HOW DO WE EVALUATE FREIGHT NETWORK CAPACITY?

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ABSTRACT

Economic and logistical changes have led to considerable growth in goods traffic for several decades. Resulting congestion on some networks, increasingly present environmental concerns and a context of public finance scarcity make infrastructure capacity and optimisation a major challenge over coming decades. The work described in this document, controlled by the Sétra, constitutes a methodological guide aimed at evaluating relevant parameters for characterising and assessing the capacity of different freight networks within each transport mode. It is intended for non-specialists in charge of analysing and clarifying prospective decisions concerning transport systems and services or conducting upstream studies of various alternatives. We will present the main lessons derived for each transport mode after explaining the context and objectives of the guide. To conclude, more detailed results for the rail-road combined transport section of our work will be studied in greater depth.

1. CONTEXT AND AIMS OF THE GUIDE

1.1. Context

Growth and persistence of a number of bottlenecks on major transport routes throughout Europe are creating an important problem for the European transport system. In 2001, the European Commission stated, in its white paper entitled “European Transport Policy for 2010" [1], that congestion in some regions or on certain routes, associated particularly with intermodal imbalance, was threatening the economic competitiveness of Europe. These saturation difficulties do indeed have significant impacts on both economic activity and the environment. This is why the European Commission has proposed adapting trans-European transport network guidelines to the now extended Europe. Bottlenecks concern all transport modes, whether they occur in major trade corridors, around urban areas, natural barriers or national borders.

Today, it is vital to optimise existing infrastructures and draw up policies allowing effective rebalancing of traffic flows by encouraging alternatives to the road transport mode, thereby anticipating growth in goods flows and possible freight network saturation. This is why it is important to possess in-depth knowledge of both transport modes and the networks supporting them and to estimate the capacity reserves of these models on the basis of this knowledge.

The General Head Office of sea and transport of the French Ministry of transport and equipment has expressed high expectation in relation to this issue and, on the strength of this, has commissioned a guide to freight network capacity. This guide stems from a desire to see the ministry involve itself in goods transport studies of “multimodal” nature.

1.2. Aims of the guide

The aim of the publication is to provide the reader with valuable information on each transport mode, for the evaluation of relevant parameters permitting characterisation and measurement of different freight networks with a view to multimodal analysis.

This document is not intended for specialists of each transport mode, but for non-specialists charged with conducting upstream studies of various alternatives or analysing and clarifying prospective decisions concerning transport systems and services. It presents a full range of knowledge helpful to understanding offer capacity-related issues and enables estimates, based on comparative capacity of different freight transport modes, to be drawn up within the framework of a cross-disciplinary problem involving goods transport systems and corridors. This guide is so intended for all the project managers of the ministry of transport and the public networks organisms, but also for private engineering departments or universities. This methodological publication will interest overall every people who deal with the transport issues in Europe.

Following introduction of the goods transport economic context, the document considers the issue of pallet and container capacity. Rail, road, combined rail-road, river, sea, air and finally pipeline transport modes are subsequently studied.

1.3. Methodology

The guide has been drafted by a working group comprising transport design managers within the French transport, public works, tourism and the sea ministry’s scientific and technical network [Réseau Scientifique et Technique du Ministère des Transports, de l'Equipement, du Tourisme et de la Mer]. This working group has sought the cooperation of competent bodies and stakeholders including Réseau Ferré de France, Voies Navigables de France [French rail and waterway networks], Institut National de Recherche sur les Transports et leur Sécurité [national transport and transport safety research institute] amongst others.

A state of the art in France and in Europe was realised for each transport mode and made it possible to enrich the guide. The originality of the document is linked to the fact that it deals with the whole transport modes.

The following methodology was applied for considering a given transport mode, wherever possible: introduction to context and mode main operating characteristics, presentation of network and its operation, consequences of all these factors on parameters determining mode capacity, followed by consideration of network node specific capacity.

2. MAIN LESSONS

The main lessons of these investigations are presented here for each transport mode : road, rail, inland navigation, maritime transport, air and pipeline.

