Is freight really flexible in the timetabling process for a mixed-use rail network? Some considerations based on French experience

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Abstract

Several demands, such as passenger traffic, freight and maintenance works, are competing for a portion of shared and scarce resource: rail infrastructure capacity. In Western Europe, recent decades have been marked by a tendency to favour the scheduling of train paths based on a regular-interval timetable. France has recently adopted this scheduling approach. The paper focuses on the position of freight in this peculiar timetabling context and addresses the specific issue of freight flexibility, based on current French experience. The analysis is above all carried out from the infrastructure manager's perspective. It is mainly supported by the results of a series of about thirty interviews, carried out in 2012 and 2013 with the parties involved in the French timetabling process. The paper highlights that rail freight flexibility in the process has limitations and supports the thesis that anticipation is an essential issue for the infrastructure manager. Fitting freight train paths into the timetable is essentially a delicate balance of interests.

Keywords: rail freight; train path; infrastructure manager; timetable planning; flexibility

Résumé

Fret, voyageurs, travaux: toutes ces activités sont en concurrence quand il s'agit d'obtenir cette ressource rare qu'est la capacité d'une infrastructure ferroviaire. En Europe de l'Ouest, ces dernières décennies ont vu s'affirmer une nouvelle manière de concevoir l'offre horaire, basée sur le cadencement. La France a récemment adopté cette démarche de planification. L'article porte sur la place occupée par le fret dans cet environnement horaire particulier et s'interroge sur le degré de flexibilité de cette activité dans le processus, à partir de l'exemple français. L'analyse est avant tout centrée sur la vision du gestionnaire d'infrastructure. Elle s'appuie principalement sur les résultats d'une série d'une trentaine d'entretiens menée en 2012 et 2013 auprès des acteurs impliqués dans le processus de planification horaire. L'article met en évidence un certain nombre de limites à la souplesse du fret et présente l'anticipation comme un enjeu majeur pour le gestionnaire d'infrastructure. Insérer des sillons pour le fret dans un graphique de circulation constitue un exercice délicat.

Mots-clé: fret ferroviaire; sillon; gestionnaire d'infrastructure; planification horaire; flexibilité

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1. Introduction

The operation planning of mixed-use rail infrastructures is complex because it requires the infrastructure manager (hereinafter IM) to cope with heterogeneous requests for a scarce resource: infrastructure capacity. In Western Europe, operation has traditionally been timetable-based but in recent decades an increasing tendency to anticipation came to light through the implementation of regular-interval timetables. France has recently implemented this scheduling approach for the sake of a more efficient capacity allocation process. The paper focuses on the position of freight in this peculiar timetabling context and addresses the specific issue of freight flexibility, based on current French experience. The analysis is mainly supported by the results of a series of about thirty interviews carried out in 2012 and 2013 with all parties involved in the process: practitioners (timetable planners (11), train dispatchers (4), customer relations staff (8)) as well as executive managers and experts (10). Although the analysis is above all carried out from the IM's perspective, the paper provides also some insights into railway companies' constraints when requesting capacity to operate their services. After a brief literature review on the issue of freight train scheduling (section 2), contextual information is given about the new organisation of the French timetabling process (section 3). Section 4 provides an overview of the key elements that are required to design a train path. The main differences between freight and passenger traffic requirements are explained. Section 5 focuses on the nature and degree of constraint when fitting freight train paths into the timetable. The issues of alternative routes and running time are analyzed. Section 6 concludes the paper.

2. Literature review

Freight has rarely been the main focus of the European literature on rail capacity allocation and timetabling. One could assume that this relative lack of interest has been the result of the preponderance and dynamism of passenger traffic. In contrast, in North America, where freight is dominant on the tracks, an extensive literature has dealt for decades with the various aspects of rail freight transport planning and operation, including the train scheduling issue. Nevertheless, the expected traffic growth of rail freight demand on some identified transnational corridors has brought new interest in thoroughly considering this issue in the European context. Broadly speaking, the challenges are far from insignificant in both contexts where some network segments, whether shared or not, are (likely to be) congested.

