february 2012

Sétra

Service d'études sur les transports, les routes et leurs aménagements

Technical department for transport, roads and bridges

Goods Transport

Characteristics of transport modes Offer and Capacity

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MINISTRY OF ECOLOGY. SUSTAINABLE DEVELOPMENT. TRANSPORT AND HOUSING

This guide is the translation
of Sétra French edition
published under the title
"Transport de marchandises",
March 2008, reference 0807.

Data of this translation are up to date.

Methodological guide

Goods Transport

Characteristics of transport modes Offer and Capacity

Edition Sétra

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- Reinhard Douté (RFF - Réseau ferré de France) ;
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- Renaud Spazzi (Port Autonome de Marseille) ;
- Gérard Thiolet and Jean-Pierre Holuigue (Ministère de l'Industrie) ;
- "Economie des Transports et Trafic" design department (Sétra) (Now DEOST/Evaluation et Organisation des Systèmes de Transport) ;
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[1] Now "Evaluation et Organisation des Systèmes de Transport (DEOST) : more at www. setra.developpement-durable.gouv.fr

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Foreword

Background, aims and scope

Background

Optimizing the use of existing infrastructures and implementing policies designed to effectively balance all traffic flows, while promoting alternatives to the road transport mode, turns out to be of prime importance in extrapolating the current increase in the flow of goods and its impact on the risk of network saturation. Excellent knowledge of the various transport modes and their supporting networks is therefore essential to assessing the inherent spare capacities of these modes.

The Direction Générale des Infrastructures, des Transports et de la Mer (DGITM, ex-DGMT) [general directorate for the infrastructures, sea and transportation] responsible for transport at the Ministère de l'Écologie, du Développement Durable, des Transports et du Logement (MEEDTL, ex-MEDAD) [French ministry of Ecology, sustainable development, transport and housing] has expressed considerable expectations regarding this subject and has therefore requested preparation of a guide to freight network capacity, with an English complete translation.

Aims and methodology

The purpose of this guide is to determine, for each transport mode, the relevant parameters that serve to characterise and gauge the capacity of various freight networks in view of multi-modal analysis.

The guide gives general information on the goods transport system and provides basic knowledge of the freight transport offer. It describes the features of each mode and provides an appreciation of capacity and size. It therefore permits comparative analysis of the freight transport modes. This publication is not specifically intended for specialists of each mode, but to those responsible for studies on the cross-disciplinary problem of goods transport systems and corridors and generally to all persons involved with freight-related problems. It contributes, in particular, to providing a common culture on the subject for ministry staff in charge of transport. It may also be of interest to our foreign counterparts who wish to compare situations and methods, or even students at engineering schools and universities.

The guide is an initial aid to an understanding of this complex subject and to conduct multimodal studies. It will be followed by more operational, methodological aids.

Following a general presentation of the economic context of goods transport, the guide provides characteristics and information on the capacity of pallet and container loading systems. The features of each each mode are then examined: rail, road, combined rail-road, inland waterway, sea, air transport and pipeline conveyance.

Wherever possible, the following methodology is adopted to assess a transport mode: description of main operational features, equipment used, infrastructure network and its operation, impact of these factors on parameters governing transport mode capacity and relevance. All these factors are not systematically addressed in an entirely uniform manner in relation to the different modes.

Preparation of this publication was supervised by Sétra. The working group included CETE Méditerranée, CETE Sud-Ouest, CETE de l'Est, CETMEF and Sétra. Studies managers based their work on the expertise of organisations, specialists and qualified experts for each section of the guide.

Work presented in this publication has been officially validated by Réseau Ferré de France (rail transport section), Voies Navigables de France (inland waterways), Direction Générale de l'Aviation Civile (air transport) and the Ministère de l'Industrie (pipelines).

Scope of this publication

This section specifies certain limits establishing the scope of this document.

Firstly, the guide describes characteristics of the available transport offer. Although care has been taken to include qualitative details for better understanding the information presented, it is not the purpose of this guide to explain the operation of goods transport and the many parameters that may justify complex situations. Concepts based on service, costs and prices are not examined in depth.

In addition, the goods transport sector is an area of ongoing development. The translation reflects the situation in 2011 (French guide edited in 2008).

This document is no doubt open to improvement and we wish to thank in advance all those who, upon reading the document, can contribute improvements to subsequent editions.

Introduction

Infrastructure capacity – What are the issues?

Development and persistence of a number of bottlenecks on trunk roads cause significant problems for the European transport system. These problems of saturation have specific impacts on both economic activity and the environment.

The European Commission stated in its 2001 White Paper [1] that congestion in certain regions and on certain routes specifically associated with imbalance between transport modes, endangered Europe's economic competitiveness. The Commission established that 7,500 km of motorway, i.e. 10% of the European network (European Union of 15 countries), were affected daily by traffic congestion and that 16,000 km of railway line, i.e. 20% of the network, were considered bottlenecks. The Commission also noted that 16 main European Union airports had recorded delays of over 15 minutes on more than 30% of their flights.

These bottlenecks involve all transport modes, whether they are located on main trade corridors, around urban areas, at natural barriers or at borders. This is why the Commission has proposed adopting the guidelines of the Trans-European Transport Network (TEN-T) to the enlarged European Union.

The European White Paper [1] also emphasised the need for sustainable development of transport systems, in particular via a modal report based on freight promoting a move towards more environmentally friendly transport modes.

In June 2006, the European Commission presented a mid-term assessment on the implementation of the White Paper [2] highlighting the new political guidelines. Movement of goods and people is an essential factor for the competitiveness of European industry and services. Dissociating growth of this movement from economic growth is no longer feasible. However, maintaining diversity in the transport modes remains essential to limit road congestion, in particular. The report specifies that a sustainable movement policy must be based on a wide range of alternatives that enable the transition of traffic towards more environmentally friendly methods. Each mode of transport must be commensurately "optimised". The co-modality concept (i.e. an efficient solution involving various isolated or combined transport modes) appears.

The purpose of this introduction is to specify for each modes studied in the guide, the context and the main challenges in terms of capacity. Information presented in this guide is based on standard concepts, providing an initial approach that will be examined in more depth in the corresponding chapters.

Defining capacity

Many factors have an influence on the capacity of an infrastructure. The physical features of a network, operation and maintenance of the network, equipment used, specificities related to demand and the presence of bottlenecks are all factors that impact the capacity of a network infrastructure. Furthermore, **consideration of passenger traffic** also has a significant influence when assessing the network freight capacity.

Work proposed in this guide highlights the difficulty in uniquely defining capacity, while accurately assessing this capacity based on freight. However, if capacity is based on a large number of factors, we can often see that it is, in fact, affected by one or two limiting factors. Firstly, the features and capacity of equipment used for each mode will be presented. Descriptions of a network, its operation and existing constraints will provide a clearer overview of the concept of capacity, providing a definition, and highlighting the drawbacks and restraints involved when presenting the means used to assess capacity.

Note : in the general case, (metric) units from the International System of Units (SI) are used. In particular, the terms "ton" and "tonne" equally refer to a metric ton (1,000 kg).

Rail sector capacity

Despite an overall significant increase in goods transport, the rail sector has seen its market share decrease since the early 1970s, which has been slowing for few years however. At European level (EU-27), we can observe an increase in traffic measured in tonnes per km, up to 2007 : 453 billion t.km compared with 384 billion t.km in 2002, 386 in 1995 and 362 in 2009 – crisis effect). To reverse this trend, a decision was made to create a unique rail sector at a European level by 2020. In France, the main milestones for development of the domestic rail sector were:

- March 2003: opening of international freight services on the 50,000 km of rail line owned by TERFN (Trans European Rail Freight Network).
- March 2006: opening of the domestic freight sector.

Rail infrastructures today have increasing difficulties to absorb the rise in overall traffic (mainly resulting from growth in passenger traffic). We can also observe the increase in rail bottlenecks within the vicinity of large urban areas, where traffics of different natures (e.g. freight trains, regional trains and long distance trains) share common infrastructures.

Many factors may have an impact on the capacity of the freight rail network:

- network configuration (block system and signalling, garages, slopes, etc.),
- network maintenance occupying important time slots; equipment performance is thus a priority for curtailing maintenance operations to an absolute minimum,
- **network operation:** integration of the various traffic types, various circulation types (speed, etc.) and the allocation of train paths,
- equipment performance and availability.

Furthermore, improvements in organisation, **equipment productivity** and operation of rail services can produce gains in capacity. For example, the design of longer (and therefore heavier) trains can produce gains in terms of productivity and capacity.

Improving European goods transport involves dedicating efficient international paths to freight transport, either by infrastructure or by periods of the day. Construction of a high speed network on a European scale thus help to meet this objective. Introducing new lines would make it possible to transfer some of the traffic from the standard line to the new line creating additional capacity on the line previously used for all traffic types. However, the additional traffic can create additional congestion at railway junctions.

Road sector capacity

Regardless of the solutions implemented to limit road traffic, this will remain the predominant inland freight mode in the long term in Europe – this is not true at a world scale, where rail freight is the second mode after sea transport. Road and motorway managers are therefore confronted with finding traffic management solutions that allow road capacity to increase or even absorb existing traffic without degrading the level of services provided while limiting the construction of new infrastructures to a strict minimum. Various measures are planned, such as: adjustment to tolls, dynamic management of speeds, prohibiting heavy vehicles (HGV) to overtake, etc.

The congestion observed on the road network is mainly caused by light cars and appears as two specific phenomena:

- seasonal congestion essentially based on summer holiday traffic or access to ski resorts in winter (weak or medium occurrence),
- recurring congestion characterised by traffic commuting on a daily basis mainly around urban areas (frequent congestion); it is this form of road congestion that causes the biggest handicap to goods transport by road.

If road congestion penalises the competitiveness of road goods transport, the presence of HGV clearly also affects the conditions of traffic circulation. The capacity of a road is reduced in proportion to the increase in HGV. On average, the proportion of HGV is estimated at 15% on motorways and around 8 to 10% on the other main traffic arteries.

Inland waterways capacity

Inland waterway navigation in Europe has seen a relative stability since 1995 in t.km (EU-27) : 122 billion t.km in 1995, 145 in 2007, 120 in 2009, but a decrease in modal share, from 4 to 3.3% - domestic sea transport included. At a French scale however, a significant increase is noticeable, remarkable when considering the increase in container traffic (+ 234% between 2000 and 2009). Inland waterway transport is clearly becoming an efficient container transport alternative to relieve sea ports, following examples as Rotterdam.

Despite continual renewal of the fleet coupled with management initiatives to attract new customers and the opening up of the market, it appears that inland waterway transport still doesn't have the importance it could have. Development of this mode therefore needs to continue as its **capacity reserves seem considerable**. There are still a certain number of obstacles regarding infrastructures (ill-adapted gauge, height of bridges, operation of locks, heterogeneity of geometrical characteristics on the same itinery, etc.) or operation impeding a free-flowing circulation of boats throughout the whole year. Another important problem is the significantly limited consistence of the large gauge network and its lack of links between river basins. The Seine - Nord canal project represents therefore high stakes.

Main points of improvement are listed below:

- elimination of the various restricting obstacles and factors (height of bridges, etc.)
- implementation of inland waterway junctions and installation of transhipment equipment
- deployment of efficient **navigational aid systems** on the river network
- harmonisation of technical requirements, navigation certicates and working conditions at a European level
- renewal of the fleet and recruitment of navigating personnel
- coordination of stakeholders.

In 2006 the European Union launched the NAÏADES action programme (Navigation and Inland Waterway Action Programme) [3]. This programme is based on an in depth analysis of the sector and proposes action recommendations for the 2006 – 2013 period. It mainly involves five interdependant fields: market, fleet, employment and skills, image of the sector and infrastructures. Implementation of this programme will coincide with close cooperation from the national and regional authorities, the inland waterway commissions and European industry.

Sea transport capacity

The increase in worldwide exchanges has been helped by the competitiveness and the possibility for expansion offered by sea transport. In Europe competition is rife between the ports in the North and those on the Mediterranean. It is essential for the economy to have competitive port locations.

In a report drawn up by the French national audit office in July 2006 – *French ports faced with sea transport developments : urgent action needed*[4], it is clearly stated that French ports that have continuously lost market share over the last few decades, particularly container traffic, must quickly overcome a number of drawbacks with the additional aid from the State.

Development guidelines are listed below:

- the ports and the state must invest in major terminals capable of handling ever increasing traffic in constantly shorter times; the Port 2000 project is the first achievement. Its commissioning coincides with a **European context of ports congestion**, which could enable the Le Havre port to become a major stakeholder at a continental level
- modernisation of port handling initiated in 1992 is showing signs of success; the arrival of international scale operators in major French ports should contribute to its achieving.
- unification of port handling operations under the full responsibility of handling companies will no doubt help to achieve **rationalisation of operational functions**
- **transport links** must be efficient ; this involves without doubt the shipowners throughout the economic chain.

These factors have a significant impact on port competitiveness and on its capacity to attract new traffic (container traffic in particular) and to handle this traffic under suitable conditions.

The main challenges concerning port capacity are, on one hand the performances of the various terminals and their capacity to handle goods with a service quality satisfying both the shipowner and ship loader, and on the other hand the capacity of land transport, which must be adapted to the flows handled by the port and hinterland transport links.

Air transport capacity

Air transport is a transport mode that is not effectively in competition with the other transport modes due to its organisation, the characteristics and value of goods transported and the small volumes this represents.

Many factors are included when determining airport freight capacity. Runway capacity, air corridor capacity, the structure of traffic (peak hours), the equipment used, the coordination between the various stakeholders are all factors to be taken into account. However, the design of cargo terminals appears to be the limiting factor that determines the freight capacity of an airport.

Pipeline capacity

The transport of petroleum products by pipeline is mainly examined in the guide as modal competition to this product type may occur.

Pipeline networks are not saturated and construction and extension projects are rare and small scale. The capacity can, however, be increased by improving the performance of operating tools (e.g. pumping stations). However, the network complexity and the high demand at certain periods may lead to an occasionally difficulty for operators to meet demand.

Section 1

Some goods transport characteristics

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Introduction

The first part of this guide reports developments in a number of factors, which explain the changes observed in the goods transport world. It also provides data comparing various modes of transport and discusses the main issues in terms of capacity.

Figure 1 shows the process which, based on trends in demand, explains the logistical adjustments and repercussions in transport terms. These developments and characteristics are described in detail in the relevant sections of the guide.

These developments imply a considerable growth in goods traffic spreading over several decades. The resulting congestion on certain networks, growing environmental concerns, the pressure of public opinion and the scarcity of public funding, make the capacity of infrastructures and their optimisation a major challenge for the coming decades.

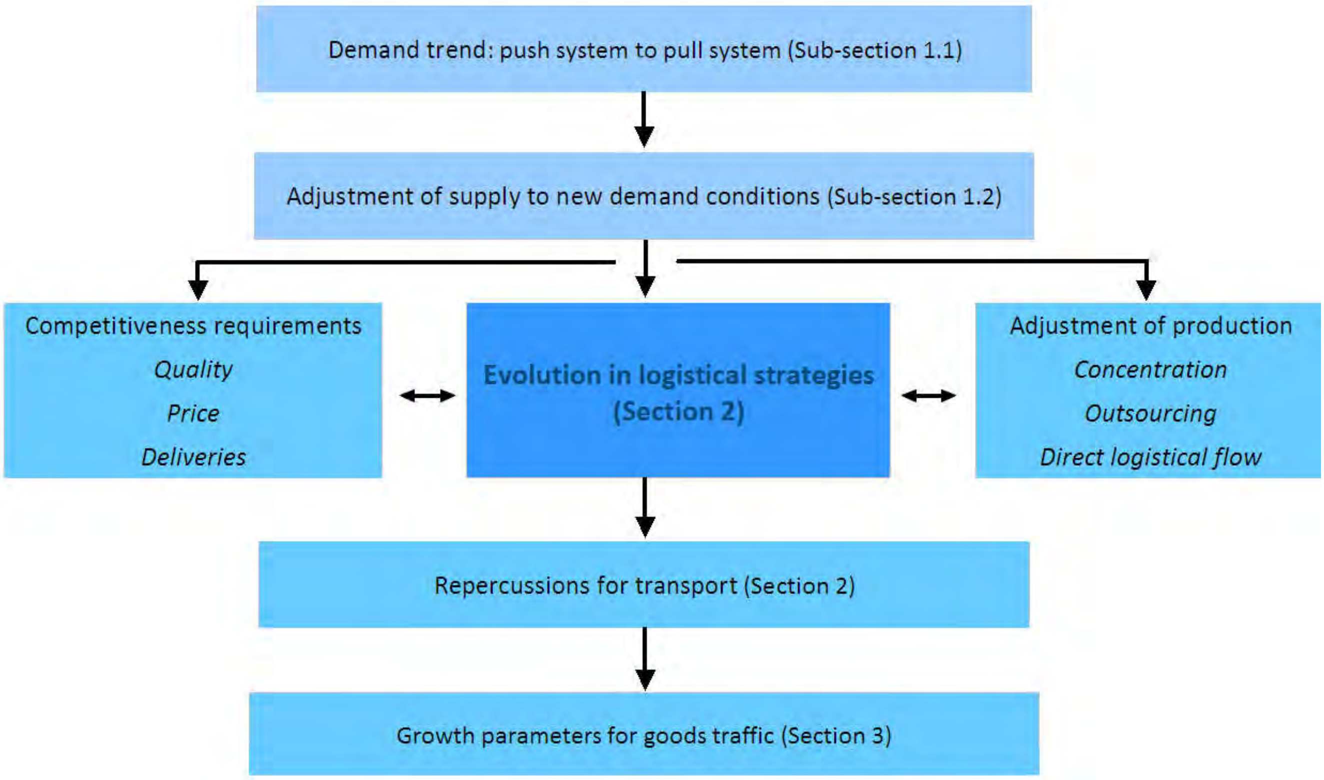


Figure 1. Demand trends, logistical strategies and transport

1 – Changes-over in Economic Processes

1.1 – Control by demand: push system to pull system

Customers previously bought goods already manufactured and stored in large quantities. Production “conditioned” the consumer. Today, consumer demand is guiding production towards more differentiated and faster changing goods (for example: the proliferation of automotive models and options).

Demand can currently be characterised by:

- **more diversified demand** to which multiple, even personalised references respond,
- **greater variability** (in response to fashion trends), driving the accelerated renewal of products and their presentations,
- customer calls for **shorter deadlines** to obtain the product,
- attention focused on the **quality of collateral services** offered by the company,
- demand for the best possible quality-price ratio.

The development of this consumerist mechanism is culminating in a downstream control of the chain: pushed flows have been replaced by pulled flows.

In terms of production, in convenience goods industries, the concept of “production on inventory” or push system has been gradually tending towards “production on order” or pull system (see Figures 2 and 3).

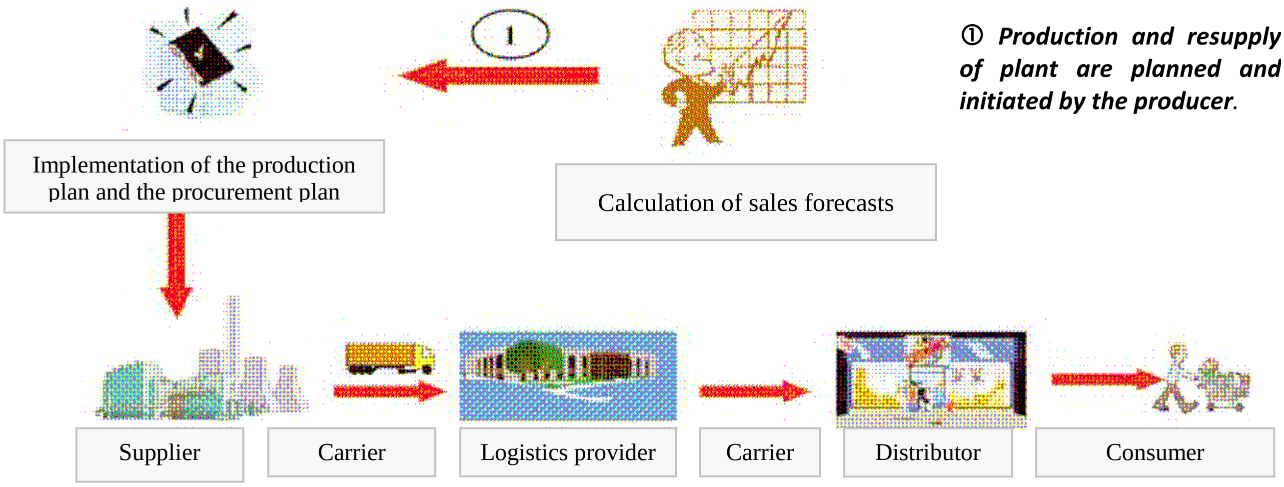


Figure 2. The “push” model or pushed flows

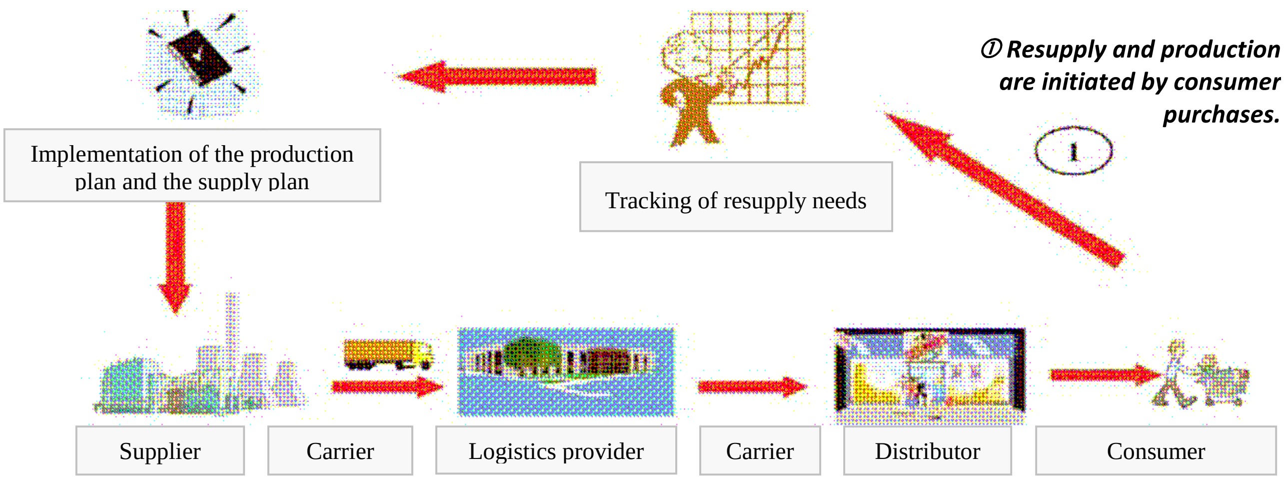


Figure 3. The “pull” model or pulled flows

1.2 – Supply adjustments

1.2.1 – Production adjustments

Concentration of production units

The concentration of production units results from a need to reduce unit costs. This is because the act of producing is reflected by fixed costs which, by definition, are independent of the volume of production (depreciation of the premises, administrative personnel, etc.) and variable costs which are directly associated with the volume produced. The consolidation of several production units results in economies of scale associated with fixed costs mainly, and possibly with variable costs, for example by purchasing groups. This concentration and sophistication of production sites and warehouses is affecting a large majority of industries: car manufacturing, mass distribution, steel, chemicals, agrobusiness, etc.

In fact, specialisation entails a **multiplication of transport inside the company**, as well as a **distancing from the overall market**, which frequently culminates in the installation of consolidation and deconsolidation platforms. The companies have therefore decided to transfer industrial costs (running of several plants) to transport costs.

In the 1980s, Yoplait had 25 plants and 70 000 delivery points in France; in 2003, Yoplait had 4 plants and 200 delivery points.

More sub-contracting and outsourcing

For labour intensive industries (mechanical engineering, textiles, chemicals) companies are delocalising, according to the comparative advantages of the countries or areas of activity:

- installation of manufacturing networks in low cost countries (China, Eastern Europe, Maghreb),
- development of activities of free zones in high cost countries, for example construction of cars at the port of Barcelona, in the free zone for the Asian market.

Smaller inventories and production with direct logistics flow

The new demand requirements are tending to expand the references and hence decrease batch sizes. This multiplication of references can lead to an increase in the total inventory. In fact, every inventory represents a financial cost, risk of obsolescence, a logistics cost: the annual cost of an inventory is estimated on the whole at about 20% of its value (fixed capital, storage, guard services, insurance, risks of obsolescence). To deal with this trend, companies increasingly operate with direct logistics flow (just-in-time): this is sometimes referred to as “zero inventory”. This is valid upstream of the company (for procurements) and within the company (for launching production). Inventories are readjusted daily (or even several times daily), depending on actual orders or sales.

Delayed differentiation

To promote products at competitive prices, it is essential to produce large quantities (economies of scale), hence the transition from regional or domestic markets to European or world markets.

Capital goods (automotive, home appliances, IT, etc.) are increasingly standardised and are the subject of a **delayed differentiation** to adjust to specific domestic markets, or are even “configured” at the last moment. These operations are considerably facilitated by the development of service providers, usually from the transport world, where they become the speciality. The more global a market, the more the goods in that market are “operated” by a logistics network formed of a limited number of very large radius sites, big transport generators.

1.2.2 – Consequences on developments in shipments

The size of the batches to be shipped tends to decrease because:

- the products are increasingly diversified
- customers want increasingly fresh products (→ more frequent deliveries)
- there are many new products, with a shorter shelf life
- shippers (see glossary) want the fastest possible stock rotation (= daily adjustment of inventories, by small shipments)

Furthermore, requirements on routing deadlines are also changing:

- in mass distribution, the distributor-customer demands increasingly short deadlines between order and delivery (from four days to two days)
- in the automotive sector, manufacturers want to shorten the time between order and delivery of the vehicle (from three to four weeks to 10 to 15 days)
- for express services, demand for day A/day B is changing towards day A/day A.

This production mode implies:

- smaller batch sizes and higher delivery frequency
- accurate control of procurement, production and delivery flows
- high quality of transport service (punctuality and traceability especially)
- extreme rigour in organisation between the different economic partners
- longer transport distance

2 – Logistical Organisations and consequences for transport

2.1 – Logistical requirements

Logistics means all activities aimed at placing, at minimum cost and within deadlines, a quantity of product in good condition at the place and time required by existing demand. Transport, storage, handling, inventory control, data transmission and processing activities form the supply chain.

Requirements on productivity factors: flexibility

One of the productivity factors for the company is **flexibility**, i.e. the ability to react in the short term to market trends. Logistics must allow for rapid adaptability to demand by optimising data and product flows.

Flexibility is also an important factor for logistics, and particularly for transport. This may appear paradoxical in a field where everything is planned. The economic consequences can be devastating. To deal with these risks, the road, in terms of transport supply, offers flexibility that other transport modes cannot propose for the time being.

The nature of the products transported and stored genuinely influences the choice of the transport mode. For example, fresh and ultra fresh products demand a mode of transport that is at once rapid, reliable and competitive: the road supplies these needs, but combined rail-road transport can also be used when it meets these conditions. Other factors must also be considered: volume, number of daily consignments, and frequency.

Logistical cost requirements

Logistics influences the cost of the product. In industrial manufacturing, goods logistical cost accounts for 10 to 15% of total cost. If logistical reorganisation can help achieve a savings of 20% in logistics cost, this means a significant reduction in total cost. This margin could sometimes prove decisive in the competitive world.

Storage cost requirements

We saw earlier that an inventory costs about 20% of its annual value. The financial objective therefore demands limiting the volume of inventories and storage facilities. For certain products, rapid routing, even at a high cost, would be less costly than the fixed capital of an inventory.

Environmental quality requirements

The major trends in logistical development require transport modes, which offer ever greater flexibility and rigour. For the time being, shippers appear to be content with a logistical organisation that relies mainly on road transport. But pan-European pressure from authorities and civic requirements for sustainable development in transport are factors that could influence these practices and logistical organisations in the future.

2.2 – Supply chain organisation

2.2.1 – Supply chain management

(Management or control of the supply chain. Refer to the glossary for the definition of this term)

Present-day logistics is characterised by the fact that the production of goods, the control of their production, the routing of the goods and their distribution are designed as one and the same entity, coordinated by using information technologies. Each of the functions involved in this process has an important role. Under existing conditions, transport is subject to a more comprehensive cost optimum which encompasses the various steps of the supply chain. ***The current growth in goods transport, particularly by road, stems from these trends which are accentuated by the current weakness of transport prices.***

2.2.2 – Logistical distribution schemes

Logistical distribution schemes (see Figure 4) embrace a requirement of flexibility and responsiveness. Logistics can combine one or more transport modes via one or more logistics platforms. Logistical models "A" and "B" are mainly used.

In the case of branches of activity such as express services, mail-order sales and specialised distribution, the logistical models implemented may be "C", "D", "E" or "F" in Figure 4.

2.2.3 – Logistics of miscellaneous manufactured goods

Very often, the logistical organisation directly affects selection of the transport modes to be implemented. For example, for the branch of activity concerning miscellaneous manufactured goods, a change is made in the logistical organisation. For economic reasons, the former scheme, which involved a plant to distributor platform (see Figure 5) has been supplanted by another scheme (see Figure 6) designed to minimise transport cost by bulking it, using the most suitable mode, mainly between the plant and the supplier platform. There are two to five platforms per brand that handle specialised distribution, on French territory. Purchasing is performed at the supplier platform and not at the plant.

The price of transport is no longer systematically a criterion determining choice. While price remains an important factor, the constant respect for agreed time-tables and the speed of response to contingencies also remain essential criteria for selecting the mode.

Freight forwarders, 2PL, 3PL and 4PL / LLP

*Traditional agreements between a company managing itself its supply chain and transporters (**2PL**, asset-based carrier providing only one mode of transport or logistics : for example, a train company running its own trains, or a warehouse owner) tend to disappear. More and more companies, often with complex flows, delegate their transport and/or their logistic to Freight forwarders, 3PL (Third Party Logistics provider) and 4PL / LLP (Fourth-Party Logistics provider / Lead Logistics Provider). These recent notions are subject to confusion, some 3PL calling themselves 4PL, etc.*

***Freight Forwarders,** also called **Forwarders** or **Forwarding agents,** are companies or often independent workers, **choosing between available transport offers** the best way (intermodal or not) to carry goods from A to B: cost, time, reliability. The Freight forwarder is the only contact of the shipper.*

***3PL** offer integrated operation, transportation and warehousing services ("one stop shop").*

***4PL / LLP** offer **supply chain optimisation,** considering all options available. They use 2PL and 3PL services – without conflict of interest ; thus great multimodal asset-based carriers such as DHL, Kühne-Nagel, DB Schenker or SNCF Geodis, which provide supply chain consulting, are not actual 4PL ; they are sometimes called "advanced logistics 2PL/3PL".*

*NB: **1PL**/First Party Logistics are cargo senders and receivers.*

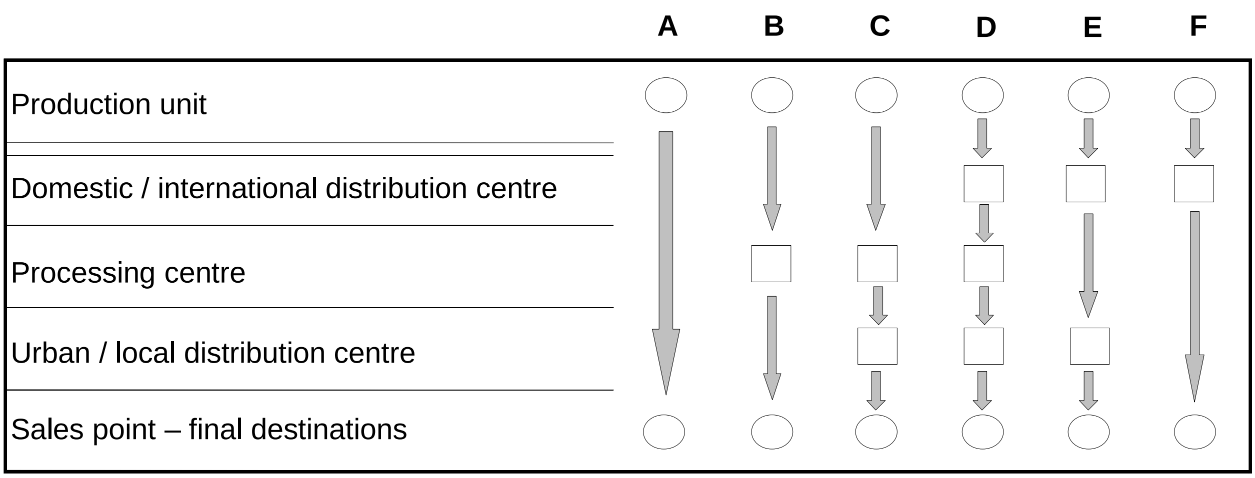


Figure 4. Logistical distribution models - Source : Ben J.P. Janssen, 1993 [5]

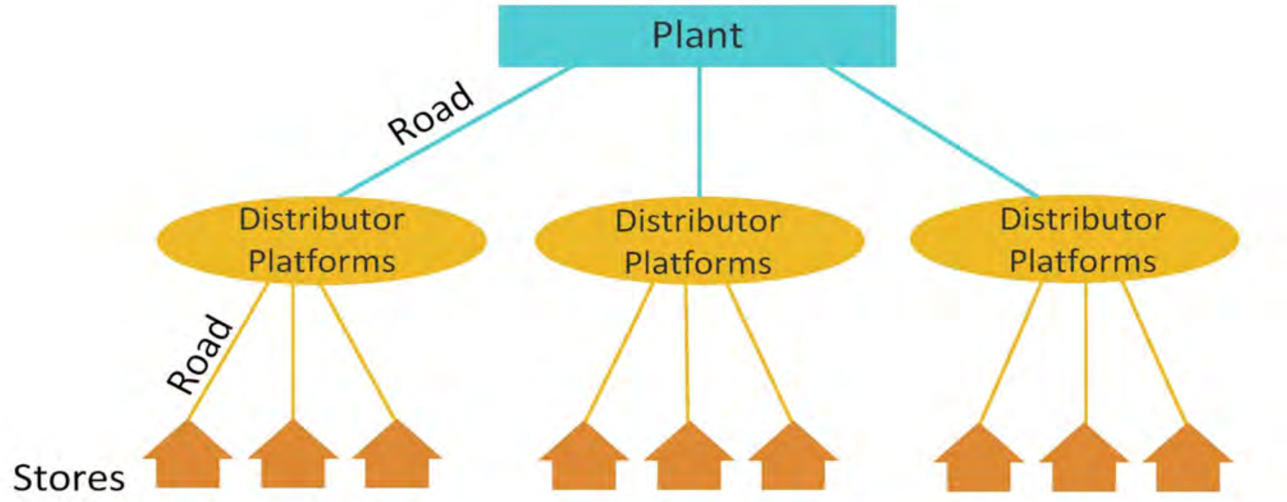


Figure 5. Former organisation of mass merchandising

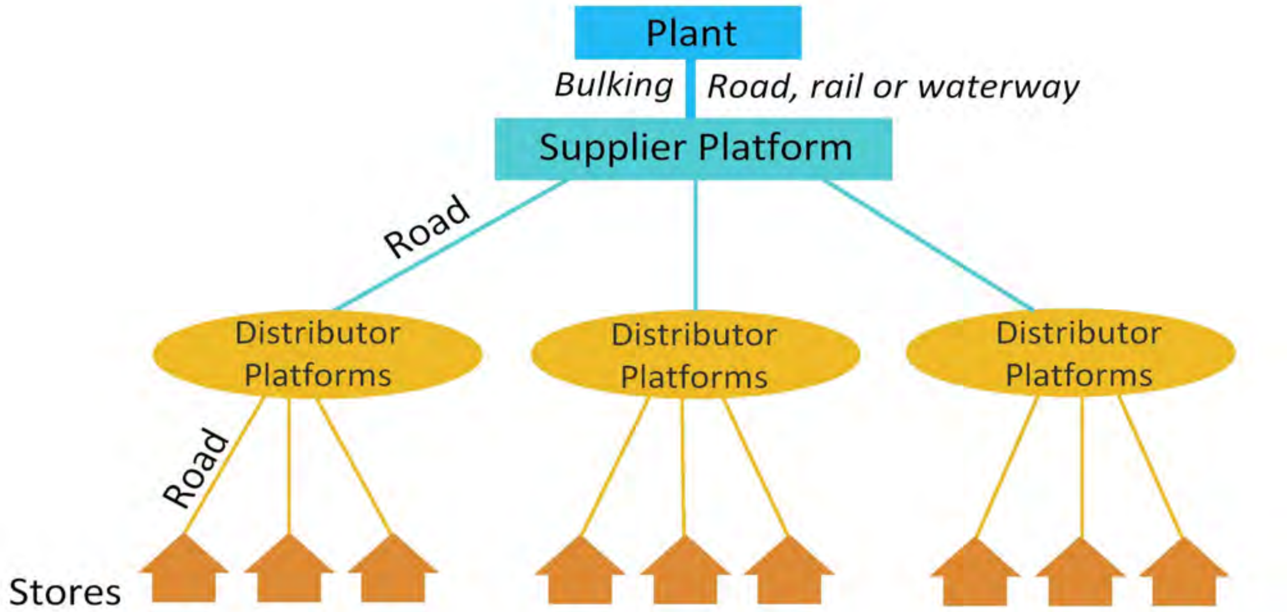


Figure 6. New organisation of mass merchandising

2.3 – Emergence of platforms

2.3.1 – Reasons for emergence

The developments described here strongly influence goods transport. Quantities transported, number of consignments, frequency of deliveries, and distances travelled are also increasing. Flows now require bulking of smaller batches and delivery schedules are tighter and more imperative.

New logistical practices have been developed to satisfy these requirements: they are focused around consolidation/deconsolidation operations for shipping small batches to customers dispersed across the relevant territory, while guaranteeing that each conveyance vehicle is properly filled to contain transport costs.

These operations are performed at logistical platforms, often at a hub location, and they serve to reduce the number of links (see Figure 7), thereby also helping to optimise filling of conveyance vehicles (larger, fewer and better loaded). This also has the effect of reducing average distances travelled and of concentrating the operations. While cross-docking operations (see Glossary) are relatively simple, certain situations indicate a growing sophistication of these platforms and intensification of their automation.

2.3.2 – Layout criteria

Platforms are located close to markets, usually along major flow corridors or at their ends. They are therefore load breaking locations capable of performing various operations:

- consolidation/deconsolidation(12)
- **upgrading of goods** (packaging, labelling, differentiation, etc.)
- **organisation of sales** (St. Charles market in Perpignan)
- **transfer between modes** associated with physical load breaking or economic optimisation (combined transport)

Trade developments and proliferation have meant that ***logistics is assuming a central role in regulating the production system****: a transport delay can effectively block production. In addition, transport only exists as one component of a set of complex means and procedures, completely integrated with the processes of production and sales. At the same time, advances in logistics and productivity gains in transport help contain higher transport costs inherent in new production organisations*

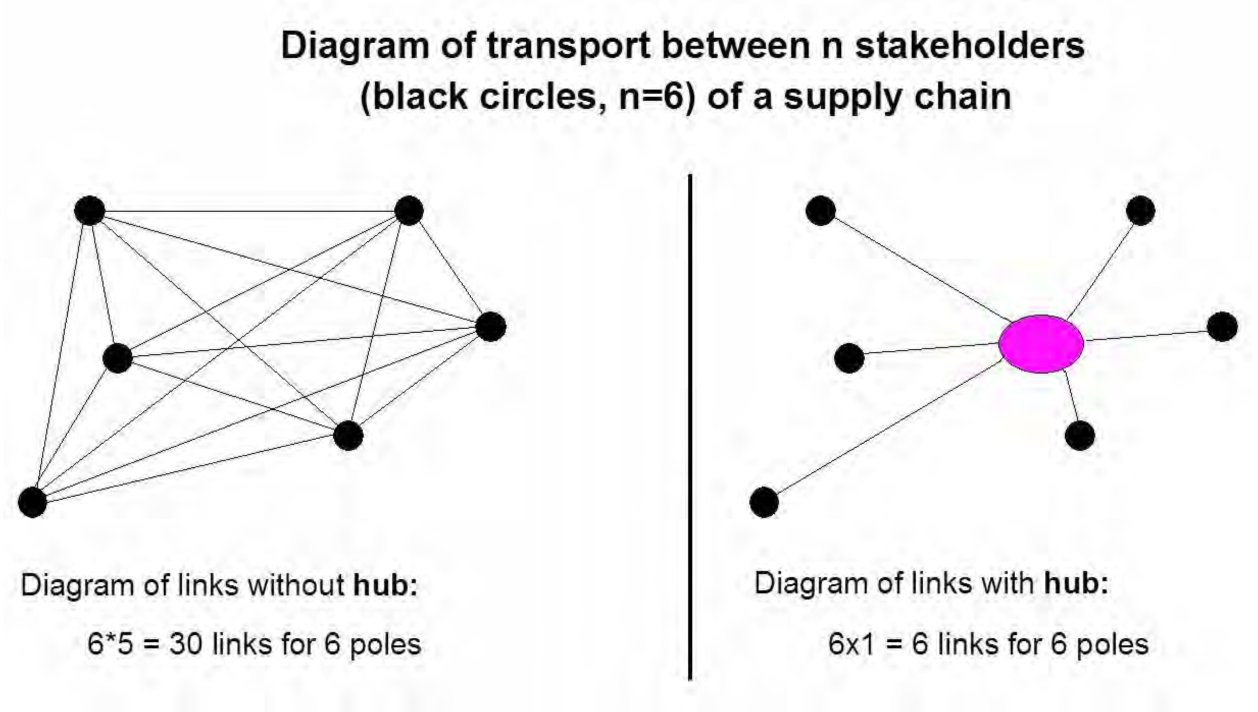
2.4 – Problems of empty transport

The concept of empty transport refers to optimised implementation of any means of transport, whether land, sea or air. Goods are transported from an origin point to a destination point, whereas the vehicle, regardless of its circuit, has to return to its point of origin. The issue of covering its return costs therefore arises.