2.1. Road freight capacity

Goods road traffic in France (measured in tonnes – km) has been multiplied by 2½ in 30 years. France’s central position in Europe makes it a transit territory, a compulsory passage for trade between surrounding countries such as Italy, Spain and Portugal. Several factors can explain this growth in road transport, including:

- new forms of industrial sector organisation, which are very demanding in relation to transport flexibility and reliability;
- strong competition in the road goods transport sector, forcing down prices, which have effectively fallen by 30% since 1985;
- road infrastructure development;
- high proportion of medium- and short-distance transport operations unfavourable to other modes.

Irrespective of the limitation solutions implemented, heavy and light vehicle road traffic continued to rise steeply until 2004; the year 2005 would appear to indicate levelling out of this trend in France. In many sectors, this high demand is reflected by the appearance of more or less regular and sustained congestion phenomena. Motorway and road operators are therefore confronted with the problem of how to ensure passage of more vehicles without degrading the level of service, i.e. ensuring the same level of safety without restricting transit speed and prolonging journey times of all road network users.

In capacity terms, a road can be considered to be a pipe conveying a vehicular flow. Flow – concentration curves allow us to reveal both inconvenience and saturation thresholds. Principal factors influencing inter-vehicular distances and driving speeds (thus road capacity) are visibility, lane width, gradient, traffic type (LV / HV distribution), movement type (regular or irregular users), operating measures, meteorological conditions, etc.

Congestion observed on the road network is caused mainly by light vehicles (LV) and its aspects are twofold. Firstly, seasonal congestion corresponds mainly to summer migrations or access to winter sports resorts (low and medium recurrence); the most obvious example in France is saturation of the Rhône valley and the Languedoc coastline, where the summer period concentrates 50 – 70% of saturation hours. Secondly, recurrent congestion characteristic of home–work journeys, which is encountered daily, mainly near urban areas; it is this latter form of road congestion that represents the most serious handicap for road goods transport.

Whilst road congestion penalises good road transport competitiveness, we observe conversely that HV presence clearly affects traffic conditions: a road’s capacity is all the less, when it carries a high proportion of HVs. Heavy vehicles take up effectively more space on the roadway and for longer periods because of their size, lower speeds and the greater inter-vehicular distances left in their vicinity. Overtaking and lane changes at low speeds also reduce traffic fluidity. On average, the proportion of HVs is estimated at 8% on motorways and around 8 - 10% on other routes.

Various operating measures can be implemented to improve traffic conditions, including:
- prohibiting HV overtaking, which has been implemented experimentally between Poitiers and the Spanish border (RN10 and A63) and will soon be experimented on the A7, A8 and A9 motorways (Rhône valley and Mediterranean coastal region); this measure should ensure greater LV fluidity by restricting HV traffic to the right-hand lane;
- information to road users;
- dynamic speed control, which involves recommending the user to drive at a lower-than-authorised speed during dense, but still fluid, traffic periods; this measure provides better traffic fluidity and delays the appearance of jams;
- price adjustment by increasing toll fees either during the most congested periods or on the busiest sections;

- access control measures, which should enable the link section to better absorb volumes entering; these measures raise a number of difficulties both because storage areas are needed near entry points and because this can only work on a grid network offering substitute itineraries with sufficient capacity reserves.

2.2. Rail freight capacity

Despite significant overall growth in goods transport, rail in Europe has seen its market share drop since the early 1970s; moreover, at European level, this mode displays an absolute reduction in its t-km traffic (249 billion t-km in 2000 compared with 283 billion t-km in 1970). A trend scenario performed in a 2002 led the European Commission to anticipate a further decline in rail goods transport's market share in the European Union member states from 8.6% in 1998 to 6.9% in 2010. To reverse this trend, it was specifically decided to create a true rail internal market. In France, in particular, the national freight market has therefore been opened to all operators since March 2006.

French rail infrastructures are not equal to the overall increase in traffic and, today, we observe a proliferation of rail bottlenecks near major urban areas, where traffic of different types (freight, regional or long-distance trains) share common infrastructures.