Operations Research has provided literature on the specific issue of freight train scheduling. A key point is that train scheduling is not an unequivocal concept and may involve different planning time horizons. In North America, freight trains commonly operate without timetable (also called "improvised operation" in the literature) whereas in Western Europe, freight trains run following given timetable and route which may have been planned up to several months before train movements ("master scheduling"). "*The scheduling may thus involve both route choice and slot allocation, where a slot is the time window a certain train is planned to use a specific track section*" (Törnquist, 2006). Among the most recent works, Kuo et al. (2010) provide a brief review focused on the different techniques and models that have been developed to cope with the freight train scheduling issue. The authors underline that all the existing literature is concerned with the satisfaction of the interests of only one of the parties involved, i.e. shippers or carriers. They develop a technique for addressing the multi-line freight train scheduling problem taking into account the perspectives of both stakeholders. They apply it to a pan-European case study. Cacchiani et al. (2010) tackle the issue for rail infrastructures that are shared with passenger traffic. They aim to fit into a timetable with pre-fixed passenger services additional freight trains while trying to respect as much as possible the initial requirements of freight operators. They apply their approach to a real-world case study using data from the Italian rail network. In the North-American context, Mu & Dessouky (2011) are concerned with scheduling freight trains on complex rail networks whereas most literature has only dealt with simplified rail networks or single lines.

To the best knowledge of the author, there is a noteworthy common point in the existing Operations Research literature which considers shared-use rail infrastructures. All authors make a difference between passenger and freight train scheduling issues. They point out that passenger services require to be early planned (from several years to several months before the train movements) according to strict requirements with regard to departure and arrival times, running time, intermediate stops (and train connections, especially in railway networks where regular-interval timetables have been implemented) and consequently, routes. In contrast, freight appears, explicitly or not, to have greater flexibility and may be easily perceived as an adjustment variable. The paper discusses this issue of freight flexibility, through the French case study, where both activities have to share a great part of the rail network.

3. Background: the French timetabling process

Access to European railway networks has been deeply changed in the last decades. The implementation of the European Directive 91/440 led, in different ways, to the unbundling of the national incumbent railway companies that previously controlled all aspects of the railway system (transport service provision, rolling stock and crew scheduling, timetabling and capacity allocation, infrastructure planning and maintenance). In France, this implementation resulted in 1997 in the creation of a new entity, Réseau Ferré de France (RFF), along with SNCF, the historic French rail carrier. According to the requirements of the European Directive 2001/14, RFF has become officially responsible for capacity allocation since 2003 in a context where the deregulation of the rail freight market was about to become effective to boost a declining activity. In France, the volume of cargo carried by rail fell by 50% (in ton-kilometers) between 1980 and 2010. The first train of a private operator on the French railway network ran in 2005. In 2012, new entrants operated 29% (expressed in train-km) of all freight traffic (Source: RFF).

Capacity allocation consists in selling portions of railway infrastructure capacity (also called “slots” or “train paths” in the literature) to the capacity applicants (“railway undertakings” or “authorised candidates”, as defined by the European regulation) willing to operate services on the national rail network. A train path is defined as “*the infrastructure capacity needed to run a train between two places over a given time-period*”. Capacity allocation is therefore closely related to the drawing up of the timetable which consists in designing the distance-time graph which positions paths in relation to each other on the network throughout the day. The European Directive 2001/14 refers to the core notion of “working timetable” which is defined as “*the data defining all planned train and rolling stock movements which will take place on the relevant infrastructure during the period for which it is in force*.” It has to be drawn up once per calendar year.

The preparation of the 2012 working timetable brought an important change in the conduct of the French process with the implementation of a new scheduling approach: the regular-interval planning of the train paths. It is essentially based on anticipation and in practical terms, on the repetition of a pattern of services throughout the day (for further details, see Tzieropoulos et al. (2010)). As a consequence, the organisation has been deeply reshaped, moving from a single-stage process to a 6-stage process (Figure 1).