Miminising empty transport and finding a return cargo is subject to a number factors:

- difficulty in finding goods on return route; differences in industrial and commercial activities in certain countries or in certain areas imply **imbalances in flows** (north – south on European scale, east – west and north – south on world scale);
- specialisation of equipment for certain types of goods: fuel tanks, food liquids, special vehicles for exceptional transport, etc.
- characteristics of certain reduced circuits (few tens of km) which make it impractical to find a return cargo;

Figure 7 : Operation of a hub.



2*Refer to the glossary for a definition of these concepts*

- legal organisation of transport, which differentiates transport for oneself from transport for someone else; transport for oneself only allows the transportation of personal goods and prohibits transport for someone else; return trips are therefore usually empty, thereby increasing the overall cost.

2.4.1 – Road

Road transport companies are expert in managing this problem because of the small batches transported, versatility of the trucks, packaging of the goods, very dense infrastructure network (possibility of triangular routings[13]), permanent availability of the network, organisation of warehouses at a hub to prevent empty returns and optimise conveyance vehicle filling. Trucks indeed have an excellent turnaround rate.

A comparison of the results of 1999 and 2004 trans-Pyrenean transit surveys thus reveals gains in productivity (see Figure 8).

2.4.2 - Rail

Empty transport is even more extensive, if the transport mode is rigid and inflexible. In particular, rail transport is strongly influenced because it is considered that approximately half of all freight trains run empty. Absence of return freight compatible with wagons in service and technical or health requirements are factors explaining this situation.

2.4.3 – Sea containerisation

Today, 60% of sea containers transported are full and 40% are empty, because of imbalanced flows, especially with East-Asia.

Sea containers are owened by shippers.

For one ship, the number of containers in circulation corresponds to 3 or 4 times the effectively used transport capacity of that ship. The objective of the shipowner is to transport full containers in both directions, both at sea and on land.

Supply industrial companies with containers often involves empty transit. The shipowner asks for his container to be returned to the port of call or an official depot for empty containers. Four alternatives are available:

- the shipper pays for empty return of the container; the cost of land transport is then multiplied by 2;
- the container is unloaded near the port and returned immediately;
- the container is conveyed to an official depot for empty containers (e.g. at an advanced port[24]); if the shipper is lucky enough to have an empty container depot close to his facility, he can ensure considerable savings in land transport
- there are also unofficial empty container depots, which are managed by large carriers and tolerated by shipowners. The carrier organises his operations such that he finds goods to be shipped at the sea port.

Managing empty containers is a major issue in optimising the supply chain. A dry port is an opportunity for a sea port to optimise management of empty containers and possess an empty container depot located in the hinterland (see Glossary).

Many handling operations concern empty containers in ports and combined transport terminals ; here Bonneuil-sur-Marne road-rail terminal, near Paris.

– photo Bruno Meignien (Sétra)

3 "Triangular" = Triangular road routing: instead of a round trip with possible empty return; carrier makes a "detour" to optimise transport with an additonal loading or unloading.

4 Concepts of dry port and advanced port are detailed in the appendix to the sea transport section.

Pyrenees barrier	Type of traffic	% empty trucks 1999	% empty trucks 2004
A 63 and A 9	Transit	3.8	3.1
	Exchange	20.3	17.9
RN 125	Exchange	39	35

"Exchange" = Transport between France and another country

Figure 8. Percentage of empty trucks at Pyrenean border between 1999 and 2004. Figures 2010 soon available, please contact us.

3 – Comparison of Different Transport Modes

This section provides basic information for comparing different land-based goods transport modes. This can help to better clarify their respective development and performance.

The shipper has a major role in the transport chain. Irrespective of his activity, it is the shipper who generates transport services, whether for his own procurement or for delivery to his customers. As a rule, the shipper himself defines the transport mode in accordance with his needs and the expectations of his customers. Sometimes, however, a number of shippers, preferring to focus their activities on their core profession, enlist the services of freight forwarders or of logistics service providers.

In this case, it is the freight forwarder or provider who organises and manages the transport chain, without losing sight of the requirements imposed by the logistics organisation of his client. The Association of Freight Transport Users (AUTF in France) represents industrial firms, traders and distributors and the "shippers" in their function as transport users.

It is also important to understand that the organisation of each transport mode demands the involvement of many different stakeholders. The complexity of this situation is shown in Figure 9.

Costs :

Comparing costs of different transport modes has no real meaning ; they vary differently according to distances, volumes to transport, economic climate, countries, etc. However, it can be stated in the general case that air transport is the most expensive mode, followed by road, rail, pipeline, inland waterway and finally sea transport. The most common invoicing unit is the tonne-kilometre (one ton of goods travelling a distance of one km)

*For example in France (**average figures,** 2011) : Air France - KLM 0.26€/t.km, road 0.06€/t.km, rail 0.045€/t.km, pipelines 0.04€/t.km, inland waterway 0.03€/t.km, sea transport less than 0.01€/t.km (down to less than 0.001€/t.km in some cases).*

Waterway transport	Road transport	Rail transport	Combined transport	Sea transport	Air transport
Shipper / Logistician					
Freight forwarder / Shipping agent					
Waterway transport operator	Road carrier	Rail carrier	Combined transport operator	Shipowner	Airline / integrator
Terminal operator		Marshalling yard operator / Siding	Terminal operator	Terminal operator / handling agent	Cargo terminal assistant
Infrastructure Manager					
State Services					

Figure 9. Main stakeholders in goods transport

3.1 – Modal split

The Economic Statistics and Observation Department (SOeS) of the French transport ministry gives the following modal split for 2010 in French territory, national, international and transit traffic included (Comptes Transports de la nation [6]) :

- 85% of t-km carried by road
- 8% of t-km carried by rail
- 2% of t-km carried by inland waterway
- 5% of t-km carried by pipelines over 50km
- Sea transport is not taken into account

Goods transport units

Two main units are used to measure goods transport flows:

- *the metric tonne (t) is used to quantify a volume of goods transported*
- *the tonne-km (t-km), corresponding to the movement of one ton of goods by one km, based on the volume and distance travelled.*

In 1984, this mode distribution was different and road transport was less predominant: 58% of t-km carried by road, 26% by rail, 4% by inland waterway and 12% by oil and other pipelines.

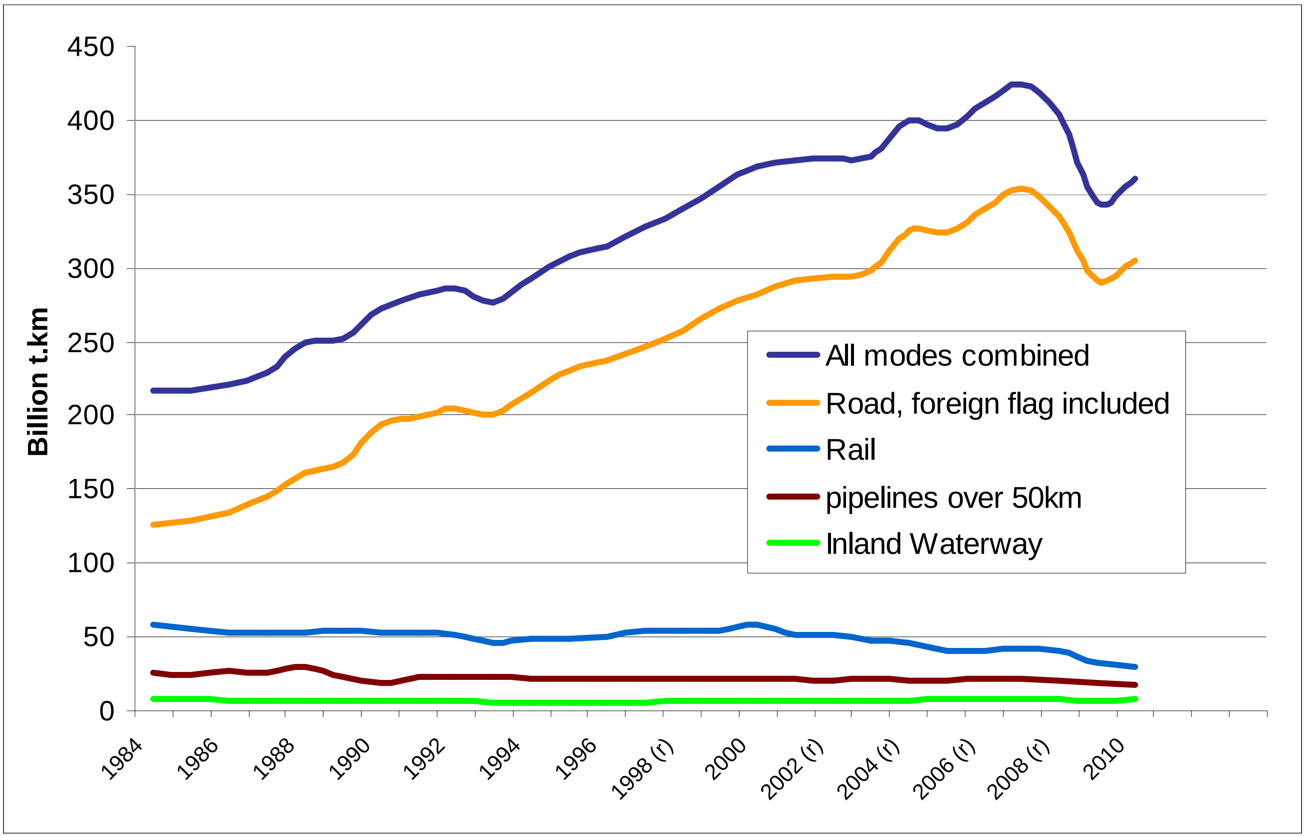


Figure 10. Mode distribution of different inland goods transport modes – excepted Sea transport – between 1984 and 2005, in France, transit and international traffic included, vehicles <3,5t included. (r)=Revised data Created with data from INSEE 2011 (French statistics office) and SOeS (Observation and Statistics Department of the Ministry of Transport)

The years 2008 and 2009 marked historical decline in inland goods carriage in France. As in many other countries in the world, the drop in road transport is especially important, equivalent to more than the t.km carried by rail. The decline in 2005 was also clearly due to economic factors and was observed throughout Europe.

The position of sea transport was further asserted and is clearly the only rival of road transport (but on sometimes different markets). This also appears in the statistics of European Union, for Europe-27, depending on whether land transport alone (see Figure 11) or all modes combined (see Figure 12) are taken into account. **At a world scale** however, in t.km, **road transport is only in 3d position, after Sea (predominant) and rail freight.**

	Road	Rail	Waterway	Pipeline
1995	67.4%	20.2%	6.4%	6.0%
2009	73.8%	15.8%	5.2%	5.2%

Figure 11. Modal split of inland modes in 1995 and 2009 for Europe-27. For Road, covers only the national and international haulage of heavy goods vehicles (>3,5t) registered in the EU-27. – source : Eurostat 2011

	Road	Rail	Waterway	Pipelines	Sea	Air
1995	42.1%	12.6%	4.0%	3.8%	37.5%	0.1%
2009	46.6%	10.0%	3.3%	3.3%	36.8%	0.1%

Figure 12. Mode distribution of goods transport in 1995 and 2009 for Europe-27, with Sea and Air transport. Air and Sea : only domestic and intra-EU-27 transport. – source : Eurostat 2011

3.2 – Carrying capacities and average transport distances

Unit carrying capacities of the various transport modes vary substantially. Some modes (e.g. rail and waterway) allow considerable bulking, whilst others (e.g. road and air) convey fewer tonnes per transport unit.

By way of illustration, France’s ADEME and the “Direction des Transports Terrestres” undertook a theoretical comparison of different transport modes in 2004. The number of vehicles required to carry 4,400 tonnes of goods was reckoned to represent between 170 and 220 lorries, 3 to 4 trains (about 110 wagons) and 1 pushed convoy of two barges. highly depends on national regulations (maximal length of trains, maximal load of trucks : in France respectively 750m and 40t)

Average load factors obtained for intercity routes can also be estimated per mode (*source*: ADEME [7]):

- Light duty vehicle: 0,7t
- HGV payload 13-24,9 t : 11,1t
- HGV payload over 25y : 18t
- Combined transport : 404t per train
- Full trains : 496t per train
- Single wagon : 13,9t (194t/train)

Transport modes also display wider disparities in average transport distances and these tend to erase themselves the wide scatter within each mode. These average distances are relatively stable over time (*source*: Comptes transports 2005 [6]):

- Nearly 140 kms for commercial road transport (own transport : much smaller distances)
- Nearly 340 kms for conventional rail transport (not including pre- and post-routing)
- Nearly 650 kms for combined rail transport
- Nearly 125 kms for inland waterways (not including pre- and post-routing)
- Nearly 270 kms for pipelines.

These French figures are close to the Europe average, slightly increasing over time.

3.3 – External costs

Current thinking, particularly at European Community level, is focusing on incorporating the cost of the adverse effects of transport (damage to infrastructures, congestion, accidents or pollution) into its costs and this approach is intended to internalise the external costs. The aim is to encourage users and manufacturers to change their attitudes to reduce the negative effects of transport.

A survey conducted by the University of Karlsruhe (IWW) and the INFRAS agency in 2000 and updated in October 2004 [8] sheds light on the external costs of the various modes. The following categories were considered: accidents, noise, air pollution (health, material damage and biosphere), risk of climate change, costs for nature and landscape, upstream and downstream impacts, additional urban costs, congestion (see Figure 13).

In France, development of the indirect effects of transport is defined by the framework instruction concerning methods for economically evaluating major transport infrastructure projects [9]. Reference can be made to Appendix 1 of this instruction for further information on the subject. For example, we can detail here the economically evaluated effects on health of air pollution, which depend on pollutant concentration and population density in polluted areas. This yields different values for internalising pollution: in a dense urban environment, in the open country and in a diffuse urban environment. By agreement, this assumed that the dense urban environment means a density above 420 inhabitants/km^2, and open country below a density of 37 inhabitants/km^2. Figure 14 shows the results for goods transport by road and by rail.

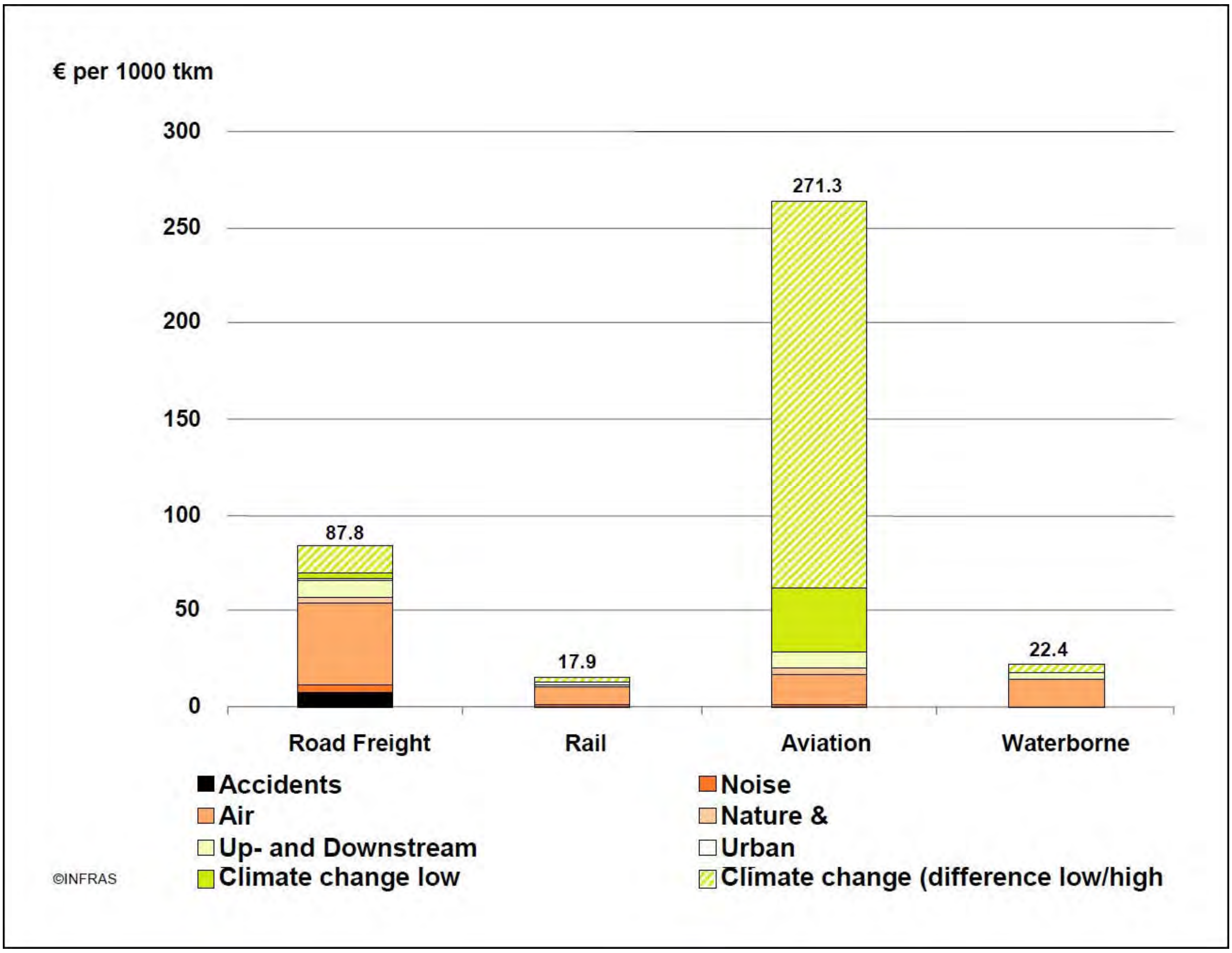


Figure 13. EU average external costs excluding congestion in 2000 – Source: IWW / INFRAS survey 2004
The huge difference for air between low and high climate change scenario is explained by a more important impact of the CO2 at high elevation.(2.5 times more impact than CO2 rejected at ground level)

2000 values	Dense urban	Diffused urban	Open country	Average
Heavy goods vehicles (€/100 veh.km)	28.2	9.9	0.6	6.2
Diesel train (€/100 train.km)	457.6	160.4	10.5	-

Figure 14. Economically-evaluated effects of air pollution due to road or rail goods transport. Values from the French "Instruction cadre" (regulation) for projects socio-economical assessment (2004, still running), calculated by the workgroup "Boîteux".

To take account of specific areas such as Alpine valleys, where the population and the atmosphere are heavily confined by geography and climate, the framework instruction proposes a correction factor to be applied to the goods vehicle traffic figures in Figure 14. This correction factor is 1.5 for gentle slopes (2 to 4%) and 2.1 for steep grades (4 to 6%).

3.4 – Energy efficiency and carbon dioxide emissions

3.4.1 – Energy efficiency

Transport-related energy consumption has grown sharply in the last 40 years in line with growth in traffic, which increased in France from 9.3 million tons of oil equivalent (MTOE) in 1960 to 50.1 MTOE in 2005. Road transport accounts for most of this growth, followed by air transport. The low cost of abundant energy has been a contributing factor.

The energy efficiency of transport depends both on consumption and on the average number of passengers (or tons of goods) per vehicle. This explains the wide differences in consumption between passenger transport (cars and trains are rarely full) and goods transport.

A survey conducted for ADEME and VNF [10] provides a number of ratios on the unit energy consumption of goods transport modes for intercity routes (see Figure 15). These calculations were made considering current fuel consumption modes and the use of hydrocarbon fuels, and include a share of empty trips. However, the results are taken from various studies, and the calculation methods may be relatively variable for the different modes. These ratios therefore provide an order of magnitude but this comparison must be considered with precaution.

3.4.2 – Carbon dioxide emissions

There are many sources of pollution today (transport, traffic, industrial and domestic heating, industries) with a considerable impact on the quality of life, particularly in urban areas. Road traffic is considered today as the main culprit in air pollution, and the CO_2 emissions from road transport are a significant contributor to global warming.

CO_2 emissions from road transport grew by a factor of 6.4 between 1960 and 2000: with a 7-fold increase in emissions from private cars and a 5-fold increase in emissions by goods vehicles, this growth is mainly explained by the increase in traffic. However, unit consumption of the vehicles has significantly decreased due to technological progress. The European agreement with automotive manufacturers (1994) contributed substantially to this trend: a car entering service in 2003 consumes 154 g of CO2/km, or 30% less than a car sold in 1975.

Unit CO2 emissions per type of vehicle, in goods transport for intercity routes, evaluated taking account of current fuel consumption modes, demonstrate the advantage of rail transport on this issue, with unit emissions more than 21 times lower than from goods vehicles (see Figure 16).

Here also, *these results are provided for information and must be considered with caution*. Real emissions are far more complicated, many hypothesis are made to obtain the average figures below.

The framework construction on methods for the economic assessment of major and transport infrastructure projects [9] provides its own details on this subject. It gives a value for carbon (in order to evaluate economically the impact of transport on the greenhouse effect). This is 100 euros/tonne of carbon over the period from 2000 to 2010, plus 3% per year after 2010. This value corresponds to a value of 6.6 c€/litre of gasoline and 7.3 c€/litre of diesel.

Reminder

3.7 tons of CO_2 = 1 ton of carbon

	Unit energy consumption (goe[1] / t-km)
Air	405.9
Light duty vehicles	120.9
Total goods vehicles	39.5
Truck payload 3 to 6.5 t	65.9
Truck payload 6.6 to 12.9 t	51.8
Truck payload 13 to 24.9 t	40.6
Truck payload > 25 t	25.8
Total rail transport	5.75
Total full trains	4.7
Diesel full trains	13.8
Electric full trains	3.2
Total single wagons	8.7
Diesel single wagons	25.4
Electric single wagons	6.3
Total combined transport	4.6
Diesel combined transport	14.1
Electric combined transport	4.5
Waterway	12

1 goe: gramme oil equivalent

Figure 15. Unit energy consumption of goods transport – Source: ADEME / VNF

	Unit CO_2 emissions (g/ t-km)
Air	1220.12
Light duty vehicles	372.02
Total goods vehicles	125.39
Truck payload 3 to 6.5 t	254.8
Truck payload 6.6 to 12.9 t	180.47
Truck payload 13 to 24.9 t	128.84
Truck payload > 25 t	79
Total rail transport	5.75
Total full trains	6.07
Diesel full trains	43.44
Electric full trains	0
Total single wagons	10.12
Diesel single wagons	79.87
Electric single wagons	0
Total combined transport	0.6
Diesel combined transport	44.21
Electric combined transport	0
Waterway	37.68

Figure 16. Unit CO_2 emissions of goods transport modes in 2000 – Source : ADEME / VNF

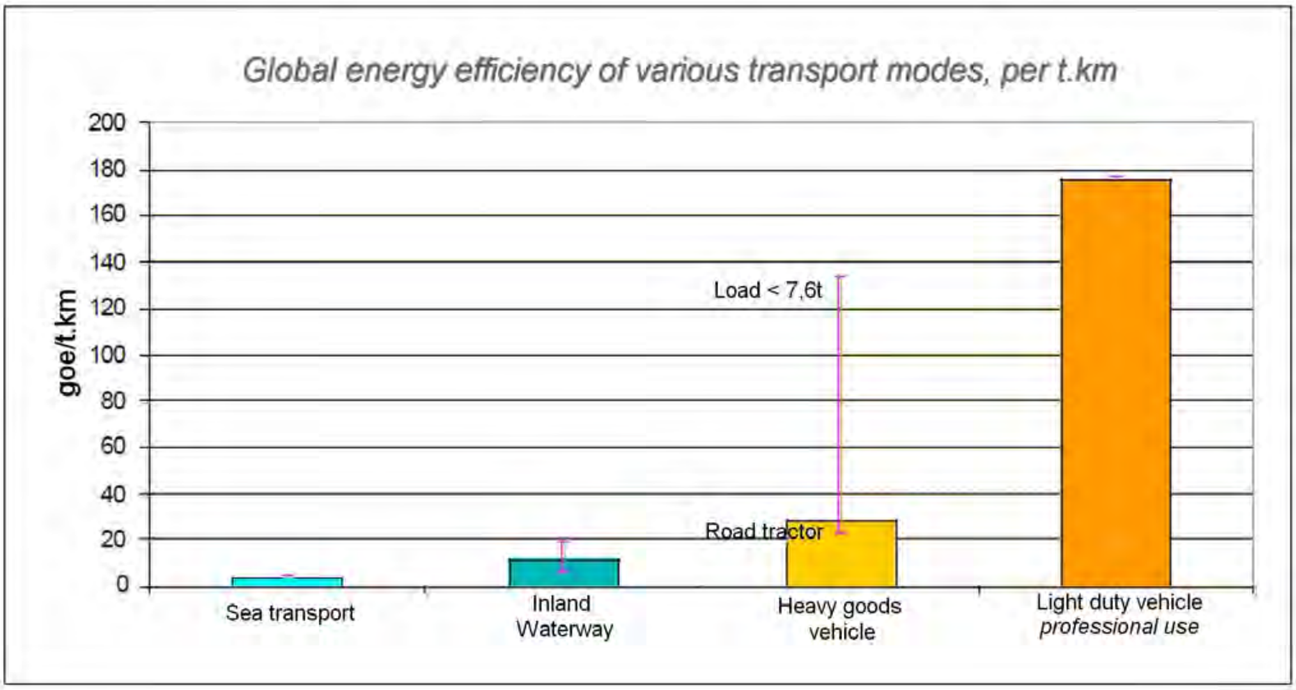


*Figure 15 bis - source : ADEME/Deloitte 2008. goe = **gramme oil equivalent**. (1 goe → ~3 g CO2)*
Note : Sea transport suffers a lack of data in this graph, but it is considered as the most energy-efficient mode :great tonnages, low speed

4 – Information and Communication Technologies in Transport

The expression "Information and Communication Technologies" (ICT) embraces a wide range of systems. Their application to transport, travellers and goods involves many issues in terms of safety (tracking and safety of goods, management of emergency situations, etc.), mode transfer (enhanced mode interoperability), European considerations (improved transborder relations) and optimising capacities (*Source: Georges Dobias [11]*):

- in relation to goods traffic: optimisation of traffic, reduction of safety intervals, information to users to adjust their behaviour, etc.
- in relation to fleet and freight management: real time fleet optimisation, simplified management of freight loadings, shorter exchange time for freight administrative documents, electronic payment of fees and tolls for goods vehicles, etc.

To meet these challenges, the ITC offer geopositioning technologies (data compilation), information to users (data sending), software and data integration platforms, allowing a multimodal synthesis of the data and the formalisation of relevant information for users.

In rail transport, the development of the European Rail Transport Management System ERTMS[(15)] – should assist, in coming years, in curtailing intervals between trains and thereby increasing transport capacity through instantaneous real-time knowledge of train positions.

In air transport, similar systems help narrow intervals between aircraft landings and thereby increase runway capacity.

In road transport, these technologies offer immediate information about incidents and accelerate first aid operations and the restoration of the lanes to full capacity. For goods transport in particular, real time tracking of the vehicles and their contents appears to be increasingly used. Tracking systems help manage the services more efficiently, with greater productivity.

[5] ***European Rail Transport Management System. Refer to the rail section for further details.***

In this connection, the ACTIF Programme (Aide à la Conception de Systèmes de Transports Inter-opérables en France) [aid to designing interoperable transport systems in France] is designed to capitalise gradually on experience and offers an architectural framework for transport systems.

4.1 – Satellite navigation: GALILEO

GALILEO, the European satellite positioning and navigation system, has been operational since 2008. In comparison with the American *Global Positioning System* (GPS), GALILEO is presented as a system offering a wide range of high performance services to users throughout the world: better accuracy, greater reliability, better guarantee of service quality and continuity. In particular, all transport modes which use precise data on positioning will be covered. Road applications will include, among other items, on board navigation, electronic toll payment (interoperable for goods vehicles on all European networks), the management of vehicle fleets and driving aid systems, while the rail sector will benefit from more efficient services for traffic control.

Another Europe wide project is the one currently under way for inland waterways. In 1998, the European Union decided to develop a concept of Information Services for Navigable Waterways, known as the RIS (River Information Services – www.ris.eu). RIS is a concept designating all harmonised information services designed to improve traffic and transport management on inland waterways, including interfaces with other transport modes.

4.2 – Vehicle fleet management

Operators of vehicle fleets, such as transport contractors, have widely adopted information systems. By mounting positioning devices on all vehicles, the managers can optimise the deployment of their fleet whilst saving time and money and improving customer service.

The basic objectives of better freight and vehicle fleet management are:

- fewer routes with empty holds or cabins
- optimisation of the distance travelled in order to minimise the impact of the vehicles on traffic and the environment

management of incidents (accidents or breakdowns).

Figure 17 provides a comparison of main existing technologies and issues to which they provide answers.

		Labelling of goods (barcodes; RFID)	Geopositioning vehicles (GSM or satellite)	Radionavigation (LORAN)	Dematerialisation of administrative transport documents	Multimodal integration platforms
Safety	Safety of goods (theft)	✓	✓			
	Regulations on health safety and safety of hazardous materials	✓				✓
	Safety of movements		✓	✓		
Less congestion and traffic management	Management of emergency situations		✓	✓		✓ (yes for hazardous material)
	Optimisation of infrastructure capacities		✓	✓		✓ (station type infrastructures)
Optimisation of logistics systems / fleet management	Optimisation of the use of fleets (preparation of rounds and itineraries; real time)		✓			
	Productivity of consolidation/ deconsolidation operations	✓				✓
	Tracking of goods	✓	✓			✓
Electronic payment of fees for infrastructure use			✓			✓
Modal transfer		✓			✓	✓
Data on movements		✓	✓			

Figure 17. ITC, technologies and issues

Appendix 1. Estimated growth in goods traffic

Several economic indicators influence transport demand: consumption, investments, imports, exports, added value, and finally GDP (Gross Domestic Product), an aggregate that represents the value of goods and services produced in the year. GDP is the indicator generally selected as representative of economic activity, even though it is biased, because the consumption of services increases the national wealth, without commensurately generating goods transport.

The price of transport as paid by the shipper is also an important factor, particularly for choosing the mode.

The developments of new infrastructures, motorways, high speed rail lines (which release passages for freight on the old track) and wide gauge canals, are likely to affect demand for goods transport. In this respect, the commissioning of Perpignan-Figueras (rail), the Seine Northern Europe canal (waterway) and Lyon-Turin (rail) are scheduled before 2025.

The main assumptions used in France by SOES (ex- SESP, service of statistics within ecology and transport ministry) for trends from 2002 to 2025 [12] are the following :

(*hypothesis 2002-2025 re-evaluated in 2007 by the transport ministry services*)

- knowledge of the GDP (1 GDP point equals 1.5 goods vehicle traffic points, in two senses) and of household consumption by 1.9% per year, as a central trend scenario, supplemented by two other growth assumptions: ± 0.4 percentage point compared to 1.9%
- price per barrel of oil of US$65 [35 ; >100] in 2025 with dollar/euro parity. (Hypothesis 2002 was 35$/bl).
- stability of gazoline TIPP (French National Tax on Petroleum Products) and 50% narrowing of the difference between diesel and gazoline TIPP; price of oil, variation in TIPP and dieselisation of cars in circulation, leading to growth of the average weighted price of mode of fuels of 0.4% per year on average from 2002 to 2025 (after a drop of 0.9% per year from 1980 to 2002)
- drop of 15% for rail prices between 2002 and 2025 (hypothesis 2002 : stability of rail, air and waterway prices)
- Relative stability in the price of road (2% on 2002-2025 compared to a yearly drop of 0.6% from 1980 to 2002)
- inclusion of new infrastructures announced at the CIADT (national planning and development) of 18 Dec. 2003

In terms of goods traffic, the combination of these assumptions results in the annual growth rates given in Figure 18, which contrasts with past patterns.

	1980 - 2002	2002 - 2025
Road transport	**2.9%**	**1.5%**
Rail transport	**- 1.2%**	**0,7%**
River transport	**- 2.0%**	**0.5%**
All modes	**1.8%**	**1.4%**

Figure 18. Average growth rate from 1980 to 2002 and 2002 to 2025 for inland goods transport in France – Source: SESP

The drop in the annual growth rate is explained by an economic context of slower growth and tariff rises. The sharp drop in the road growth rate is explained by a less favourable economic context, an increase in road prices and a slower expansion of the road network. The growth of rail from −1.2 to +1.2 reflects the increase in road transport prices, and the increase in trading of consumer goods and the creation of new international lines. It could occur in the context of a return to balanced accounts. The anticipated growth in waterway traffic is due to the strength of transport on the wide-gauge network and the construction of the Seine Northern Europe canal. However, traffic of Freycinet units (350 tonnes) is decreasing.

Apart from the forecasting work of the Sesp, mention can also be made of the results published by the General Council for Roads and Bridges in March 2006 [13], where 4 scenarios are considered: “World governance and environmental industry”, “European retreat and decline”, “Greater economic Europe” and “European governance and regionalisation”. For each of these scenarios, the modelling of trends in transport flows (passengers and goods), of energy and CO_2 emissions, take account of the demographic and economic assumptions and energy price assumptions, carbon tax and TIPP (petroleum products national tax) varying over a wide range.

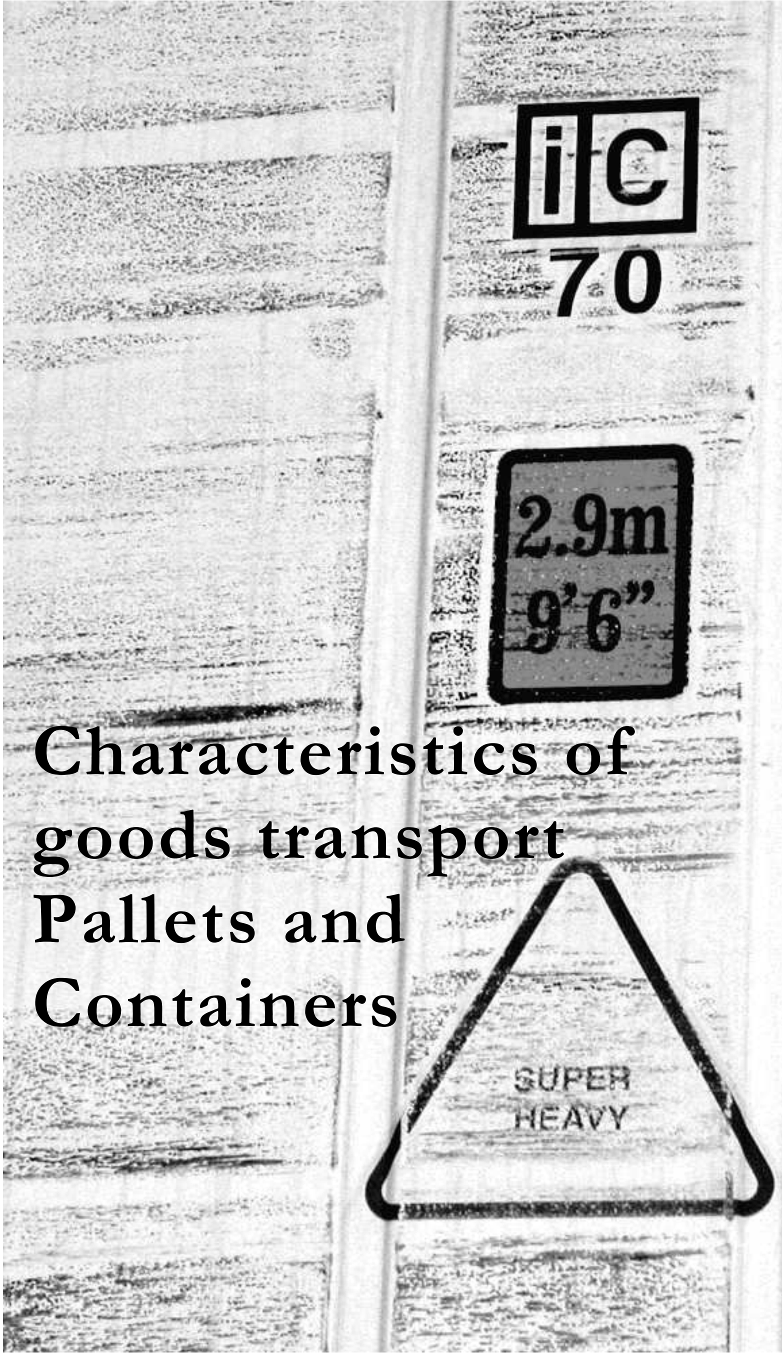
2 – Agence de Financement des Infrastructures de Transport de France [French Agency for Financing Transport Infrastructure]

French Decree No. 2004-1317 dated 26th. November 2004 [14] created the Agence de Financement des Infrastructures de Transport en France (AFITF), a public financing institution now responsible for allocating the State share of major transport infrastructure funding (for motorway, rail line, inland waterway, port development projects).

Note

*Following sale by the French State of its stakes in motorway operating companies, AFITF no longer earns dividends from the motorway companies. In 2006, this public institution was therefore granted permanent resources levied by a number of taxes and fees (land fees paid by motorway concessionaires, territorial development tax, 40% of the fines generated by automatic radar units). In the same year, the agency also received a State subsidy of 394 M€ as well as an exceptional grant of 4 billion € generated through privatising motorway concessionaires. This exceptional capital grant was allocated to investment expenditure between 2006 and 2009. It was replaced by a State dotation of ~1 billion € in 2010. AFITF spent 2,1 billion € in 2010. Major infrastructures investments, particularly railways projects, are planned for the coming decades in the 2011 SNIT/*Schéma National des Infrastructures de Transport *(National Scheme for Transport Infrastructures)*

Section 2.



Characteristics of goods transport Pallets and Containers

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Introduction

This section of the guide discusses the characteristics of the pallets and containers used in goods transport.

Details are provided on:

- dimensions
- capacities: fully loaded weight (GVWR[6]), payload, number of pallets, etc.
- advantages and drawbacks, particularly concerning weight, cost, stackability[7], service life.

The characteristics of the containers dedicated to road, rail and air transport will be addressed respectively in the "road", "rail" and "air" sections of the present guide.

1 – Pallets

1.1 – Definitions[8]

A pallet is a platform, generally made of wood, allowing easier handling of goods. It is a loading deck used to combine packages and form a loading unit. It is a storage, handling and transport platform. It is designed to be handled by forklifts (or hand-pallet trucks). Its role is important: the pallet supports the goods and is used in each of the steps of the supply chain.

Palletizing (loading goods on a pallet) helps:

- facilitate handling operations
- count the goods easily
- protect and stabilise the goods
- save ground space in warehouses (stackable).

The various techniques for securing loads to a pallet are:

- metal strapping
- wrapping with stretch or shrink plastic film
- shrink covers
- strips, ties or wrap
- cardboard-reinforced corner stays to strengthen the corners.

The pallet may be made of wood, metal, aluminium, plastic or cardboard.

Many types of pallet are available (e.g. block pallet, stringer pallet, multiple-entry pallet, standard pallet). Many standards, national (e.g. NF for France), European (EN) and international (ISO) govern the pallet characteristics. In particular, standard ISO 6780:2003 [15] sets the main pallet dimensions and tolerances for handling and transport in intercontinental trade.

Some pallets are built for a single trip or supply chain. They are called "expendable pallets". However, they can be used again if in perfect condition. Stronger multi-trip pallets are designed to be used several times after the first delivery of "palletized" products to the customer. The average service life of a pallet of this type varies considerably according to its type and conditions of use. It is estimated at about 4 to 5 years (for Europe pool pallets for example), and 8 to 10 years when part of a pallet leasing pool.

Pallets are designed to support various loads:

- semi-heavy pallets: supporting a load of 800 kg to 1200 kg
- heavy pallets: supporting loads up to 1500 kg.

1.2 – Pallet management

1.2.1 – Europe pool pallets

This is the most widely used system in many branches of activity. A company that ships its goods on Europe pallets recovers an empty pallet from his customer in exchange. The pallet is returned directly by the customer or via the carrier. The advantage of this one-to-one pallet swap system, during loadings and deliveries, is its simplicity.

However, many problems may arise; companies have difficulty retrieving the pallets, or recovering them in good condition. The carriers assume most of the costs of the Europe pallet swap system, because they still have to pay the empty pallet turnaround cost and recovery of the pallet generally requires a second presentation at the customer, also at their expense.

[6] Refer to Sub-section 2.2 for further details on this concept.
[7] Refer to the glossary for further details on this concept.
[8] Source: http://www.planetpal.net (technical file)

1.2.2 – Private pool pallets or stamped pallets

These pallets are designed for very specific uses corresponding to the demands of a given market. They belong to the shippers and, as a rule, serve exclusively for the company's own needs. The following types of pallet can be identified for example :

- CP (Chemical Pallets) for the European chemical industries
- VMF (Verreries Mécaniques Françaises) pallets for French mechanical glassware manufacturers for beverages
- cement pallets for the building works
- Galia pallets for the automotive industry

Sometimes, the pallets owned by the company, require a deposit. This very expensive system is mainly used by glass manufacturers and in the beverage sector.

1.2.3 – Leasing pool pallets

Leasing pool pallets are pallets belonging to lessors-managers who release, maintain and repair the pallets, thus relieving the users from all the management operations as well as the need to buy a large number of pallets. The leading managers are CHEP (blue pallets), LRP (red pallets) and IPP Logipal (brick coloured pallets).

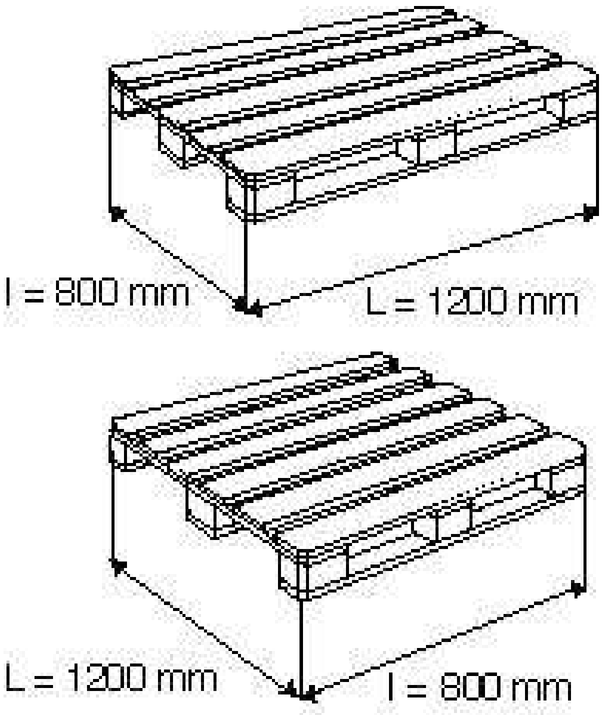


Figure : 800×1200 mm pallets. These are generally made of wood, but can be in plastic, chipboard, etc
-Source: www.planetpal.net, 2006

1.3 - Dimensions

The dimensions of the pallets vary considerably. A number of standards are privileged for the various geographic areas and company requirement.

