dependable, which can be hard to deliver with long lead times and changing assumptions and expectations. This is very much at the heart of the ability of the railway system to meet the customers' expectations now and in the future.

To eliminate this kind of waste in the planning process, it is important to reduce the time between scheduling decisions and operations. See Figure 3. This does *not* mean waiting too long to decide. Then, control is instead lost. Instead, it means planning based on known firm knowledge, being able to plan at different levels of detail: more abstract plans earlier which encompass a large number of more detailed schedules that are implementable later. Industry largely uses modularisation techniques: the same modules or semi-finished products can be used in many different situations later. The TTR process capacity model (RailNetEurope, 2021) is such an attempt to implement modularisation in the railway capacity allocation process.

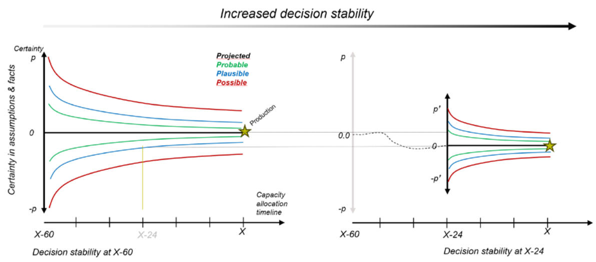

Figure 3. The uncertainty cone. The later planning decisions are made, the more likely they are to be correct with respect to external factors. In this particular case, the forecast at X-60 was only 'plausible' when it reached X-24, but the predicted uncertainty at X-24 is decreased as the cone of (un)certainty is smaller in the figure on the right.

The fourth observation is that since (in Europe) most of the railway infrastructure is publicly owned it is important it is utilised in society's best interest, i.e. transparent and known principles are used by the allocation body to prioritise the allocation of capacity on publicly owned infrastructure. This is not only about putting as many trains as possible on the infrastructure, but also very much about the value to society, the *utility* that the different trains generate. Without a valuation function, there is no firm basis for prioritising one schedule over another, and transparency is lost in how the allocation body will solve the scheduling task in congested areas.

It is not sufficient to only allocate capacity; the allocation body must also allocate capacity in such a way that the utility to society is as high as possible once the trains run. Therefore, it is not just about getting the annual or daily timetable as theoretically efficient as possible, it is *delivering* trains on time that ultimately makes a transport system dependable and used. This is related to the first observation made earlier: not to contract the plan but to contract the delivery. Therefore, *dependability* should also be part of the utility function, i.e. the probability of delivering the service as expected. It is not sufficient to just concentrate on how the allocation is made, but attention needs to be given to how value is delivered to society.

This leads us to some rules of thumb regarding planning under uncertainty in the capacity allocation process:

Stay on an abstract level as long as possible. Fewer details lead to increased decision stability.

Apply fact-based decision-making. Less replanning is needed as assumptions underlying decisions are valid over time.

Objective prioritisation depends on having an explicit objective function.

Keep flexibility. Options kept open as long as possible give greater possibilities to adapt the plan to changes.

Agree on deliverables, not the plan. It is the delivered service that someone is paying for, not what is in the plan.

By striving to follow these rules, the planning process and the resulting plan will generally be more fit to cope with a changing environment, leading to improved quality and efficiency of operations. Flexibility, not to be confused with sloppiness, is crucial for the future of the railway system.

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Past Issue

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Türkiye as an infrastructure pivot?

In this issue of Network Industries Quarterly, we present and discuss the gradual ascent of Türkiye to become a global or at least a regional 'infrastructure pivot,' as we call it.