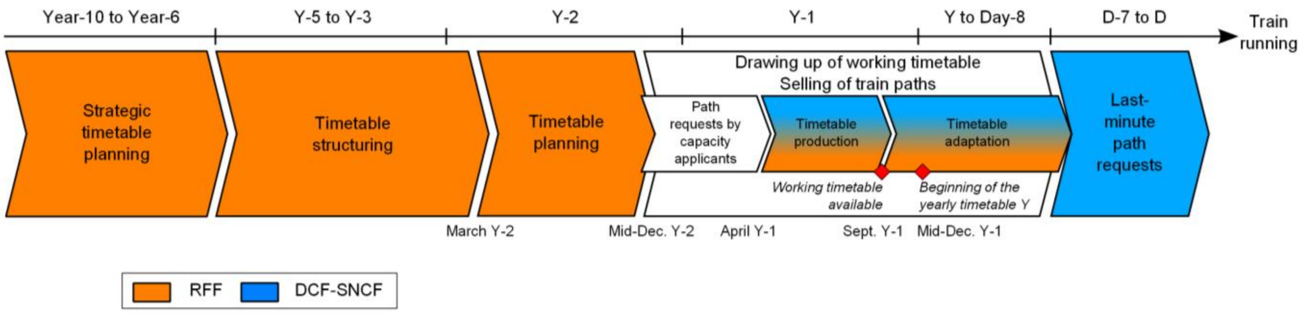

Fig. 1. The French timetabling process: organisation and stakeholders (Source: Adapted by the author from RFF’s reference document on capacity (2012))

The new process stretches from ten years to a couple of hours before the train movements. In the earliest stages, the studies focus on defining satisfactory 2-hour patterns (strategic planning and structuring stages) and identifying associated investments (strategic planning stage). Two years before the trains run, the regional and national 2-hour service patterns are duplicated to create a generic 24-hour timetable (planning stage). “Pre-built paths” for passenger and “catalogue-paths” for freight services are then available to guide and facilitate the upcoming path orders. Between December of year-2 and April of year-1 (eight months before the working timetable comes into force) capacity applicants can place their formal path orders, either choosing from among the pre-built (or catalogue) paths or asking for tailor-made paths. This begins the timetable production stage which runs until August of year-1. From September of year-1 to seven days before the train movements, timetable planners deal with late path requests according to the remaining capacity (adaptation stage). In the last days or last hours before the trains run, “last-minute path requests” can be made. In 2012, around 90% of them were submitted by freight operators (Source: RFF). The entire process draws on an iterative dialogue with all capacity applicants. The aim is to have a final timetable which meets their commercial expectations as much as possible while guaranteeing an optimal use of network infrastructure capacity.

To date, the French timetabling process still remains carried out by two distinct entities, as a result of an ambiguous implementation of the European Directive 91/440. RFF defines the guiding principles (compiled in an annual *Network Statement* (RFF, 2012)), sells the train paths, performs the earlier stages of the timetabling process and is associated to the later stages of the timetable preparation. SNCF timetable planners, acting on behalf of RFF, prepare and adapt the working timetable. Last-minute paths are exclusively handled by SNCF staff (timetable planners and train dispatchers). Since 2009, all these SNCF employees have been brought together in an independent division within SNCF, the so-called “Direction des Circulations Ferroviaires” (DCF). Employees from both DCF-SNCF and RFF were interviewed (35% / 65%). This peculiar organisation should be modified in the near future with the recently launched reform of the French railway system.

A key concept of the timetabling process is the train path. How similar are train path requests from freight and passenger carriers? The following sections mainly focus on the four last stages of the timetabling process (i.e. from two years before the trains run), when infrastructure is invariant or may only be marginally improved by investments. The timetable planning stage is also the time when freight train scheduling actually starts in the current French timetabling process.

4. Cross-analysis of the key features of freight and passenger train paths

When a capacity applicant, whether it operates freight or passenger services, wishes to submit a path request, the IM requires the following elements: origin and destination; intermediate stop(s) (if any); train characteristics (type of traction unit(s) and train length as well as, for freight services, train weight and any specific features like oversized gauge or dangerous goods); departure and arrival times; tolerances (+/- min); requested schedule; any useful detail that would help timetable planners to handle the path request in a satisfactory manner (e.g. time constraints at the border for international trains). Thus, a train path essentially involves two main dimensions: time and space. A classification of the aforementioned elements according to these dimensions is given in Table 1. In the following subsections, the three categories are detailed and illustrated in the French context, with an emphasis on the differences between freight and passenger traffic requirements.