In September 2005, a French rail network audit conducted on behalf of Réseau Ferré de France and SNCF [2] reported "very significant aging of the network". The study reveals that France invests significantly less in maintenance of its rail network than the United Kingdom, Italy, Spain and Switzerland. This has resulted in a reduction of infrastructure mean service life and a rail network reliability, which "is decreasing slowly but surely".

Many constraints can have an impact on rail network capacity for goods transport, including:

- network configuration (gauge and number of tracks, maximum allowable mass per axle, authorised speeds, block system and signalling, sidings, gradients, etc.);
- network operation: consideration of different types of traffic (passenger and goods), different types of movement (speeds, etc.), train path distribution and graphic timetable, disturbance management and use of system recovery capacities);
- network maintenance including regular maintenance and renewal operations, which can monopolise long time intervals; in this sense, maintenance work is performed with a twofold objective of productivity and minimum operating disturbance;
- technical performance characteristics and equipment availability.

Improved organisation and greater productivity of equipment, operation and train services can lead to capacity increases. For example, design of longer (and therefore heavier) trains can prompt increases in both productivity and capacity. The time-phasing system (succession of trains at regular intervals ensuring the same service), which Réseau Ferré de France [French rail network operator] wishes to install on the network appears to be not only a user-readability solution, but also a repetitive, regular block system production solution.

Recovery of European rail goods transport depends on the action of dedicating effective international block systems to freight transport based either on infrastructure or period of the day. Today, rail competitiveness is limited by the differences in equipment, technology, signalling, safety regulations, braking, traction current and speed restrictions amongst Member States. This situation compels international trains to stop at national borders. For example, the European Rail Traffic Management System (ERTMS) aims to remedy this fragmentation by standardising the multiple signalling systems currently in existence.

2.3. River freight capacity

French inland navigation has recorded a steady, average annual growth of 3% over the last decade. This rise is even more spectacular if we consider container traffic, for which river transport clearly positions itself as an efficient means of serving sea ports.

However, despite advances following fleet renewal, opening up of the market and managers' efforts to attract new customers, it would seem that river transport has not yet achieved the level of importance it could enjoy and development of this mode should be pursued because its capacity reserves appear considerable. In particular, there remain a number of hindrances in infrastructure terms (unsuitable clearance, bridge height, lock operation, lack of transhipment equipment, etc.), preventing fluid movement of vessels throughout the year.

In 2006, the European Union launched the NAÏADES (NAvigation Intérieure: Actions et Développement en Europe) [internal navigation: actions and development in Europe] programme based on in-depth analysis of the sector. Recommendations have been issued for the 2006-2013 period. This programme focuses mainly on five interdependent areas, namely the market, the fleet, jobs and skills, sector image and infrastructures.

The river transport mode is characterised by both network properties and operation, and by the fleet, which can use the network. Parameters influencing capacity stem from two different thought processes. Some constraints are linked to demand, including fleet distribution, maximum tonnage per vessel, average loading coefficient and empty return rate. Other constraints are linked to the offer, including clearance, lock capacity, operation (navigation opening hours, number of navigation days in the year. It is therefore important to understand that, independently of theoretical route capacity, the true figure can be limited by external factors, for example slipway availability in a basin.

In operation terms, the Schéma Directeur d'Exploitation des Voies Navigables [French waterway master operating plan] [3] is intended to specify levels of services that Voies Navigables de France (VNF) [French waterways] undertakes to establish between now and 2009 throughout the network entrusted to this authority. The trend is towards an increase in navigation amplitude and a limitation in the number of days, when navigation is stopped for maintenance.

Lock size and flow mainly determines waterway capacity. The French circular of 1st March 1976 [4] laid down a method for evaluating lock capacity, which depends on the lock cycle duration, the number of navigation days per year, the number of daily opening hours, the maximum tonnage supported by the route, but also the average loading of the boats and the average occupation of the lock hopper. Application of this method allows us to observe that waterway saturation is not currently a subject of concern. Shippers will undoubtedly complain about certain size restrictions rather than excessive traffic for another few years.