The most common dimensions are[(1)]:

- North America: 40 × 48 inches or 1016 × 1219 mm
- South America: 1000 ×1200 mm
- Australia: 1140 × 1140 mm
- Japan: 1100 × 1100 mm
- Europe (*Europallet*): 800 × 1200 mm and 1000 × 1200 mm

To increase freight palletizing, European professionals in the rail sector developed a standard pallet in the early 1950s, measuring 800 by 1200 mm (Figure 1). This "Europallet" meets a precise specification, defining the characteristics of the manufacturing components, dimensional tolerances, location of the nails and the moisture content of the wood. Europe pallets are white and stamped "EPAL SNCF EUR". They are increasingly used in goods packaging and transport, regardless of the transport mode.

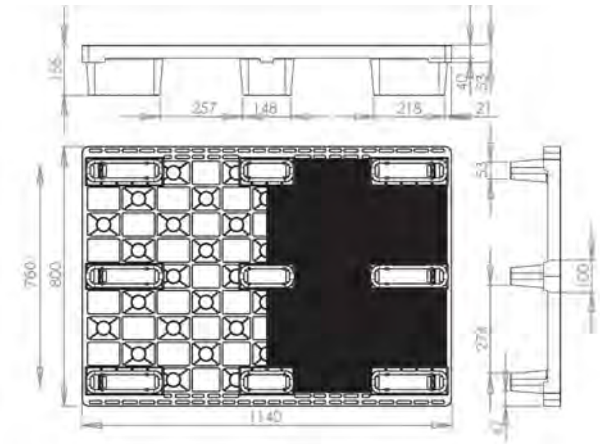


Figure 1. "Maritime pallet" *from Smartflow, with slightly lower dimensions (760*1140 or 800*1140), to ensure optimization of maritime container space (see figure 11). As shows the photo below, this pallet is in plastic and stackable - © Smartflow*

2 - Containers

2.1 - Definitions

A container is a box designed to transport goods, sufficiently solid for repeated use, generally stackable and provided with elements for intermodal transfer. It is a rigid box designed to contain the goods. It is equipped with corner devices to facilitate handling and stowage. Standard ISO 6346:1995 [16] provides a system for the identification and presentation of data about containers. The most common lengths are 20 feet and 40 feet. Information on the boxes allow permanent checking of the identification of each container (Figure 2).

Various types of container are available:

- **standard or "dry" container** (Figure 3). These are closed containers with a top, side walls and rigid ends. They are equipped with doors at one end and are designed to transport products of all types

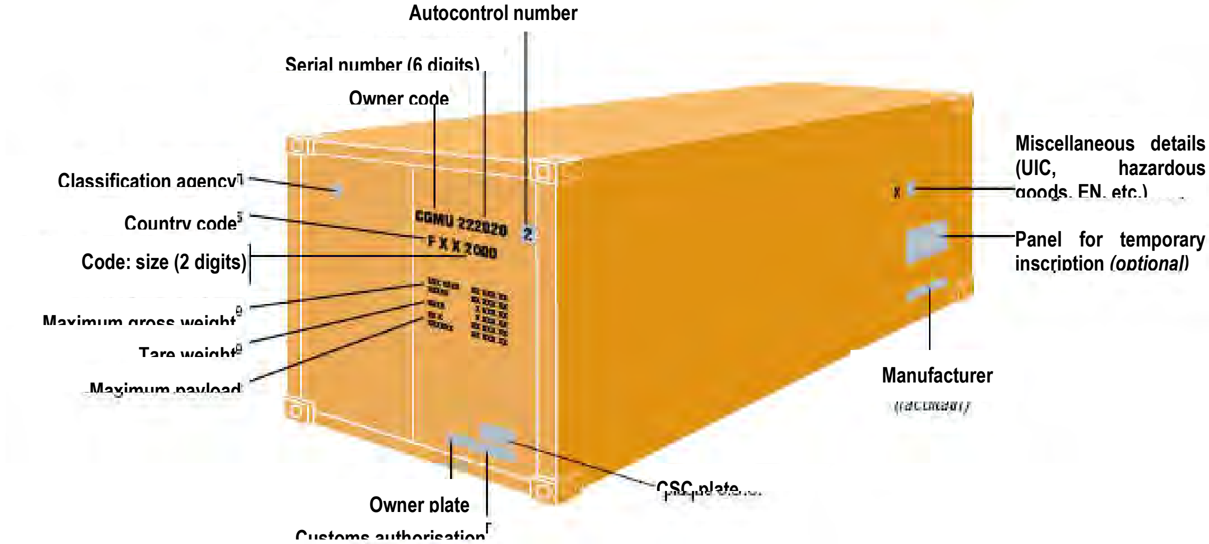


Figure 2. Description of standard container – Source: MEDDTL, ex MTETM/DTMPL

Figure 3. Standard containers at Port of Gennevilliers
Source: © MEDDTL, ex MTETM/SG/SIC - 2006, Photo: G. CROSSAY

Containers and swap bodies are handled and positioned by simple twistlocks, or even just lock as on this flatcar at Bonneuil-sur-Marne road/rail terminal (yellow) – photo Bruno Meignien (Sétra)

- **open top container** (Figure 4): the top is a removable tarp. This container has a structure adapted to transporting solid bulk goods. They are equipped with top loading hatches, and bottom loading hatches at one end (front or back)
- **tank container** (Figure 6): these containers have two basic components: the tank and the frame. They must correspond to very clear technical specificities (tests, valves, etc.) according to the goods transported. The tanks of the fleet are classed in two categories: food (22T0) and chemical (22T4)
- **flat container** (Figure 5): open on the sides and top, allowing filling from the top, and adapted for example for extra high loadings
- **reefer container** (Figure 7): these containers have thermal features (insulated walls) and are equipped with a refrigeration and heating system.

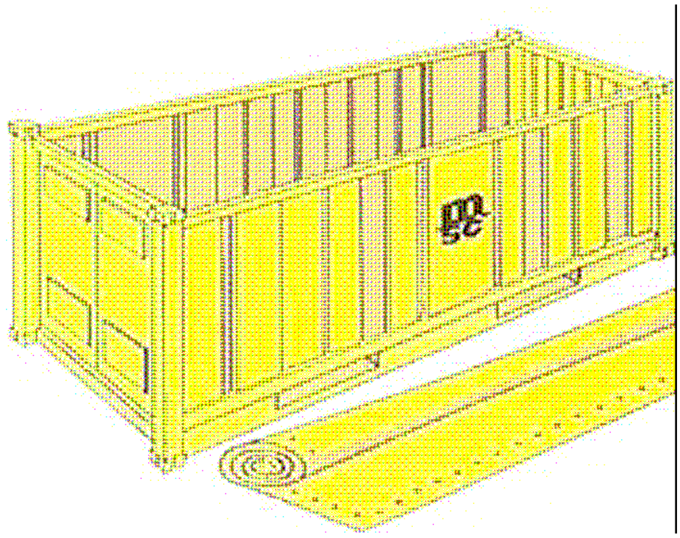


Figure 4. Open top container

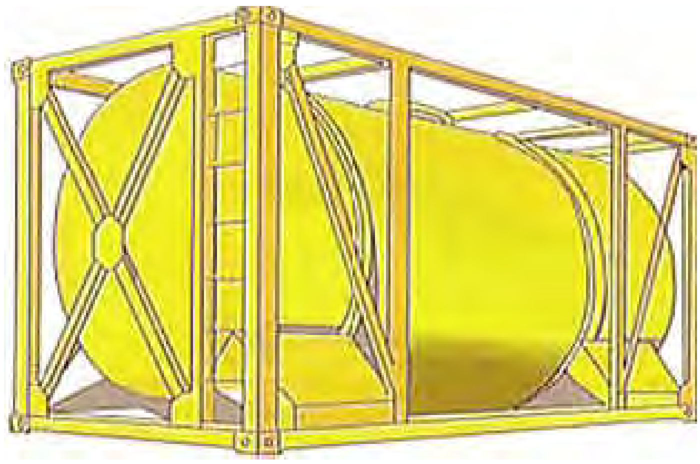


Figure 5. "Flat" or open container

Figure 6. Tank container

Figure 7. "Reefer" or refrigerated container

2.2 – Advantages of the container

- Worldwide standardisation
- Solid and stackable, hence ideal for sea and waterway transport
- Rapid handling
- Goods secured (protection against theft, impact, environment)
- Dimensions adapted to sea and rail standards
- Average service life 10 to 15 years.

2.3 – Drawbacks of the container

- Costly investment and maintenance (yet cheaper than a semi-trailer or a swap body)
- Dimensions (ISO) do not offer optimised carrying capacity for European pallets (see section 2.5.1)

2.4 – Standardised dimensions

Containerisation began in the 1960s, when SEALAND, a US road carrier, developed the first containerised sea vector. In 1965, the International Organization for Standardization (ISO) recommended standards, thereby facilitating the growth of containerising. The first containers built in the United States were designated as category 20 or 40 according to the length expressed in feet: 20' (twenty feet) or 6.05 m long for 30 m^3 containers and 40' (forty feet) or 12.19 m long for 65 m^3 containers. As required, many forms of containers were developed on the basis of the 20 and 40 feet categories.

ISO standards, in agreement with the International Railway Union (UIC) help, among others, to facilitate rail transport.

The ISO standard contains an international container identification system (Figure 8).

The maximum gross weight and the tare weight must also appear on the container, in kg and in lb. The International Convention and Container Safety (CSC) [17] also defines construction rules, aimed to guarantee the safety of handling, stacking and transport. Approval of a container is granted by an organisation qualified for the purpose by order of the French Minister for Ecology and Sustainable Development:

Owner code - four letters	Serial number - six digits	Autocontrol number
DVRU	128 428	6

Figure 8. ISO system for international identification of containers

Outside dimensions	20' × 8' × 8'6"	40' × 8' × 8'6"	40' × 8' × 9'6"
Inside dim.			
Length (mm)	5900	12 033	12 033
Width (mm)	2352	2352	2352
Height (mm)	2386	2389	2694
Door openings			
Width (mm)	2340	2340	2340
Height (mm)	2280	2275	2580
Weight			
Maximum gross weight (kg)	24 000	30 480	30 480
Tare weight (kg)	2240	3730	3800
Payload (kg)	21 760	26 750	36 680
Net capacity (m^3)	33.0	67.6	76.3

Figure 9. Characteristics of sea containers – Source: CATRAM / DTT - DTMPL [95]

- approval of a new container is subject to test of the container, or to test of a prototype and examinations and tests of serial produced units, following procedures and in conditions set by order of a Minister for Ecology and Sustainable Development;
- the safety of a container in service is checked on initiative and are the responsibility of its owner.

The table in Figure 9 gives the dimensional characteristics and carrying capacities of sea containers. While the outside dimensions are strictly codified by the ISO, the other characteristics may vary slightly from one series to another. Appendix 1 gives wider ranges of these characteristics, for different types of equipment.

45' containers also exist, "temporarily" authorised subject to being bevelled, but which were to be prohibited in Europe from 2006 pursuant to the provisions of European directive 96/53/CE [18]. Even after this date, however, 45 feet long units can be carried by road if their front corners are rounded at the distance of the length of 13 600 mm.

2.5 – Evolving dimensions

Recent years have witnessed a trend to the growing use of large containers: 40' and 45' and High Cube containers. The latter offer additional height capacity: 9'6" (2895 mm) instead of 8'6" (2591 mm) for standard containers.

This development is based on the finding that the goods transported weighed less and less and were more and more bulky. This is the case in particular of the East/West transcontinental trade in various goods.

Thus the world sea container fleet was 10.7 million Twenty feet Equivalent Units (TEU[9]) in June 1999. Three years later, in June 2002, the fleet grew to 15.1 million, reflecting a 40% increase in three years. Among these containers, the 40 feet showed the highest growth, going from 6.6 million in 1999 to 9.8 million in 2002, an increase of 48%[10].

[10] *Refer to Glossary for further details on this concept*
[11] *Source Cnt Marc*

figure 10. A 40' container at the Port of Marseille – Source: CETE Méditerranée

2.5.1 – ISO containers

The inside dimensions of the ISO sea container are adapted to the US market, but not to the European market, due to the dimensions (metric) of the Europallets, whose sides may measure 80, 100 or 120 cm. Furthermore, ISO sea containers are inappropriate for intra-European transport of lightweight goods, because the competitor is the road and road carriers have large boxes. Light goods consist in particular of all finished products with sophisticated packagings, whose relative share of transport is growing.

In the case of transoceanic transport, these factors are obviously irrelevant: the ISO container is the only possible container and the shippers have no choice but to use the least restrictive ISO unit, but are expressing growing demand for large units (40' High Cube) compatible with the capacity of present day container ships.

ISO sea containers are therefore not imposed in intra-European transport, except for short distance sea transport. Theoretically adapted to changes in transport modes, these containers do not offer sufficient space for an optimal loading of the pallets or to fully exploit the maximum dimensions authorised in land transport in certain countries.

Used in land transport, the standard 40' long sea container can in fact only load 25 Europallets, owing to its outside width of 2.44 m, which corresponds to an inside width of 2.33 m. The capacity of a standard 40' container on a road platform is thus 32% lower in Europallets than that of a road trailer (25 against 33).

2.5.2 – Palletwide containers

To tackle the problem of palletization, some sea container manufacturers have devised solutions to increase the widths of the sea containers without increasing the outside widths set by the ISO standards and the cellular guide rails of container ships. These containers are called "*Palletwide*" and represent a recent market. There was no "*Palletwide*" in the world in June 1999 and only 96,500 in June 2002. In 2006, three manufactures put "*Palletwide*" on the market, GE SeaCO, Cronos and Container Leasing UK. A manufacturer like GE SeaCO produced more than 1000 "*Palletwides*" per month in 2004, corresponding to 10% of its production.

Figure 11 shows the advantages of the *palletwide* system for pallet loading.

This type of container has many advantages:

- optimisation of Europallet loading (30 Europallets in a 40 feet, 33 in a 45 feet)
- good locking of the Europallets to prevent pallet movement inside the container, thereby avoiding impacts, breakages and losses
- adaptation to all present day fleets (4 modes)
- financial benefits, despite the extra cost of leasing of €0.50 per day (€3.00 instead of €2.50), allowing the shipment of 10 000 Europallets with 333 40' *Palletwides* instead of 400 standard 40' containers and an economy of 67 lorries or wagons.

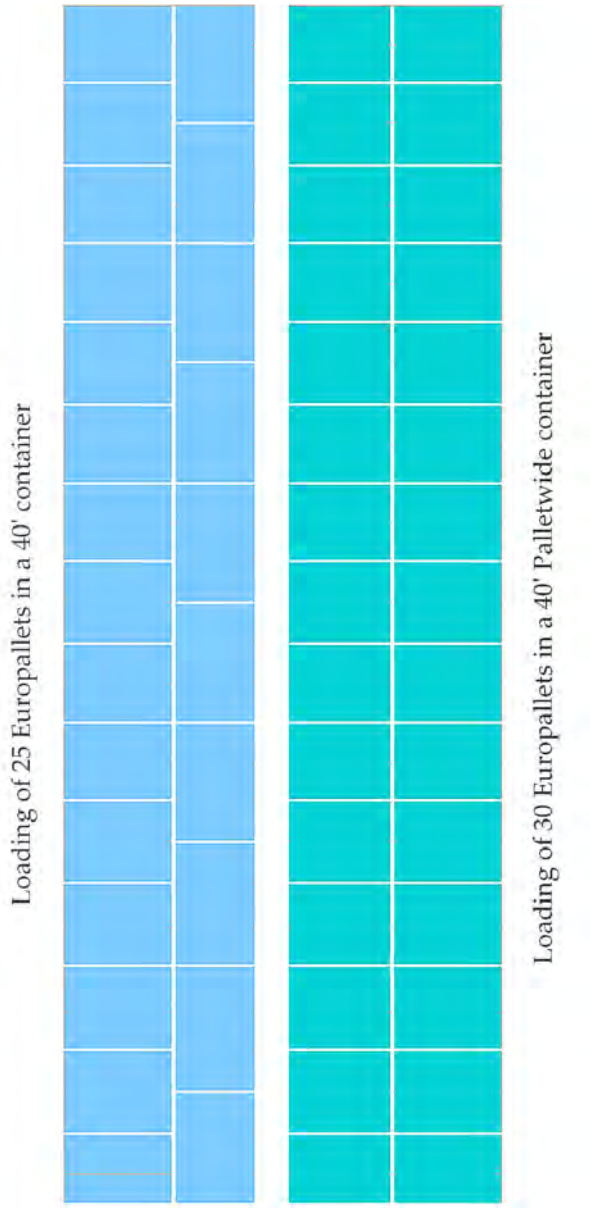


*Figure 11. Loading of Europallets **80*120cm** in an ISO container and a Palletwide container*

2.5.3 – The European Intermodal Loading Unit (EILU) Project

On 30 April 2004, the European Commission adopted an amended proposition of directive on intermodal loading units [19]. The general aim of the proposal was to reinforce the competitiveness of intermodal freight transfer by creating a framework to promote the better use of intermodal loading units, particularly containers and swap bodies, via sea, waterway, road and rail modes.

It proposes the development of a new type of container, the European Intermodal Loading Unit (EILU), designed to optimise the loading and stacking space. Thus, two EILU versions are proposed, one short and one long, determined by the desired loading capacity, and stackable on 3 or 4 heights and an identical inside width.

This width should allow the loading of three pallets side by side, i.e. 3 times 0.8 m, or two pallets in the lengthwise direction, i.e. 2 times 1.2 m, plus the necessary margin, without the outside width exceeding 2.55 m, the maximum width authorised in road transport.

The long version designed for the maximum authorised length in road transport, must not exceed 13.6 m. As to its inside length, it must allow the loading of eleven 1.2 m Europallets in the lengthwise direction with any margins that may be required, or a useful length of 13.2 m. The short version will have a length of 7.45 m, close to the maximum transportable in pairs by trailer trains. It should allow the loading of 6 Europallets in the lengthwise direction. The proposal of the Brussels Commission raised the outside height to 2.9 m (i.e. height of the High Cube containers).

The table in Figure 12 shows the potential productivity gains offered by the use of the EILU in comparison to the ISO containers (*Source: CCE [20]*).

As to the main pitfalls concerning the use of this type of container, they have been emphasised by the Commission and the transport professionals. Every standardisation approach implies restrictions and limitations and, according to the Commission, the dimensions of the EILU could raise the following problems:

- ***Length***

  On cellular ships and barges, the guides must be adjusted to a new length, which incurs marginal induced costs. In some cases, when the ships are designed for certain container lengths, the structural requirements could mean a less advantageous use of the loading space. The long EILU would not fully exploit the capacity of present day standard railcars.

- ***Width***

  An outside width of over 2.5 m could create problems, for example under certain cellular ships where the cells only 2.5 m wide, requiring adjustment of the guides. Loading space could also be lost on some inland waterway vessels, particularly those designed to carry four ISO containers side by side without margin.

- ***Height***

  The United Kingdom rail gauge does not permit a height above 2.54 m for the ILU, or 2.67 m with a lowered wagon deck height for the major lines serving the Channel Tunnel.

Waterway transport professionals, particularly via the European Barge Union (UENF - EBU), like the Commission, find that the dimensional characteristics of the EILU would only allow for 3 rows of EILU side by side compared to 4 rows of ISO containers so far. As a consequence, they feel that instead of gaining productivity, the river feeder would lose up to 25% of loading capacity.

Handling agents and multimodal platform operators appear to temper their backing for the Commission's project. They claim that the new European standard must meet two requirements to be accepted: it must not incur additional costs for the transhipment infrastructures, and its dimensional and weight characteristics must allow its integration in existing loading/unloading procedures.

Figure 12. Comparison EILU/ISO containers

	Europallets	UK-pallets or USA pallets
Short EILU (inside length 7.2 m)	18	14
ISO 20' container	11	9
EILU/ISO difference	7 (+ 63%)	5 (+ 55%)
Long EILU (inside length 13.2 m)	33	26
ISO 40' container	25	22
EILU/ISO difference	8 (+ 32%)	4 (+ 18%)

Appendix 1. Characteristics of sea containers

Container type	Inside dimensions (mm)	Door opening (mm)	Volume (m^3)	Tare weight (kg)	Payload (kg)
20' DRY / GP / CLOSED / ISO 22G1 20' × 8' × 8'6''	L: 5884 to 5910 W: 2230 to 2380 H: 2238 to 2405	W: 2230 to 2370 H: 2139 to 2295	31 – 33.4	1960 – 2400	21600 - 28080
40' DRY / GP / CLOSE ISO 42 G1 and 43 G1 40' × 8' × 8 '6"	L: 12010 to 12075 W: 2330 to 2370 H: 2375 to 2391	W: 2330 to 2370 H: 2270 to 2296	66.6 – 68.1	3500 - 4000	26480 - 26970
40' HIGH CUBE 40'× 8' × 9'6"	L: 12030 W: 2350 H: 2700	W: 2 340 H: 2590	76.3	3910	26570
20' BULK ISO 22B0 20' × 8' × 8'6"	L: 5895 to 5910 W: 2317 to 2342 H: 2361 to 2385	W: 2317 to 2334 H:2272 to 2295	32.3 - 33	2520 - 2600	22980 - 27400
20' ISO TANK 22 T0 and 22 T4			19.2 - 24	2560 - 4000	19000 - 24000
20' ISO REEFER 22R1 20' × 8' × 8'6"	L: 5427 to 5485 W: 2260 to 2298 H: 2260 to 2286	W: 2260 to 2286 H: 2224 to 2270	Nominal volume: 27.9 – 28.6 Net capacity : 26.9 – 27.7		21620 - 27820
40'' ISO REEFER 42R1 40'' × 8' × 8 ''6"	L: 11548 to 11585 W: 2242 to 2298 H: 2248 to 2286	W: 2264 to 2286 H: 2204 to 2264	Nominal volume: 59.2 – 60.1 Net capacity : 56.6 – 57.5		27600 - 28040
40' HIGH CUBE REEFER 40' × 8' × 9'6"	L: 11570 W: 2290 H: 2560	W: 2290 H: 2570	67.9	5150	28850
20'' BOLSTER PLATFORM ISO 29P0	L: 6058 W: 2438 H: 270			1890	22100

Figure 2. Characteristics of sea containers (Source: www.lomag-man.org and [95])

Appendix 2. Summary table

Container type	Dimensions	Payload	Advantages	Drawbacks
Container	20' 40' 45'	21.6 to 28 t, 11 Europallets 26.48 to 26.97 t, 25 Europallets 27 Europallets	Solid and stackable, hence ideal for sea and waterway transport Rapid handling Goods secured (protection against theft, impact, environment) Dimensions adapted to shipping standards	Costly investment and maintenance Its dimensions (ISO) do not allow optimised carrying capacity for European pallets
Palletwide container	20' 40' 45'	28 t, 14 Europallets 30 t, 30 Europallets 29 t, 33 Europallets	Allows loading of 2 rows of Europallets on the same plane Compatible with sea standards imposed by the present structure of container ships	Higher leasing cost than a standard container (about €3/day instead of €2.50/day) Investment cost currently higher (non-industrial manufacture)
Swap body	L: 6.052 to 13.60 m	Up to 29 T. 17 to 33 Europallets according to size	Size (series A) of a semi-trailer box Thin walls, width less than 2.44 m, allows loading of two Europallets side by side, or a gain of 25% compared to the 40' container	Confined to rail transport and road extension because nonstackable, so cannot be used either for coastal trading or for inland waterways
Semi-trailer		33 Europallets	The dimensions of the semi-trailer allow full use of the maximum dimensions authorised by the regulation Optimised pallet loading	The semi trailer does not allow intermodality except in specific cases

Characteristics of "swap body" and "semi-trailer" units are described in greater detail in the "combined rail-road transport" and "road" sections.

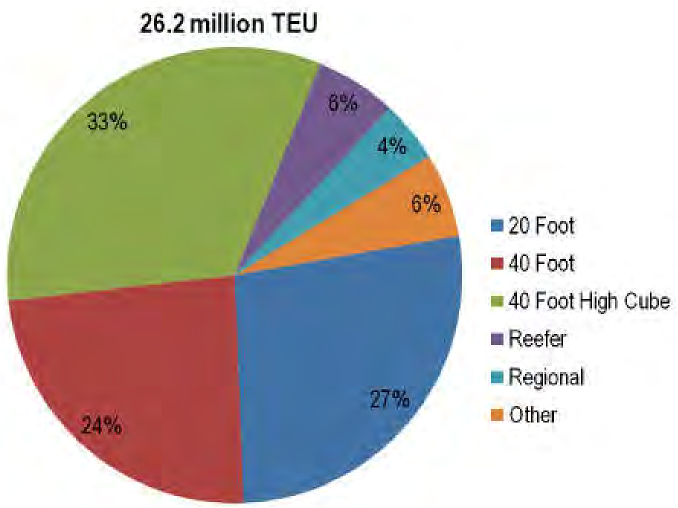
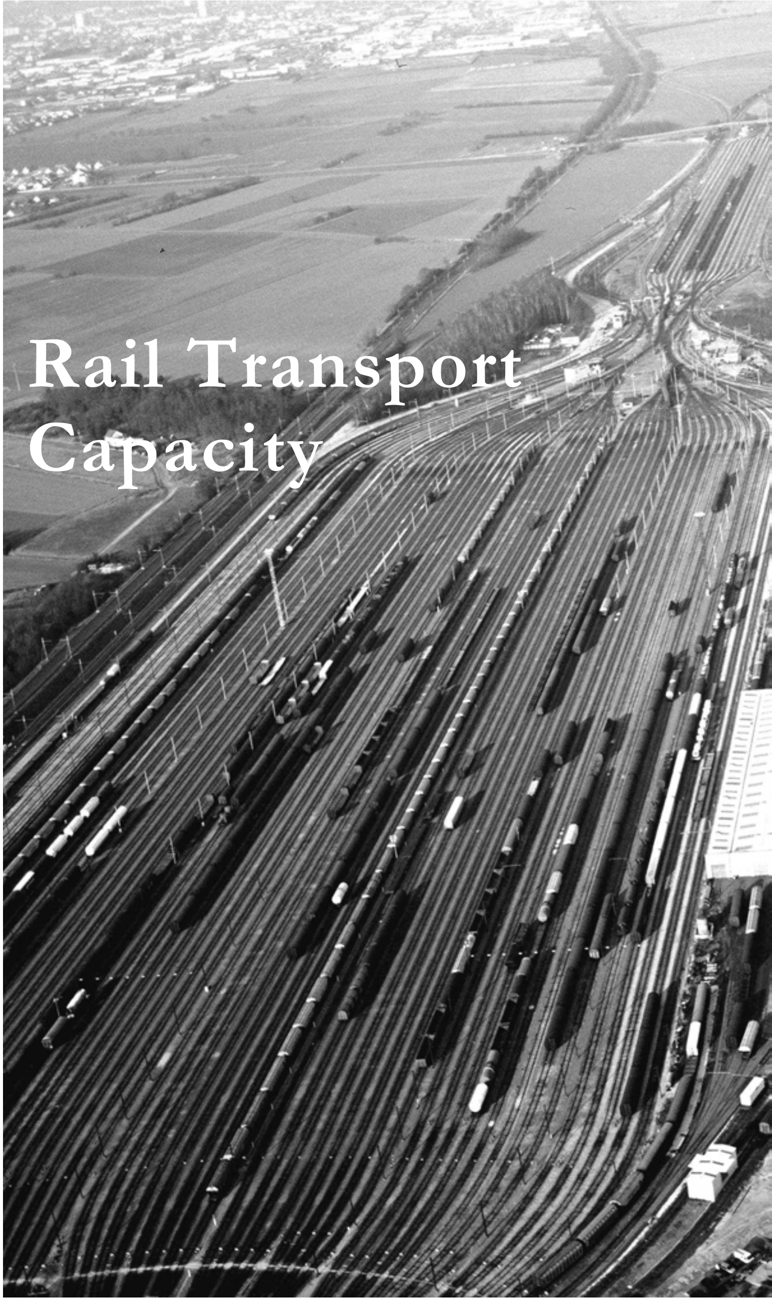


Figure 3 :Container capacity available in the world. Use of one or another type of container depends on cubing and admissible weight considerations. Taking into consideration storage of containers, the maritime containership capacity is about 1/3 of total.
source – Contenairisation international, Market analysis : world container census 2008
According to the world shipping council, there are in 2011 28.5 million TEU, for 18.6 million containers

Section 3



Rail Transport Capacity

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Introduction

The volume of goods transported by rail in France continues to fall, from 67.6 billion tonne.km in 1970 to 30.1 in 2010, the latter Figure representing only 8,3% of the total inland freight transport market. Over the same period, the proportion of goods carried by rail in Western Europe has fallen from 31% to 16% – with great variations depending on the countries, and a slight modal split increase in the last years. Consider that in the USA, the proportion of goods transported by rail reaches 43%, pipelines and domestic sea-transport included, slightly more than in Russia (42%).

This change is linked to the growth in road transport, which has been effectively proportional to the construction of major European motorway infrastructure, particularly in France, and has benefited from the strong reduction of costs. This is due to the fact that transport of goods by rail, compared to road transport, suffers in not being able to respond more effectively to requirements because of the way that goods transport is currently organised: lack of quality of service and reliability, lack of flexibility, lack of commercial partnerships between shipment and rail operators and difficulties linked to insufficient traceability of goods transported by rail.

This state of affairs contrasts strongly with that of rail passenger transport, in France, which has seen the development of high-speed lines (LGV) that compete directly with road transport on national intercity routes and with air transport on major European routes. Interaction between rail passenger transport and rail freight must also be taken into account. The impact of regional express trains (TER) on freight train traffic and also the freeing of train paths for freight trains through construction of new LGVs are examples of those impacts, which are currently difficult to measure.

Potential solutions for improvement do nevertheless exist, including,

- Market emergence of alternative operators in competition with the French national rail operator SNCF
- Opening of national and international freight transport markets to rail companies with European rail operator licence
- Accounting for international concern for global warming (report dated January 2007 by an Intergovernmental Panel on Climate Change) IPCC) and the resulting implications for fossil fuel consumption
- Pertinence of rail transport in crossing natural barriers to international traffic between countries (Alps, Pyrenees, Channel, etc.)
- Necessary improvement in serving ports and bulk distribution of goods there from in a highly competitive international trade context.

The purpose of this section on the rail freight sector is to evaluate relevant parameters allowing characterisation of rail network capacity for goods transport. Successive sub-sections will describe the general rail freight organisation, the equipment currently in use, the French national rail network, the main rail transport operating principles and the concepts of network capacity and saturation.

Heavy train in the USA – credit Bruno Meignien (Sétra)

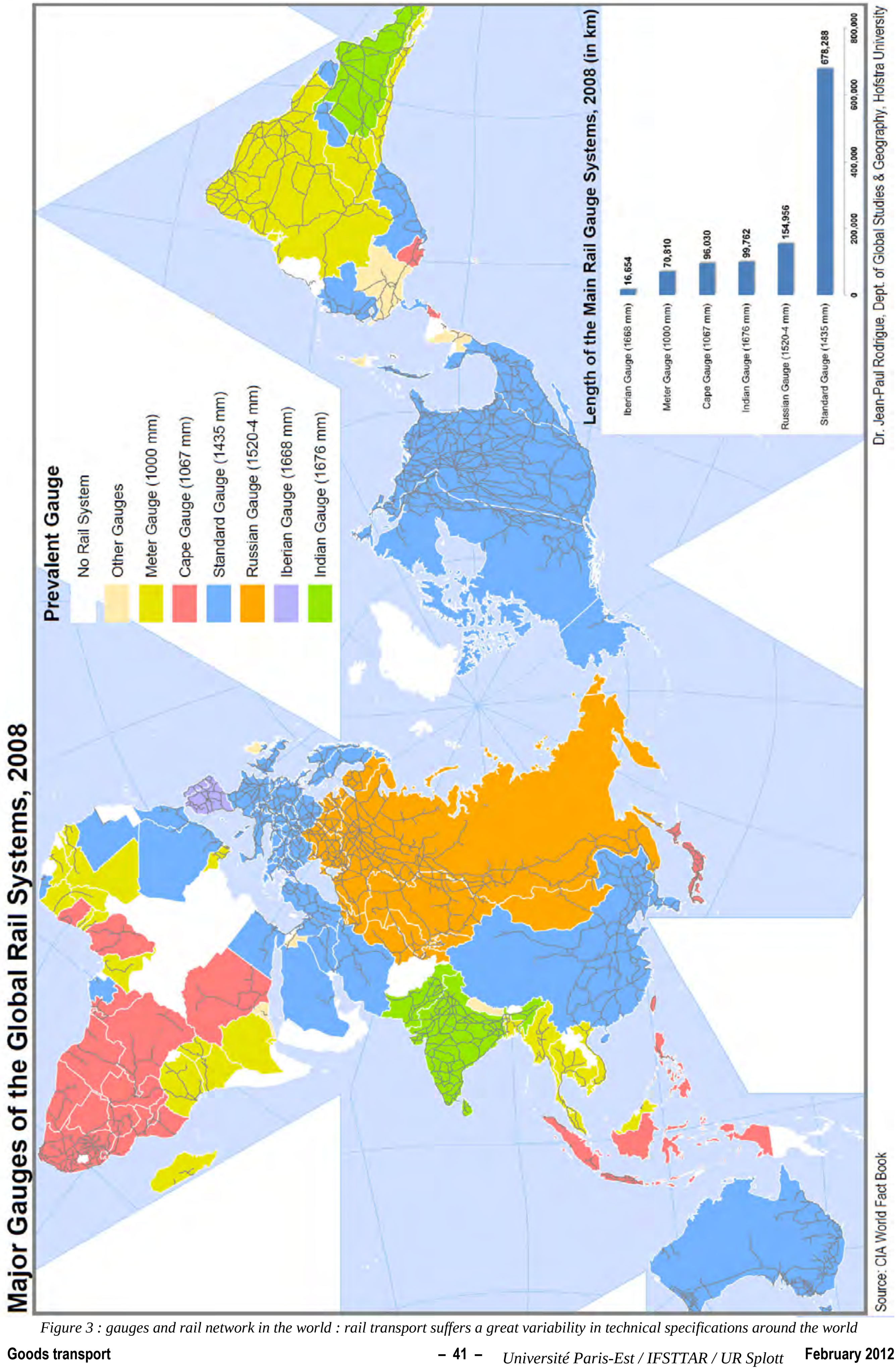


Figure 3 : gauges and rail network in the world : rail transport suffers a great variability in technical specifications around the world

1. Regulatory and organisational framework of rail transport

1.1 - New institutional and regulatory framework

1.1.1 – The European Community rail context

On 31st March 2006, France joined Great Britain and Germany in opening the market to freight on its national rail network. This was the result of the harmonisation process led by the European Union since 1985 and whose first legislative directive was 91/440 dated 29th July 1991 [21], requiring in particular that distinct accountability be established for railway infrastructure (infrastructural management) and operation of transport services respectively. Opening of the rail freight market was extended by Directive 95/19 [22], requiring member states to create an organisation responsible for allocating railway capacity (resources) in an equitable and non-discriminatory way. This was followed by two specific rail transport packages of 2001 and 2004[11], the second of which opened the entire European rail network to competition for the transport of freight from 1st January 2007.

Safety regulation was simultaneously upgraded in terms of licences awarded to transporters and creation of a European railway agency responsible for safety and interoperability (Directive 2004/49 [23]). Safety-related issues in fact constituted one of the main obstacles to effective opening of the market because of differences in national legislation in this regard.

1.1.2 – Opening of French rail freight market

The main milestones in opening this market were:

- 15th March 2003: market opened to international rail freight on a series of routes dedicated to the Trans-european Rail Freight Network (TERFN);
- 1st January 2006: market opened to international rail freight throughout the French rail network;
- 31st March 2006: competitors offered access to French domestic market.

New operators wishing to access the market are subject to conditions. To have a right of access to the French network, rail freight operators (decree No.2005-101 [25b]) must be holders of a rail freight company licence and a safety certificate issued by the Ministry of Transport. Additionally, they are dependent on the availability of infrastructure capacity by the national rail network manager, (RFF/Réseau Ferré de France).

1.1.3 – Separation of infrastructure management and transport service roles

French law of 13th February 1997 [21b] transposed the requirements of the European directive of 29th July 1991 [21] into French legislation by separating the roles of railway infrastructure management and transport service operation. A new national industrial and commercial public undertaking (in French *EPIC / Etablissement Public à caractère Industriel et Commercial*) was created : Réseau Ferré de France (RFF), which became the owner of the national rail network and thus assumed the infrastructure-related debt owed to French railway operator SNCF.

The transposition of this European Directive 91-440 was very different in the 27 countries of the union, from a pure holding – Germany, just accounting separation between DB Netz and other subsidiaries – up to a total separation – United Kingdom, although the system was revised few years ago with more intervention of the State, the separation remains total. A general movement of consolidation in freight concurrency is noticeable in Europe (see illustration below).

1.1.4. Role of distributor in freight capacity: European Directive 2001/14 [24]

Adopted by the European Parliament on 26th February 2001, Directive 2001/14 [24] constitutes the legal framework for change and lays down the principles relating to levies / toll collection and allocation of rail capacity. It enacts the principle of legal, decision-making and organisational independence between the rail capacity distribution function and the railway operating companies. French Decree No. 2003-194 [25] published on 7th March 2003, transposed the requirements of the European directive into national law and conferred

[11] ***Further details on rail transport packages are available at*** http://ec.europa.eu/transport/rail/index_fr.html

on RFF a mission to allocate rail capacity and, more specifically:

- to define and evaluate available capacities (see section on rail operation);
- to process railway companies applications for routes and allocate them available routes ;
- to determine track occupation diagrams and the time periods required for maintenance and work on the network;
- to finalise 12-month operating timetables.

The latter decree states that RFF shall confer on SNCF, for its account and under its control and responsibility, the engineering studies required to examine route operating applications. The payment conditions under which this mission is performed are included in the management agreement drawn up by RFF and SNCF. This same agreement assigns SNCF a role in delegated infrastructure management (SNCF managing works on behalf of RFF).

1.2 - Roles of various stakeholders

The State prepares and implements rail transport policy and supervises both SNCF and RFF. It should be remembered that, since 1st January 2002, the French administrative Regions have organisational authority over regional passenger rail services and thus organise the regional rail services. To improve the quality of these services, some Regions have decided to take part in financing infrastructure modernisation and development projects, which essentially aim to improve passenger traffic – but rail freight also benefit from these works.

It should be reminded that rail freight is an activity supposed to be economically viable, as following the European doctrine (fair concurrency between all modes of good transport). Thus, no subsidies are allowed by Europe. some indirect subsidies are however granted.

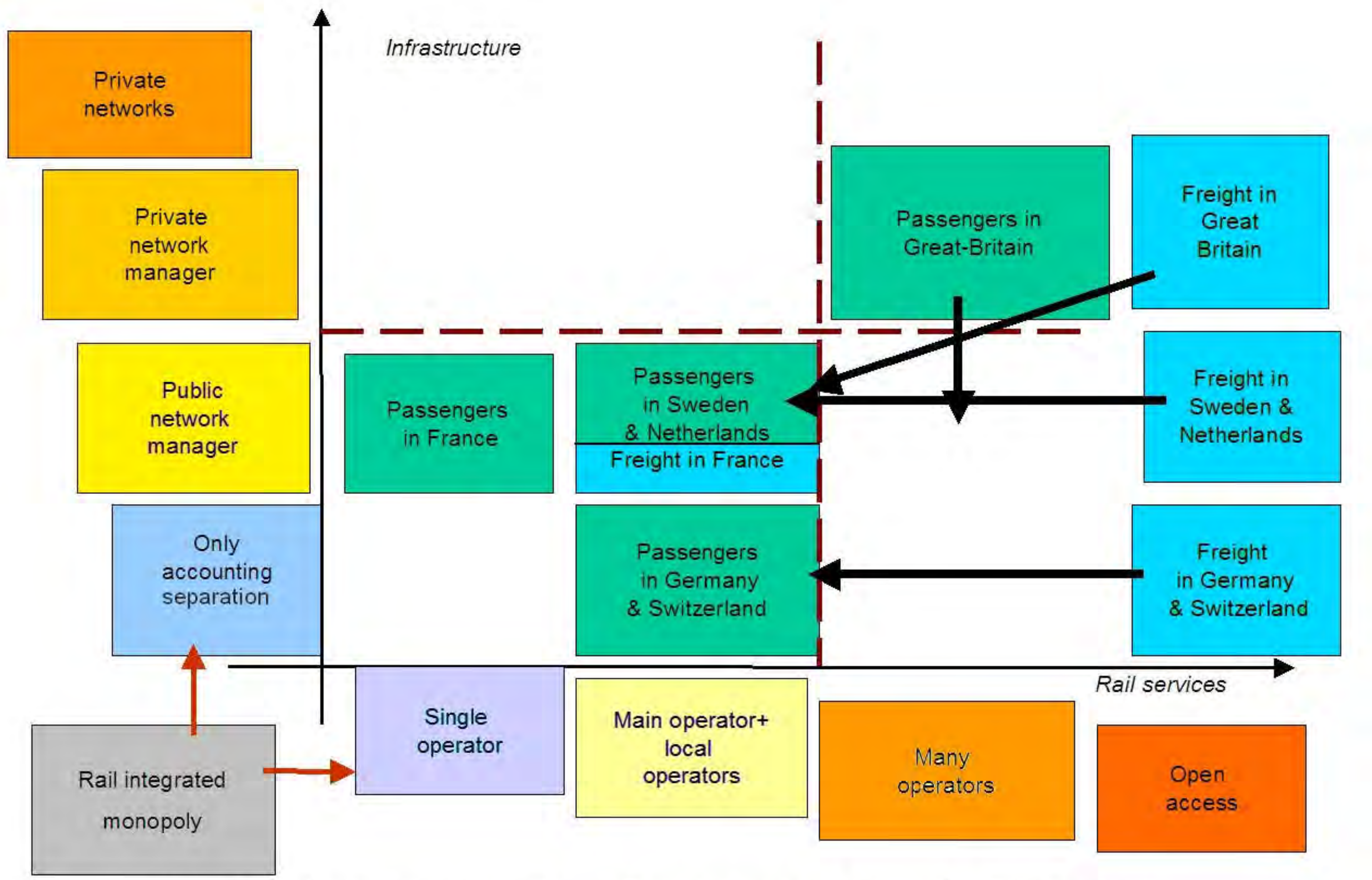


Figure 1 - Rail system organisations in some European countries - ⟶ Recent tendancies
Created from a presentation of Yves Crozet, LET/Laboratoire d'Economie des Transports - 2010

1.3 - Organisation of rail freight

1.3.1. Transport of freight by railway wagon

Transport of freight by railway wagons is adapted to the specific characteristics of the sector (iron and steel products, coal, cereals, chemicals, food products, mineral water, etc.). Depending on shipper requirements, market conditions and commercial agreements between shippers and railway companies, freight is transported by the railway companies in individual wagons or whole trains. Whole trains are suitable for important tonnages, whereas individual wagons are more often used for smaller volumes.