Table 1. Classification of the key elements required for a train path request

Time dimension	Space dimension	Both dimensions
Departure time	Origin	Traction unit(s)
Arrival time	Destination	Train length
Tolerances	Intermediate stop(s) location	Train weight
Intermediate stop(s) duration		Oversized gauge
Requested schedule		Dangerous goods

4.1. Train characteristics and the speed limit of train path

Train characteristics are key information for timetable planners insofar as, together with infrastructure features, they may influence: (1) the route in the case of specific restrictive features of the convoy (e.g. oversized gauge) and (2) the speed limit of the train path, i.e. visually, the “slope” of the path on the distance-time graph (figure 2.a.). The steeper the slope is, the faster the train runs.

In France, the standard weight/length combination of loaded block freight trains is 1800 tons/750 meters. Since 2012, some 850-meter/2400-ton freight trains have run on identified routes (including the four daily return trips of the rolling highway between Le Boulou (France) and Bettembourg (Luxembourg) operated by Lorry Rail). Broadly speaking, loaded freight trains are longer and heavier than passenger trains. In terms of traction units, freight and passenger trains are mainly electric-powered. In 2010, 78% of the overall traffic (expressed in train-km) operated on the French rail network was electrically powered (Source: RFF). But it should be pointed out that the new entrants providing freight services predominantly use diesel traction. In 2012, only SNCF's main competitors – the ones that provided long-distance services (ECR, Europorte and VFLI) – had electric locomotives[†]. Moreover, behind overall traffic volumes, rail freight consists also of many local and shunting movements that are commonly carried out by diesel-powered locomotives.

Given the standard freight train characteristics, the performance of freight paths is lower than the one of passenger paths. Around 95% of the freight paths (requested at the timetable production stage) are designed with a theoretical speed of 100 km/h. The 5% remaining are specific services (including intermodal traffic) that are given paths with a speed of 120, 140 or 160 km/h. In contrast, passenger trains commonly run at between 160km/h and 220 km/h on the shared-use segments of the network. Because they are slower than passenger trains (with the exception of local trains with many stops), freight trains need more capacity.

4.2. The space dimension of train path

Freight trains materialize flows of goods that transit between different spatial locations at the national and international levels on rail infrastructures with a geographical organisation and technical characteristics that are strongly influenced by historical legacy (Zembri & Bavay, 2011). Freight train departure and arrival points can be ports, intermodal terminals, marshalling yards, freight terminals or private sidings. They are more or less accessible according to the local trackage configuration (See an example in Niérat et al., 2009). A noteworthy point is that a freight train is not always based on a single path. By freight train, one should understand a set of loaded and/or empty wagons operated between two or more defined points with a given rolling stock (one or several traction units). For block trains, the overall route might be divided into several train paths for organizational reasons on the part of the operators. The train uses successive paths to reach its final destination. To achieve higher volume traffic, carload services are essentially based on several trains using several interdependent paths. A single path may also hide changes in train composition (e.g. the intermodal train between Paris and Toulouse with an intermediate stop in Bordeaux to drop off wagons). Thus, freight flow, train and train path are three concepts that partially overlap.

Location of intermediate stops has also to be filled by operators when requesting paths. For freight services, these locations depend on the operators' geographical coverage and organisation. New entrants may have, for instance, different crew-change locations from the freight division of the incumbent company, Fret SNCF. As a consequence, these stops are important since they can influence the route to be used (figure 2.b.). The specific issue of alternative routes is addressed at subsection 5.1.

4.3. The time dimension of train path

The time dimension is important when considering a path request because the use of the network capacity is not evenly spread throughout the day. Passenger trains mainly run during the day, with two identified peak hours, in the mornings and evenings. In contrast, freight trains appear to be more flexible because they can also be operated at night. An emblematic example is the case of overnight intermodal services between the Paris area and Avignon and Marseille. Long-distance international freight trains are often a combination (e.g. a train between Germany and Spain typically runs overnight between Germany and Paris and in the daytime between Paris and Spain, or the other way round).

In terms of departure and arrival times, passenger services are commonly requested with restricted tolerances in order to meet commercial expectations. Yet, the recent implementation of a regular-interval timetable has changed the prospect since the point is to develop train connections rather than only point-to-point trains running at record speeds. In this new configuration, the scheduling flexibility for all services concerned by regular-interval timetable planning is supposed to be very limited, up to the minute. The nature and meaning of "strict" tolerances have therefore changed. In contrast, some freight path requests may be expressed in less precise terms

[†] For further details about locomotive pools of new entrants, see Grouillet, A. (2012). Un parc moteur diversifié et coloré. *Rail Passion*, Hors-série « Les nouveaux acteurs du fret en France », n° 20, juillet, 64-98.

that, paradoxically, are not so easy to handle for timetable planners (e.g. two return trips between point A and point B at three-day intervals). But most freight path requests have at least an imperative requirement on departure or arrival time, deriving from supply chain management considerations. Within the rail freight market, tolerances to operate services may vary from some minutes to some hours. The issue of running time and tolerances is further described and analyzed at subsection 5.2.