The notion of river port capacity should be considered, in the same way as the notion of sea port capacity, by distinguishing three components: quayside or transhipment capacity, storage capacity and goods reception / hinterland servicing capacity. It should be noted that a port is a homogeneous unit; failure at one of the three levels could have repercussions on the other two.

2.4. Sea freight capacity

Growth in worldwide trade has been facilitated by the massification possibilities offered by sea transport. In Europe, competition is very strong amongst, on the one hand the northern range ports and, on the other hand the Mediterranean ports. It is essential that French ports possess competitive berths and areas of development are as follows:

- state-owned ports must invest in major terminals capable of handling an ever-increasing tonnage of traffic in ever-decreasing time; the realisation of new containers terminals in Le Havre (Port 2000 project) is the first realization of this concept and its commissioning is taking place in a European context of port capacity congestion, which may enable the port of Le Havre to become a major stakeholder at continental level;
- modernisation of port handling launched in 1992 is in the process of succeeding; arrival of international scale operators at the main French ports should contribute to its finalisation;
- unification of port handling operations under the full and whole responsibility of handling companies can allow achievement of operating function rationalisation;
- land services must be efficient, especially in rail and river transport terms; this undoubtedly implies the presence of ship-owners throughout the economic chain.

In this context of global expansion in sea transport, container traffic is subject to the greatest growth. In particular, the increase in container vessel displacement obliges ports not only to adapt to its accessibility conditions and berthing lengths, but also to offer efficient handling facilities and services (speed, frequency, reliability, safety).

Principal issues involving port capacity are on the one hand the performance characteristics of different terminals and their capacity for handling goods with a quality of service that satisfies ship-owners and shippers and, on the other hand the capacity of land services and the general organisation of these land deliveries, which must be suited to both the flows handled by the port and hinterland servicing.

2.5. Air freight capacity

Air transport's organisation and characteristics, the value of goods transported and the small volumes it represents do not place this transport mode in real competition with other goods transport modes.

Many factors contribute to determining airport capacity. Runway capacity, air corridor capacity, traffic structure (peak and off-peak hours) and the equipment used are all factors to be taken into account.

More specifically in freight terms, the air transport logistical chain is complex and subject to many (especially safety-related) constraints causing intervention of numerous stakeholders. The main capacity-related issues referred to by freight handling agents in particular, are as follows:

- the reduction of the road congestion with the accesses of the airport to improve pre- and post- air freight road deliveries;
- capacity of freight handling agent and airline warehouses, in particular import/export-related developments imply warehouse capacity adaptation;
- fluidity of transmission between forwarding agent taking receipt of goods and loading onto aircraft; increasingly stringent administrative procedures involving safety, customs and health controls cause hold-ups in logistical chain fluidity.

Unlike express services (transport of small parcels under 24 to 48 hours), the issue of air route saturation is not a real problem for general cargo (standard air transport), given that time constraints are not essential for this type of goods.

On the other hand, airport freight terminal dimensioning appears to be a factor, which limits and determines airport freight capacity. A freight handling terminal represents and essential link in the goods transport chain. A terminal's handling capacity varies considerably, depending on traffic regularity, product characteristics (volume, etc.) and storage times. Number of aircraft berths is also an important parameter.

2.6. Pipeline conveyance capacity

Conveyance of oil products is a good example of pipeline goods transport, given the fact that there can be competition with other transport modes.

Oil pipeline capacity depends on the capacities of its constitutive components (line, pumping stations and terminal installations) and on the "network" effect. Oil pipelines are not saturated in France and construction or extension projects are infrequent and small-scale. Their capacity can also be increased by improving operating tool (e.g. pumping station) performance. However, network complexity and strong demand at certain times can occasionally cause operators difficulty in responding to demand. A contingency process (postponement of part of a delivery) can then be implemented.

3. RAIL-ROAD COMBINED TRANSPORT CAPACITY

Rail-road combined transport is intermodal (i.e. involving two or more transport modes, but with the same loading unit or the same road vehicle and with neither stuffing nor stripping of goods). Main European routes are rail-operated and their initial or final road journeys are as short as possible.