Whole trains: whole trains or trains composed entirely of wagons loaded at the same place, intended for the same destination and having a minimum load per train (i.e. they do not need to be reorganised by marshalling).

Groupage: routing of single wagons, picked up each day from feeder depots or from main freight depots. The different consolidated wagons are conveyed from the depots to a marshalling yard, where they are grouped according to their final destination. The trains, once assembled, are conveyed to another yard (inter-marshalling trains) from where the individual wagons are conveyed to their final destination.

Transport of hazardous goods in wagons – essentially tank wagons – constitutes a large part of rail freight transport and is subject to specific regulations. In 2010, SNCF Freight ("Fret SNCF", which represented 4/5 of the national rail freight) transported approximately 12 millions tonnes of hazardous goods (18 millions in 2005), i.e. around 220,000 wagons or 18% of the total of the tonnages carried by SNCF Freight.

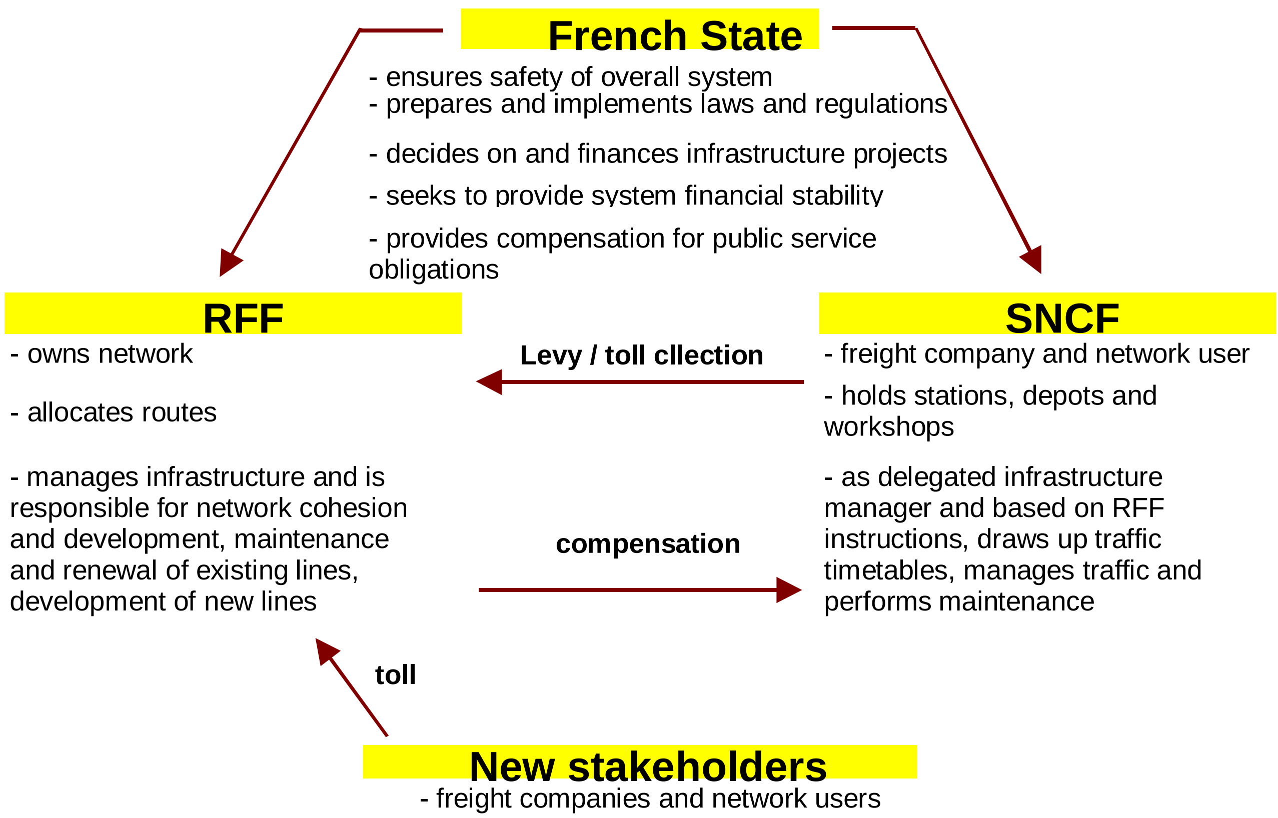


Figure 2. Main railway stakeholders in France

1.3.2 - Combined transport by container

Railway transport in containers, combined with other modes of transport (road, sea or inland waterway) represents a quarter of freight traffic in France. See section "Rail-road combined transport" in this guide for more information on this subject.

1.3.3 - Transport of lorries

See Appendix 2 of the section entitled "Rail-road combined transport" in this guide for more detail on the railway shuttle system enabling flatbed wagons to be loaded with cabs and trailers (commonly known as rolling motorway or rolling road).

1.3.4 - Special consignments

An item for transport is said to be special or exceptional, when its characteristics (unit weight and size of the goods, packing, etc.) can be accepted only under special conditions. Any train including one or more items having one or more of the following characteristics is considered special:

- a unit length greater than 18.50 metres;
- dimensions exceeding the clearance of the lines taken;
- a unit weight in excess of 30 tonnes;
- the need to provide a special wagon.

Special consignments specifically affect international freight traffic with Germany, Belgium and Italy in particular.

In 2010, SNCF Freight – which holds ¾ of the French rail freight market – transported approximately 65 million tonnes of freight, all transport types included.

2 - Equipment used for Rail Freight

Trains are composed of:

- Wagons for goods and carriages (coaches, sleeping cars, dining cars, etc.) for passengers
- Locomotives for traction or motor coaches/multiple units (where propulsion is integrated into the train itself e.g., TGV and some regional trains).

2.1 - Main freight wagon types

There are two types of wagon in France :

- *"Réseaux"* (Network) wagons, owned by SNCF: at 1st January 2011, SNCF owned 18,000 of these (2005 : 28,000). Figure 3 shows examples of different types of wagon
- "*Particuliers*", Privately-owned wagons : in 2005, there were approximately 60,000 of these.

Privately-owned wagons are those registered by railway companies in the name of a physical person. They fall into four main categories:

- Tank wagons for transport of liquids
- Covered hopper-wagons (for transport of goods in bulk) and silo wagons
- Open hopper-wagons and flat-bed high-sided open wagons, other than those owned by the SNCF
- Special double-deck car-carrying wagons

Fig 3: Covered wagon, covered hopper-wagons, high-sided open wagon - Source SNCF

Cat.	Type	Example Type	Tare	Useful length	Type of load
E	Standard high-sided open wagon	E78	24 t	12.78 m	Steel floor wagon used for scrap metal
G	Covered wagon	G12	21.7 t	15.5 m	38 Euro pallets (800x1200) 30 industrial pallets (1000x1200) 12 pallets 1200x1200
H	Sliding wall covered wagon	H96	31 t	22.53 m	Pallets : 56 / 44 / 36
I	Temperature-controlled wagon	I87	24 t	14.3 m	Pallets : 34 / 28 / 22
K	Standard 2-axle flat-bed wagon	K50	12.2 t	12.5 m	
L	Special flat-bed wagon	L00	11.5 t	9.34 m	Wagon for transporting very long loads
R	Standard flat-bed wagon	R20	26.5 t	18.5 m	Pallets : 46 / 36 / 30
S	Special flat-bed wagon bogies	S56	21.7 t	10.8 m	Transport of sheet-steel in rolls
T	Sliding roof wagon	T14	25,25 t	13,86 m	Non-palletised packed goods
U	Special wagon	U13	29 t	6.5 m (low-loader section)	

Figure 4. Examples of railway network wagons (source: http://fret.sncf.com/fr/)

Design example. Train transporting pallets of water

Take as an example a train 750 m long (maximum) composed of standard flat-bed wagons (type R20) with two identical locomotives (BB 27000). Each locomotive is 19.7 m long and each wagon is 21 m long. The train is therefore made up of 33 wagons.

36 pallets (1000 x 1200 mm) are loaded into each wagon. The train therefore carries 1188 water pallets.

We know that one semi-trailer carries 26 pallets (1000 x 1200 mm), so this train therefore transports the equivalent load of 45 semi-trailers. (But returns empty with a great probability).

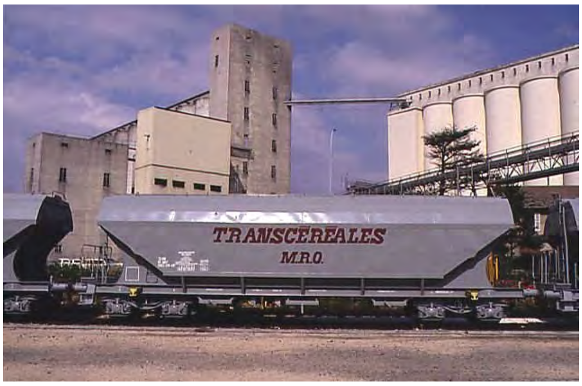


Figure 5. Examples of specific wagons (SNCF / P. Raud

2.2. Locomotives

In 2005, there were 1,500 SNCF locomotives (50% diesel and 50% electric) dedicated to freight trsport. Figure 4 shows examples of locomotive models (arbitrary non-exhaustive selection).

Locomotives	Photo	Motive power	Length	Power	Weight	Speed
BB 66410		Diesel	15 m	830 kW	68 t	120 km/h
		Dating from 1968 - 1971, these are still in service, notably for freight trains.				
BB 67300		Diesel	17.1 m	1,765 kW	80 to 83 t	140 km/h
		Reliable locomotive with acceptable performance used mainly to pull rapid passenger trains and light freight trains.				
BB 36000		25,000 V @ 50Hz, 1,500 VDC and 3000 VDC	19.1 m	5,600 kW	89 t	200 km/h
		Air-conditioned locomotive (Astride). Developed from the dual voltage BB 26000, widely used by SNCF Freight. Capable of operating with three types of voltage supplies: it can operate in Belgium, Luxembourg, France Italy and, lately, in Holland. Significant time is saved by preventing breaks in power supply at the borders.				
BB 27000		1,500 VDC, 25,000 V @ 50 Hz for the dual voltage version	19.7 m	4,200 kW	89 t	140 km/h
		This locomotive dates from 2001 and was designed to pull freight trains. It has contributed to the growth in freight productivity by its low maintenance costs. It is available in three dual or triple voltage versions allowing it to work in France, Germany, Switzerland, Holland, Belgium and Italy.				

Figure 6. Examples of locomotives (source: www.entreprise-sncf.com)

3 - The French national Rail Network

3.1 - Railway lines and tracks

3.1.1 – Lines

The lines of the French national rail network allow trains to circulate between different geographical areas where installations part of the network (passenger platforms, combined transport facilities, marshalling yards, port tracks, etc.) or connected to it (freight terminals, port access tracks, etc.) are to be found. These lines also provide connections to the rail networks of neighbouring countries.

Source: RFF, reference document [26]

In 2011, the national rail network included approximately 30,000 km of lines owned by RFF/Réseau Ferré de France, and accessible to railway companies.

The Union Internationale des Chemins de Fer (UIC) [international railway union] has drawn up a railway line classification based on traffic density, infrastructure and type of traffic. The different UIC line groups are:

- Group 1 to 6 (> 5,000 tonnes gross / day): 15,000 km of lines carrying more than 80% of rail traffic
- Group 7 to 9 AV (with passengers): 9,000 km of lines carrying mainly regional passenger traffic
- Group 7 to 9 SV (without passengers): 5,000 km of lines dedicated to freight terminal traffic.

See Appendix 1 for more details on this subject.

3.1.2 – Tracks

Different sections of line include either:

- one main track ("single-track line"), or
- two or more main tracks (known as a double-track line).

A distinction is made between the single-track service (same track used in both directions), including many regional sections in France, and the double-track service (traffic on left in France, except in Alsace / Moselle). Compliance with railway safety regulations implies implementing suitable signalling equipment and operating methods on single-track sections. Since the capacity of a single-track line is very much less than that of a double-track line, track doubling works are sometimes undertaken on sections approaching saturation (examples: Marseille - Aix-en-Provence, Toulouse - Saint-Sulpice, etc.).

The French national rail network also includes service tracks, allowing in particular:

- *Marshalling operations before departure of a train from its origin station, on arrival at the terminus or during stops during its journey*
- *Shunting operations necessary to transport service performance by railway companies*
- *Short- or medium-term storage of rolling stock between missions*
- *Tracks known as 'relay lines' are normally set aside – unless an exemption is expressly granted by RFF – for trains using slots to stop during the journey to allow drivers or locomotives to be changed or sometimes to allow turning back.*

Source: RFF, reference document [26]

Private sidings

In railway terminology, a private siding is a facility that allows rail transport users to access the national railway network, owned by RFF, via tracks either privately owned or privately used for loading and unloading. This arrangement allows goods to be transported from their production or storage locations to the national rail network without break of load. By this definition, a private siding comprises:

- a first part, owned by RFF, located within the public domain and including all equipment required for connecting the privately owned or privately used track to the national rail network;
- a second part, built by the private siding owner, located on his premises or on premises rented to him by RFF or SNCF.

All French national rail network tracks are standard European gauge (1.435 m). There are some exceptions however: 165 km of single-track lines are 1.000 m gauge and a few kilometres connecting to the Spanish rail network are 1.680 m gauge.

Source: RFF, reference document [26]

3.2 - Engineering characteristics

Rail network engineering characteristics are described in reference document [26]. Revised each year, this document is available on the RFF[12] Internet site.

It will be seen in the section on railway capacity that these engineering data are significant in defining railway network capacity.

3.2.1 – Loading gauges

Rolling stock, loaded or not, travelling on the railway network lines must not exceed certain dimensions. Limiting clearances to be complied with by combined wagon-loads are:

- *the loading gauge to be complied with; this is the route-dependent clearance with respect to installations along the tracks (civil engineering structures, platform roofs, signals, etc.),*
- *the boundary not to be crossed by the limiting clearance of rolling stock that is stationary or moving on adjacent tracks.*

Source: RFF, reference document [26]

UIC distinguishes loading gauges (upper and lower) based to a classification that takes into account their clearance (see Figure 5).

Main loading gauges:

- G1: minimum guaranteed on standard European track gauge lines,
- GA: standard loading gauge for French national rail network. Sufficient for containers (h = 8’6’’) and for most swap bodies,
- GB: applies to several main lines on the French national rail network. Sufficient for 'high cube' containers (h = 9’6’’),
- GB1 or B+: allows acceptance of extra-large containers ('super high cube') or unaccompanied semi-trailers,
- GC: reserved for high-speed lines.

These different loading gauges co-exist on the French rail network[13]. Setting to upper loading gauges may be required to implement a new freight service, such as a rolling highway, depending on goods container characteristics.

3.2.2 – Axle loads

The UIC classification distinguishes maximum permissible mass per axle from maximum permissible mass per metre of track.

Standard gauge lines on the French national rail network are classified under categories C4 and D4; For locomotives and wagons respecting the classification basic characteristics, this permits:

- *a maximum permissible mass per axle of 22.5 tonnes in category D4 and 20 tonnes in category C4*
- *a maximum permissible mass per metre run of 8 tonnes/metre.*

Source: RFF, reference document [26]

The majority of the French national rail network is classified under category D4[14]. To compare with 35t per axle allowed on the USA main lines.

3.2.3 – Speed limits

Speed limits apply to all sections of line and are determined by infrastructure management based on infrastructure characteristics[15]. In general, the speed limit for freight trains is 100 to 120 km/h. Certain trains with specific characteristics are authorised to travel up to 140 or 160 km/h

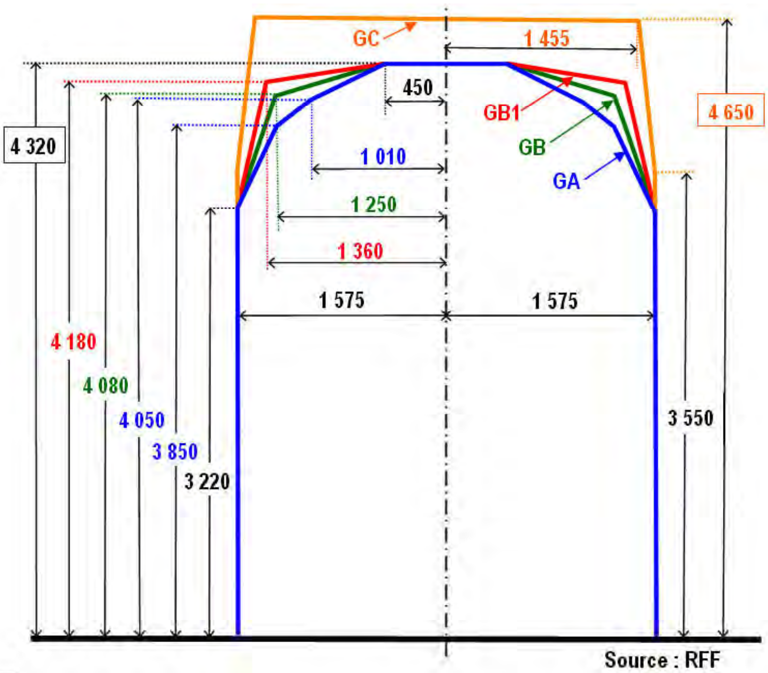


Figure 7. Main railway loading gauges - Source: RFF

[12] See link http://www.rff.fr/pages/docref/autre/accueil.asp?lg=fr

[13] See link: http://www.rff.fr/biblio_pdf/fr_docref_anx_6_1.pdf

[14] See link: http://www.rff.fr/biblio_pdf/fr_docref_anx_6_2.pdf

[15] See link: http://www.rff.fr/biblio_pdf/fr_docref_anx_6_3.pdf

3.2.4 – Electrified lines

Two types of electric power supply co-exist on the French railway network, namely:

- Direct current at 1,500 V (for conventional Atlantic and Southeast networks)
- Alternating current at 50 Hz / 25 kV, introduced around 1955, is currently the cheapest system (for other conventional networks and high-speed lines).

Approximately half of the French national rail network is electrified, 60% with alternating current 25 kV / 50 Hz and 40% with direct current. Many other currents are employed in Europe and the world : 15kV 16,7Hz (Germany, Swiss, etc.), 3kV (Italy), etc. due to historical reasons

The power supply network delivers electricity to the motors via an equipment chain including:

- Substations
- Overhead lines (catenaries)
- Locomotive
- Current return systems.

Advantages of electrification

- *Energy costs, especially during off-peak periods,*
- *Performance and availability of traction equipment, greatly reduced maintenance costs,*
- *Acceleration and braking performance,*
- *High traction force,*
- *Respect for the environment by reduced emission of greenhouse gases based on using French nuclear energy and elimination of local pollution in the most densely populated regions (city centre railway stations, etc.);*

… but electrification requires major investment!

For overhead line routes equipped with different systems, two solutions are available to the railway company, namely:

- Change locomotive at interface between systems; this requires an appropriate organisation
- Use multi-system locomotives; but their greater cost is an obstacle to bulk acquisition by railway companies.

It should be noted that dual-mode power cars (multiple units / motor coaches), currently under development in France, represent a very attractive solution in cases where electrification of a final section cannot be economically justified (examples: Paris - Auxerre, Bordeaux - Mont de Marsan).

3.3 - Track components

The following description applies to ‘standard’ tracks.

Rails

Rails guide and support the train wheels and, through their sleepers, they contribute to transferring loads to the track formation. There are several different types of rail but the one most commonly used today is the standard UIC 60. This is the only rail authorised for use on high-speed lines. Its linear mass is 60 kg/lm (lm : linear meter).

Rigid or flexible fastenings connecting rails to sleepers

Modern fasteners are flexible and are especially used with continuously-welded rails. They are essential for high-speed operations, whereas rigid fastenings are suitable for heavy goods trains.

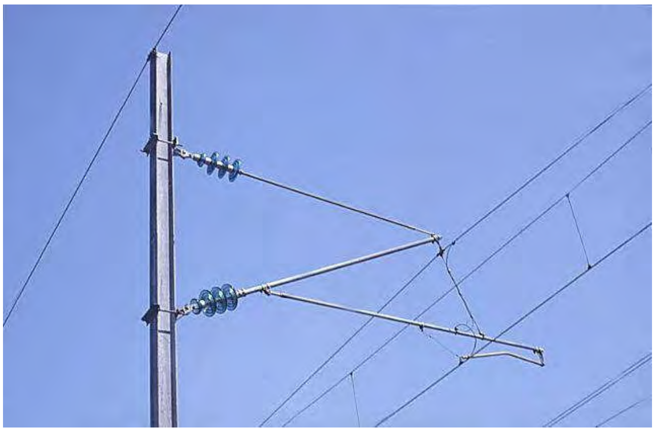


Figure 8. A catenary (source: SNCF)

Figure 9. A pantograph (source: SNCF)

Sleepers

Sleepers are anchored in the ballast; their role is to transfer loads to the track formation. Different sleepers are distinguished by their constitutive material, including:

- Timber sleepers made of oak or African hardwoods; their rapid wear (due to load accumulation and temperature variations) along with economic and ecological considerations mean that timber sleepers are being gradually replaced
- Steel sleepers
- Mono- or bi-bloc concrete sleepers. The drawback for concrete sleepers is their weight, making handling more difficult (approximately 225 kg compared with only 80 kg for a timber sleeper). On the other hand, they contribute to track stability and their service life is much longer. Disposing of them at the end of their service life is not prone to the same environmental problems as with timber sleepers. Historically, France features mainly bi-bloc sleepers, but this is gradually changing towards mono-bloc sleepers and these will very soon become standard.

3.4 - Maintenance

3.4.1 - Definition

Maintenance includes all those activities intended to enable installation performance under anticipated service conditions (traffic flow, maximum speed, axle loads, etc.) and within given conditions of safety, availability and infrastructure service level.

Maintenance objectives are:

- to ensure safety of goods and passengers transported, staff and railway surroundings,
- to ensure installation availability for operating needs at optimal cost
- to guarantee installation forecast service life at optimal cost.

Maintenance includes:

- Annual maintenance: SNCF GID (GID for "delegated infrastructure manager") provides supervision, regular maintenance, repairs, breakdown recovery and other measures necessary to network operations and for all technical installations. Payment conditions for this mission are laid down in the management agreement between the two public bodies. Its cost is established on an annual basis. In 2010, this represented a budget of 1,7 billion Euros, thus the average maintenance unit cost was approximately 35 K€ per kilometre (48 000 km of single tracks opened to traffic);
- Renewal or "regeneration": this implies replacing part of an installation at the end of its engineering life (obsolescence) or at the end of its economic life. RFF receives a subsidy for operations to renew or bring a rail network up to standard. This work is managed by RFF and by SNCF GID as delegated manager. In 2011, this work was covered by a budget of 1.7 billion Euros – 1,2 billion for 1100 km tracks, i.e. 1 million euros/km, to compare with 500 km in 2005 – within a 13 billions 2008-2015 renewal convention with the French State.

3.4.2 – Procedure changes and impact on capacity

Infrastructure maintenance work is performed with the dual aim of productivity and minimum disturbance to business operations. These aims are contradictory and depend strongly on actual line use.

On a high-speed line, normal interference is a maximum of one hour during the day and six hours at night, with at least four hours for simultaneous working (both tracks simultaneously closed safety reasons). On double-track line equipped with IPCS (stationary wrong-track running signalling), it is preferable to work during the day (periods of four hours or longer) on a single track. In the case of dense traffic, night working is necessary despite reduced productivity (increased salary costs and working conditions affected by reduced visibility).

The current RFF – SNCF joint project "maintenance consolidation" follows an assessment of the state of the French national rail network (2005, see below) [27]. Its aim is to eliminate the practice of "maintenance interruptions" (short daytime maintenance periods where track is out of service for no longer than 1h50) by working longer periods, in principle four to five hours but sometimes longer. The main difference is that these longer working periods, complemented by an inspection/visit of one hour per day per track, as on high speed lines, do not take place all year round but only a few weeks per year. With rigorous maintenance scheduling, the infrastructure availability to handle traffic is thereby increased. Due to massive renewal works, RFF and SNCF are still working on this project.

Assessment of the state of the French national rail network:
Source: **Audit on the state of the French national rail network** [27]

An assessment on the French national rail network carried out in 2005 on behalf of the Ministry of Transport and Equipment noted that the network showed signs of "strong ageing". The study was based on an international comparison showing that France invested appreciably less in renewing its rail network than Great Britain, Italy, Spain or Switzerland. The consequence was a reduced infrastructure average lifetime and steadily decreasing rail system reliability.

Following publication of this report, extra funding was released for network renewal (tracks, signalling, etc).

In addition to marked improvement in maintenance productivity, freight will benefit most from maintenance consolidation because long distance routes, in particular, were most impacted by multiple daytime maintenance periods across the entire network.

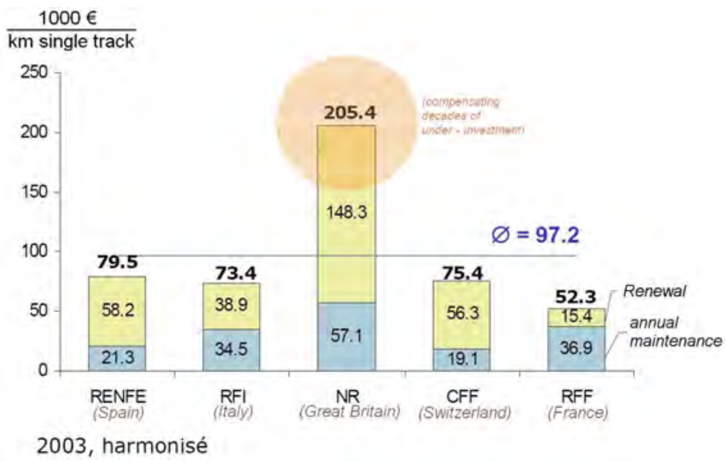


Figure 10 : maintenance costs (renewal and annual) per year in some European countries – source : EPFL, 2005 (figures 2003)
French renewal effort will double in 2011 (average 29 k€/km)

Figure 11 : tracks - source B. Meignien – Sétra

4 - Operating the Rail Network

4.1 - Railway Operations

4.1.1 – Railway operation objectives

Railway operation involves organising railway services and activities to ensure service quality (performance and respect for its commitments), on-time performance and successful management of disruptions. Railway operation:

- conveys traffic according to scheduled train paths;
- allocates working periods (maintenance and new development) according to the planned programme;
- exploits the capacity of the railway system for self-recovery to manage disruptions.

The quality and performance of railway operations is measured by operator satisfaction, notably by the calculation of a punctuality quotient (proportion of delayed trains).

Controlling the railway system relies, on the one hand, on the system capacity for self-recovery and back-up options during periods of degraded performance and, on the other, on an organisation with adequate personal and technical skills, demonstrating a high degree of reactivity.

Capacities for recovery:

These correspond to margins built into railway system design:

- additional tracks on main lines or in stations;
- latitude in train running times (allowance for unforeseen events, margin for recovery);
- separation between trains, in stations and on main lines.

Recovery margin is calculated either by time (5 to 7% of time on high-speed lines) or by distance (3 to 5.5 minutes per 100 km on standard lines), to absorb time delays induced by maintenance working or unexpected operating events in stations or on main lines.

The main aim is to prevent the 'snowball effect' (i.e. to prevent one train incident leading to numerous other delays) by ensuring that all margins are set sufficiently wide. The robustness of the railway system depends on having a complete and certain image of the infrastructure, timetables and equipment, as well as back-up staff available to mitigate against unforeseen events.

4.1.2 – Different train categories

There are four train categories:

- **passenger trains (France) :** international (Voyages France Europe - VFE), national (Corail Inter-Cités - CIC), regional (Trains Express Régionaux - TER), Metropolitan (around Paris, known as "Transilien"). These trains run at 80 to 220 km/h on standard tracks and at 270 to 320 km/h on high speed lines;
- **freight trains** known by their descriptors:

MA for freight trains
ME for parcel trains
+ a number giving the train speed (80, 100, 120, etc.)

eg. MA 80 = a freight train ("Marchandises") operating at 80 km/h.

- **work trains**, for repairing infrastructure and inspecting the catenaries, etc.;
- **empty** or **light running trains** (repositioning – see glossary).

For freight trains limited to 120 km/h or less, the maximum length is 750 m, locomotives included (1000m in project for some lines). For comparison, the maximum train lengths are 650 m in Belgium, 550 m in Italy and 400 m in Spain, which restricts the length of cross-border trains (Spain recently allowed 750m trains on one line for exchanges with France). And 3 700 m – limit of the air brake system, but often more limited by length of installations – in Canada and the USA, 3 200 m in China, more than 2 500 m in Mauritania…

Figure 12 : train carrying more than 100 wagons with four locomotives (~2000m) : USA, far west – B. MEIGNIEN, Sétra

4.1.3 – Railway operation resources

Different railway operating functions exist at different levels.

The national supervision function manages and conducts major arbitrations at network level, including the interface with neighbouring networks.

The traffic control function which, in the event of network disturbances, prepares scenarios and takes decisions to re-establish as well as possible the planned service timetable. The control function aims to minimise the difference between theoretical and actual practice. Pre-established scenarios (for two types of disturbance) assist in real-time control:

- small-scale disturbances, controlled within the hour, where 'standard procedure' methods are applicable;
- large-scale disturbances, which can require trains to be diverted. In these cases, series of standard responses and decisions are planned using information from SNCF in the sector concerned.

The traffic function is the real-time management of train movements, their routing and track allocations. This function depends on train monitoring, route scheduling, work scheduling and telecommunications.

Interlocking towers are located near stations and junctions. Until 1950 these were mechanical. Changing technology has brought successive system developments, described here for France :

- free-lever signal boxes with permissive passage (PRS);
- signal boxes with microprocessor control (PRCI);
- solid-state interlocking signal boxes (PAI);
- computerised signal boxes based on PC technology (PIPC);
- on single-track lines, centralised single-track control (CCVU);
- on high speed lines, signalling and control stations (PAR) or remote control centres (PCD).

Appendix 2 gives details of control and scheduling structures for freight activities.

4.1.4 – Different categories of accidents linked to railway operations

There are four categories of accidents associated with operating faults:

- **Overtaking** : a train must not catch up with its predecessor. Separation by time or by distance prevents this type of accident. Thanks to the use of automatic blocks[16], manual blocks, cab signalling on high speed lines (TVM300 and TVM430) and also the European Rail Traffic Management System (ERTMS), currently being developed for use on the European railway network (*see Appendix* 3);
- **Slanting (Side-on) collision**, safety at junctions: two trains of different origin destined for the same destination must not share a section of track and collide. To prevent this, stop signals and speed-restriction signals must be combined with either mechanical or electrical interlockings;
- **Head-on collision**. Mechanical or electrical interlocking is used to prevent two trains moving in opposite directions from colliding. In the absence of these interlockings, strict regulations are applied by points men and traffic managers in order to allow train movements in the direction opposite to normal;
- **Obstruction collision**: an unexpected obstruction on the line (eg. rock fallen onto track) or on a level crossing (statistically the most dangerous). Accidents on level crossings are steadily decreasing. In order to reduce the risk of accidents, where possible at an acceptable cost, level crossings must be removed. Only in very exceptional cases are new level crossings permitted.

4.2 - Signalling and block working

4.2.1 – What is signalling?

Safety requirements and the specific characteristics of railway operation imply the installation of signalling systems with the objective of preventing accident risks whilst maximising traffic flow. Examples of these specific characteristics include a controlled system that makes catching up impossible on a single track, varies speeds according to traffic density, extends braking distances, etc.. Railway signalling comprises a set of signals, devices and regulations intended to guarantee the safety of railway traffic.

This specific signalling requires installation of systems including block system, switch control, interlocking, etc., all are intended to control the working space and to implement command and control functions of the routes in operation.

4.2.2 – What is block working?

A block is a section of railway track and is the basis of a system allowing trains to keep separated. Block length vary according to the geometry of the track, the traffic frequency and density, its operating mode and the block system in use. Block lengths vary from between 1,200 and 1,500 m on busy tracks up to several kilometres. However, in zones with dense traffic it can be very much shorter (600 m or even less). The entrance to a block is preceded by signals which warn the driver and the electronic safety systems of the presence of a train within his stopping distance, i.e. two or three blocks ahead (6 on high speed lines).

Block system is generally employed to ensure separation of trains moving in the same direction on the same track. The principle is to allow only one train in any given block. Block working is implemented by:

– Trackside signals on standard lines (at the trackside to the left or to the right of the driver depending on the country sense of circulation)
  - manual mechanical system (baton, station-to-station telephone);
  - automatic systems (automatic colour-light block, limited permission automatic block system): see illustration below;
  - stationary wrong-track running signaling (in French "IPCS").

– On-board signalling ("cab signal"), installed on high speed lines. Used because the trains move at high speed in all meteorological conditions. Data is transmitted from track equipment to the driver's cab. TVM300, TVM430 and ERTMS are examples (*see Appendix* 3).

[16] *See Section 4.2 concerning signalling for more details on these concepts.*

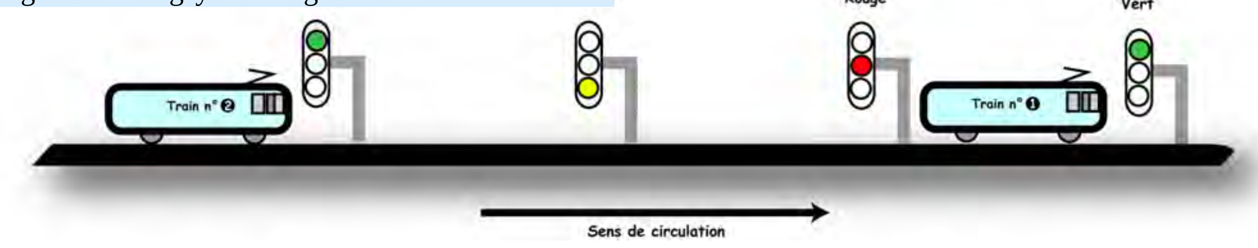
Principle of automatic colour-light block (BAL)

- a green signal in front of train 1 authorises the train to proceed within its speed limit;
- the signal behind this train shows red;
- the signal at red is preceded by a signal at yellow;
- once train 2 reaches this yellow signal, it must start its braking sequence.

Sometimes, the system is supplemented by flashing lights: flashing yellow lights for short blocks and flashing green lights when speeds are over 160 km/h.

The system operates via electrical circuits, whether the rails are continuous or not.

Limited permission automatic block (BAPR) works as automatic colour-light block, but on lines of medium density traffic with longer blocks



4.3 - Time-distance graph

Time-distance graph (or traffic diagram)

This is a system for organising not only all allocated train paths on the national railway network, but also the time periods reserved for maintenance operations and development works on each section of the network.

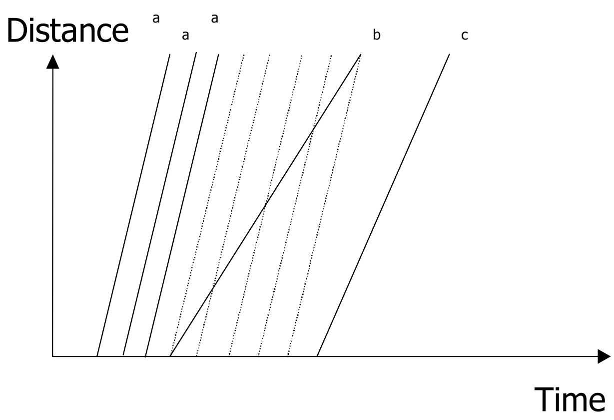
4.3.1 – How to read time-distance graphs

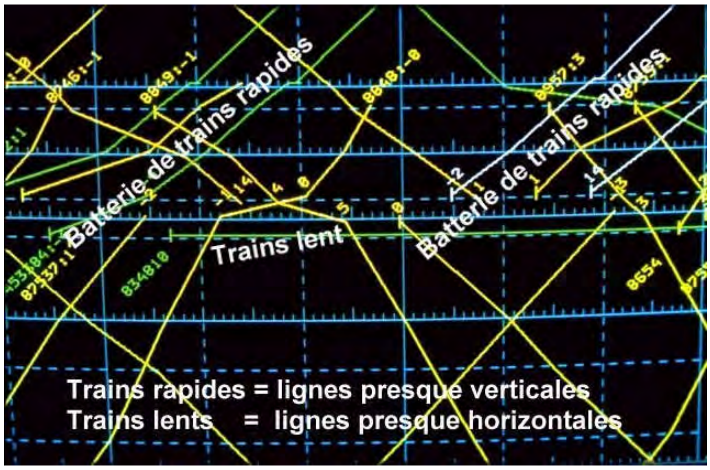
On timetable grids, the x-axis represents time and the y-axis represents displacement or distance travelled (stations, particular features). The time-distance graphs provide essential data on:

- train speeds: the steeper the slope, the faster the train;
- space-time occupied: the slower the train, the more train paths it occupies (these are assumed to be calculated as for the fastest trains);
- stops in stations are represented by horizontal lines (v = 0);
- direction of travel.

Simplified representation of time-distance graph and real one

- train "a" is faster than train "c", which is in turn faster than train "b";
- "a" could represent a TGV, "b" a freight train and "c" a TER;
- "b" occupies 5x type "a" train paths.





("Set of slow trains"; "Slow trains"; "Set of fast trains"; "Fast train = almost vertical lines"; "Slow trains = almost horizontal lines")

Figure 13. Time-distance graph (copy from a signalling tower screen) (source: ex-DGMT, ministry in charge of transports)

Note: all train movements are identified by a number (an even number when moving on an even-numbered track) shown on the timetable grid.

4.3.2 – Train paths

The capacity of a railway line *(Source: RFF)*

The capacity of a line is defined as the number of trains that the line is able to accommodate over a given period, for given conditions of speed and regularity. Capacity depends largely on the situation at network nodes.

Train path *(Source: RFF)*

A train path represents the infrastructure capacity required to accommodate a train movement between two points on a railway network in a given time period. Train paths can be regular, ad hoc, catalogue or custom (cf. Glossary).

4.3.3 – Background

The train path principle was set out in the European directive published on 26th February 2001 by the European parliament [28]. The law of 7th March 2003 [25] makes RFF responsible for allocation of train paths in France (*see Section* 1.1.4). RFF prepares with SNCF the time-distance graphs – More exactly DCF, "direction des circulations ferroviaires" which was created within SNCF in 2010 to ensure independence toward operators. DCF centralises requests for train paths in the RFF network. In particular, the department receives requests from regional councils for TER services. For its part, RFF receives requests from private operators and sends these to the Train Path department. RFF validates the time-distance graph elaborated with SNCF. It should be noted that as the influence of the new freight operators increases – 18,8% of train paths "consumed" in 2010 – internal pre-arbitration and pre-studies made by the Train Path department for SNCF train movements are more and more undergoing arbitration by RFF, depending on the requests from private operators and thus subject to later modifications.

In the interests of transparency, RFF is required to take responsibility for more and more of the above functions. The recent DISCO software for constructing traffic diagrams and allocate capacities is a recent milestone.

There are several new principles linked to this regulation:

- the will to make train paths available (for all operators) ;
- the distinction between the allocator of train paths and the companies using them;
- the concept of infrastructure tariffs benefiting the infrastructure manager .
- train paths are granted for one year only (renewal is not automatic and requires a re-application each year); adjustment of train movements and release of capacity for new train operators strongly improves the availability of train paths but leads to increased complexity since, previously, 70% of the train path network was duplicated from one year to the next.

Therefore, in order to (greatly) simplify the task, it is useful to restructure the time-distance graph (equivalent to the concept of time-phasing/clock-face scheduling), with more "interchangeable" catalogue train paths; That is what happened to Swiss rail timetables in 1982 – time-phasing, all timetables changing in one night – and 2004 – rail 2000 first step, linked to infrastructures project planned 20 years before. Next step planned in 2022 !

4.3.4 – Drawing up the time-distance graph

Once RFF has detailed the general layout of the time-distance graph, the train paths are set up based on the following sequence:

- Preparation phase (figure below):

Time-distance graph preparation: fields reserved for work & maintenan

Fields reserved for work are unchangeable in nature
and are finalised prior to allocation of train paths.

Positioning train paths once feasibility studies are complete

These studies could modify network consistency,
change certain services and outcome of work.

Prioritising long distance train paths

Allocating train paths for each route as European freight corridors.

- Publication phase: each stage is covered by publication of:

-the preliminary timetable grouping all envisaged train paths (start of July);
-the final proposed timetable sent to each railway operating company for train paths allocated for its use (start of August);
-the yet finalised timetable at end of august year N-1

Applicant railway operating companies can submit comments at each stage of publication.