Operators have also to carefully indicate the duration of intermediate stops. These stops are indeed vital for long-distance trains to change the crew and/or the rolling stock, drop off or pick up wagons, organise the takeover of the convoy by another operator... These must be planned to adapt the train path profile (figure 2.c.). Stops are represented by horizontal segments in the distance-time graph. Their length is proportional to the stopping time.

The requested schedule is another crucial element of the time dimension of a train path since it defines how many times the path will be repeated in the distance-time graph during the timetable period. This may vary from once per year to five to seven days per week throughout the timetable period, depending on the type of service operated. Passenger traffic is mainly based on regular services while freight traffic consists of a wider mix of both regular and occasional services. Moreover, fitting a given path into the timetable is not equally easy throughout the year, especially because of planned maintenance works that reduce the available capacity. As a consequence, timetable planners may need to build several train path variants from a single path request.

A last aspect can be pointed out when speaking of the time dimension of a train path. It is related to the planning time horizons in the timetabling process. As shown with French figures by Morvant (2013), passenger and freight traffic have actually two different train path request profiles. As passenger traffic requires early planning (up to several years before the trains run), freight rather leads to an intense activity later in the process (i.e. several months to several hours before the train movements), as economic, organizational or contractual uncertainties with shippers are gradually removed (Figure 1, at the two later stages of the process). In such a configuration, freight train path scheduling tends to be influenced by all elements (paths or maintenance windows) that have been previously fitted into the graph (Figure 2.d.). Maintenance windows are commonly represented by trapeziums. In the example, the departure of the freight train is slightly delayed and the second intermediate stop is longer than requested in order to fit into the graph in a conflict-free way (i.e. a way that guarantees safe movements).

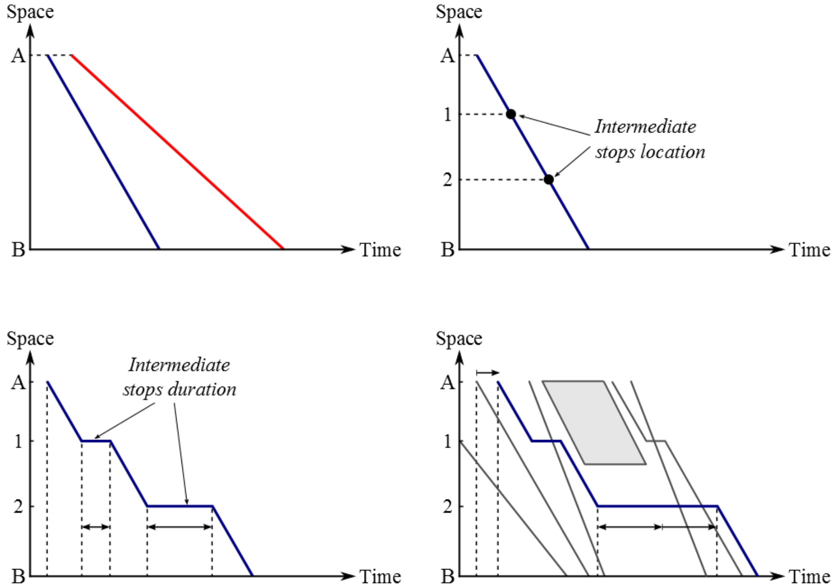

Fig. 2. (a) speed limit of train paths (b) intermediate stops location; (c) intermediate stops duration; (d) fitting a freight train path into a graph with pre-planned train paths and a maintenance window (Source: author)

5. Fitting freight train paths into the timetable: a delicate balance of interests

In section 4, the design of a single standard train path has been explained. But as already outlined, more than passenger paths, freight train paths have to fit into a graph taking into account constraints which may lead, to a greater or lesser degree, to depart from operators' requested requirements. The aim of this section is to provide further insight into the various constraints the IM has to consider when dealing with freight. To this end, a focus is given on two concepts which can be analyzed both as performance drivers and flexibility indicators: alternative route (space time) and running time (time dimension).