The figure below provides a description of a rail-road combined transport chain (routing visualised by following the journey of an Intermodal Transport Unit (ITU) from its origin to its destination) and compares it with a simple road transport mode. Use of rail-road combined transport means placing the goods in a mobile container, transporting this container by road to the departure terminal and recovering it at the destination terminal before transporting it by road to its final destination. We observe, in particular, that the combined transport method generates a series of isolated acts (including handling operations), which are avoided by road transport and are difficult to synchronise and make profitable.

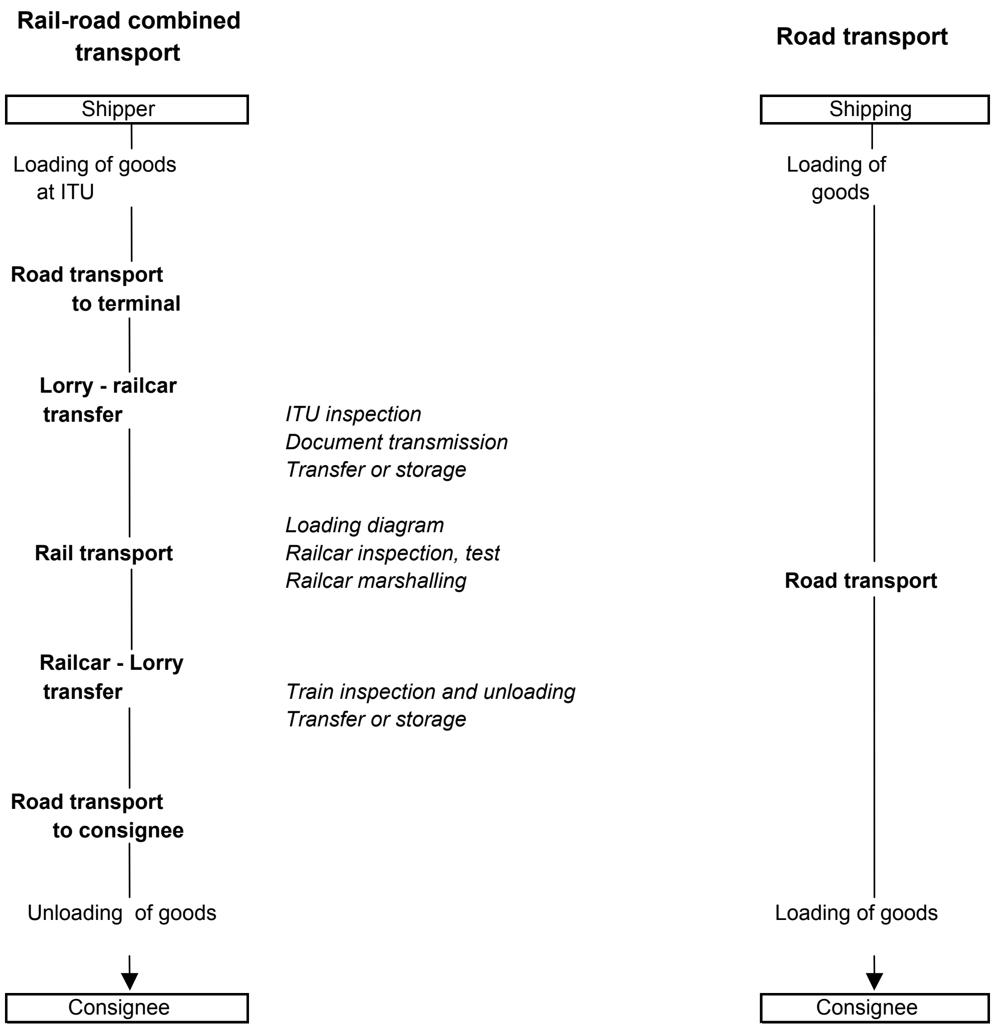


Figure 1 – Description of rail-road transport chain and comparison with road transport

3.1. Swap bodies

A swap body is a unit designed for transporting goods and is fitted with handling devices allowing transfer between modes. The main advantage of a swap body is its dimensions, which are those of a road semi-trailer, i.e. 13.60 m long and 2.55 m wide overall; its internal width is 2.44 m, allowing two Europallets to be loaded side-by-side. This optimisation provides a 25% saving in space compared with a standard 40’ container. On the other hand, this equipment can only be used for rail transport and its extension to road transport because swap bodies cannot be nested (stacked); it cannot therefore be used in sea or river transport.