The construction procedure for the time-distance graph allows coordination through:

- exchanges between railway operating companies requesting train paths and RFF at successive phases of the construction of the time-distance graph and document publication;
- the feasibility study procedure, which constitutes an iterative coordination phase between a railway operating company and RFF;
- the train path request form, which allows railway operating companies to prioritise their request criteria in advance.

For more details, refer to national railway network reference document [26].

- Residual capacity: adjustment until J-7;

Requests are dealt with in order of arrival depending on the remaining train path availability. After J-7, adjustment is made "in the field" by DCF (*Direction des Circulations Ferroviaire*) with "last-minute" train paths.

- Under-utilised train paths;

Train paths with their entire lengths operating at less than 75% of the regime demanded over a period of one calendar month can be deleted by RFF after giving one month's notice.

5 - Railway Capacity

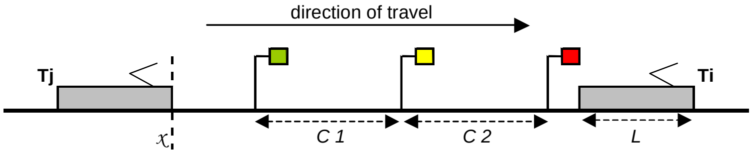
5.1 - Concept of capacity

5.1.1 - Minimum sequence time (t_s) between two trains

The following assumptions are made when calculating the technically possible time between two trains:

- consider part of a line composed of sections and blocks;
- calculation performed for two trains T_i and T_j (T_i preceding T_j) with known characteristics;
- schedule for train T_j is drawn up in such a way as to not be impeded by train T_i;
- signalling used is automatic block with colour-light signals.

According to SNCF historical operating procedures, train T_j must be at least χ = 35 s from the first signal before this changes to green (to avoid the driver having to brake prematurely). Then, SNCF adds a rounding margin 'm" to this time, which is intended to correct for round-ups applied in drawing up the timetables (m = 30 s if the round-up is to the nearest minute and m = 15 s when round-ups are to the nearest half-minute).



Therefore, the minimum planned sequence time t_s between T_i and T_j is given by:

$$t_s = (L + (C_1+C_2)) / V_i + \chi + m$$

where V_i is the velocity and L the length of train T_i (according to SNCF, V_i = 90% of the train speed limit).

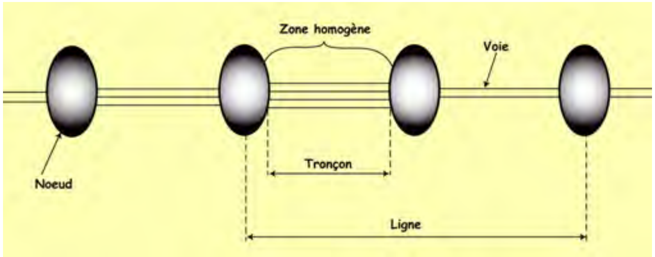
An example:

For identical 1,500 m sections over the entire line length, for a train 400 m long travelling at 160 km/h (V =160 x 0.9 = 144 km/h), the time period after which a second train can pass is 2 minutes and 15 seconds (where m = 15 s).

5.1.2 – Theoretical capacity

All railway networks face difficulties with regard to the capacity of their installations, especially the lines and the transport nodes (stations and junctions). The theoretical capacity for a line is taken in general to mean the "maximum number of trains which can in theory travel on the line within a given period". In this document, maximum signifies that these trains operate permanently with a minimum sequence time t_s.

The theoretical capacity of a railway node can be defined similarly: it is the maximum number of trains that can in theory travel through the node in question over a given period.



("Node";" Uniform zone"; "Section"; "Line";" Track")
Figure 14. Different railway infrastructure components

The difficulty in evaluating railway infrastructure capacity is that this depends to a great extent on infrastructure topology. The capacity of a uniform zone (i.e. a zone without point control and with no authorisation for stops or changes in train direction) or a section can easily be calculated by adding the capacities of the different parallel tracks of which it is formed. However, this is not applicable to mixed, non-uniform zones. Neither is it possible to calculate the capacity of a line or node (and certainly not a complete network) by combining the capacities of the different constituent parts, using any function (minimum or maximum, for example).

5.1.3 – Practical capacity

The concept of practical capacity takes account of a margin of flexibility, introduced to prevent saturation and successive network delays in the event of incidents. Indeed, theoretical capacity cannot be used over long periods without affecting operating quality, therefore a reduced capacity should be used.

There are two ways in which this may be achieved:

- increasing the sequence times t_s - resulting directly in a practical capacity;
- or calculating the theoretical capacity and reducing it outright as follows:

$$C_{practical} = k * C_{theoretical}$$

where k is the coefficient of flexibility – k ε]0;1[.

UIC - *Union Internationale des Chemins de fer* (International Railways Union) has set the coefficient of flexibility at k = 60% for off-peak capacity and at k = 75% for peak capacity. In this way, k corresponds to the maximum admissible occupation rate which guarantees satisfactory performance in normal operations and which allows micro-disturbances to be absorbed and also to prevent the occurrence of a disrupted regime with catastrophic consequences for rail travel (thus k is never near to 1). **This definition is thus closely linked to the desired quality level**.

5.2 - Basic parameters

5.2.1 - Infrastructure

The theoretical capacity of a line depends very much on its engineering characteristics. The most dominant characteristics are, in particular:

- the number of tracks allocated to rail travel (and the number and location of loops/passing tracks, crossings and stabling tracks/tracks in stations);
- signalling (monitoring-control system);
- whether the line is electrified or not;
- the maximum speed authorised on the different sections;
- restrictions imposed by particular features (curves, profile, zones with speed restrictions, branch line points, crossings, bottle necks);
- essential maintenance requirements (maintenance interruption periods).

Example: in Figure 10 graph below, the train separation system allows freight trains (in pink) to give way to TGVs (in blue) travelling on a conventional mixed traffic line.

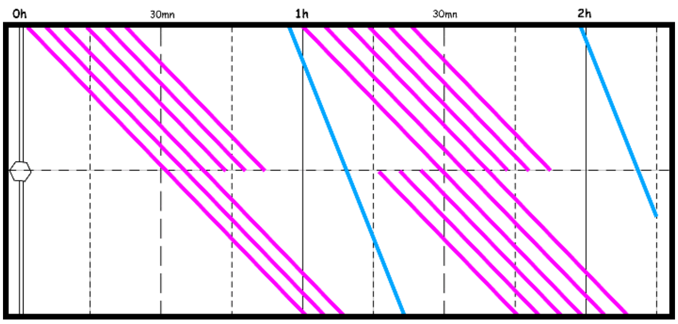


Figure 15. Train separation system

5.2.2 – Transport plan: non-uniformity, scheduling, restrictions

Non-uniformity

It is rare that lines be dedicated to a single type of traffic ensured by equipment with equivalent characteristics. In general, passenger traffic (regional, main line and TGV services) and freight traffic are superimposed. Each train must therefore have its own "space-time" trajectory. Therefore, the nature of mixed traffic working poses the question of how to schedule trains throughout the day.

Scheduling

Trains are scheduled in a time-distance graph in their order of succession. Trains having different speeds or different directions of travel, the case with single-track working, affect the capacity considerably as shown by the time-distance graphs in Figure 11. Whereas in both cases there are three fast trains (a) and three slow trains (b), it is seen clearly that $T_{ref\ 2} >> T_{ref\ 1}$. This demonstrates the importance of scheduling to network capacity.

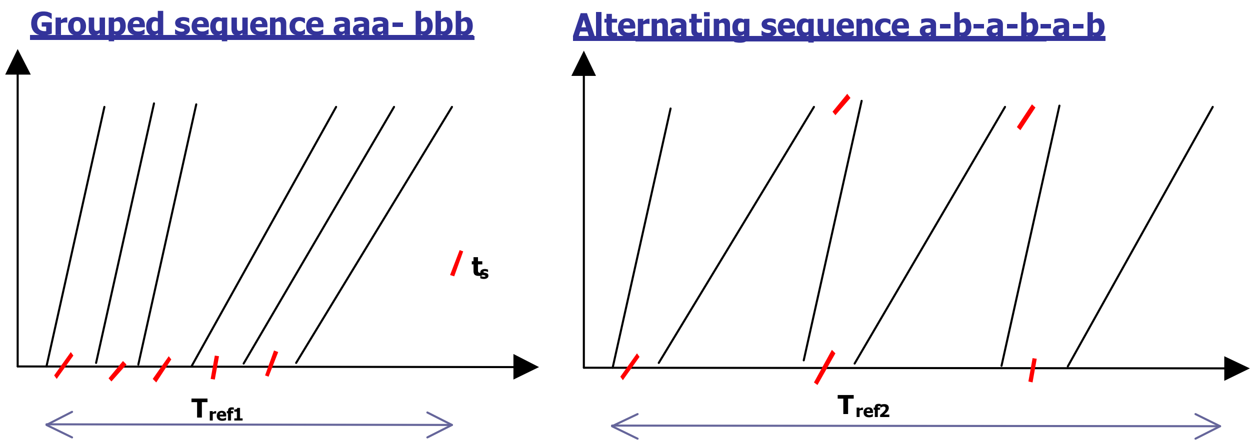


Figure 16. Scheduling and time-distance graph

Timetable constraints

Constraints on timetable positioning, as a result of tight connection times between two trains or a strictly timed passenger service, also reduce network capacity because trains are slowed down or stopped for longer periods in order that a greater number of trains can circulate. Similarly, capacity is strongly affected by the number of stoppage points on the line and their service conditions.

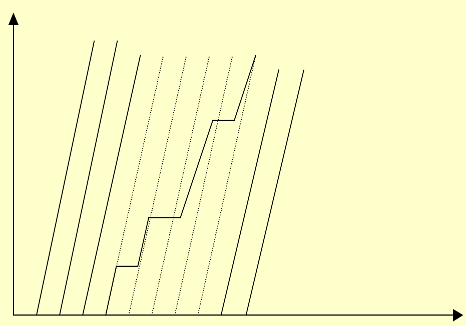
Consequently, the phenomenon of capacity loss due to station tracks being occupied becomes apparent. It is also important that stoppage times in stations be as brief as possible.

5.2.3 – Required quality of operation

The concept of operation quality has already been introduced in the definition of practical capacity. This is an essential characteristic to be considered when comparing two given cases. Operation quality is measured mainly in terms of train punctuality.

If trains follow each other very closely, the case when seeking to maximise capacity, a delay affecting one train will delay the following train and so on. This is the snowball effect, which can affect one line or perhaps other connecting lines. Therefore it is an important parameter if the infrastructure management wishes to guarantee high quality levels of service: a consequent reduction in the practical capacity.

Stopping trains with frequent stops use more train paths



5.2.4 – Rolling stock characteristics

Rolling stock performance (locomotives and passenger carriages) plays a determining role on quality and, particularly, if the potential offered by the line is to be fully or partially realised. For example, a higher maximum authorised speed could result in increased capacity; a train limited to 140 km/h travelling on a track suitable for 200 km/h operation does not allow the benefit of travelling at the higher speed offered by this track to be realised.

In the same way, if a train making frequent stops or a freight train is introduced into the time-distance graph, acceleration and braking characteristics become significant. This is because, as shown in Figure 12, performance depends on the time needed to stop and the time needed to accelerate after stopping at a station. Therefore, the better the train acceleration and braking performance, the higher the increase in capacity. Lastly, as has already been stated, the length of the train affects the minimum sequence time between trains, because the longer the train, the later the block is cleared.

This introduces the concept of an optimum travelling speed in order to optimise flow rate, which is a function of acceleration and braking rates as well as train length.

In practice, regional trains with infrequent stops (≥10 km between two stations) and freight trains operate well together. On the other hand, the TGVs travelling at 220 km/h between Tours and Bordeaux strongly reduce the overall speed of freight trains since these must come to a halt to be overtaken 5 or 6 times in 350 km.

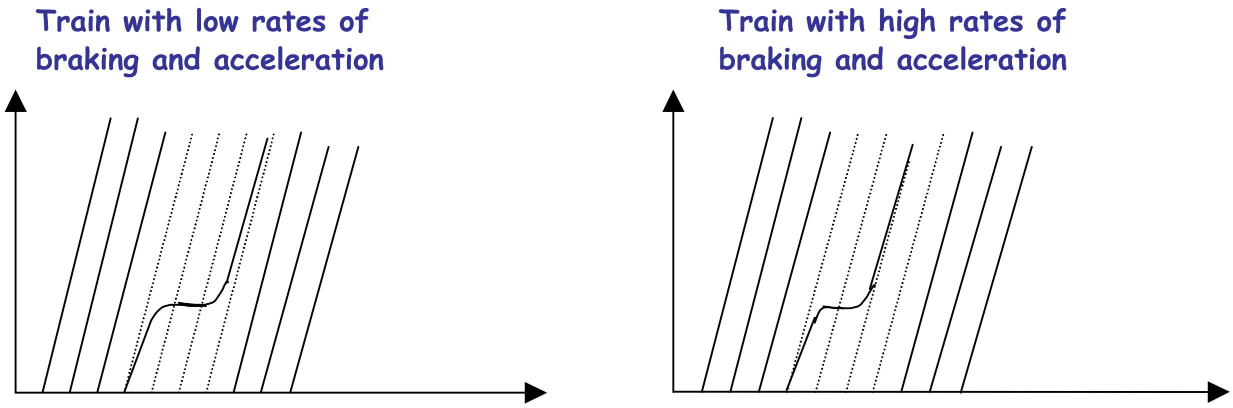
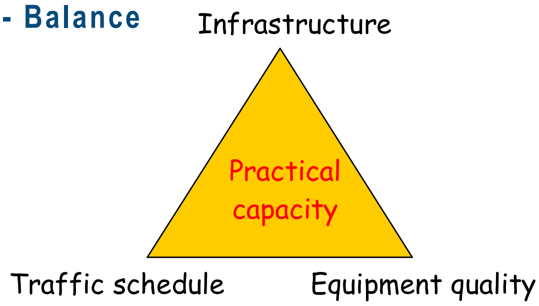


Figure 17. Effect of braking and acceleration characteristics on capacity

5.2.5 - Balance



5.3 - Capacity of a marshalling yard

5.3.1 – Marshalling yard operations

In 2006, there were eight marshalling yards in France. The purpose of the marshalling yard is to form trains from wagons having the same geographical destination.

A marshalling yard (see Figure 14) with gravity shunting has three fans/sets of tracks:

- a set of reception sidings (A), on which trains arrive: here the trains are prepared (wagons or sets of wagons uncoupled) in order that the wagons can be sorted;
- a set of marshalling sidings (B): shunted from the receiving area, the wagons pass over a hump whose slope propels the wagons to the marshalling area; wagons are directed to their destination track by a specialised signal box;
- a set of sorting sidings : once the trains have been formed (wagons coupled, brake lines attached, technical checks carried out), they wait for a locomotive and train path before joining the main line (the train path is pre-defined and reserved, but it can be decided to despatch a train beforehand if the current time-distance graph can accommodate it); trains wait on the marshalling tracks if there is a shortage of departure space.

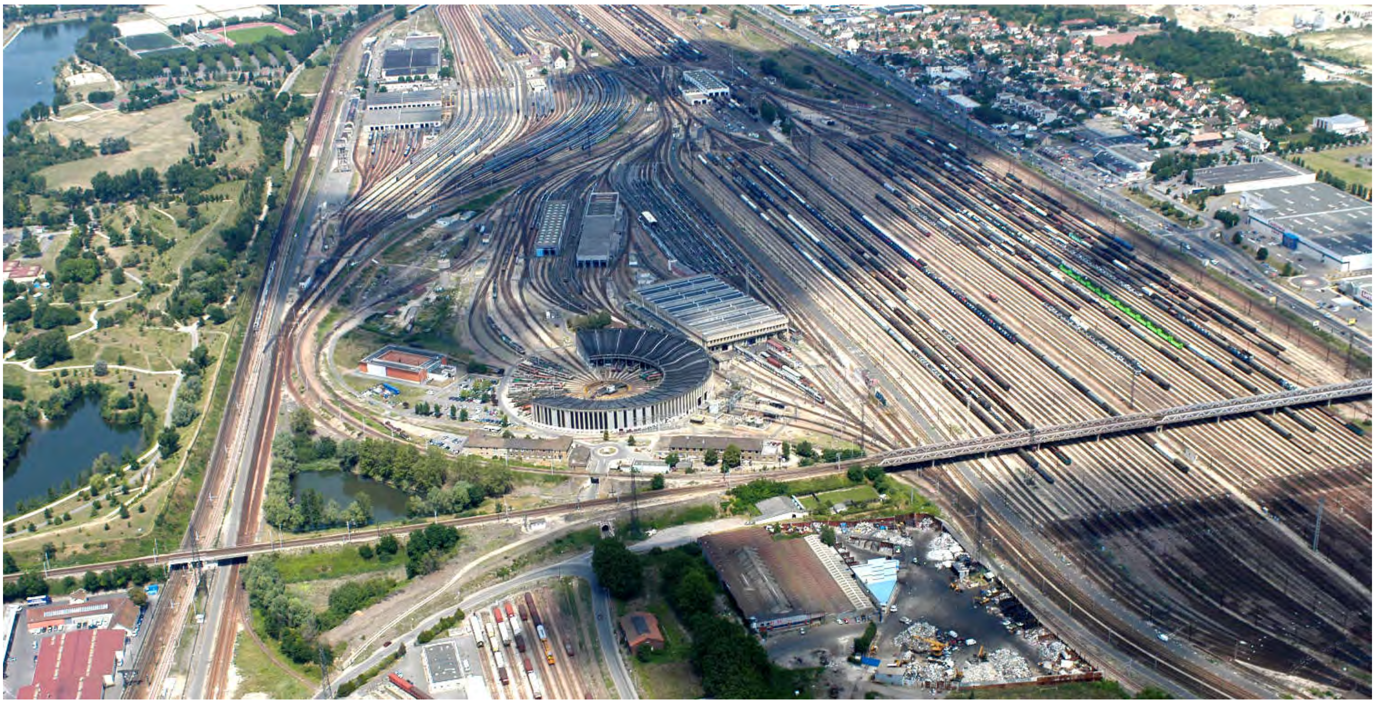
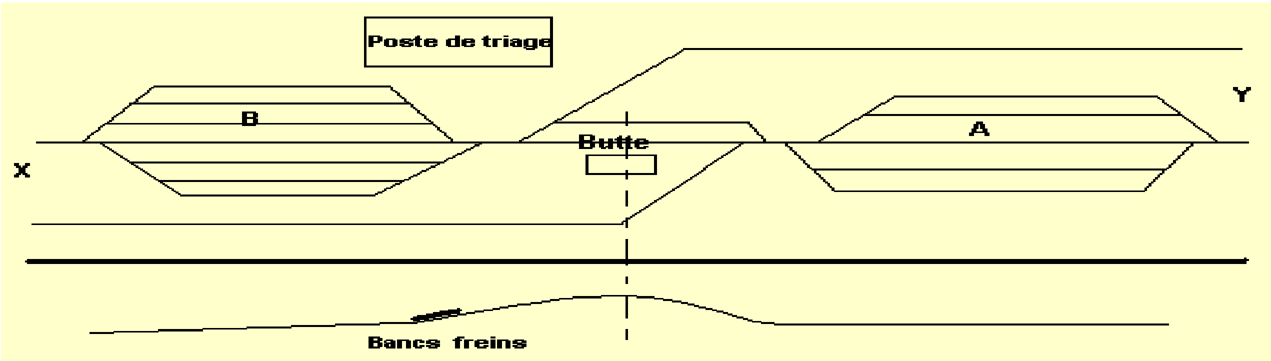


Figure 18: Marshalling yard at Valenton (© DREIF / Gobry)



("Marshalling yard"; "Hump"; "Braking units")

Figure 19. Marshalling yard with gravity shunting

5.3.2 – Capacity of a marshalling yard

In France as in Europe, the number of single wagons continues to diminish, though remaining a significant part of railway freight working (~ 25% in France 2010, 50% few years ago). Whole trains become relatively more important through being more profitable (less handling and therefore reduced labour costs) and being easier to guarantee good service quality for these types of train (fewer operators and thus fewer commercial risks).

Due to the decline in single wagon number, certain tracks in marshalling yards have been neutralised in order to restrict their costs of maintenance and others have been converted into passing sidings, i.e. reserved for trains waiting for train paths or for changing drivers. The main former marshalling yards have in general become places for separating and/or regrouping wagons for area services but without gravity shunting.

As for marshalling yards now closed but with a strategic location, these can be reused as a platform for composing trains for future rolling-highway operations, if they have suitable road access (a current example being investigated is Brétigny, for a potential rolling-motorway service between Southwest France and the Parisian area).

Marshalling yards take up a great deal of space, on average occupying 100 hectares (4 km long x 250 m wide). Their location depends mainly on the local topography (requirement for a level surface, proximity to a main rail junction and/or a built-up area providing traffic) but also on its historical use (general network structure).

With regard to their capacity, this depends on the number of tracks, the number of freight traffic destinations, the periods of activity (3 x 8-hour shifts or otherwise, more or less activity at the week-end, etc.) and the level of modernisation (depending on automation and thus the speed of sorting). Capacity is calculated as the number of wagons handled each day.

In every case, in the light of reduced activity in marshalling yards since the 1970s, the marshalling yards themselves are not saturated. Problems of saturation do currently exist however at nearby railway nodes, which interferes with the reception or despatch of trains at certain times ; e.g. Sibelin, one of the most important marshalling yard, near Lyon, with all traffics going through the Part-Dieu station.

Example: the marshalling yard at Miramas:

1,330 wagons were handled there each day in 2008. It is the second largest marshalling yard in France, with 14 millions tonnes of freight handled.

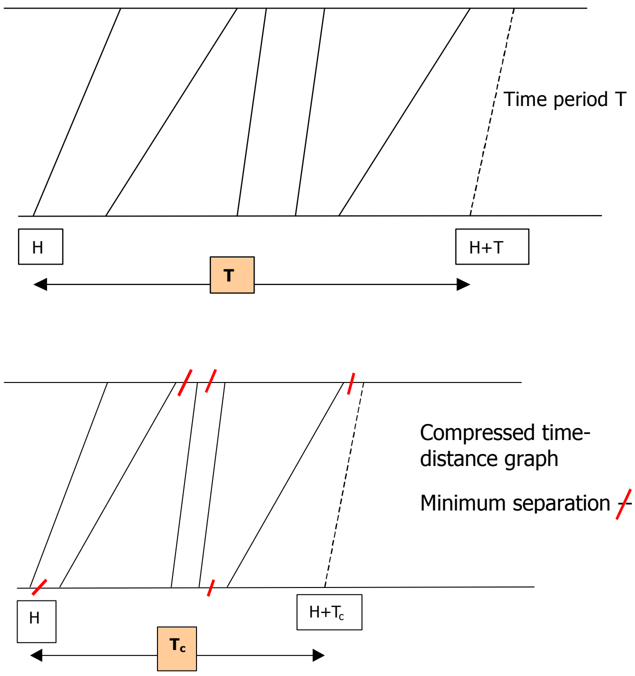


Figure 20. Saturation rate, reference period T and compressed period Tc

5.4 - The concept of saturation

Saturation can be defined from the concept of line capacity, defined as the ratio of effective number of reserved train paths on a given section over a given time period, to the maximum number of trains that might reasonably be travelling on the same section over the same time period. The term 'reasonably' recalls the concept of flexibility and the levels of quality and punctuality of the trains required by the infrastructure management. Indeed, the higher the number of trains travelling on a line, the higher the risk of the snowball effect appearing.

There are various present-day methods for evaluating line saturation. They can be grouped into four methodologies (see Section 5.4.2).

5.4.1 – Saturation rate

For SNCF, saturation rate is a reflection of the desired level of quality in the transport plan, i.e. (amongst others) the capacity for the level of quality to become re-established after an incident. SNCF defines the infrastructure saturation rate (= rate of occupation on the graph ς) for a given section over a reference time period T, as the time the infrastructure is occupied under compressed conditions T_c (i.e. trains with minimum sequence times t_s) divided by the reference period T.

Thus: $\boxed{\varsigma = T_c / T}$

It can also be seen that there is another approach to the concept of line saturation rate. The saturation rate S of a section of line over a time period T corresponds to the number of trains N actually scheduled in the timetables during this period divided by the practical capacity of the section during the same time period T.

Thus: $\boxed{S = N / C_{practical}}$

The saturation rate of a railway node is more difficult to evaluate. This is because there does not seem at first sight to be any correlation between the unit saturation rates of the various elements constituting this node, because saturation, just like capacity, is not necessarily cumulative. Therefore, there is no practical formula which evaluates saturation at a railway node.

5.4.2 – Method typologies

Analytical methods

These are based on an evaluation of the average of minimum sequence times t_s for the different trains. These formulae differ according to the different ways of considering t_s and the different margins adopted based on the level of quality required. They lead to a calculation of capacity.

Probability methods

These can be used when the timetable is not yet definitive. They are based on a probabilistic evaluation of the distribution of trains and make assumptions on the distribution of train movements.

Timetable construction methods

On the basis of a given timetable, these use theories to prepare a time-distance graph which is as dense as possible without train paths 'dropping out': this would correspond to the most saturated situation.

IT simulation methods

Here, theoretical calculations are not involved, instead simulations are made on the circulation of different known trains and different incidents occurring on the network. In this way, the level of quality and the robustness of a time-distance graph can be demonstrated.

5.4.3 – Development of an analytical method: SIMON

Swedish national railways developed simulation software (SIMON) which allows a line capacity analysis to be verified. The SIMON method is elaborated on here because it is a fast and effective method to evaluate the overall capacity of a section with homogenous traffic movements. It is also a method independent of the time-distance graph. However, since it is a method which applies mainly to homogenous traffic movements on a section, it cannot on its own determine capacity in a sure and reliable manner.

The software uses the following formula to evaluate capacity:

$$C_{pratical}=k\times\frac{T_{ref}}{\frac{L}{V}+m},$$

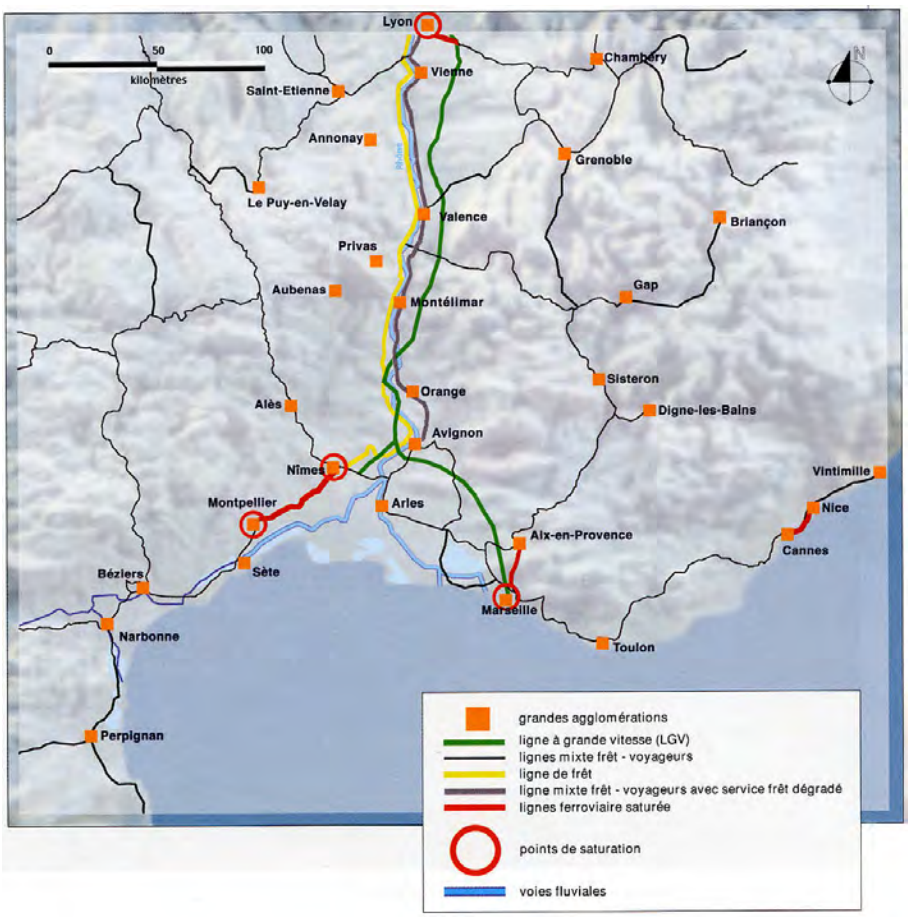
where: T_{ref} = *the reference period,*
L = the length of limiting block (corresponding to the block with the longest travelling time),
V = train speed,
k = coefficient of flexibility as defined by UIC/Union Internationale des Chemins de fer (International Railways Union)
m = the margin to be added to the sequence time because of approximations.

More details on methods for evaluating saturation and capacity of railway infrastructure are given in the study "Research on saturation in railway lines", produced by SYSTRA [29] on behalf of the Ministry.

5.4.4 - Saturation points on the south-eastern network

Figure 16 shows the main saturation points on the southeast railway network.

Appendix 4 includes a detailed account of the case study involving the Nîmes – Narbonne rail link.



("Large urban areas"; "high speed line"; "passenger-freight mixed line"; "freight line"; "passenger-freight mixed line (downgraded freight service)"; "saturated lines"; "saturation points"; "waterways")

Figure 21. Saturation points on the southeast network (source: RFF)

5.5 - Infrastructure components limiting network capacity

The section from Bordeaux to Coutras [29] was analysed to evaluate the impact that infrastructure components can have on capacity. On this section, there are three particular layout constraints: junction with contraflow, crossings and railway nodes. For this reason, the Bordeaux East sector is known as the "Bordeaux railway bottleneck".

5.5.1 – Junction with wrong-track running (contraflow)

The most major constraints arise from the freight train services from Bastide to Bordeaux (normally 26 trains per day). This is because, at Cenon junction (4 km before the station at Bordeaux Saint-Jean), trains take track 2 in a contraflow direction for 1,500 m and are therefore incompatible with trains leaving Bordeaux for the north. This is highlighted with a green ring in Figure 18.

This constraint occurs on average 15 time per day, but never during the evening rush-hour period.

This can impose major constraints on other trains. For example, a passenger train from Dax arrives in Bordeaux station at 20h28. But, because a freight train arrives at the Cenon junction at 20h35, the passenger train is obliged to wait in Bordeaux station for 19 minutes, thereby reducing the availability of the tracks in the station. It can leave only after 20h47.

5.5.2 - Crossings

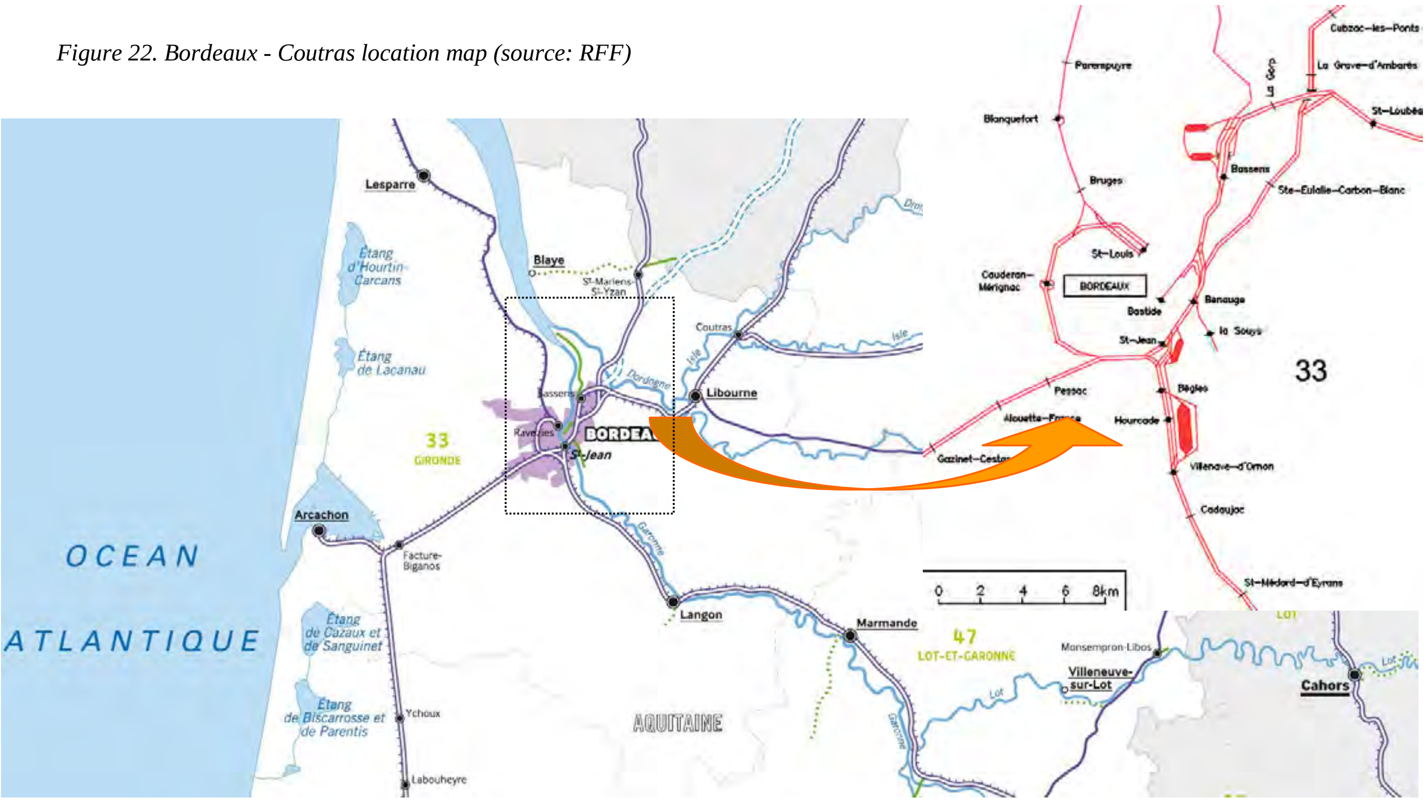
Trains arriving from Hourcade (south of Bordeaux) create a crossing hazard on track 1 because they bypass Bordeaux passenger station in order to join track 2 (yellow ring in Figure 18).

Similarly, at the Saintes junction, trains coming from Bordeaux (on track 2) travelling to Saint-Mariens cross track 1, creating potential crossing hazards for trains from Paris to Bordeaux (blue ring in Figure 18). In this case, the crossing imposes constraints on these train paths:

- the passage of train 4374 at 17h07 (after the passage of train 96998 at 17h22) induces a very obvious train path drop-out on the time-distance graph (Figure 19);
- between trains 8537 and 97569: a 13-minute delay in Coutras station and above all, a 27-minute delay in Bordeaux station.

However, if one considers basically that the sequence time at the junction is 4 minutes, the train 97569 service cannot be compressed because it is restricted by train 96998 passing through (on the other hand, train 96998 could leave earlier and compress the graphic).

Figure 22. Bordeaux - Coutras location map (source: RFF)



5.5.3 – Railway node

The river Garonne is crossed immediately north of Bordeaux Saint-Jean station by a 2-track iron viaduct built in 1860. The 2-track section of the line between Saint-Jean station and the junction at Cenon which on average carries 250 train movements per day, is saturated. Therefore, it is no longer possible to offer freight activities, main line passenger or regional trains the extra train paths that these require.

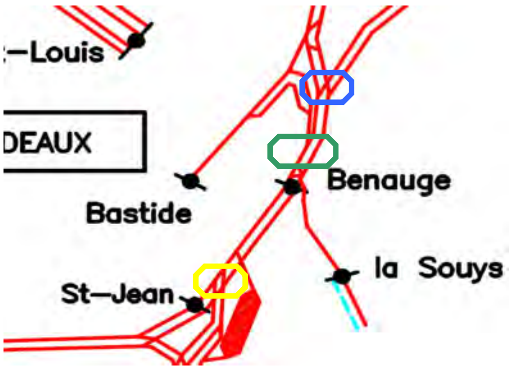


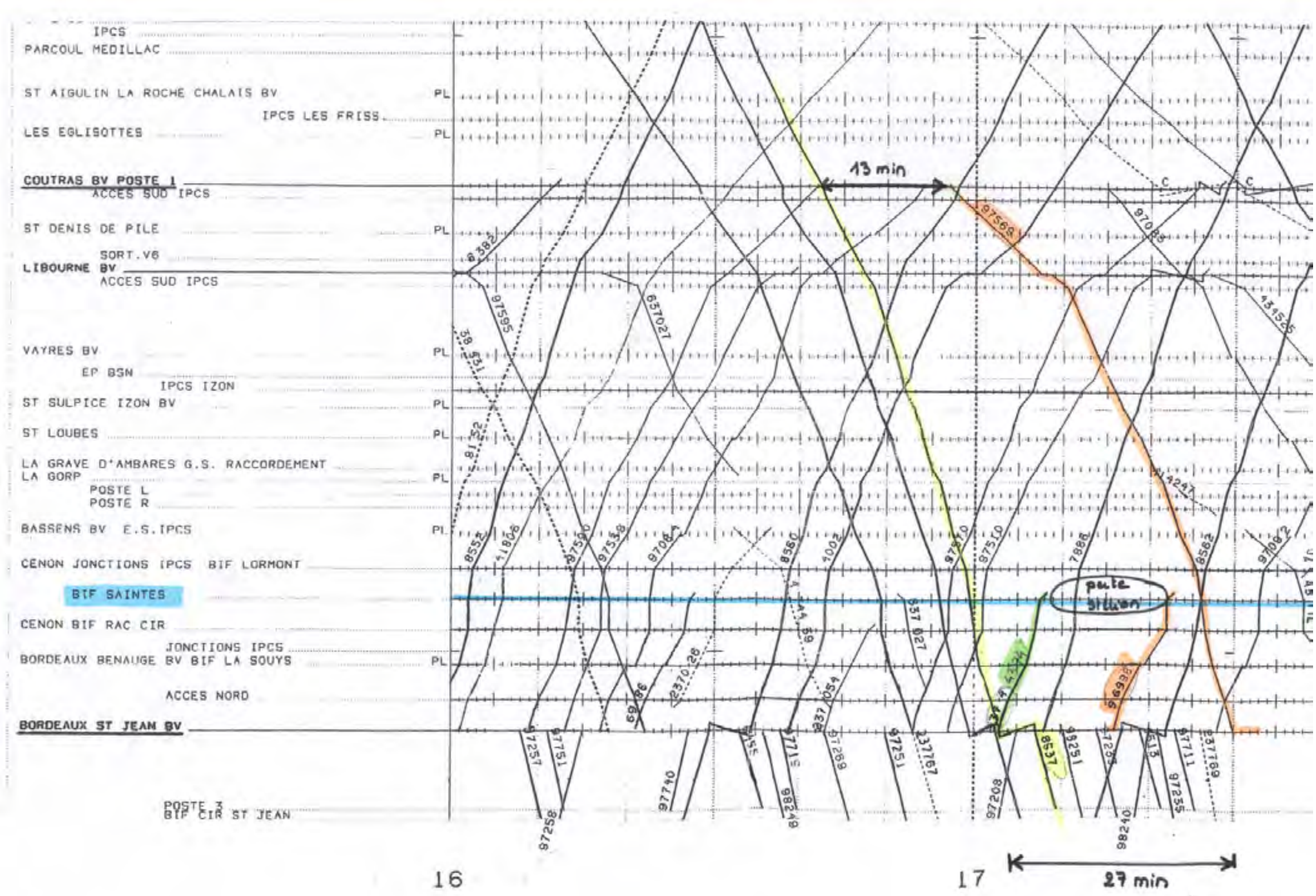
Figure 23. Diagram of a railway node (source: RFF)

The 'Bordeaux railway bottleneck' project consists in:

- replacing the current 2-track bridge, at the end of its working lifetime, with a new, 4-track crossing;
- progressively extending these four tracks up to Cenon junction;
- dedicating these tracks by traffic type, in view of the forthcoming high speed line.

Figure 24. Junction and crossovers on Bordeaux network (source: RFF)

Figure 25. Time-distance graph for Saintes junction (source: RFF)



6 - Appraisal and Development Prospects

6.1 - Appraisal

Railway line capacity is a relative concept, linked to numerous parameters, and is a function of railway system characteristics:

- the separation between two trains;
- the characteristics of the infrastructure: gradients, type of signalling and electrification, single or dual track, permitted speed limits;
- the physical and dynamic characteristics of the trains: weight, length, speed, stoppages in stations, acceleration and braking performance;
- the traffic schedule: organising the sequence of different types of train movements: freight, high speed (TGV), regional (TER).

Therefore, capacity is affected by the railway infrastructure configuration, the uniformity or otherwise of the traffic and the sequence of train movements.

The overall capacity of an entire complex railway network consisting of lines, junctions, crossings and nodes depends only partly on line capacity. This is because nodes are places where various types of traffic converge and flow. Nodes limit the network capacity.

6.2 - Some development prospects

6.2.1 – Clock-face scheduling

Basically, this concerns successive trains on the same service operating at regular intervals i.e. with departure times, arrival times and any intermediate stops occurring every two hours, one hour, half-an-hour, etc. The frequency of the service would depend on need: for example, thirty minutes in the suburbs, every hour on regional and international services. These intervals can also vary according to the time of day since the traffic during the morning and evening rush hour periods is more dense than in off-peak periods.

Advantages

If the main attraction of regularisation seems to be commercial (better comprehension for the customer and optimisation of connecting services in particular), substantial technical advantages also become apparent:

- the production of the train paths and the annual setting up of the service are simplified, with significant benefits offered by a train path catalogue;
- classifying trains by origin/destination allows certain types of trains to be allocated to particular tracks in stations, thereby making it easier for passengers to identify the service they require;
- staff and equipment rotation is simplified;
- the regularity of timetables makes easier the management of disrupted situations;
- network capacity is slightly increased (approximately 10% according to experts, but varying according to situations and sources).

Drawbacks

In general, regularising train departure times, as a minimum, represents an additional non-negligible constraint on the time-distance graph and seems to decrease flexibility. A simple example demonstrates an immediate difficulty: if a line has a capacity of seven train paths per hour, regularisation to a half-hour service would imply only six train paths. Some train paths can be lost thereby and the capacity reduced.