5.1. Alternative routes: does the French rail network provide a real spatial flexibility?

The routing issue can be addressed at two levels: local (track level) and national (network level). According to the interviewed timetable planners and train dispatchers, freight can be considered as more flexible with regard to alternative routes at the local level because it does not require any platform when stopping to maintain the distance block between trains or to be overtaken by a faster train. But a noteworthy counter-example is the rolling highway between Le Boulou and Bettembourg which can only use a limited set of upgraded tracks and sidings because of its specific gauge features. Broadly speaking, all trains with an oversized gauge or carrying dangerous goods are under strict restrictions related to stops location and routes, especially in tunnels. At the national level, “alternative routes” are not numerous on the French rail network. By alternative route, one should understand a route provided with performance features (electrification, signalling system, speed limit, axle load limit and wagon size depending on gradient profiles, track condition and gauge) as close as possible of the major route ones. Hereinafter, special attention is given to this second level of analysis.

To date, only three geographic areas are provided with such alternative routes (the regions Nord-Pas-de-Calais and Lorraine as well as the Dijon-Avignon axis (including both sides of the Rhône)). Most freight traffic travels through these parts of the rail network (Figure 3)[‡]. Yet, the problem is that these alternative routes represent limited portions of the rail network and enable only adjustments at the regional level (e.g. when maintenance work is carried out or in case of disruption on the major route). Besides, when closely considering some trackage configurations, it might be more or less easy to reach all destinations with all routes (e.g. from the marshalling yard of Miramas, the route via Cavaillon is much easier to use than the route via Tarascon to reach the right side of the Rhône (which is a dedicated freight line)). At the national level, “equivalent” options for long-distance trains are limited and the choice between them has always to be anticipated because switching from one route to another would induce long detours (up to several hundred kilometers)[§].

In 2010, around 80% of the overall traffic (passenger and freight) was concentrated on 30% of the French rail network (Source: RFF). The development of dedicated lines for high-speed passenger trains should have released capacity for freight on the segments that were previously shared. But from the 2000s, the increase of regional passenger traffic but also of possessions for maintenance work has limited the available capacity, thereby contributing to the failure (up to now) to reverse the downfall of freight traffic. In 2012, rail freight carried only 32 billion ton-kilometers and represented a train volume of 76 million train-kilometers (Source: RFF). In this context, developing a meshed network of alternative routes on the mid-long term appears to be highly desirable for the IM in order to: (1) give capacity to freight and foster its development; (2) limit the negative impacts of maintenance work which is mainly carried out at night and therefore disturbs overnight and long-distance freight services and (3), generally speaking, address any failure on major routes and so, enhance robustness.

For some freight services, new entrants tried to develop alternative routing strategies to those of Fret SNCF in order to avoid congested segments and nodes (see examples in Zembri & Bavay, 2011). But they had to face important difficulties related to the poor performance of some parts of the rail network although the planned route was shorter and more direct to reach the final destination. This should have resulted in substantial productivity gains in terms of infrastructure charges, running time, crew and rolling stock use. Sometimes, the

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[‡] It is worth noting a lack of alternative routes on the following main axis: Bordeaux-Hendaye, Nîmes-Perpignan and Bordeaux-Narbonne.

[§] For example, to reach Perpignan from the Paris area, there are two possible routes on both sides of the Massif Central: a Western one (via Orléans, Limoges and Toulouse) and an Eastern one (via the Rhône valley).

lack of routing flexibility may also be the result of shippers' requirements. To continue with the example of mineral waters given by Zembri & Bavay (2011), since 2012, Danone has required from ECR to carry them from Evian to Great Britain with electric traction units only, which significantly influences the route. Direct consequences for the operator have been the increase of the infrastructure charges** but the decrease of the maintenance cost of the rolling stock (maintenance of electric locomotives is cheaper than diesel-powered ones). Thus, the deregulation of the rail freight market introduced a new consideration in the timetabling process concerning the routing strategies. These may differ from a capacity applicant to another, even if, most of the time, real alternatives still remain constrained.