3.2. Constraints of rail-road combined transport

3.2.1. Available network

Rail-road combined transport presupposes the existence of equipped sites, also called terminals, permitting ITU handling and forming a network. Rail-road combined transport requires flow massification and so rail-road terminals must be located in high economic activity density areas ensuring sufficient freight volume. The terminal network cannot therefore constitute a dense territorial grid of rail-road sites is of no economic value.

3.2.2. *Terminal accessibility*

Rail-road sites are located near major economic centres and road congestion therefore impedes their servicing. Indeed, without curtailing rail-road terminal activity or capacity, road congestion obliges the transport contractor to organise his operations to make available all the swap bodies required on site at the appropriate times.

Constraints have an impact on the road terminal servicing efficiency. Research performed by Patrick Niérat in 1992 [5] provided, in particular, two results, which illustrate the low performance of these road pre- and post-delivery operations: on average, more than a third of journeys are unproductive in the sense than the movement is performed by the tractor unit alone or with an empty swap body; the average number of swap bodies handled per day and per driver (swap bodies arriving and leaving by train) varies from 2 to 4, for an average number of operations (number of journeys made) of 6.15.

The cost of road pre- and post-delivery operations represents between 30% and 50% of the combined transport cost. The essential cause of this high proportion is low terminal servicing performance, associated with the combined transport environment and constraints.

3.2.3. *Rail-road terminal market area*

Research performed by Patrick Niérat in 1992 [6] is based on the market area theory. Through cost comparison, this approach allows determination of the area linked to a transfer site, for which rail-road combined transport is cheaper than pure road transport.

This work shows that the empty journey rate (i.e. the percentage of unproductive journeys during pre- and post-delivery operations) would seem to be one of the basic ingredients of combined transport competitiveness: the higher this rate, the more the combined transport solution turns out to be confined to a restricted area around the transfer centre.

Transfer centre market areas therefore depend on terminal servicing productivity. Other parameters have an impact on combined transport competitiveness and make a terminal’s market area more or less large: for example, goods weight and flow imbalance, which reflect on market area range through rail pricing.

3.3. Rail-road combined transport site dimensioning

Rail-road terminal handling capacity is determined by the following factors:

- infrastructure and superstructure: transfer line number and length, handling machine number and type, storage area;
- terminal organisation process: road and rail access, rail operation performance, information flows, etc.;
- customer behaviour (adherence to collection and delivery times) and opening hours;
- type of services offered: domestic / international, hub function.

Rail-road site capacity depends primarily on its physical dimensions. A site must be capable of receiving (in a receiving yard) trains of a length suited to the potential of the rail network to which it is linked. The maximum length of a train is 750 m in France (soon to be 1000 metres on certain European priority routes).