In fact, the rigidity of the system is only apparent: it is train paths that are actually considered, not gains, and an unused train path provides a time-distance which can be used for a train movement on a different time schedule. A non-regularised system is often as rigid as a regularised system. And sometimes much more.

6.2.2 – Interoperability of a trans-European railway system

Interoperability is defined as the capacity for a train to operate on any section of line on the European railway network without having to change or modify the rolling stock.

What takes place at European Union railway borders?

Source: European Commission, General Directorate for Energy and Transport

- *change of driver and guard personnel;*
- *change of locomotive;*
- *drawing up of train make-up;*
- *train inspection;*
- *checks relating to hazardous materials;*
- *checking train documentation (accompanying documents);*
- *potential train reformation;*
- *tagging the wagons;*
- *checking the tail light;*
- *changing axles (e.g. between Spain and France);*

the situation is improving, not all these difficulties occur at all borders.

At present, the competitiveness of rail transport is limited by the different national standards for equipment, technology, signalling, safety rules, traction voltages and speed limits. Consequently, international trains often have to stop at borders.

Within the framework of the common transport policy, the European Community introduced legislation aimed at the progressive construction of an integrated European railway area, both from a legal and technical point of view. This is achieved by the development and implementation of technical interoperability specifications and a shared approach to issues concerning railway safety. The EU website[17] has more details on this subject.

Furthermore, opening the international railway market is a complex issue because until only very recently, the national operator was the single operator in his country. Some common structures for train path reservation have been introduced progressively by European railway infrastructure companies: eg. the publication of an international freight train path catalogue (Railnet Europe) and installation of 'single window' offices in each country.

Appendix 3 describes the ERTMS-related issues at stake.

6.2.3 – Other options for overcoming network saturation

- Improvements to infrastructure: building new lines (new tracks), as is the case in bypassing Nîmes and Montpellier, electrification (insofar as this allows improved regional train accelerations), replacement of flat crossings with flyovers;
- 4-aspect signalling, rather than 3-aspect, allows sequence times to be reduced by 15% (see Figure 21). Throughput is increased by shortening the block lengths. This system is not widespread and its use is reserved for slow trains (suburban-type trains) or fast trains (200-220km/h).
- Improvement in braking and acceleration rates for passenger carriages;
- Reducing speed of the quickest trains in order to harmonise transit times (a solution contrary to the aims of the present company);
- Modification to train capacity:

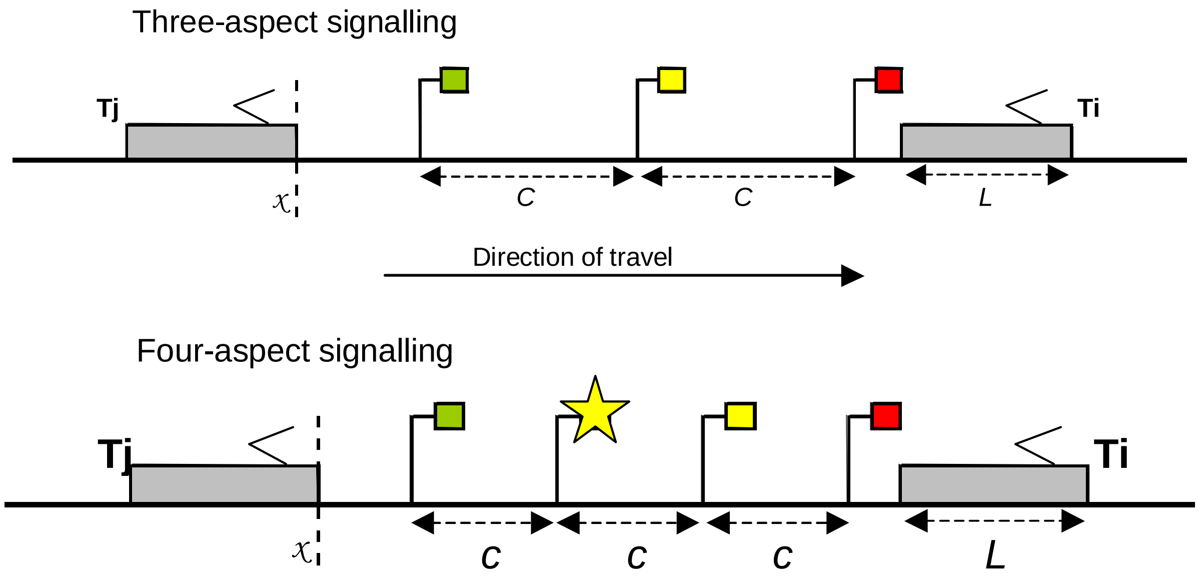
- by extending the use of double-deck (duplex) rolling stock: implementation of the duplex solution concerns TGVs, main line, regional and suburban services. It allows train lengths to be reduced, thereby freeing train paths and yet avoiding costly reconstruction work (platform extensions);

- for freight, exploiting as far as possible, the possibility of operating trains 750 m long (action undertaken by SNCF in recent years), even operating very long train lengths (up to 1,500 m,) although this presents considerable technical constraints as much with regard to infrastructure (length of sidings, power of electric traction installations, greater separation distance between two trains, management of any breakdown) as to the train itself (strength of the couplings and positioning of locomotives in the train, sufficient acceleration and balanced braking).

- Reduction in the number of Regional trains halts on busy routes: serving less frequented halts is counter-productive: heavy employment of railway capacity for low passenger volumes.

[17] http://europa.eu/agencies/community_agencies/era/index_fr.htm

Figure 26: Three- and four-aspect signaling. The yellow star can be in fact a green flashing light



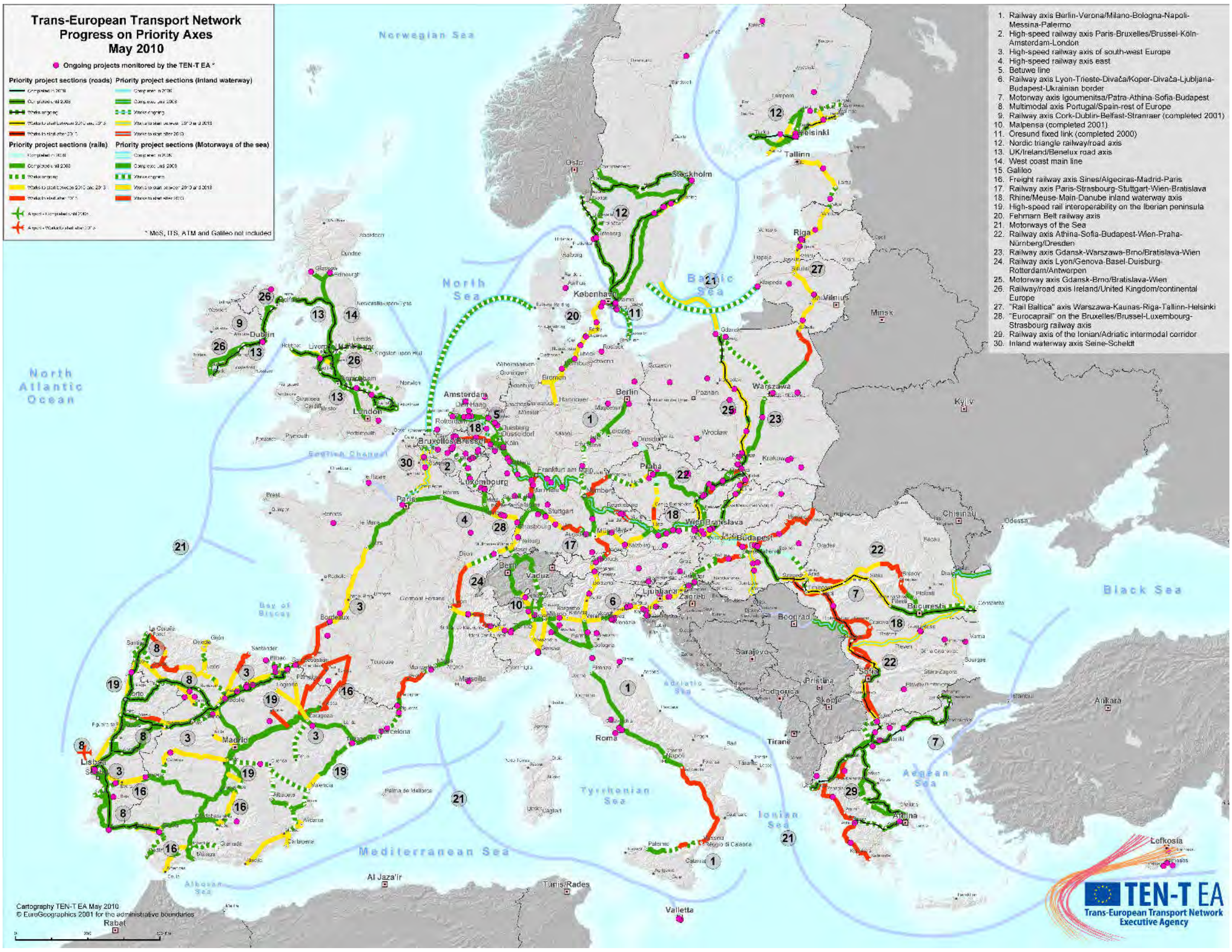


Figure 27 : The Trans-European Transport Network (TEN-T). Main projects are railways operations, in many cases for freight
Source : TEN-T Executive Agency

Appendix 1. UIC Line Classification

UIC group classification is based on calculating the traffic coefficient T_{f2}.

Notional tonnage T_{f1}

$Tf1 = Tv + Km * Tm + Kt * Tt$

where Tv = **daily** passenger tonnage in gross tonnes drawn,

Tm = **daily** freight tonnage in gross tonnes drawn,

Tt = **daily** tonnage of locomotives in tonnes,

Km = coefficient of 1.15 (1.30 if traffic is mostly 20 t/axle),

Kt = coefficient of 1.40.

Traffic coefficient T_{f2}

$Tf2 = S \times Tf1$

where S = 1 if line has no passenger or local passenger traffic,

S = 1.10 if line has passenger traffic at $V \leq 120$ km/h,

S = 1.20 if line has passenger traffic at $120 < v \leq 140$ km/h,

S = 1.40 if line has passenger traffic at $V \geq 140$ km/h.

Group classification

Group 1	$T_{f2} \geq 120{,}000$
Group 2	$120{,}000 \geq T_{f2} \geq 85{,}000$
Group 3	$85{,}000 \geq T_{f2} \geq 50{,}000$
Group 4	$50{,}000 \geq T_{f2} \geq 28{,}000$
Group 5	$28{,}000 \geq T_{f2} \geq 14{,}000$
Group 6	$14{,}000 \geq T_{f2} \geq 7{,}000$
Group 7	$7{,}000 \geq T_{f2} \geq 3{,}500$
Group 8	$3{,}500 \geq T_{f2} \geq 1{,}500$
Group 9	$1{,}500 \geq T_{f2}$

Appendix 2. Scheduling Freight Operations

Control and scheduling structures

Train movements are controlled and scheduled at three levels:

- signal cabins: over a thousand in number today, their number will decrease considerably with the introduction of automation. Signal cabins are the fundamental components of the train movement control system;
- Traffic Management Operational Centres (COGC): there are 23 of these regional centres. The centre in each region coordinates the basic actions taken by the signal boxes;
- the National Operations Centre (CNO): based in Gare de l'Est (Paris). It coordinates all the actions taken by the COGC.

These structures take decisions and manage crises with regard to train movements.

The CNO supervises all activities: freight, passengers and infrastructure, and management of the LGV Méditerranée. The CNO has a real-time view of what occurs on the French rail network. It receives data from all regions and must manage disrupted situations following an incident or a reduction in capacity and act accordingly. It is responsible for the safety of the entire network. In the event of an incident or dispute, its role is to clear the line as quickly as possible while estimating the length of the delay in order to divert trains if necessary. The traffic information service ("infolignes" website and hotline 3635) is also based at the CNO.

The current ambiguity of the system is that this organisation was designed and put in place in the rationale of a single integrated Railway Company. The decisional neutrality of the CNO and the COGCs between different Railway Companies is not yet proven.

Freight activity

Freight is no longer managed by the COGCs but by the CNO directly. The CNO freight department operates 24 hours per day and controls the movements of over a thousand trains over a 24-hour period, with especially heavy traffic at night.

The Road-rail Production Optimisation Organisation (EPOC) was established in January 2004. EPOC controls 117 locomotives dedicated to SNCF road-rail traffic and monitors these trains across France. Most SNCF freight locomotives are today equipped with GPS, which allows them to be tracked and their speed measured by the CNO. The train-loads for each locomotive are also known by CNO staff.

Main line activity is monitored in the same way as for freight activity. However, the TGV ("Train à Grande Vitesse" / high speed train) Méditerranée management is much more sophisticated: the line operation software COLT (Coopération Opérationnelle Lignes TGV) manages traffic and LGV ("Ligne à Grande Vitesse" / high speed line) Méditerranée data in real-time. Eventually, all TGV and Corail Teoz (Intercity Express trains) routes will be managed in the same manner.

Appendix 3. European Rail Traffic Management System (ERTMS)

The European rail traffic management system ERTMS is a control-command system intended to replace the 23 signalling systems in Europe and aims to improve European railway network interoperability. It consists of installations on the infrastructure (track magnets, processing centres) and installations on the locomotives. Today, it has two basic components:

GSM-R (R for railway): this is a radio system used to exchange data between the trackside and the train. It allows the driver to communicate with the control centres and can be used to transmit the maximum permitted speed to the train.

The European Train Control System (ETCS): this European system for train control allows not only data relating to maximum permitted speeds to be transmitted to the driver, but also respect for the signal indications to be permanently monitored. An onboard computer compares the actual train speed with the maximum permitted speed and applies the brakes automatically in the event that the limit is exceeded.

There are three levels of ETCS.

ETCS level 1

ETCS-1 can transmit data from the trackside which allows the maximum permitted speed to be calculated. These data are transmitted by standard beacons (Eurobalise) placed alongside the track and connected to existing signalling systems. This is now an approved technology. ECTS-1 is installed at each signal.

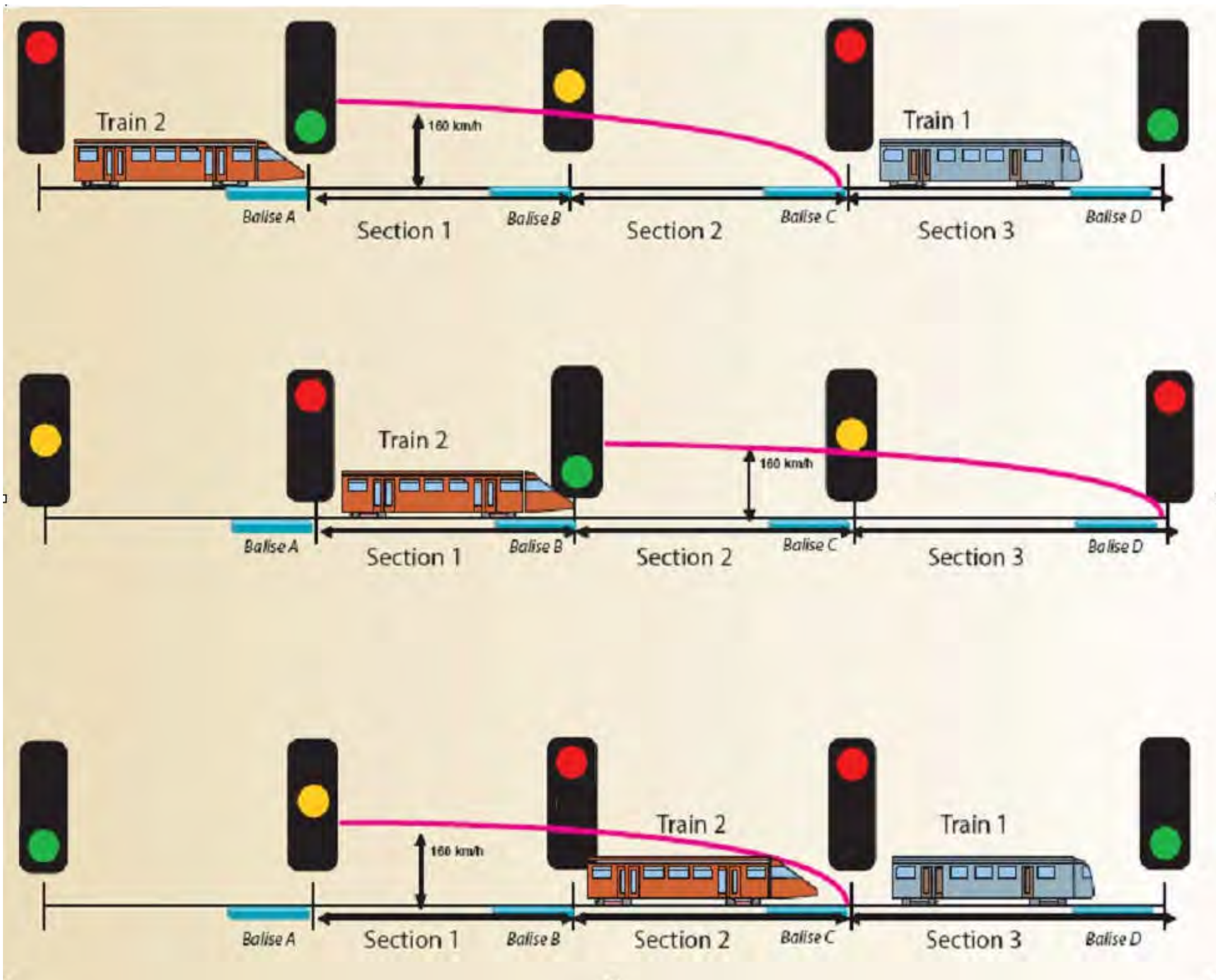


Figure 28. ETCS level 1 - "Balise A/B/C/D" = "Beacon / track magnet" A/B/C/D

In the first diagram in Figure 22, train 2 passes beacon A and receives authorisation to proceed to the end of section 2. This authorisation allows the train to proceed at the maximum line speed until reaching beacon B. In the second diagram in Figure 22, train 1 has left section 3. While passing beacon B, train 2 receives authorisation to proceed to the end of section 3. This authorisation allows the train to proceed at the maximum line speed until reaching beacon C. In the third diagram in Figure 22, train 1 has not left the section. Beacon B confirms the prohibition to pass the signal at beacon C. The implication is that the train must decelerate before stopping at beacon C.

ETCS level 2

Data can also be transmitted by radio (GSM-R). In this case, the trackside signals are deleted.

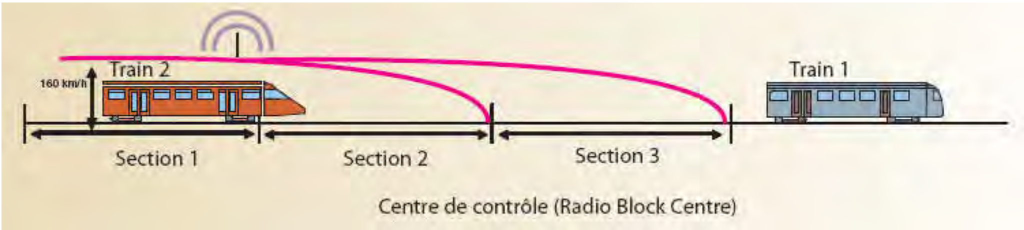


Figure 29. Communication by GSM-R

A train equipped with ETCS can receive a new "authorisation to advance" at any moment. Therefore, in the preceding configuration, as soon as train 1 leaves section 3, the Radio Block Centre receives this information from the ground-based system and can immediately transmit a new authorisation to advance to section 3. With the level 1 system, this new data would only have been received once the train arrived at the end of section 2, whereas, with the level 2 system the information is available immediately, contributing to traffic fluidity.

ETCS level 3

Trains should be able to transmit their exact position themselves. This, notably, allows line capacity to be optimised and to reduce further the trackside equipment. ETCS level 3 is still being developed but would, in time, allow significant improvements in maintenance and in capacity.

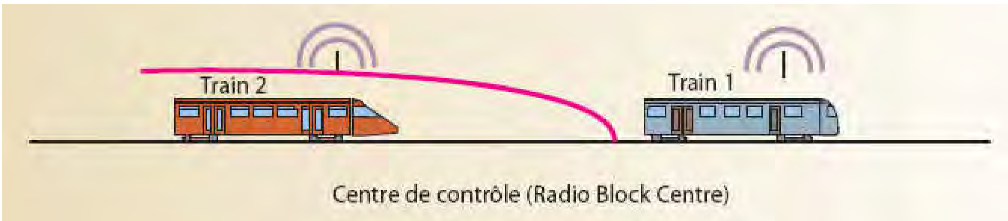


Figure 30. ETCS level 3

Installation of ERTMS represents a significant financial investment in the railway world, with a budget of five billion Euros over the next 10 years: two billion for trackside equipment and three billion for locomotive equipment. This involves equipping all main European routes on which 20% of all European traffic movements occur.

Appendix 4. Case Study – Nîmes to Narbonne Line

Note

Data are taken from the study carried out by SYSTRA in 1997 on behalf of the Ministry entitled “Recherche sur la saturation des lignes ferroviaires” [study of railway line saturation] [29]. This study presents the analysis principle of railway line section saturation.

Analysis of study section infrastructure

Location

The section studied was that between Nîmes passenger station and Narbonne passenger station Signal Cabin 1

Figure 31. Location map (source: RFF)

The direction of travel from Nîmes to Narbonne is designated track 1, the direction from Narbonne to Nîmes is designated track 2.

Characteristics

Length

The length of this section is 147.2 km and can be sub-divided according to the following line features:

- from Nîmes passenger station to Montpellier passenger station P1: 49.8 km;
- from Montpellier passenger station P1 to Sète passenger station P1: 28.6 km;
- from Sète passenger station P1 to Béziers passenger station P1: 43.3 km;
- from Béziers passenger station P1 to Narbonne passenger station P1: 25.5 km.

Number of tracks

This section of line is double track between stations. In the passenger stations, the numbers of tracks are:

- 5 tracks for platforms at Nîmes;
- 3 tracks for platforms at Lunel;
- 5 tracks for platforms at Montpellier;
- 4 tracks for platforms at Sète;
- 4 tracks for platforms at Agde;
- 5 tracks for platforms at Béziers (3 tracks for platforms for the single track line to Millau);
- 5 tracks for platforms at Narbonne.

From Sète to Frontignan (6.8 km downstream from Sète), the two tracks are standard. The rest of the line is equipped with IPCS.

Speed

For the section studied, tracks 1 and 2 have a speed restriction (depending on the train type) between 120 and 160 km/h for passenger trains, between 80 and 140 km/h for parcel trains, and between 80 and 100 km/h for freight trains.

Analysis of operating parameters

The section studied is controlled by the Train Control Section in Montpellier. Traction for the trains is provided a 1500 V supply and the substation controller is in Montpellier. The minimum train spacing times (t_s) provided by the SNCF southeast subdivision are given in Figure 26.

	Following a TGV		Following other express trains		Following a Z2		Following a ME120		Following a MA100	
	t_s peak	t_s off-peak	t_s peak	t_s off-peak	t_s peak	t_s off-peak	t_s peak	t_s off-peak	t_s peak	t_s off-peak
Nîmes Lunel	4 min	5 min	4 min	5 min	4 min	5 min	5 min	6 min	6 min	7 min
Lunel-Mtpl	4 min	5 min	4 min	5 min	4 min	5 min	5 min	6 min	6 min	7 min
Mtpl-Lunel	4 min	5 min	4 min	5 min	4 min	5 min	6 min	7 min	6 min	8 min
Lunel Nîmes	5 min	6 min	5 min	6 min	4 min	5 min	6 min	7 min	6 min	8 min

Figure 32. Minimum train sequence times between Nîmes and Montpellier

The train sequence times t_s for the section from Montpellier to Narbonne are not provided because they are not as restricting as those from Nîmes to Montpellier.

Particular layout constraints affecting capacity (direction 1)

Section V has already described this aspect of railway timetable constraint, which can appear very restrictive and which can limit the number of train movements on the section in question.

Thus, the constraints on time scheduling due to the TGVs on the line section are significant: on average 11 TGVs per day, between 12.00 and 23.00, travel on this section, thereby imposing their schedules (10 trains stopping at Montpellier and one through train to Perpignan).

Moreover, the Maréchal Foch lifting bridge at Sète, on which the line passes, is opened three to six times each day to allow maritime traffic to pass. This disrupts rail traffic and reduces line capacity considerably, since no train can operate there during these periods.

Finally, trains on the route Mende - Alès - Nîmes - Montpellier (normally three per day, in both directions) impose their schedules because the Mende to Alès line is single track and thus has very tight scheduling. What is more, trains on the line Alès to Nîmes (on average 23 per day, in both directions, 21 of which are passenger trains) must carry out a manoeuvre at Nîmes-goods station (see Figure 26) in order to change direction of travel, since there is (up to 2013) no direct connection, thereby adding to the saturation at Nîmes station.

At Saint Césaire, 4.8 km downstream from Nîmes station, the junction at Grau du Roi (a single-track line) creates head-to-head constraints (see Figure 32).

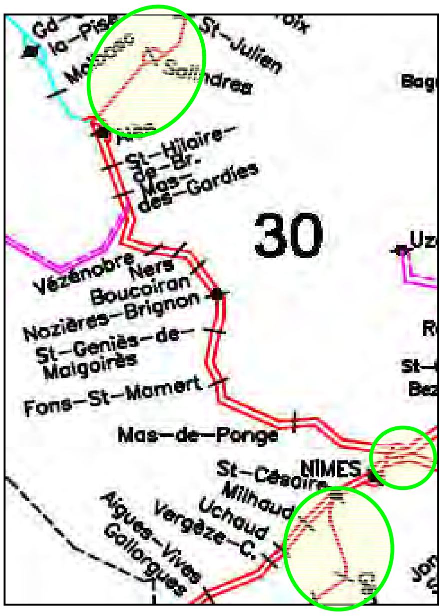


Figure 33. Constraints on railway network near Nîmes (source: RFF)

Additionally and as elsewhere, maintenance breaks are highly constraining, especially on this section according to the infrastructure managers. Maintenance work has been consolidated here, but at present on an annual basis (excluding summer) (situation in 2007).

Study of saturation at a specific point

A study was made of a single Friday's winter service in 1996/7 for the scheduled train movements through Colombier (7 km downstream from Béziers). The geographical position of this point is such that it is representative of trains travelling along the entire section from Montpellier to Narbonne. The number of trains scheduled for both directions of travel is 194:

- 104 trains scheduled for direction 1, consisting of: 33 passenger trains (22 express trains, 9 regional trains, 2 extra passenger trains); 67 freight trains (34 specially formed or grouped freight trains, 14 full trains or pick-up good trains (trains destined for railway-wagon terminals), 19 optional freight trains); 4 other trains (empty, light-running or service trains);
- 90 trains scheduled for direction 2, consisting of: 32 passenger trains (20 express trains, 11 regional trains, 1 extra passenger train); 53 freight trains (32 specially formed or grouped freight trains, 7 full trains or pick-up good trains, 14 optional freight trains); 5 other trains (empty, light-running or service trains).

Because this line section is relatively long, the same study was also carried out for train movements at Milhaud (7.2 km downstream from Nîmes), since this is representative of train movements on the section from Nîmes to Montpellier. The number of scheduled train movements in a typical day for both directions of travel is 235:

- 126 trains scheduled for direction 1, consisting of: 52 passenger trains (32 express trains, 19 regional trains, 1 extra passenger train); 71 freight trains (30 specially formed or grouped freight trains, 18 full trains or pick-up good trains pick-up good trains, 23 optional freight trains); 3 other trains (empty, light-running or service trains);
- 109 trains scheduled for direction 2, consisting of: 48 passenger trains (29 express trains, 18 regional trains, 1 extra passenger train); 56 freight trains (33 specially formed or grouped freight trains, 11 full

trains or pick-up good trains, 12 optional freight trains); 5 other trains (empty, light-running or service trains).

The overall breakdown of rail traffic at this point, therefore, is 43% passenger, 54% freight and 3% other.

Comparison of the two reference locations studied (Colombier and Milhaud) shows a difference of more than 40 trains. The section closest to Nîmes has the highest occupation, the maximum being between Nîmes freight station and Nîmes passenger station where the traffic on the Alès line is added to that on the main line.

Detailed study of a typical section

The time-distance graph shows that the station at Montpellier is apparently very saturated during the evening peak service due to the large number of services to Nîmes. Therefore, the train movements in direction 2 on the section from Montpellier to Nîmes (for 16h00 – 18h00 period, approximately) was selected for a more detailed study.

Express trains travel this section in 25 minutes, semi-direct regional trains in 30 minutes, stopping trains in 50 minutes and freight trains in 40 minutes. These running times and the standard contracts were in fact designed for a reference equipment type and for a given tonnage, as detailed in the timetables.

During this period, there are 12 train paths corresponding to the following scheduled service numbers:

- 58128: regional train V140, drawn by locomotive BB7200, 500 t, from Perpignan;
- 435624: grouped freight, MA100, drawn by locomotive BB8100, 1600 t, starting its voyage in Montpellier;
- 41512: parcel train, ME100, drawn by locomotive BB8100, 1000 t, from Perpignan;
- 42806: road-rail - specially formed, ME120, drawn by locomotive BB7200, 1200 t, from Perpignan;
- 58336: regional train service (V < 160) provided by multiple-unit 4500, starting its voyage in Montpellier;
- 41336: cars and car parts - specially formed, MA100, drawn by locomotive BB8100, 1 000 t, from Perpignan;
- 6452: main line service V160, drawn by locomotive BB9200, 700 t, from Perpignan;
- 872: main line service provided by electric multiple unit, single TGV rake, starting its voyage in Montpellier;
- 58130: regional train V140, drawn by locomotive BB9200, 300 t, starting its voyage in Montpellier;
- 58132: regional train with reversible rake AR140, drawn by locomotive BB9600, three carriages, starting its voyage in Narbonne;
- 874: main line service provided by electric multiple unit, double TGV rake, starting its voyage in Montpellier;
- 58338: regional train service (V < 160), provided by a double X4500 electric motor-car, starting its voyage in Montpellier.

Reference should be made to the time-distance graph in Figure 28, which displays the train paths for the trains considered in the compressed service study.

Calculation of the rate of saturation through compression gives the results shown in Figure 29.

Calculation of saturation rate	
Method: $T_{compressed}$ / $T_{reference}$	
Line:	Nîmes - Montpellier
Direction:	2
Section:	Montpellier - Nîmes
Start time:	15 h 59 min
End time:	17 h 35 min
thereby, T_{ref} =	01 h 36 min

Average sequence time t_s:	See table
Train number	Clear track margin
58128	00: 00
435624	00: 00
41512	00: 00
42806	00: 00
58336	00: 00
41336	00: 00
6452	00: 00
872	00: 02
58130	00: 04
58132	00: 00
874	00: 00
58338	00: 00
Total	00: 06
thus, $T_{compressed}$ =	01 h 30 min
Balance	
Graph occupation rate:	94%

Figure 34. Calculation of saturation rate through compression

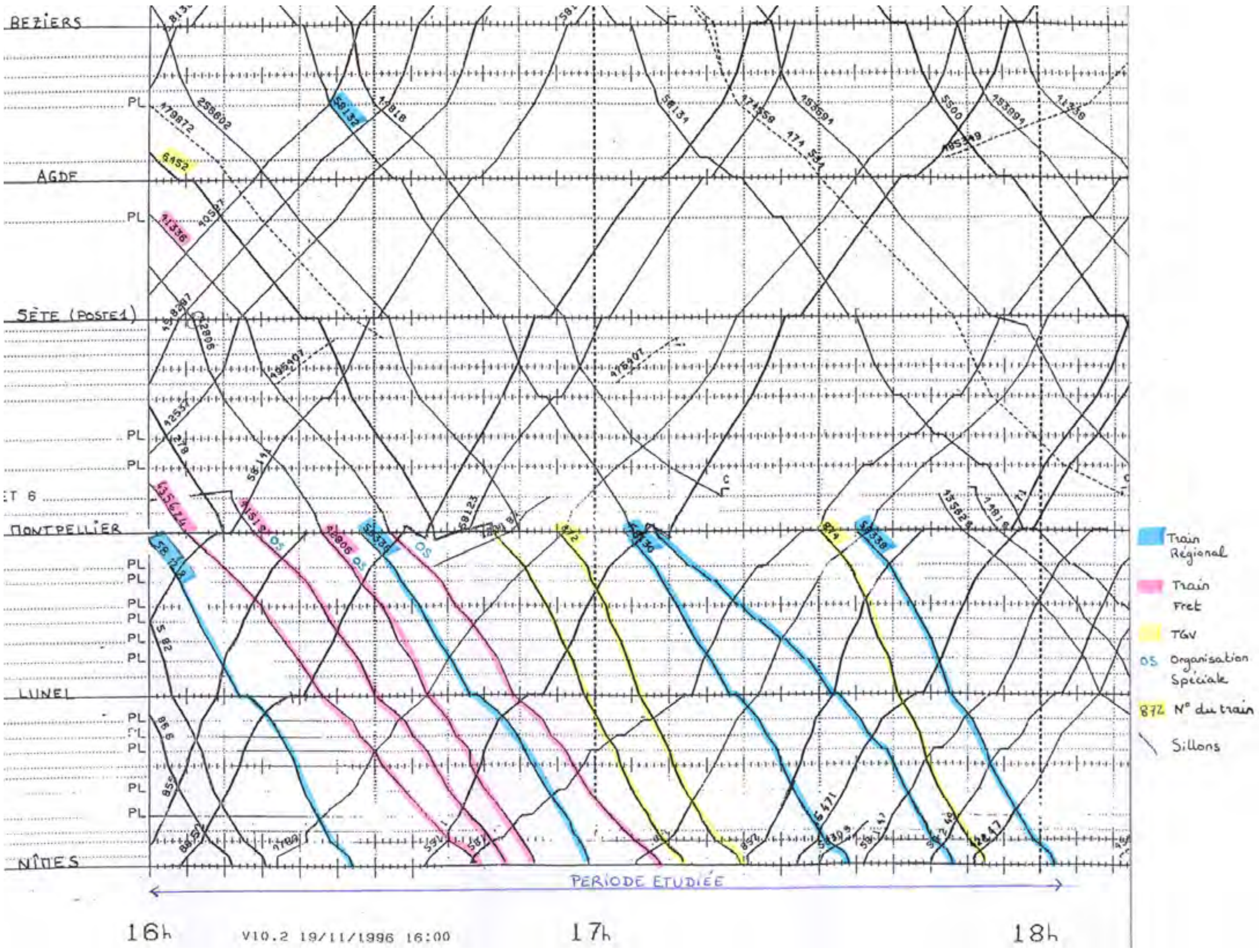


Figure 35. Time-distance graph of study section – source RFF ***. Blue regional train, Rose Freight, Yellow TGV, OS parcel train***

Calculation of the rate of saturation by the SIMON method

The SIMON method is fairly characteristic of analytical methods: it is simple in application but make too many approximations for its results to be really significant. As was stated in Section 5, analytical methods are applied mainly to line sections and for that reason this method is applied to the following actual example.

The assumptions are the same as for those of the compression study:

- the reference time is 1 h 36 min, i.e. (60 + 36) x 60 = *5,760 seconds*;
- the reference speed is taken as *V = 100 km/h*, i.e. 27.8 m/s, since this speed corresponds to the minimum speed of trains travelling during this period, namely freight trains MA100 and parcel trains ME100;
- the length of the most restricting block is taken to be *L = 2,800 metres,* which corresponds to the longest block on this section of line.

The other parameters are considered to be equal to those recommended by the Swedish railways, namely: *k = 75% and m = 3.3 minutes = 198 seconds*[18].

The calculation is made using:

$C_{practical} = k * (T_{ref} / ((L/V) + m)) = 0.75 * (5760 / ((2*2800 / 27.8) + 198)) = 14.46$ *trains,*

[18] ***Reminder: k is the coefficient flexibility and m is the margin to be added to the sequence times because of approximations.***

which rounds down to 14 trains as capacity during this period.

Calculation of saturation rate S	
Method: N / $C_{practical}$	
Line:	Nîmes - Montpellier
Direction:	2
Section:	Montpellier - Nîmes
Capacity of network (SIMON): $C_{practical}$	14 trains
Train paths actually scheduled: N	12 trains
Therefore S =	86%

Figure 36. Calculation of saturation rate using SIMON method

Case study conclusion

On the Nîmes-Narbonne line, saturation is felt primarily in Nîmes and Montpellier, the traffic flow being higher than on the other sections due to the passage of certain scheduled services (TGV, services between Alès and Montpellier, amongst others).

Moreover, what in particular reduces the capacity of the section from Nîmes to Narbonne for two trains moving in parallel (night freight trains primarily) is the fact that the blocks are relatively long. For example, almost 2/3 of the blocks are longer than 2,200 m, whereas the reference lengths of the blocks is between 1,500 and 2,000 metres. Amongst these are some of even longer length and might merit attention (subdividing block lengths here and there). A particular instance on the section from Nîmes to Montpellier is the presence of several seldom-used halts. Maintaining a service to these stations could be discussed with the organising authority (regional council).

It should be noted that the situation today (in 2011) has improved slightly since the time of this study, due to the withdrawal of low performance locomotives (BB 8100, X 4500).

Appendix 5. Average Speed

The 'average speed' parameter is a service quality indicator, notably in comparing with other modes of transport.

This map is taken from the report "Monitoring indicators for strategic routes and nodes of transport policy" [30].

This indicator describes the average road speeds between city centres and the scheduled railway speed between nodes.

For road transport, the speed calculation made in 2001 takes into account the following cycle: 4 h 30 minutes driving / 45 minutes rest/ 4 h30 min driving / 11 hours of rest, using solitary drivers.

For rail transport, the theoretical train speed is the average speed of trains on 8th January 2002. Other than full trains, travelling between private sidings, rail speeds do not take into account the times before and after train movements, nor the associated handling times (**total average speed can thus sink to less than 15 km/h**). The very great variability of the average speeds must be noted, and especially the great discrepancy between day and night operations, this last being more effective (less restrictions due to passenger services and maintenance periods). The very wide differences in train speeds (from 90 to 140 km/h, or even 160 or 200 km/h) is another key point. With regard to the connection between Poitiers and Bordeaux, RFF estimate that the speed of 74 km/h is high and in any case only feasible at night.

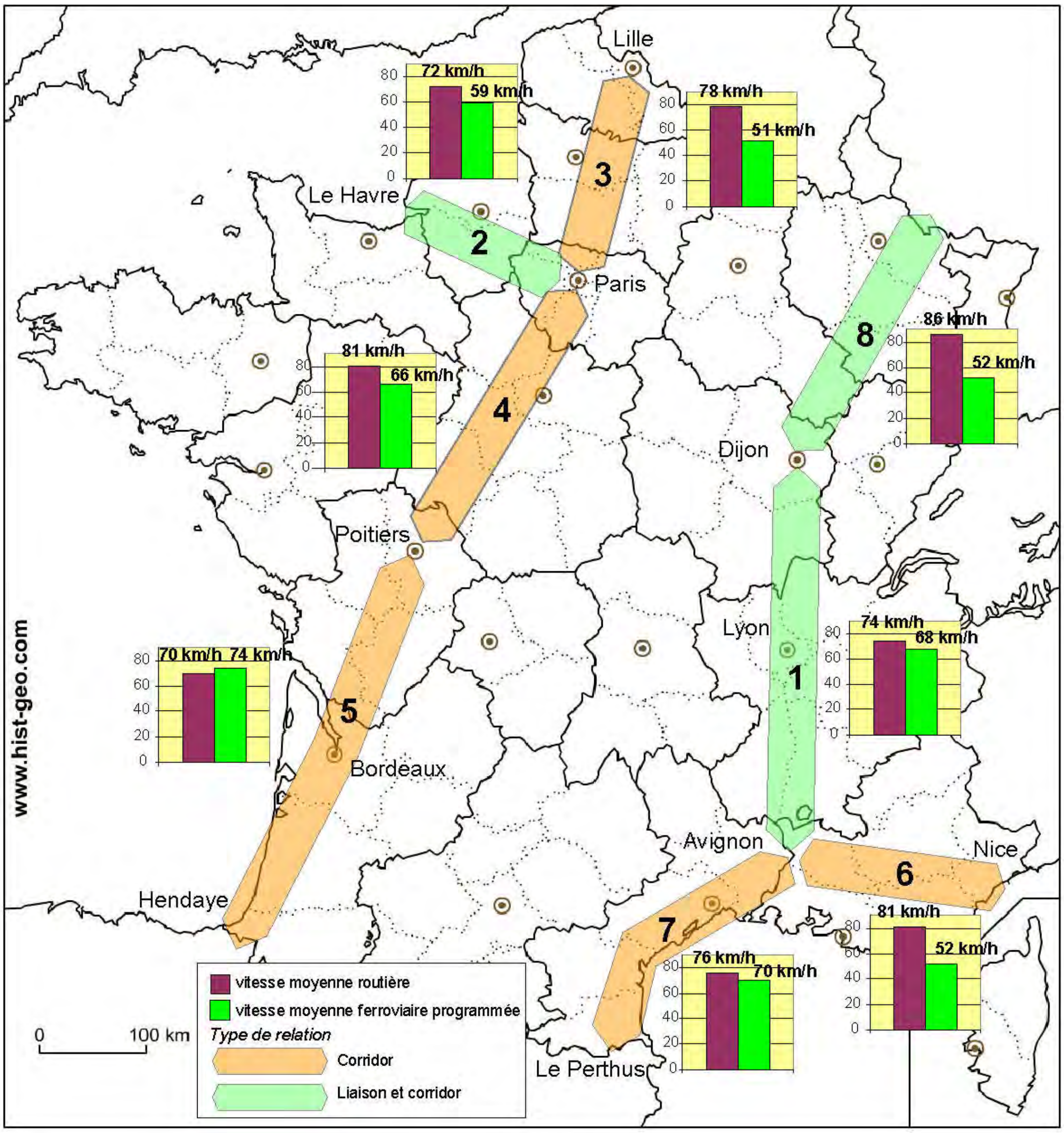


Figure 37. Average road speeds (purple, 2001) and scheduled rail speeds (green, 2002) for main freight corridors – www.hist-geo.com

However, certain freight services such as express parcel trains can reach **high commercial speed** under specific conditions. French examples:

- Up to 2011, SNCF used the so-called "*Trains Bloc Express"* to link Paris to Toulouse and Marseille, by night. These parcel trains were partly running on high speed line at 200 km/h

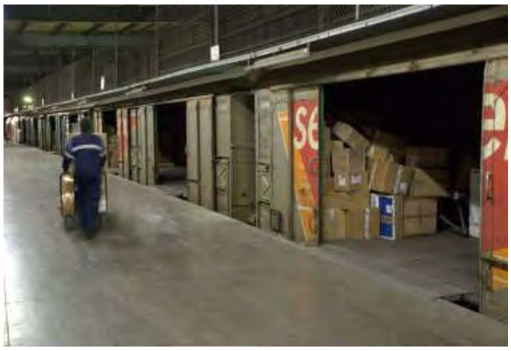


Figure 38 : Loading/unloading facility of TBE/Trains Bloc Express – image IPB.