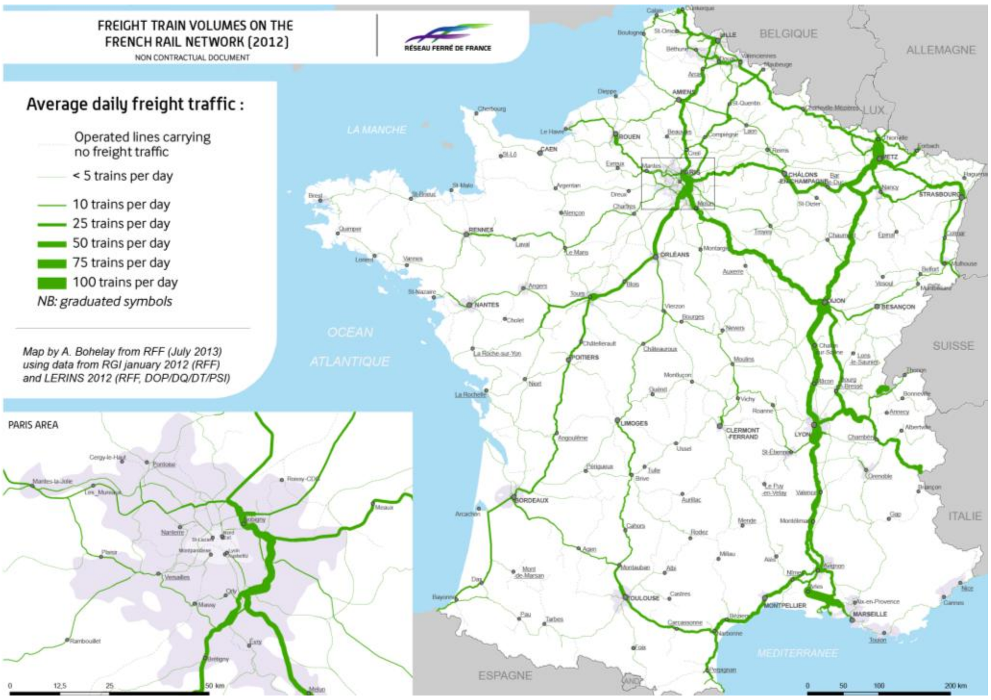

Fig. 3. Freight train volumes on the French rail network (2012) (Source: RFF)

5.2. Is running time a key requirement for rail freight traffic?

The interviewed timetable planners stated that freight paths are generally designed with larger time allowances than passenger paths. On tracks, freight trains can therefore be stopped and parked for a while without affecting the time the cargo is delivered to the final customer. Freight paths are more "malleable", visually speaking (Figure 2.d). One could easily assume that the issue of running time arises differently for passenger and freight traffic. Yet, the rail freight market is essentially a heterogeneous market within which different performance expectations coexist. For example, the two trains carrying perishable goods every night from Perpignan to the international market of Rungis have strict requirements in terms of departure and arrival times. In this case, a later arrival (e.g. within 30 minutes from the tolerances given by the operator) may be very detrimental because goods are unloaded when sales to retailers have already begun. The rail mode becomes therefore irrelevant for a few minutes, especially as road haulage is more reliable in a context where the amount of maintenance works is substantial on the French rail network (and will remain so for at least a decade). A similar situation can be described with regard to the departure time of intermodal trains (Niérat, 2011). Rail transport is discontinuous in time as opposed to road transport: when a container cannot be loaded for a delay of one minute, according to the service frequency, 24 hours may be added to the total travel time, making road haulage much more competitive. Thus, intermodal competition with road haulage has to be kept in mind when designing freight paths.

Short travel times could have been a selling point for some new entrants when they started their services on the French rail network since they were able to significantly reduce some transit times because of a more flexible

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** Among other considerations, infrastructure use charges are modulated according to the traffic volume on the different segments of the rail network. The busiest lines are the electrified ones. For further details, see RFF (2012).

organisation compared with Fret SNCF's one. But when speaking of time dimension, other elements may be of greater importance than a record transit time from the operator's perspective and put further constraint on the graph. According to the spatial organisation of operators (depot locations, size and assignment of their locomotive pool…) and the traffic they operate, the sequence of services at given intervals and corollary, the rolling stock rotation may involve interdependencies between path requests. For instance, grain traffic is less time-sensitive but seasonally requires several successive return trips per day to empty silos, often located along single lines with traffic restrictions. To give another example, the rolling highway services are commercially based on sequences of services at evenly spaced intervals (every six hours for Bettembourg-Le Boulou) with dwell times that are incompressible both at the origin and destination points for loading/unloading and shunting movements. In addition, terminals may have capacity restrictions (e.g. two trains cannot be handled at the same time at Le Boulou).