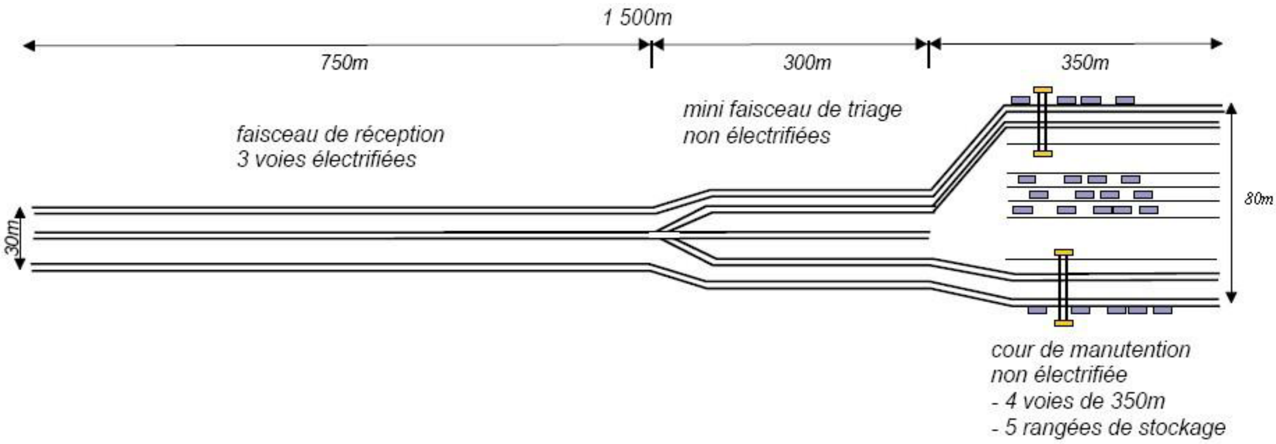


Figure 2 – Example of a rail-road terminal: diagrammatic longitudinal view

The handling yard must include an area allowing ITU temporary storage. Unlike port areas, ITUs are usually handled during the day and 90% are usually in half a day.

There are two types of handling machines for transferring ITUs at a rail-road terminal. The overhead travelling crane is a 20 – 30 m wide gantry crane capable of moving a load in three dimensions (height-, width- and length-wise) and is self-moving over the site itself on either rails or pneumatic tyres. The "reach stacker" is mobile crane fitted with a front lifting device, which allows it move swap bodies. This machine ensures great operating flexibility and can access the whole site, whilst the overhead travelling crane is most often restricted by its track. The overhead travelling crane investment cost is higher that that of the reach stacker, but it is compensated by lower operating costs. Operating ratios for such and such machine type cannot be generalised: terminal geometry and traffic characteristics influence handling machine performance.

Combined transport site handling capacity depends on the least productive link in the site operation and therefore most often on the railcar / lorry transfer time for the ITUs. A railcar / lorry transfer can take 3 – 4 minutes, depending on the type of handling machine. For a 35-container train used in a national transport operation, average loading or unloading time is therefore estimated at approximately 2 hours, using a single overhead travelling crane. French rail-road terminals are often equipped with two overhead travelling cranes. The handling time to move an ITU from or to a storage area is estimated at 10 minutes. For a train with 25% ITUs to place in, or remove from, storage, the overall unloading or loading time will be 3 hours, again if a single overhead travelling crane is used. Use of several lines and overhead travelling cranes will offer time savings, but subject to limits associated with parking and traffic lane congestion.

3.4. Roll-on/roll-off (Ro-Ro) railways

A roll-on/roll-off rail service allows HVs to be transported by rail in trains specially designed for this purpose. This transport service involves setting up viable, regular and frequent connections. It differs from conventional combined transport in that the conveyed equipment is a road transport vehicle (tractor unit and semi-trailer). The roll-on/roll-off (ro-ro) railway can be used as an “accompanied transport” (tractor unit and driver accompany the trailer on the train, a railcar being provided for travelling drivers) or as an “unaccompanied transport” service (driver leaves his trailer at the departure terminal and another driver recovers it at the destination terminal).

As any rail traffic, setting up a roll-on/roll-off rail service requires allocation of a train path, i.e. existence of a right to circulate on the railway at specific times. Moreover, there are clearance restrictions, given the size and shapes of both lorries and transporting railcars.