- Froid Combi, road-rail company, operates two night services of refrigerated swap bodies (2*5 round trip per week), at a maximum speed of 160 km/h between Avignon and Dourges, and 140 km/h between Avignon and Paris. This implies some constraints, particularly limitations of weight and length of trains, but leads to very interesting journey durations : 8hrs for Paris-Avignon link (740 km, average speed 93 km/h), 9hrs for Avignon-Dourges link (~950km, average speed 106 km/h).

- The "autoroute ferroviaire" (~rolling motorway – see section 5 : combined road-rail transport) between South of France near Perpignan and Bettembourg in Luxembourg, *via* Avignon and Lyon (1050km), achieve 4 daily round-trip within 14h30 (average speed: 73 km/h, faster than road), with brief loading and unloading operations. This is permitted by good performance train paths, with few stops.

- Since 1984, *La Poste* owns a fleet of 3 (and half, for maintenance scheduling) TGVs (*Trains à Grande Vitesse* / high speed trains). These trains allow a 300 km/h speed for postal services.

Figure 39: La Poste operates with SNCF yellow high-speed trains at 300km/h at night, since 1984 : Paris - Mâcon (north of Lyons) and Paris - Cavaillon (North of Marseille) – © Bruno Meignien.

- Carex, an European project, aims to do the same at an European scale between airports, transporting at high-speed, with a fleet of dedicated high-speed trains, high-value cargo between airports. This project suffers however a fragile business model, strongly economic climate - dependent.

Section 4

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Introduction

In the last 30 years in France, road transport traffic (measured in t-km) has increased 2.5-fold whereas, over the same period, goods transport by rail has dropped by 50% (see graph p 21). Many other European countries know a similar growth in road transport – contrary to France, some countries, as Germany, have much increased their rail transport too.

Being centrally positioned in Europe, France is a transit country, a mandatory thoroughfare for trade between peripheral countries such as Italy, Portugal and Spain. In addition to this overland through traffic, Spain and Italy entertain special business relations with the greater south-east area of France (Italy is the leading customer of the Provence-Alpes-Côte d'Azur region and the second-biggest of the Rhône-Alpes region, and the main supplier to both of these regions).

Growth in road transport can be explained by several factors:

- new forms of organisation of industrial processes and the economy that are highly demanding in terms of flexibility and reliability of transport (just-in-time), and rely in particular on the complementarity of sea/road freight;
- strong competition reigning in the road transport sector that is pulling prices down: road transport prices have dropped by 30% since 1985;
- development of highway infrastructures;
- high proportion of short or mid-distance transport, to which other modes are less suited;
- dismantling of customs barriers, which has resulted in faster growth in exchanges – and therefore partly in road traffic – within this new space.

Regardless of the measures implemented to limit road traffic, it continued to rise significantly until 2004 ; an apparent levelling-off occurred in 2005, and a strong decrease happened in 2008, linked to the crisis : one week after the bankruptcy of Lehman Brothers (15th September 2008), France's motorway traffics dropped by 20%. In one day – because of the common one week delay for orders. An increase in road transport occurred in 2009, but recent figures do not confirm this trend (stagnation).

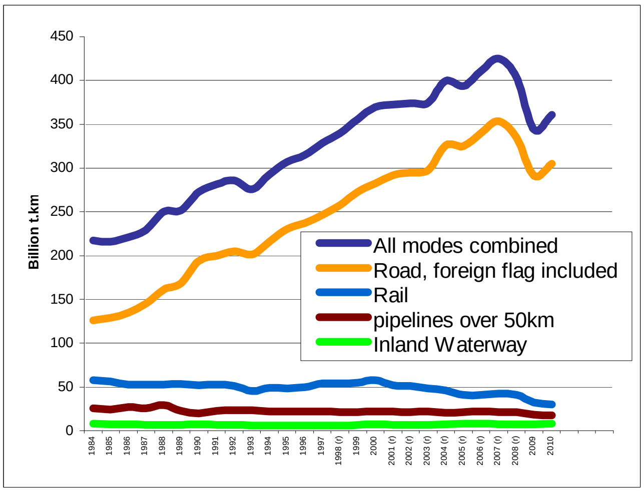
The issue facing highway and motorway authorities centres on getting more vehicles using the motorway without affecting the level of service, in other words:

- with the same level of safety;
- with no constraint on speed;
- without increasing the travel times of all road network users.

This high demand has led in many sectors to more or less sustained congestion phenomena appearing on a more or less random basis.

The purpose of this part is to evaluate the relevant parameters enabling the capacity of the road network to be characterised and measured. To provide a clearer understanding of the area of road transport, this section will successively deal with the following subjects:

- organisation of road transport (general characteristics, legislation, traffic flows, etc.);
- vehicles;
- road network characteristics;
- notions linked to highway infrastructure capacity.



For reference, graph normal size p 21 (billions t.km transported in France, 1984-2010)

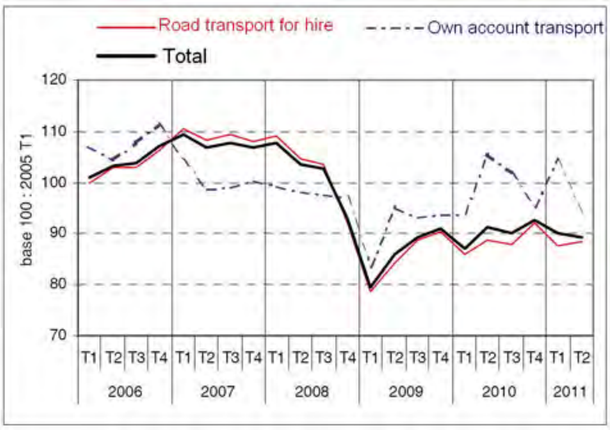
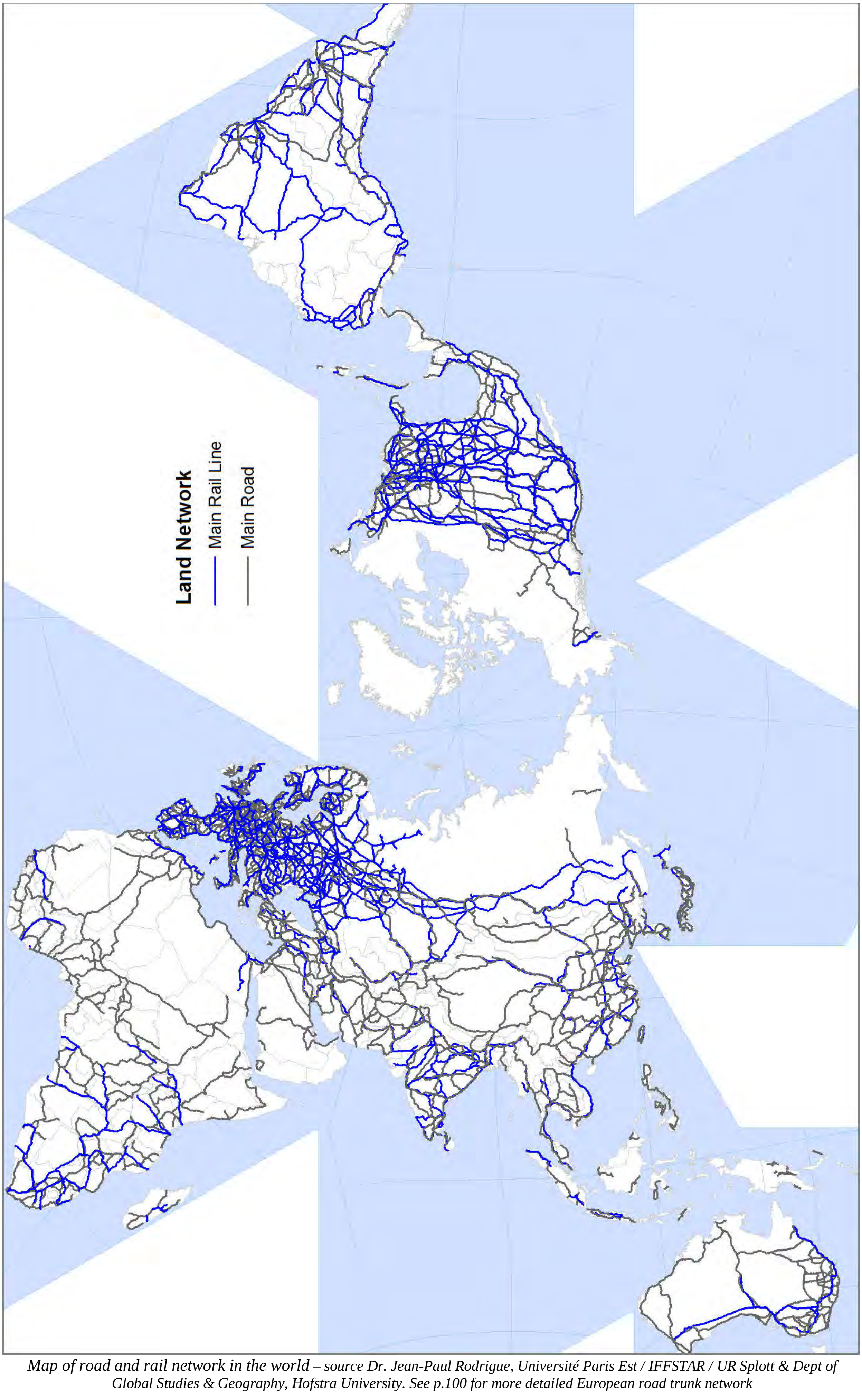


Figure 1: t.km transported by road in France – source SOeS



Map of road and rail network in the world – source Dr. Jean-Paul Rodrigue, Université Paris Est / IFFSTAR / UR Splott & Dept of Global Studies & Geography, Hofstra University. See p.100 for more detailed European road trunk network

1 - Regulatory and Organisational Framework of Road Transport

1.1 - Stakeholders

The main stakeholder in goods transport is obviously the road carrier. Carriers comprise private transport companies and self-employed truck drivers. They are classified according to the length of their routes or according to their specific services.

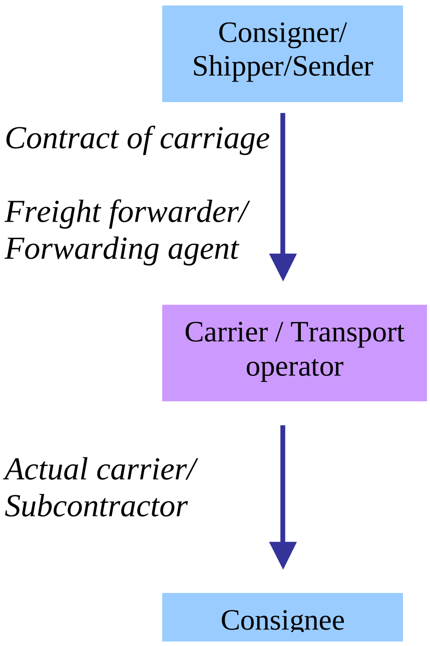


Figure 2. Road transport chain (applicable to all modes).

The following distinctions can therefore be made according to the road carriers' activity (French business classification (NAF) code, relating to transport for hire - *cf.* 1.2.). Note that businesses involved in the organisation of transport may also provide a carriage service:

- Transport
  - community transport (60.2L)
  - intercity transport (60.2M)
  - removals (60.2N)
  - truck hire with driver (60.2P)
- Organisation of freight transport:
  - parcel delivery and express freight services (63.4A)
  - freight contracting (cf. lexicon) (63.4B)
  - organisation of international transport (63.4C)

In France 2010, the road transport sector comprised 41,000 companies, around 75% of which employed fewer than five people – comparable to European situation, with very little companies ; average number of employees by road transport company in EU 2008 : 4,1. A total of 330,000 people were employed in the sector. Drivers accounted for some 75 to 80% of salaried staff. The average workforce per company is increasing regularly every year. These firms own 130,300 fifth-wheel tractors and 52,200 rigid trucks.

The organisation of freight transport (parcel delivery services, express freight and charterers) comprised in 2005 3,600 firms employing around 225,000 people and having over 67,000 trucks and 142,000 fifth-wheel tractors at their disposal.

Professional organisations and the French road transport committee (CNR = "Comité National Routier") also exert considerable influence on the orientation of the activity.

<u>The CNR</u> was originally set up by decree on November 14, 1949 with the purpose of managing the mandatory road tariff system (TRO = Tarification Routière Obligatoire). Its missions have changed over the years due to the liberalisation of transportation resulting in the abolishment of the TRO. It was transformed into a "Professional Committee for Economic Development" by decree of March 13, 1989. The premier mission of the CNR involves monitoring the functioning of road transport markets (and particularly changes in operating conditions and cost components).

<u>Road transport representative organisations</u>, the main ones being:

- The French road transport federation (FNTR = Fédération Nationale des Transports Routiers): historically the oldest, and also the largest organisation in the sector. It has a comprehensive territorial structure and is present in most districts of France. Its missions include supporting the development of the sector, defending and promoting its interests and preparing for the future of road transport.

- The national union of road hauliers' associations (UNOSTRA = Union Nationale des Organisations Syndicales des Transporteurs Routiers Automobiles) was created as a result of a rapprochement between the national federation of small and medium-sized transport companies and the "self-employed drivers' movement".

- The federation of French transport and logistics companies (TLF = Fédération des Entreprises de Transport et Logistique de France): its essential missions are to defend, promote and enhance the transport and logistics industry.

1.2 – Own account and for hire

Transport "for hire", or common carriage, in the field of goods transport, relates to a transport service provided by a professional carrier, on behalf of another person (legal or physical), in return for payment. Transport for hire is the opposite of transport "on own account".

Transport for hire must fulfil certain characteristics:

- it is the company's main activity;
- the company is entered in the register of carriers and rental agents;
- the vehicles used have operating licences.

Transport on own account relates to transport by a company on its own behalf. Transport on own account fulfils three conditions:

- the vehicle must belong to the company or be hired from a rental agent authorised to exercise this function;
- in this vehicle belonging to the company or regularly hired by it, the company can only transport goods:
  - owned, sold, produced, repaired, transformed, converted, etc., by the company;
  - or which have been entrusted temporarily to the company for the purposes of transformation, repair, machining, etc.
- transportation must only be an incidental or complementary activity to the main business conducted by the company.

Companies operating transport on own account work in a less restrictive manner, from the point of view of legislation, than a professional carrier. The crucial problem for transport on own account is the one of empty return legs, notably higher than for transport for hire.

Transport for hire, the largest sub-sector, represents 84% of t-km and 61% of tonnage (source: SESP/road transport survey[1]).

[1] ***The permanent road transport survey relates to transport for hire and on own account, using trucks with a GVWR in excess of 3.5 tonnes and fifth-wheel tractors less than 15 years old, and covers domestic transport and the French leg of international transport.***

1.3 – Organisation of transports

Road transport practices are highly varied, adapting to demand and its evolution. A distinction can therefore be made between several segments of road transport according to:

- the structural characteristic of the consignments transported:

- **full truckload (FTL):** a FTL covers a single consignment, issued by a single consignor and addressed to a single consignee, and occupying the totality of a unit load;
- **groupage**: action consisting of grouping together consignments of goods from several consignors or addressed to several consignees, organising the carriage of the resulting load and having it transported by a carrier;
- **parcel carriage**: this differs from less-than-truckload (LTL) freight (to give an order of scale, "parcels" weigh less than 500 kg, with some services taking loads of up to 3 tonnes). In the strict sense of the term, it should only cover transportation involving five successive operations: collection round, groupage after cross-docking, transfer from consignment hub to destination hub, cross-dock break-bulk and delivery round. Where inter-hub transfer is outsourced to a road transport contractor, reference will be made to consolidated truckload transport;

- certain specificities of the goods affecting transport conditions:

- controlled temperature (transport in insulated vehicles, particularly concerning fruit and vegetables, fresh meat products, milk and dairy products, sea food, pork products and cured meat, fresh or frozen ready-made dishes, cakes, pastries, croissants and other bakery products);
- bulk solids and bulk liquids;
- hazardous materials, etc.

Today, the major transport groups tend to propose the widest possible range of services covering practically all segments of road transport. As a result, they optimise their transport networks and guarantee specific solutions for each business sector and each customer. The contract of carriage by road is materialised by the CMR waybill[2]. Pricing takes account of the weight and nature of the goods and the distance to be covered.

[2] ***The Geneva Convention, known as the "CMR Convention" (CMR =*** **Convention de Marchandise par Route,** ***or contract for the international carriage of goods by road) governs transport conditions and the carrier's responsibility. The TIR Convention (TIR =*** **Transport International par Route,** ***or International Road Transport) applies to goods originating from or addressed to a non-European Union country having ratified the convention.***

1.4 – Road transport regulations

1.4.1 – Access to profession

Road transport is a regulated profession. These regulations, harmonised at European level, apply to companies whose business is transport for hire. In particular, they include **rules governing access to the profession of road transport operator**: the three qualitative criteria are good repute, financial standing and professional competence and admission is granted through inscription on a register held by departments within the French Transport Ministry (regional-level offices for infrastructure). Companies undertaking transport on own account are not subject to these rules.

The fully liberalised European market is subject to evolving regulations aimed at:

- technical harmonisation of vehicles;
- social harmonisation (European social regulations) setting rules specific to the occupation of truck driver (driving and rest times, work time, vocational training, driver accreditation, etc.);
- harmonisation in the taxation of infrastructures for road users.

In this context of European competition, the French Government must be attentive to the competitiveness of national road transport firms[3] and to the economic vitality of this sector.

1.4.2 – Social regulations and driving time

For drivers of vehicle with a GVWR/Gross Vehicle Weight Rating (or aggregate GVWR for a tractor-trailer combination) of over 3.5 tonnes, loaded or empty, in the territory of all Member States of the European Union, the maximum driving times are as follows (cf. EC regulation n° 561/2006 [31]):

- continuous driving period: maximum of 4h30 without interruption followed by an uninterrupted break of at least 45 minutes;
- daily driving time: maximum of nine hours, with a possibility of extending to 10 hours on two days per week;
- daily rest period of 11 hours, with a possibility of reducing the rest period to nine hours no more than three times per week;
- maximum driving time of 56 hours per calendar week, with a 90-hour limit over a two-week period;
- no more than six consecutive days of driving.

All vehicles must be equipped with an approved control device.

From January 1, 2006, all road transport vehicles (over 3.5 tonnes) and passenger vehicles (with more than nine seats) newly entering into service must be equipped with an electronic tachograph. The introduction of the electronic tachograph is designed to fulfil various improvement targets and generate new behaviours:

- improve road safety;
- ensure reliable monitoring of driver activity (driving time/rest periods);
- guarantee fair competition;
- achieve gains in the processing of social data;
- develop use of onboard computing;
- bring innovative tools to transport operators.

1.4.3. Traffic restrictions for heavy goods vehicles (HGVs)

Today, there is a certain amount of arbitration (to the detriment of HGVs) to improve vehicle traffic flow at peak times: general restrictions prohibiting HGV traffic over the entire French road network are also established annually by Ministerial Order. Vehicles and combinations of vehicles with a gross vehicle weight rating in excess of 7.5 tonnes, used for goods transport by road, excluding special vehicles and farm vehicles and equipment, are prohibited from travelling on the entire network from 22h on Saturdays to 22h on Sundays, and from 22h on the day preceding a public holiday to 22h on the following day[4]. Additional restrictions

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[3] Today, the cost of road transport mainly results from the evolution in energy costs, salaries and social security contributions and taxes. The Government is therefore seeing to it that more balanced competitive conditions are established between French companies and those in other European countries, notably through greater fiscal flexibility (reduction in local business tax, consideration to lower contributions, etc.).

[4] This is not a satisfactory situation as this measure is not generalised at European level; consequently, a HGV stacking area forms at the borders with a sudden release at 2200 hours on Sundays. As the stacking area is vacated (the duration of which depends on the number of HGVs stacked at the border), uninterrupted lines of HGVs form on the motorway, creating highly dangerous situations. On certain sections, HGVs are prohibited from overtaking in an attempt to keep passenger

prohibiting HGV traffic in the winter period on a part of the network and in the summer period over the whole network are also established every year.

Prefectorial or municipal orders can also restrict HGV traffic locally.

Regulations governing the **transport of hazardous goods** by road are essentially established through international agreements: the ADR agreement for carriage by road (ADR : from French *"Accord européen relatif au transport international des merchandises Dangereuses par Route"*). These international agreements are supplemented in French law by Ministerial Orders (December 22, 2006 Order relating to the carriage of hazardous goods by road, known as the "ADR Order" [32]) and are mandatory for national and international transport. Locally, the authority responsible for policing traffic on the roads in question (the Prefect, the mayor in built-up areas, etc.) can prohibit vehicles transporting hazardous goods, and identified as such, from using certain routes. Hence the local authority can take into account certain situations presenting particular risks, such as the road's environment, for example.

1.4.4 – Charges for infrastructure usage

Several types of instrument are used for levying charges in relation to road transport:

- taxes on vehicle ownership: a special tax on certain road vehicles, known as "**axle tax**", is intended to compensate for the additional expense incurred in maintaining and reinforcing roads due to high-tonnage vehicle traffic. It applies to road transport vehicles with a Gross Vehicle Weight Rating (GVWR) of 12 tonnes and over. In the total cost of goods transport by road, this tax represents a relatively low fixed cost. A European fiscal harmonisation directive has set scales for this tax which is levied on HGVs of 12 tonnes and over;
- fuel taxes: domestic tax on petroleum products (**TIPP** = *Taxe Intérieure sur les Produits Pétroliers*) applies to all products which are intended for use, sold or used as engine fuel. This tax is collected on volumes and not on the selling price of the product; a fixed sum in euro is therefore collected on each unit sold. It represents approximately half of the price of diesel (excluding VAT, as this is reclaimed), which corresponds on average to 12% of the total cost of transport;
- fees for the use of infrastructures: these fees primarily consist of tolls, as described in section 3.2.2.

The Eurovignette

The Eurovignette Directive was adopted by the Transport Council in March 2006. It establishes a European framework for charging for the use of infrastructures, applies to the trans-European road network and increases the possibilities of charge differentiation and levying toll surcharges in sensitive areas (by up to 25% if revenues are allocated to cross-border projects and to the development of alternative modes to road transport). It is therefore up to the member states whether or not they use the significant margins of flexibility offered by the Directive to implement a "greener" policy.

This new Directive approaches the subject of internalisation of external costs by requesting a methodological document from the Commission. The Commission presented by June 10, 2008, "*a generally applicable, transparent and comprehensible model for the assessment of all external costs*" to serve as the basis for a new legislative proposal, which was adopted by the European Parliament by 6th June 2011. The directive 2011/76/UE allow Member States to levy **3 to 4 cts/km** on the trans-european network for road noise and air pollution, with modulation in relation to age of the vehicles (EURO class, from –100 to +25%) and congestion (up to +175%). It should apply at the end of 2011, after formal adoption by the State Members.

The Heavy Goods Vehicle toll in Germany (LKW Maut)

The German HGV toll is a mandatory distance-based tax for trucks over 12 tonnes which has been in effect since January 1, 2005. The toll is levied on over 12,500 kilometres of the German network. In 2006, the 25.8 billion kilometres covered generated 3.08 billion euro in revenue (compared with 600 million euro of operating costs). One of the consequences is that, as in Switzerland, loads have been optimised. Moreover, as the toll is modulated, there is an incentive to invest in more environmentally-friendly vehicles. As a result, the vehicles on the roads are being rapidly renewed.

vehicle traffic flowing smoothly. This HGV stacking problem is a crucial issue: transit plans have been set up on some routes.

1.4.5 – European regulations governing pollutant emissions

Regulations developed at European level[5] provide for the continuation of efforts to reduce all regulated pollutants (nitrogen oxides, unburnt hydrocarbons, carbon monoxide and particulates). In parallel, by virtue of the Kyoto agreements, the public authorities are focusing their action on reducing emissions of CO_2. However, in 2011, there were no CO_2 antipollution standards for HGV

The Euro 5 antipollution standard currently in force applies to all vehicles registered since October 1, 2006. This standard, defined in Directive 98/69/EC [35], imposes a reduction of 40% for emission of NOx, compared with Euro 4. CO, HC and particulates remain at the same levels.

The Euro 6 standard will apply to all vehicles registered after December 31, 2012. Compared with Euro 5, pollutant emission levels will be even more drastic for NOx, HC and particulates, whereas Euro 5 concentrated on NOx.

Older vehicles are also the most polluting. However, the increasingly strict antipollution standards implemented since 1988 only apply to new vehicles. Various sorts of fiscal incentives (tax credits, scrappage premium, progressive tax systems, no-claims bonus, etc.) designed to encourage fleet renewal have been introduced.

At the same time, the running characteristics of a vehicle change with age: the average annual distance covered and the split in runs between urban areas and open countryside are all factors which have a bearing on pollution.

Factors of progress enabling the implementation of these standards particularly include technical solutions with new engine concepts (use of diesel particulate filters to minimise the hydrocarbon level or a catalytic converter to burn exhaust gases). Some techniques, however, can sometimes cause over-consumption and therefore an increase in CO_2 emissions (catalytic converter in particular).

Optimisation of tyre texture (tread design) and vehicle aerodynamics makes a positive contribution to energy savings. This would also be the case if heavy goods vehicle traffic were facilitated by special HGV corridors and less frequent stops.

The delay between the implementation of regulations and their impact on emissions due to the vehicle renewal rate must also be considered.

As far as pollutant emissions from HGVs are concerned, speed is an important factor: the speed at which minimal CO_2 is emitted, with present-day fuel compositions, is around 80 km/h. Discussions are currently on-going in France to limit HGVs speed to 80 km/h (it also reduces road damages).

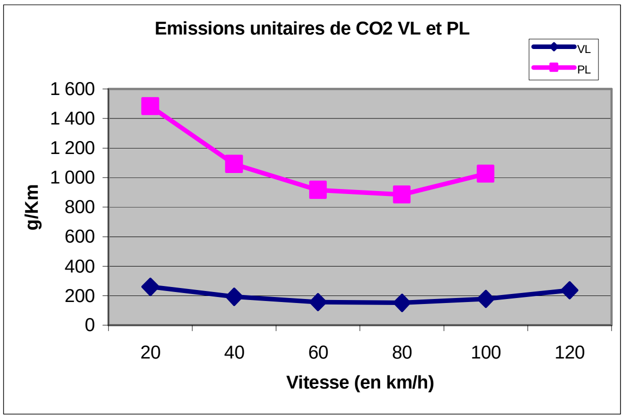

Figure 3. CO2 emissions w.r.t. speed (Source: Copert III) VL = Light Vehicles, PL = Heavy Goods Vehicles, Vitesse = speed. Statistics before the CO2 no-claims bonus for LVs

Standard	Date	Carbon monoxide (CO)	Nitrogen oxides (NOx)	Hydrocarbons (HC)	Particulates
Euro 0	1988/1990	12.30	15.80	2.60	
Euro 1	1992/1993	4.90	9.00	1.23	0.36
Euro 2	1995/1996	4.00	7.00	1.10	0.15
Euro 3	2000/2001	2.10	5.00	0.66	0.10
Euro 4	2005/2006	1.50	3.50	0.46	0.02
Euro 5	2008/2009	1.50	2.00	0.46	0.02
Euro 6	2013/2014	1.50	0.40	0.13	0.01

Figure 4. Antipollution standards applicable to HGVs (g/kWh)

[5] Air quality is governed by Framework Directive 96/62/EC [33] and three daughter directives defining the limit values for various pollutants. In parallel, Directive 2001/81/EC [34] sets the national annual pollutant emission ceilings to be complied with in 2010 and concerns Nox, VOC, SO_2 and NH_3 emissions.

5 - Analysis of traffic flows and road transport activity

For all notions mentioned and data given in this section, maps and more precise statistics are presented in Appendix 1.

1.5.1 – Traffic, major corridors and percentage of HGVs

Appendix 1 features maps showing French and foreign heavy goods vehicle traffic on the national road network. These maps reveal that the main HGV corridors in France correspond primarily to the North/South routes joining Spain/Italy, the Paris region and Northern Europe. A third map shows HGV flows across the Alpine and Pyrenean borders in 2004 – figures 2009 soon available by Sétra.

The proportion of HGVs on motorways is estimated at an average of 15%, and between 8 and 10% on highways.

In 2005, in terms of traffic, French-registered HGVs represented 4.9% of vehicle-kilometres (veh-km), while foreign HGVs represented 1.4% of veh-km. In total, HGVs therefore represented 6.3% of veh-km on the French road networks.

1.5.2 – Average distances covered by HGVs

In view of the diversity of road transport practices and routes, consideration of the average distances covered by HGVs is not very meaningful as these averages do not take account of the various transport structures. It does, however, allow the overall activity of road carriers to be quantified.

In 2007, a heavy goods vehicle registered in France covered on average around **50,000 km per year**; a value that had remained fairly stable since 1999 (source: INSEE, road transport survey) – This figure dropped to 43,000km in 2009 due to the crisis. The CNR considers however that a large-volume (26 tonne) truck tractor covers an average of 117,000 km per year and that an 11/13-tonne rigid tilt truck (see page 18 for definition) covers around 49,000 km per year (CNR long distance survey). As an indication, the lifetime of a fifth-wheel tractor or truck can reasonably be expected to approach 750,000 km.

SOeS statistics (2005 road transport survey) give average distances (relatively stable[6] since 1996) for the various types of road transport:

- goods transported by road on own account cover an average distance of 40 km as quite often it involves a local service;
- goods transported by carriers for hire cover average distances of 140 km;
- the average distance for transport on own account and for hire is around 95 km.

The 2010 SoeS statistics also reveal that 58% of tonnage is transported less than 50 km, but if tonnage is weighted by distance, the greatest distance class is the “over 150 km” category with 70% of t-km – 73% in 2005 : long distance was more impacted than short distance by the 2008-2009 crisis.

1.5.3 – Average loads and empty HGV rates

An important element in the activity of a road carrier is the average HGV load. This has been regularly increasing for a number of years: it was 11.7 tonnes in 1990, 12.4 tonnes in 1999 (an average of 7.4 t for rigid trucks and 18.5 t for articulated vehicles),12.9 tonnes in 2004, 14.2t in 2006. These figures exclude empty vehicles (source: SITRAM database). The increase in average loads is largely explained by the evolution in the structure of the HGV fleet : rigid trucks are being abandoned in favour of articulated vehicles.

The issue of empty HGVs is also to be taken into account as this is one of the elements having a strong influence on the organisation of transport systems, in order to restrict unladen journeys to a minimum and make the trip as profitable as possible. Taking all types of carriage into consideration, the number of unladen journeys amounts to 43%. There are, however, great disparities according to the type of journey : there is an especially high rate of unladen journeys in own account transport (for hire : only ¼).

A heavy goods vehicle is considered to be full when its load:

- has reached its weight limit;
- or has reached its volume limit;
- or, in certains cases, has reached its floor area limit.

[6] These are averages which conceal the significant disparities that exist in goods transport.

1.5.4 – HGV traffic distribution over time

It is important to understand that light vehicles and HGVs do not have the same traffic time distribution, and not just on motorways.

If monthly traffic variations are considered, it is observed that **HGV traffic is almost constant throughout the year in terms of numbers of HGVs**. Given that light vehicle traffic fluctuates considerably with the summer migrations in particular, the percentage of HGVs falls quite naturally during this period.

As far as hourly traffic variations are concerned, a **high level of regularity** is observed in the **spread of HGV traffic throughout the day**, whereas fluctuations in light vehicle traffic are much more marked (except in proximity to built-up areas).

Statistical applications of these elements are presented in Appendix 1.

2 - Road Transport Vehicles

The "heavy goods vehicle" umbrella term covers a number of types of vehicle with varied characteristics:

- silhouette: rigid truck or tractor, length, etc.;
- trailer body;
- capacities;
- multiple models according to the type of goods carried, etc.

A heavy goods vehicle is a road vehicle with a gross vehicle weight rating (GVWR) of over 3.5 tonnes, used for goods transport (truck, semitrailer or road train).

A **heavy goods vehicle** differs from a light vehicle not only on a technical level (much greater axle load, dimensions, etc.), but also on an administrative level: a specific licence and appropriate training are necessary to drive a HGV and special traffic regulations apply.

Furthermore, in the context of freight transport, utility or light commercial vehicles (less than 3.5 tonnes) also play an important role, especially for parcel delivery and transporting goods by road in towns and cities.

2.1 – Composition of an HGV

The terms used to define trucks and their equipment by the public authorities, insurance companies and manufacturers are as follows:

Rigid truck : utility motor vehicle equipped with a loading capacity.

Fifth-wheel tractor: motor vehicle. It is designed to tow semitrailers attached to the tractor by means of a fifth wheel. This fifth wheel, bolted to the tractor chassis, receives the semitrailer kingpin which forms the hitch pivot point.

The European Commission, the ECMT/*European Conference of Ministers of Transport* – now the ITF/*International Transport Forum* – and the UNECE */United Nations Economic Commission for Europe* have developed and adopted the following definitions in the document entitled "Terminology on combined transport" [36]:

Rigid truck or carrier: self-propelled vehicle.

Trailer: non-powered vehicle for the carriage of goods, intended to be coupled to a motor vehicle, excluding semi-trailers.

Road train: motor vehicle coupled to a trailer.

Semi-trailer: non-powered vehicle for the carriage of goods, intended to be coupled to a motor vehicle in such a way that a substantial part of its weight and of its load is borne by the motor vehicle. Semi-trailers may have to be specially adapted for use in combined transport.

Articulated vehicle: motor vehicle coupled to a semi-trailer.

2.2 - Weights and dimensions

The various terms referring to vehicle weights and loads are as follows:

- **Kerb weight (unladen weight)**: this is the weight of the vehicle in running order, i.e. with a full tank of fuel, the maximum oil and coolant levels, and the tools and spare wheel supplied by the manufacturer, and excluding a driver or passengers;
- **GVWR (Gross Vehicle Weight Rating)**: weight limit in the country of registration for a vehicle or a trailer with its load (passengers, driver and cargo). This weight appears on the vehicle registration document and the manufacturer's identification plate. The GVWR cannot be exceeded;

- 1 rigid truck (63% of industrial vehicles in France 2010)

- 2 trailer

- 1 + 2 = truck + trailer, forming a road train

- 3 tractor (37% of industrial vehicles in France 2010)

- 4 semi-trailer

- 5 articulated vehicle with tridem semi-trailer

- 6 double train with tractor, semi-trailer and dolly trailer

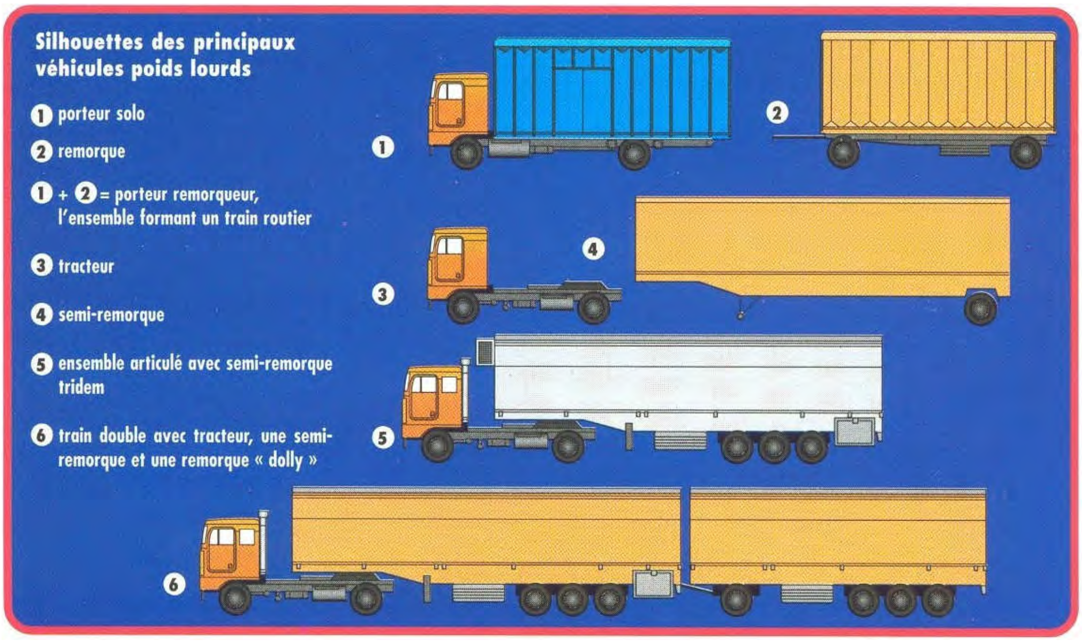

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Figure 4. Silhouettes of the main heavy goods (Source: Editions Atlas)

- **GCWR** (**Gross combined weight rating**): weight limit of the double train or articulated vehicle. This weight appears on the motor vehicle registration document (it is not equal to the aggregate GVWR);
- **Actual weight**: weight observed on the weighbridge scales (this weight cannot exceed the GVWR of the vehicle or the GCWR of the double train or articulated vehicle);
- **Payload**: this is determined by the difference between the GVWR and the kerb weight. It corresponds to the maximum load that it is possible to put in a vehicle.

Maximum vehicle dimensions are set by national and European regulations (Directive 96/53/EC [18]). In France, vehicle dimensions are laid down in Article R. 312 of the Highway Code

Consequently, vehicle **width** must not exceed 2.55 m (except for controlled-temperature vehicles which may be 2.60 m wide). Lengths vary according to the type of vehicle:

- rigid truck: max. 12 m;
- trailer: 12 m excluding the hitch device;
- semi-trailer: 12 m from the kingpin and the rear of the semi-trailer and 2.04 m between the kingpin axis and any point at the front of the semi-trailer;
- articulated vehicle: 16.50 m;
- road train: 18.75 m.

In France, there are no vehicle **height** limits although they are subject to certain gauges both nationally (bridges, tunnels and rolling roads) and internationally (generally 4 metres in European countries). Consequently, the headroom (height clearance) under an engineering structure is limited in France to 4.30 m over the entire national network, to 4.50 m on the major international traffic routes described in the 1975 Geneva Agreement [37] and to 4.75 m on motorways (Highways Directorate circular of October 17, 1986).

The **axle maximum load** is 13 tonnes in France (being discussed, as generally 11,5t in Europe), except for tandem axles for which the limit is 19 tonnes. The **GVWR** also depends on the type of vehicle (see Figure 5).

A table in Appendix 2 presents an overview of the maximum weights and dimensions of vehicles on the road in the Member States of the European Union (source: ECMT).