Furthermore, for some services, timetable planners may also have to consider the opening times of freight terminals and lines (those equipped with manual block or non-signalled). They indeed increase the headway between trains (and consequently reduce the available capacity) and might lead to charge the operator with additional fees. If a station is closed by the time the train is planned to arrive, it has to be parked on sidings until its opening (chargeable service) and might require a new train driver. This results in a lower productivity. Operators are sensitive to all these time thresholds beyond which new resources (crew or/and rolling stock) are required to operate services, especially if there are interdependencies and possible snow-ball effects if rotations cannot be ensured. For example, to operate a daily service it is interesting to be given paths that enable a return trip in less than 24 hours in order to optimize the rolling stock rotation. From 25 hours, a second locomotive will be required.

If one adds track possessions for maintenance to the equation, timetable planners' hands are tied by numerous technical and commercial constraints. Since the preparation of the 2012 timetable, maintenance work on the French rail network has been planned according to both axial and radial perspectives (from/towards Paris) above all in order to limit impacts on passenger trains (which are the most remunerative movements for the IM). Freight trains that use several segments for which the planning of maintenance works is conflicting (i.e. maintenance windows are not coordinated) are the most difficult to serve. The aforementioned rotations may therefore be compromised although requested performance requirements appeared, at first glance, to be easy to meet. Long-distance trains are particularly put at risk because they are disturbed by maintenance works at night and by passenger trains during daytime, especially at peak hours near major cities. Thus, strict traffic separation over time (freight traffic at night and passenger services at daytime) is impossible.

Running time is a multidimensional issue. It may be, to a greater or lesser degree, a key requirement according to the operational organisation of operators and/or contractual agreements with shippers. In any case, it remains subject to threshold effects that influence productivity (for operators) and attractiveness (for shippers) of rail freight. Reliability is an important related issue when considering the materialization of the planned freight train paths in train movements. As such, the value of reliability has been a topic for Economic research (Zerguini & Savy, 2010). For shippers, being delivered on time may be more crucial than being delivered in record time. From the IM's perspective, low reliability of train movements inevitably impacts on the timetabling process because it may influence the operators' strategies when requesting paths. The last-minute path is a good example. It is the ultimate tool to ensure flexibility in the process but the current large volume of requested last-minute paths is also a symptom of a lack of confidence on the part of operators, especially because of the current failings in the planning of maintenance works that generate uncertainty.

6. Concluding remarks

Is freight really flexible in the timetabling process? Based on current French experience, the paper highlights that, on the whole, freight services cannot be planned at any time using any part of the rail network. As obvious as it may sound, this point is essential. Fitting freight train paths into the timetable is essentially a delicate balance of interests. When designing paths, timetable planners have to take into account both technical rules and commercial expectations (i.e. requirements of operators deriving, to a certain extent, from those of shippers). Although freight traffic can generally be considered as more flexible than passenger traffic, especially with regard to the location and duration of stops, providing opportunities for optimization of the graph, the IM has to closely consider the issue of the performance of freight paths. It should ensure that the product it builds up can meet the demand for rail freight transport while keeping in mind that the rail freight market is heterogeneous. Nevertheless, the point is not that all specific requirements of operators impact on the timetabling process, without which there is a danger of excessively constraining the process and the deriving distance-time graph. This would result in suboptimal use of network infrastructure capacity.

For organizational reasons, shippers, operators and the IM share the need for anticipation, but according to different key planning time horizons. For the IM, anticipation is typically measured in years. That is why it should focus on all aspects which could increase visibility and transparency throughout the timetabling process as well as the reliability of the freight train movements deriving from the paths it sells. Even if regular-interval timetabling is firstly tailored to meet passenger traffic expectations, freight can also take advantage of such a rigid – when strictly implemented – conduct of the process, provided that some capacity is set aside by the IM at the very start of the timetabling process, which is currently not the case in France. Further investigation on the issue of rail freight flexibility from the operators' perspective would enable to refine this paper's findings. Especially, the key concept of "good-quality train path" would require to be specified.

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