3.4.1. Modalohr railcars and transfer sites

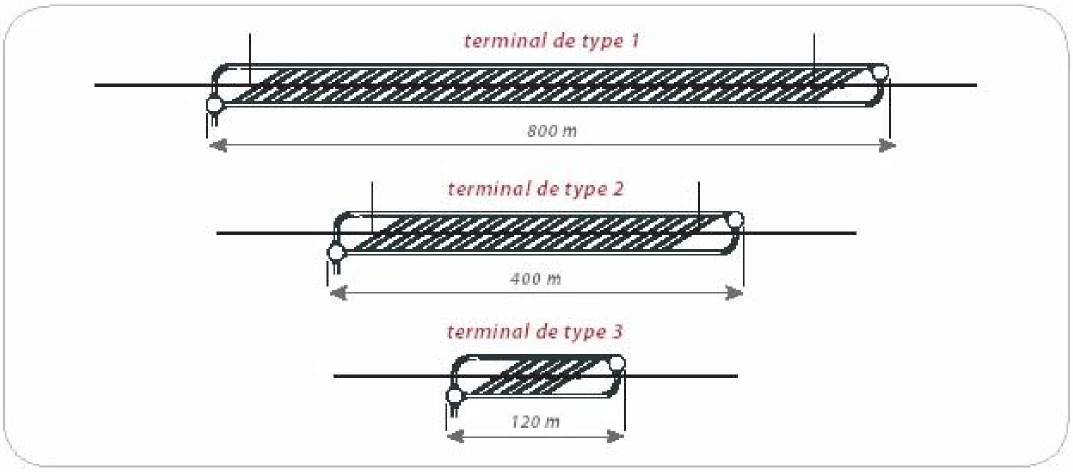
Lohr Industrie has developed the Modalohr railcar used on the Autoroute Ferroviaire Alpine (AFA) [Alpine ro-ro railway], between Aiton (Maurienne valley) in France and Orbassano (near Turin) in Italy. It is an articulated low-loading railcar specially designed for transporting non-specific standard road vehicles. It is characterised in particular by an "angled" lateral lorry loading configuration, in which the road vehicle tractor unit itself ensures trailer loading (no handling machines), allowing very rapid, simultaneous lorry transfer.

Figure 3 – The Modalhor railcar

3.4.2. Capacity notions

A double Modalohr railcar is 33 m long and comprises two positions for transporting two semi-trailers or one semi-trailer and two tractor units. At the end of 2006, the AFA train was made up of 11 railcars or 22 transport positions (14 full lorries or 22 trailers). From 2007, the Perpignan – Luxemburg service will be ensured by 700 m long trains comprising 20 railcars (40 positions).

Site capacity depends on the number of sidings, their length (sidings that are too short mean dividing and marshalling trains) and the number of transfer facilities (because some systems, other than Modalohr, require handling operations and the use of transfer machines). The figure below gives reception capacities for different transfer site sizes (source: Modalohr).



Terminal type	Capacity	Train frequency	Lenght (750 m train)	Number of movements on terminal (750 m train)
Type 1	high	1 - 2 trains/h	800 m	0
Type 2	medium	1 train/2h - 1 train/6h	200 - 400 m	1 - 2
Type 3	low	1 - 3 trains/day	120 - 200 m	3 - 6

Figure 4 – Modalohr terminal capacity

Train path (on line and at transfer site entry), train and terminal site capacities must be combined to obtain the service capacity. It should be recalled that demand can also be a capacity determining parameter. In particular, terminal occupancy level has an impact on the capacity of a roll-on/roll-off railway service and this is often of the order of 75%, once the service has reached full operation. Service capacity also depends on the number of annual operating days.

4. CONCLUSION

This paper allows us to appreciate the capacity-related issues involved in each transport mode. Very many factors influence infrastructure capacity. Network physical properties, network operation and maintenance, characteristics of the equipment used, specific demand characteristics and presence of bottlenecks are as many factors having an impact on infrastructure network capacity. Moreover, taking into account passenger traffic obviously has a strong influence on evaluation of freight network capacity.

Even if proposing a unique definition of network capacity or assessing accurately this capacity in relation to freight are a difficult task (because network capacity depends on a great number of parameters), we observe however that it is effectively often determined by one or two limiting factors specific to each transport mode. Evaluation of these limiting factors thereby allows us to perform capacity estimation.

With regard to rail-road combined transport, it is frequently the configuration and performance characteristics of the transfer terminal that determine the system’s capacity limit. However, we have shown that a multitude of other parameters influence this capacity: road transport servicing conditions, rail network train path availability, demand characteristics, etc.

The guide to freight network capacity will be published in 2007 by the Sétra and will be referred in the "Documentation des Techniques Routières Françaises" (DTRF / http://dtrf.setra.equipement.gouv.fr/).

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