As a general rule, in France, the gross combined weight rating of a vehicle must not exceed 40 tonnes for road vehicles with more than four axles (Article R. 312-4 du Code de la route). However, special provisions make it possible to raise this ceiling in certain cases:

- transport of a **certain type of merchandise**: logs and roundwood (up to 72 tonnes);
- **combined transport**: pursuant to point III of Article R. 312-4 of the French Highway Code, the gross combined weight rating of an articulated vehicle, double train or a train consisting of a motor vehicle and a trailer comprising more than four axles, used for combined transport, may exceed 40 tonnes but not 44 tonnes;

PERMISSIBLE MAXIMUM WEIGHTS IN EUROPE (in tonnes)							
Country	Weight per bearing axle	Weight per drive axle	Lorry 2 axles	Lorry 3 axles	Road Train 4 axles	Road Train 5 axles and +	Articulated Vehicle 5 axles and +
Austria	**10**	**11.5**	**18**	**26**	**36**	**40**	**40**
Azerbaijan	**10**	**10**	**18**	**24**	**36**	**42**	**44**
Belgium	**10**	**12**	**19**	**26**	**39**	**44**	**44** (1)
Bosnia-Herzegovina	**10**	**11.5**	**19**	**26**	**38**	**40**	**40**
Bulgaria	**10**	**11.5**	**18**	**26** (2)	**36**	**40**	**40**
Croatia	**10**	**11.5**	**18**	**24**	**36**	**40**	**40**
Czech Republic	**10**	**11.5**	**18**	**26** (2)	**36**	**44** (2)	**42 / 48**
Denmark	**10**	**11.5** (3)	**18**	**26** (2,3)	**38**	**42 / 48**	**42 / 48**
Estonia	**10**	**11.5**	**18**	**26** (2)	**36** (4)	**40** (5)	**40**
Finland (6)	**10**	**11.5**	**18**	**26** (2)	**36**	**44 / 60** (7)	**42 / 48**
France	**13**	**13**	**19**	**26**	**38**	**40**	**40**
Georgia	**10**	**11.5**			**44**	**44**	**44**
Germany	**10**	**11.5**	**18**	**26** (2)	**36**	**40**	**40**
Hungary	**10**	**11.5**	**18**	**25**	**30**	**40**	**40 / 44** (8)
Iceland	**10**	**11.5**	**18**	**26** (2)	**36**	**40**	**44**
Ireland	**10**	**11.5** (9)	**18**	**26** (2)	**36**	**44** (2)	**44** (2)
Italy	**12**	**12**	**18**	**26** (2)	**40**	**44**	**44**
Latvia	**10**	**11.5**	**18**	**26** (2)	**40**	**40**	**40**
Liechtenstein	**10**	**11.5**	**18**	**26**	**36**	**40**	**40**
Lithuania	**10**	**11.5**	**18**	**26** (2)	**36**	**40**	**40 / 44**(10)
Luxembourg	**10**	**12** (11)	**19**	**26**	**44**	**44**	**44**
Malta	**10**	**11.5**	**18**	**25**	**36**	**40**	**40 / 44** (8)
Moldova	**10**	**10**	**18**	**24**	**36**	**40**	**40**
Montenegro	**10**		**16**	**24**	**36**	**40**	**40**
Netherlands(12)	**10**	**11.5**	**21.5**	**33**	**40**	**50**	**50**
Norway	**10**	**11.5**	**19**	**26**	**37**	**42**	**44**
Poland	**10**	**11.5**	**18**	**26** (2)	**36**	**40**	**40**
Portugal (4)	**10**	**12**	**19**	**26**	**37**	**40**	**40**
Russia	**10**	**10**	**18**	**25** (2)	**36**	**38**	**38**
Slovakia	**10**	**11.5**	**18**	**26** (2)	**36**	**40**	**40**
Slovenia	**10**	**11.5**	**18**	**26** (2)	**36**	**40**	**40**
Spain	**10**	**11.5**	**18**	**26**	**36**	**40**	**44** (13) / **42** (14)
Sweden	**10**	**11.5**	**18**	**26** (2)	**38**	**48/60** (10)	**48/60** (10)
Switzerland	**10**	**11.5**	**18**	**26** (2)	**36**	**40**	**40**
Turkey	**10**	**11.5**	**18**	**25/26** (16)	**36**	**40**	**40/44** (10)
Ukraine	**11**	**11**	**16** (17)	**22** (17)	**38** (17)	**38** (17)	**38** (17)
United Kingdom	**10**	**11.5**	**18**	**26** (2)	**36**	**40** (18)	**40 / 44** (10, 18)

Source : International Transport Forum, 2009

1. 2 axles tractor + 3 axles semi-trailer: mechanical suspension = 43t ; pneumatic suspension = 44t
2. With air suspension or similar
3. Weight per drive axle: national traffic = 10t; international traffic = 11.5t; Lorry 3 axles: national traffic = 24t; international traffic = 26t
4. 3 axle tractor + 1 axle trailer = 35t
5. 3 and + axles tractor + 3 and + axles trailer = 44t
6. For vehicles registered in an EEA member country
7. 5 axles = 44t; 6 axles = 56t; 7 axles = 60t
8. 44t is applicable for 40 feet long ISO containers
9. Weight per drive axle: mechanical suspension (national traffic) = 10.5t; road friendly suspension (national traffic) = 11.5t; international traffic =11.5t
10. For vehicles engaged in combined transport
11. Weight per drive axle: mechanical suspension = 11.5t
12. Under specific conditions EMS (European Modular System) combinations may have a maximum length of 25.25 m and maximum mass of 60t
13. 3-axle motor vehicle with 2 or 3 axle semi-trailer carrying a 40 feet ISO container as a combined transport operation
14. 2 axle motor vehicle with 3 axle semi-trailer carrying a 40 feet ISO container as a combined transport operation
15. 5 axles = 48t; 6 axles = 58t; 7 axles = 60t
16. With the conditions laid down in Regulation for type approval.
17. Container trucks 2 axles = 18t; 3 axles = 24t; road train 4 axles, 5 axles and + and articulated vehicles 5 axles and + =44t; container trucks licensed by the state Motor Road service of Ukraine and State traffic Inspection Department: road trains and articulated vehicle 5 axles and + = 46t
18. For general operation at 44t, at least 6 axles are requires. The drive axle(s) must not exceed 10.5t and have twin tyres / road friendly suspension. Vehicles not having road friendly suspension on the drive axle(s) must have twin tyres and a maximum axle weight not exceeding 8.5t. Each part of the combination must have at least 3 axles and the trailer must have road friendly suspension

- **abnormal transport**: vehicles transporting containers with a combined weight of up to 48 tonnes (pursuant to the November 26, 2003 order [38]) are allowed on the road within a district or its adjacent districts provided that the Prefects have issued "*arrêtés de portée locale*" (local orders) in accordance with Article R. 433-3 of the French Highway Code;
- **transportation to and from ports**: pursuant to point III bis of Article R. 312-4 of the French Highway Code, vehicles up to 44 tonnes are allowed on roads around a shipping but solely to carry goods shipped by sea to or from this port. This provision was introduced by decree n° 2004-27 of January 7, 2004 [39].

On a European level, international transport is limited to 40 tonnes. Vehicles in excess of 40 tonnes are however allowed on the road for national transport in nine countries out of 25 – up to 60t in Sweden – some of which are France's immediate neighbours: Italy, Belgium, Luxembourg and the UK (all 44 tonnes).

2.3 - Speed limits

Articles R. 413-7, R. 413-8 and R. 413-9 (road

Outside built-up areas			Motorways	Priority roads signposted as such	Other roads	Discs to be displayed
Goods transport 	**3.5 t < GVWR or GCWR < 12 t**		**90**	**80** (**90** on roads separated by a central reservation only)	**80**	90 80
Articulated vehicles and road trains 	Tractor vehicle **GVWR < 3.5 t** **3.5 t < GCWR < 12 t**		**110**	**80** (**100** on roads separated by a central reservation only)	**80**	110 100 80
	**GVWR > 12 t** (non-articulated)		**90**	**80**	**80**	90 80
	**GVWR > 12 t** (articulated) (semi-trailers)		**90**	**80**	**60**	90 80 60
Transport of hazardous materials	**3.5 t < GVWR or GCWR < 12 t**		**90**	**80** (**90** on roads separated by a central reservation only)	**80**	90 80
	**GVWR and articulated vehicles /**	Not equipped with ABS brakes	**80**	**60**	**60**	80 60
		Equipped with ABS brakes*	**80**	**70**	**60**	80 70 60

* Order of November 23, 1992

Figure 6. HGV maximum speed limits in France (Source: http://www.code-route.com/vitesse.htm)

transport) of the French Highway Code set the speed limits for heavy goods vehicles and public transport vehicles (see Figure 6).

Harmonised community rules also exist regarding the limitation of speed at HGV manufacturing level (R. 317-6 and R. 317-6-1). Changes to traffic rules (R. 413-x) are in progress as a result

In built-up areas, speed is of course limited to 50 km/h, and sometimes less depending on local regulations.

2.4 - Vehicle types and characteristics

2.4.1 – Rigid trucks

A rigid truck is a utility motor vehicle equipped with a loading capacity. Rigid trucks have the cab and a platform for transporting goods on the same chassis. A trailer may be attached to increase the vehicle's capacity. Rigid trucks are essentially delivery vehicles. They have a wide variety of uses and dimensions although their maximum weight and dimensions are set by legislation.

Apart from the traditional box truck, there are numerous other types of rigid truck:

- **flat-bed trucks** are designed to carry voluminous and/or very long products (automobiles, steel products such as rails, tanks, joists, etc.);
- **tankers** are equipped with a permanently fixed tank;
- **tipping trucks** are vehicles designed to transport goods such as sand, rock, powder, earth, etc. Several configurations are possible depending on working environment and its maximum load capacity: 4 x 2, 4 x 4, 6 x 2 or 6 x 4 (total number of wheels x number of driving wheels);
- **refrigerated trucks** are rigid trucks equipped with an insulated body and a cold generator;
- **hook-lift trucks:** this type of rigid truck is equipped with a removable body. The hook lift is a hinged arm system which enables the truck to be equipped with various types of bodywork according to requirements.

2.4.2 – Semi-trailers

A semi-trailer is a non-powered vehicle for the carriage of goods, intended to be coupled to a motor vehicle in such a way that a substantial part of its weight and of its load is borne by the motor vehicle. Semi-trailers may have to be specially adapted for use in combined transport. The trailer is hitched to the tractor via a platform called a fifth wheel. A few examples of semi-trailers are presented below.

Curtainsider or tilt (Source: CETE Méditerranée)

Rigid truck (Source: CETE Méditerranée)

Semi-trailer for vehicle transport (Source: MTETM)

Flat-bed semi-trailer (Source: CETE Méditerranée)

Owing to the dimensions of the semi-trailer, advantage can be taken of the maximum dimensions allowed by the regulations and pallet loading is optimised. On the other hand, the semi-trailer does not permit intermodality except in the special case of semi-trailers reinforced for grappler handling. Systems for loading "normal" semi-trailers do however exist. In this case, a specific handling system is required at the ends of the services using this device. It should also be emphasised that, in certain cases, pallets need to be wedged on semi-trailers.

The other advantages of semi-trailers are their height and volume, the size and relative good health of the fleet, the existence of multiple bodies suited to various needs, their prices, etc.

The advantages and drawbacks of semi-trailers can be broken down according to vehicle types:

- **the tilt** is the most versatile vehicle which can be used to transport all sorts of goods. It is a light, relatively inexpensive vehicle. It can be loaded from the rear, from the sides and even through the roof. The drawback is that the tarpaulin is not always easy to remove, especially in rain or high wind;
- **the Tautliner** or curtainsider has practically the same advantages as the tilt except that the tarpaulin is drawn like a curtain in a few seconds and this operation is completely safe. This semi-trailer can have several loading levels;
- **the box** is a vehicle with rigid wall panels and is therefore more resistant. On the other hand, it can only be loaded from the rear. Some boxes have thick walls to transport products at a controlled temperature;
- **the tipper** comes in several forms. It is used to transport bulk goods. As a general rule, tippers are equipped with a cylinder to tilt them rearwards;
- **the tanker** is used to transport liquids for food and non-food purposes. They are often with compartments to prevent liquid displacement (surge effect).

2.4.3 – Utility or light commercial vehicles

At the end of 2005, some 5,530,000 light commercial vehicles (LCVs - GVWR < 3.5 t) with a gross vehicle weight rating of 3.5 tonnes or less were in service (a 10% increase since 2000). These vehicles play an important economic role. They travelled 91 billion vehicle kilometres in 2005, three times more than the 560,000 heavy goods vehicles in France. More than half of these vehicles are used by the general public and sole-ownership businesses, but corporate fleets are showing the greatest growth.

2.5 – Growth in numbers of vehicles registered in France and Europe

Estimated at 560,000 vehicles, the number of HGVs registered in France represents barely more than 2% of all vehicles on the country's roads. Between 1990 and 2005, the number of passenger cars rose by 29%, LCVs by 31% and HGVs by just 4%. The number of HGVs has therefore remained fairly stable, but the composition of the fleet has evolved considerably: the proportion of rigid trucks is falling significantly in favour of tractors (articulated vehicles). Whereas rigid trucks previously accounted for over 90% of the total number of HGVs, the figure is around 55% today. The growth in the number of semi-trailers is similar overall to that of fifth-wheel tractors.

Vehicles on the road

According to the central automobile database (source: SOeS), there were 37,664,000 vehicles on the road in France on January 1, 2010, including cars, buses and :

- 5,405,000 trucks, vans and special self-propelled vehicles less than 15 years old;
- 212,000 fifth-wheel tractors less than 10 years old;
- 52,000 trailers less than 20 years old;
- 313,000 semi-trailers less than 20 years old;

According to the annual survey conducted by the Department of Industrial Studies and Statistics (SESSI = *Service des Études et des Statistiques Industrielles*) of the French Ministry of the Economy, Finance and Industry on industrial bodywork, the highest-selling vehicles in recent years, in terms of registrations, are:

- tippers (around 7,200 tippers registered in 2004) in the case of rigid trucks (22,800 rigid trucks registered in 2004);
- curtainsiders, also known as Tautliners (around 6,500 in 2004) for articulated vehicles (20,800 vehicles registered in 2004).

In the 25-nation European Union, the number of HGVs on the road was estimated at 2,770,000 in 2000 and over 3,100,000 in 2004.

Refer to Appendix 3 for further information on this subject.

2.6 - Heavy goods vehicle classification on toll networks

For heavy goods vehicle classification from toll data, a distinction needs to be made between classes 3 and 4[7] :

- **class 3**: HGVs, motor-coaches and other vehicles with two axles, with a total height equal to or greater than 3 metres or with a GVWR in excess of 3.5 tonnes;
- **class 4**: HGVs, motor-coaches and other vehicles or combined vehicles (vehicle towing a trailer or caravan) with more than two axles, with a total height equal to or greater than 3 metres or with a GVWR in excess of 3.5 tonnes.

As motorway company counts for classes 3 and 4 also include motor-coaches, the number of motor-coaches must therefore be deducted from each of the classes to obtain the number of HGVs per class. However, such data is rarely available and it is very difficult to estimate the number of motor-coaches per class, as this figure can vary considerably depending on the region and the day.

Motor-coaches represent between 1% and 10% of class 3 and, as they mainly have two axles, are almost non-existent in class 4. It is also notable that, at some conspicuous points (border crossings, in particular), these figures may be much higher. For example, at Le Perthus (on the A9) in 2004, motor-coaches represented more than 50% of class 3 and 0.4% of class 4.

[7] ***For information, the other toll classes are: Class 1: vehicles or combined vehicles with a maximum total height equal to or less than 2 m and with a GVWR equal to or less than 3.5 tonnes. In the case of vehicles towing a trailer, its load is not taken into account. Class 2: vehicles or combined vehicles with a maximum total height strictly between 2 and 3 m and with a GVWR equal to or less than 3.5 tonnes. Class 5: motorcycles with or without a trailer or sidecar and trikes.***

3 - Description of French Road Network

3.1 - Types of roads

3.1.1 – Property ownership

Roads in France belong to a number of different areas of property ownership: private roads, municipality roads and streets, district roads, state highways and motorways. These various roads also have specific characteristics and sometimes a specific status (road with limited access, toll section, etc.).

Each type of road has a policing authority that sets traffic and parking rules which are brought to the attention of users by road markings and signs.

	1980	1995	2000	2005	2007
State highways	28,515	28,097	27,500	25,182	9118
District roads		368,054	359,051	359,957	377,000
Local roads		609,635	609,635	609,635	630,000
Conceded motorways	3,707	6,321	7,333	8,179	8,427
Non-conceded motorways	1,155	1,975	2,500	2,625	2,577
All motorways	*4,862*	*8,296*	*9,833*	*10,804*	*11,004*
All roads		**1,014,082**	**1,006,019**	**1,005,579**	**1,038,000**

Figure 8. Length of French road network (km) (source : URF)

In 2007, the minister announced that the Government would henceforth be focusing on the trunk network of national or international interest. The fine mesh of the national road grid is the responsibility of the districts and municipalities to whom the Government has transferred almost 18,000 kilometres of roads. In addition to the 8,500 kilometres of toll motorways under concession, the Government retains responsibility for 11,700 kilometres of non-conceded motorways and state highways.

3.1.2 – Geometric characteristics

These roads have variable geometric characteristics (cross-section, junctions, etc.):

- motorways: dual 2-lane, 3-lane or 4-lane roads with a speed limit of 130 km/h (for light vehicles);
- dual 2-lane intercity roads: this appellation covers two types defined in the catalogue of road types in intercity environments (circular of 9/12/91):

  - type 1 – "motorway" but with the status of a "road with limited access": they are not narrower than motorways (the ICTAAL [45] applies) but have a speed limit of 110 km/h (French Highway Code);
  - type 3 – "intercity arteries", with separate carriageways but at-grade junctions (roundabouts or traffic light-controlled junctions). The speed limit on such roads depends on the application, but it is usually 90 km/h and exceptionally 110 km/h;
- dual 2-lane roads in urban and suburban areas: widely varying characteristics with 110, 90, 80 and 70 km/h speed limits;
- major roads: three-lane or alternate two/three-lane roads, limited to 90 km/h;
- other roads, limited to 90 km/h, and 50 km/h in built-up areas.

3.2 - Concessionary motorway network

3.2.1 – History

For many years, motorway concessions were allocated on a negotiated basis according to a geographical network logic. Although the motorway funding system implemented in France with the April 18, 1955 act [40] enabled a modern motorway system to be built almost without budgetary contribution, the motorway sector has had to evolve due to the need for it to adapt to its legal environment and fall more closely into line with the present-day political and economic context. For these reasons, the reform undertaken[8] has aimed to increase competition for the allocation of new motorway concessions, give the motorway system the financial resources to accomplish the building programme and ensure greater neutrality in the choices made between types of investment and between modes of transport.

With the exception of Cofiroute, a company that has been involved in the management of motorway infrastructures in France since 1970, most conceded motorways were run by semi-public companies (SEMCAs) until April 2005 when a privatisation process began. Only the companies managing the Mont-Blanc tunnel (ATMB) and the Fréjus tunnel (SFTRF) have kept their SEMCA status, all of the other having been transformed into *sociétés anonymes* (private corporations), most of which have been sold to private shareholders. At the same time, the implementation of public-private partnerships (PPPs) for the construction of new motorways is developing and opening this activity up to companies other than those already with a foothold in the market.

3.2.2 – Tolls

The toll, the basic principle of the concession system, is used to fund the development of a reliable, high-performance motorway network with quality amenities and services. Motorway tolls – provided for in the concessions specifications – are set each year by the Economy and Finance Minister after consulting the Minister of Transport following a proposal submitted by each concession holder. The toll fee varies on average and for each company according to the evolution in the network structure, financial charges, roadwork and maintenance costs, salaries, tax burdens and traffic[9].

3.2.3 – Motorway companies

In France, 13 companies operate toll motorways and other toll structures: ALIS, APRR, AREA, ASF, ATMB, COFIROUTE, ESCOTA, SANEF, SAPN, SFTRF (Fréjus Tunnel), Le Havre CCI (Normandy and Tancarville bridges), CEVM (Millau Viaduct) and SMTPC (Prado-Carénage Tunnel). Their "estate" varies considerably: from over 2000 kilometres for ASF to a few kilometres for CEVM.

***

[8] *Act n° 2000-1 of January 3, 2001 conferring powers to the French Government to transpose Community directives, by orders, forced the Government to take steps regarding the modernisation of the motorway operating system. In particular, Order n° 2001-273 [41] set new terms for the concession contracts awarded to semi-public concession holders (SEMCA =* Société d'Economie Mixte Concessionnaire d'Autoroute*) as notified to the European Commission and anticipated these extensions being effective for the drawing up of the accounts for financial year 2000, in order that the accounting reform would apply to the accounts for Financial Year 2000. This order was ratified by Act n° 2001-1011 of November 5, 2001 [41].*

[9] *In 2005, the average fee including VAT was €0.0712 per kilometre for light vehicles and €0.206 per kilometre for HGVs. The latest increases implemented in 2005 amounted to an average of 2.14% for light vehicles and 3.06% for HGVs. Out of every €10 of toll fee paid, €3.49 are used to pay taxes and duties, €1.92 to cover operation and services and €3.27 go towards the construction and modernisation of the networks. The remainder (€1.32) is paid in the form of dividends to the shareholders (Source: ASFA annual report, 2005). In 2005, revenue across all conceded motorway networks amounted to €6.2 billion, with light vehicles accounting for €4.2bn and HGVs for €2bn (source: ASFA annual report, 2005).*

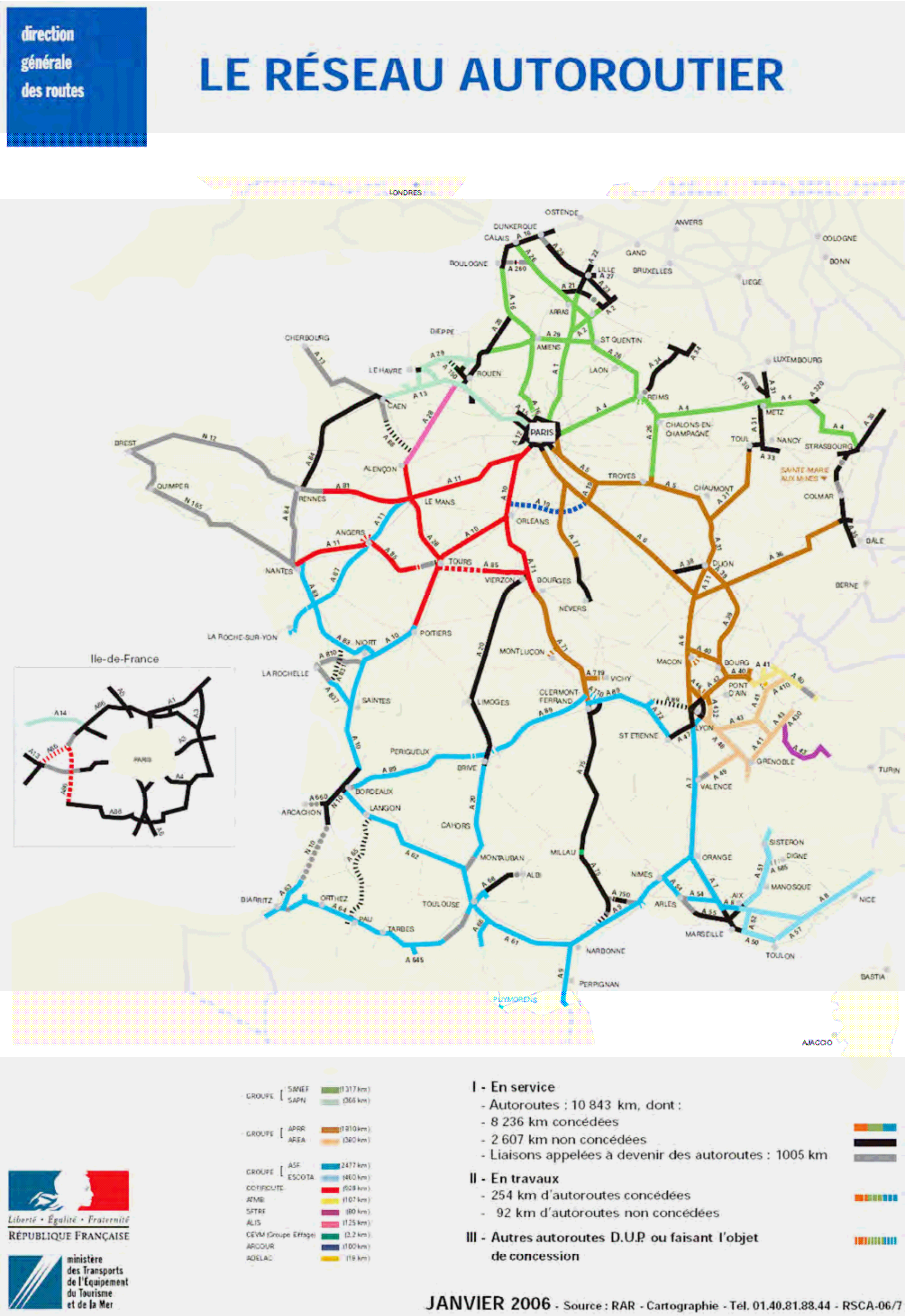
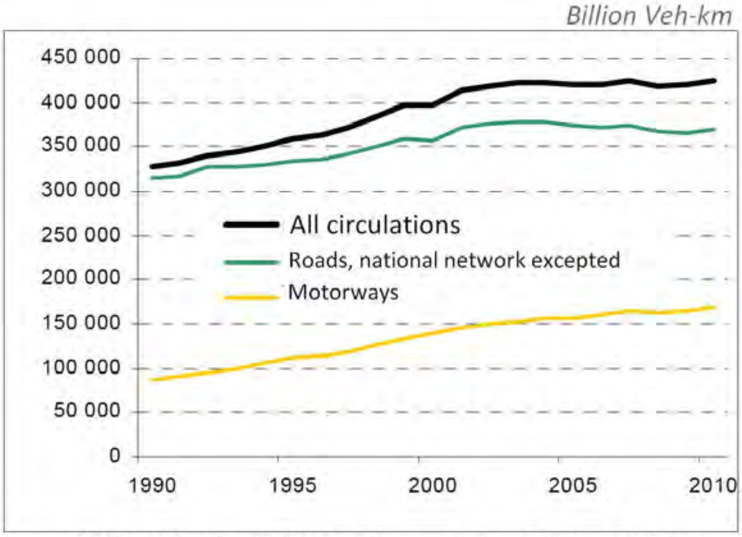
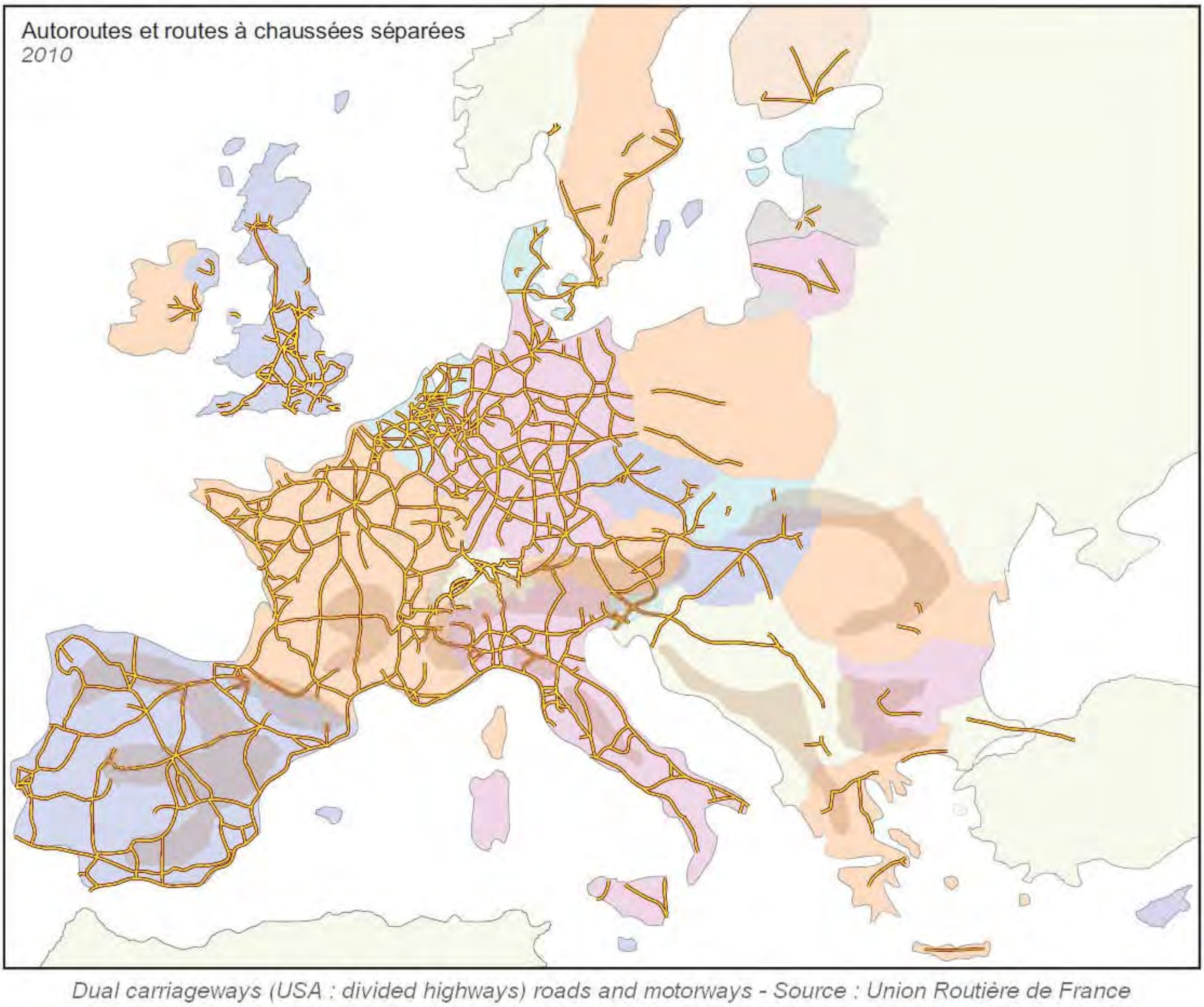


Figure 9. Map of French motorway network and concessionary company distribution



Traffics on French roads by network - source Comptes de Transports de la nation

Figure 1 : Traffics, <u>personal cars only</u> . Notice that motorways (more precisely dual carriageways), which represent only 2% of the total road network, support more than 1/3 of traffics. This trend is valid for Heavy Goods Vehicles.



Dual carriageways (USA : divided highways) roads and motorways - Source : Union Routière de France

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3.3 - Non-concessionary national road network (trunk network)

The split in administration of the road network between the French Government (state highways and non-conceded motorways) and local authorities (local and district roads) was fundamentally modified in December 2005. As a result, 18,000 kilometres of the national network were transferred under the responsibility of the districts the following year.

At the beginning of 2007, the road network under central government responsibility broke down as follows:

- non-conceded motorways 2,400 km
- dual 2+-lane state highways 4,000 km
- other roads 5,400 km
- total 11,800 km

Appendix 4 includes a map of the national road network.

3.4 - Travel aids, information and operating measures

The management of a road and motorway network can prove on a day-to-day basis to be a difficult business, especially with regard to the network traffic load. Some operations must be optimised to guarantee the best conditions for safe, smooth travel:

- the organisation and scheduling of roadworks, which disrupt traffic;
- response and clearance times in the event of incidents or accidents, to limit the subsequent lane closures as much as possible.

To improve conditions of safety and/or comfort (free flow of traffic) on the road networks, several types of traffic management measures can be used:

- **information to road users**, to inform them of any incidents and make them aware of the risks of congestion. Information can be given at the entry point to the network or in rest areas. It can be broadcast via Variable Message Signs (VMS) or a wide range of media (radio (107.7 FM on French motorways for example), the Internet, onboard terminals, mobile phone, etc.);
- **no overtaking for HGVs**: by restricting HGV traffic to the right-hand lane, this measure improves the traffic flow for passenger vehicles;
- **dynamic speed control** helps to improve traffic flow and avoid excessively sharp stop-go effects. In this case, it involves forcing the user to travel in periods of heavy, but free-flowing traffic, at a speed below the legal limit in order to homogenise the speeds adopted in the stream. This control measure helps to delay the occurrence of traffic jams and therefore allow traffic to move more freely. The results of the experiment also show that the number of accidents is reduced

Figure 38. Congestion and user information on A6 motorway (© DREIF / Gauthier)

- **toll modulation** (variable charging) can be implemented on the basis of various parameters, including in particular[10] :
  - time modulation, set up in specific periods and sections to limit congestion through an increase in the toll charge in the heaviest periods;
  - geographical toll modulation on the most heavily-used sections;
  - toll modulation according to pollutant emission levels in order to stimulate the emergence of more environmentally-friendly vehicles;
- **access control measures at entry points to the network** can also help to limit congestion. Access control acts directly on traffic demand by splitting the stream into groups of vehicles separated by a time interval. This interval should enable the link (the motorways) to absorb the entering volumes of traffic better by only allowing access when the capacity reserve is sufficient.

Finally, the motorway companies are also concerned with comfort and amenities:

- **rest and service areas** allow drivers to stop and take a break. In 2005, 700 rest areas and 417 service areas were dotted around the conceded and non-conceded motorway network;
- **special HGV service areas**: HGV drivers have specific needs which the motorway companies are recognising by making special service areas, open 24/7, available to them. In 2006, four such areas were proposed to professional drivers across the entire motorway network. Three secure parking areas reserved for HGVs have also been created.

[10] *Decision of December 4, 2006 following the public debate on transport policy in the Rhône Valley and the Languedoc Arc.*

4 - Highway Infrastructure Capacity

4.1 - Capacity and flow rates: theoretical data

When the capacity of a highway infrastructure is considered, it is seen as a “pipe” through which vehicles flow. The type of vehicles and the shape of the “pipe” have a significant effect on the characteristics of this flow.

4.1.1 – Flow rates and road traffic quantification

There are several ways of counting road traffic, including the following notions:

- **hourly traffic**: this corresponds to the number of vehicles flowing through a given point per hour. It is generally measured by direction and is used in particular to study congestion phenomena, especially at peak hours (PH);
- **annual average daily traffic** (AADT): this measures the average number of vehicles flowing through a given point per day. It is either indicated per direction, or for both directions. This indicator is generally used to study intercity routes and is particularly suitable for socio-economic calculations. The AADT is an appropriate indicator in the open countryside but is limited in an urban environment where it needs to be supplemented by peak hour traffic measurements[11]. The AADT, which is sometimes the only item of data available, is ill-suited to determining the available capacity reserve of a road as a significant variation in the traffic flow is observed between the busiest hours and quietest hours of the year.

In these definitions, traffic flow rates are measured in vehicles per unit of time without differentiating between light vehicles and HGVs, and yet the heterogeneous composition of road traffic has a considerable effect on its flow. HGVs do not have the same influence as light vehicles on traffic flow. Due to their size, the greater distances left in their

[11] *A distinction is made between the morning peak hour (MPH) and the evening peak hour (EPH).*

vicinity (psychological effect), their lower speeds (and the inconvenience caused by overtaking), HGVs occupy a larger space on the carriageway and for a longer time. Consequently, the expected capacity of an infrastructure is significantly lower in the presence of HGVs.

Consideration of the composition in traffic management is generally limited to the introduction of a coefficient of equivalence between HGVs and light vehicles to deduce the equivalent flow rate of homogeneous traffic consisting only of light vehicles. The unit used is the Passenger Car Unit (PCU).

This coefficient of equivalence is defined by the number of light vehicles that would use the same fraction of capacity of the infrastructure as a HGV, under the same infrastructure, traffic and control conditions. It is generally between 2 and 3 for an average relief.

4.1.2 – Capacity and congestion

The most usual definition of the capacity of a section of road is the one which evaluates the maximum number of vehicles that can travel through any point of the section in one hour.

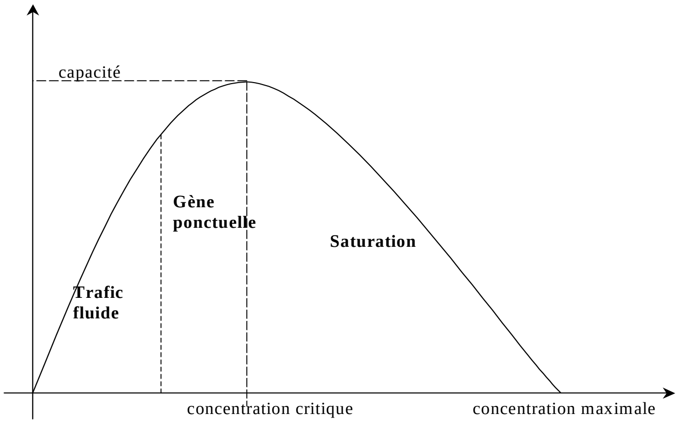
It is generally accepted that a road lane with a standard width of 3.5 m has a capacity of approximately 1,800 passenger cars per hour. This value can be modulated from 1,400 to 2,000 PCUs/h on the basis of the factors mentioned in paragraph 4.1.3. Capacity is a predominant element for the choice of investments, for the design of infrastructures and for traffic management measures.

In practice, various methods can be used to estimate the capacity of a road[12]. One of them consists of determining the **fundamental diagram**, a graphic representation of the relation between traffic flow and concentration[13]. The curve is thus adjusted from experimental data. The capacity of the road is deduced from the peak of this curve.

[12] *In particular, the Highway Capacity Manual (HCM), which was first published in 1965 and has been updated several times since, especially in 2000 [42], is taken as the authority on the subject. In France, research on this topic has essentially been conducted at INRETS (Transport Research Institut, now IFFSTAR). On renewing the flow/speed curves for intercity motorways (2001), SETRA determined motorway capacity using the "average flow per class of speed" method after excluding unstable periods.*

[13] *Number of vehicles per unit length*

The diagram in Figure 11 shows that, as the concentration increases on a road, the flow (in terms of the number of vehicles per unit of time) also increases, up to capacity; then, once maximum flow is reached, if the concentration continues to increase, the flow then falls. Maximum concentration is reached when the flow is zero, when the vehicles are at a standstill.



Capacité	*Capacity*
Trafic fluide	*Free-flowing traffic*
Gêne ponctuelle	*Occasional inconvenience*
Saturation	*Saturation*
Concentration critique	*Critical concentration*
Concentration maximale	*Maximum concentration*

Figure 39. Example of a fundamental diagram

In other words, the flow can be low either because there are few vehicles (as the vehicles are spaced apart, the concentration is low) or, conversely, because there are a lot of vehicles which obstruct each other and cannot circulate freely (in which case the concentration is high).

Congestion is the whole disruption generated by a build-up of vehicles travelling along a road. Congestion covers a range of situations from relatively slight inconvenience to the most severe obstruction. A distinction can be made between:

- **occasional inconvenience** between vehicles occurs when hourly traffic flows exceed 60% of the capacity of the road, and becomes "major" when the traffic flows exceed 90% of the capacity, although the average speed of the stream is still above the speed at capacity;
- **saturation**, where the instantaneous demand exceeds capacity, is the most severe form of congestion. It is characterised by the formation of a permanent queue over a certain period of time and a sharp drop in average speeds to below the speed at capacity.

There are three aspects to congestion (on motorways, but also on other highways):

- **seasonal congestion** essentially linked to summer migrations or access to ski resorts (low to medium recurrence);
- **recurrent congestion** characteristic of home-to-work journeys and which therefore occurs daily at the same spots (high recurrence);
- **exceptional congestion**, in the event of an accident for example.

Irrespective of the regime, congestion over a period can be measured with the aid of traffic state variables: flow (veh/h), speed (km/h) and spatial density (veh/km, equivalent to occupancy which is the proportion of time during which a point on the road is occupied by a vehicle). Speed, in particular, makes it possible to distinguish two conditions: unsaturated and saturated. Saturation is characterised by a lowering of the average speed of all vehicles to below the speed observed at capacity. This speed corresponds to the speed from which each vehicle in the stream is restricted by its immediate predecessors, and where it is almost impossible to overtake.

In recent years, Sétra[14] has sharpened the notion of inconvenience to road users, for congestion situations other than saturation. This approach consists of a theoretical calculation to produce a behavioural indicator of inconvenience (cf. Appendix 5). Inconvenience is considered to be a situation where a light vehicle is unable to proceed freely without being held up by a preceding vehicle.

The inconvenience indicator is the proportion of time spent by light vehicles in a slower-than-normal state. In order to calculate this indicator, hourly traffic figures and hourly HGV percentages over an entire year are necessary.

Other mathematical tools can be used to connect various traffic parameters. These include flow/speed curves which are used to calculate road user assignment on routes and to simulate journey times; they concern mainly free-flowing traffic conditions, unlike the fundamental diagram which describes all traffic situations. Further information on these flow/speed curves is provided in Appendix 6.

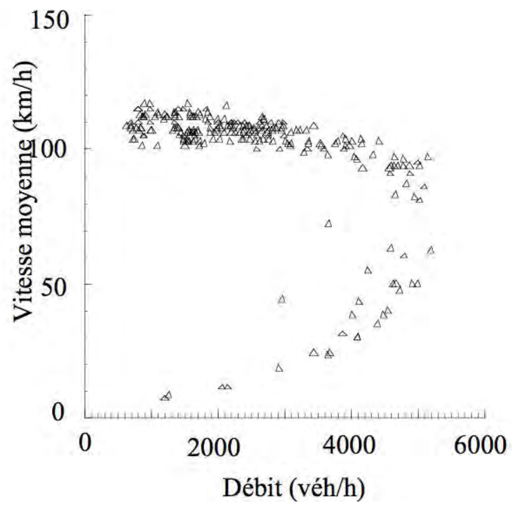
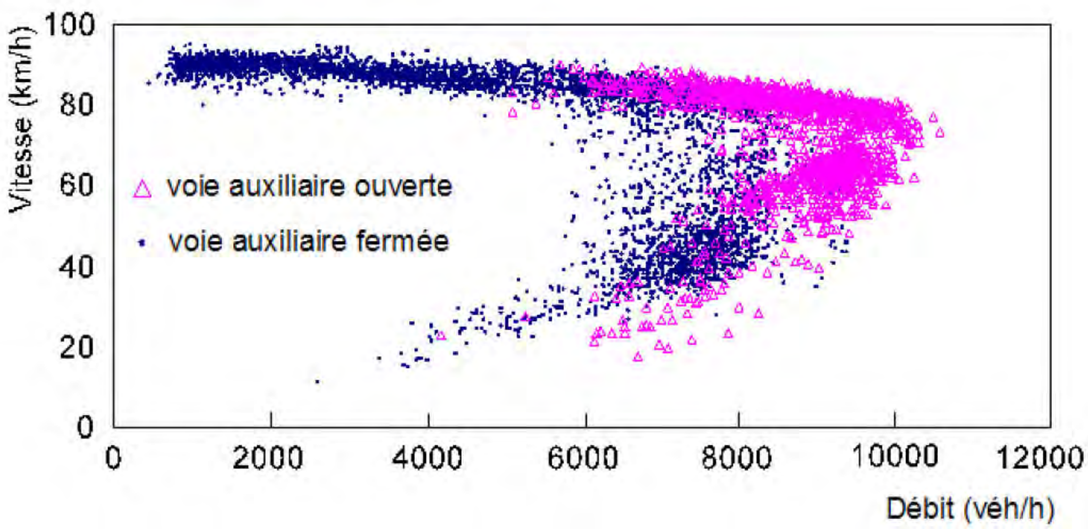


Figure 40 :Examples of Flow/speed measures : Dual 3-lane motorway (above) and A86 (south of Paris) Dual 4- or 5-lane (depending on congestion, opening – "voie auxiliaire ouverte" – of the hard shoulder). Source : CERTU



[14] For further information on the methods of calculating periods of inconvenience, refer to document "Projet d'annexe 15 - Congestion routière et Gêne à l'usager" by Tram Simonet and Patrice Danzanvilliers, Sétra - Highways, Transportation and Safety Centre - September 2005.

4.1.3 - Factors affecting capacity

Capacity depends on several parameters, and notably on the average safety distances observed by drivers according to the speeds at which they travel: the lower the headway, the higher the concentration may be. The shortest headways are observed in urban environments; consequently, the maximum capacity for an urban road, at speeds approaching 50 km/h, is of the order of 2,100 to 2,200 PCUs/lane.

Headways vary from one road to another and the main f actors affecting these distances, and therefore the capacity, are as follows:

- **characteristics of the infrastructure**: number and width of the lanes, visibility, gradient, width of the clear, hardened verge and traffic management measures (traffic lights, speed limit, etc.);
- **composition of the traffic**: traffic distribution per direction, nature of the journeys (regular users or not), composition of the traffic (light vehicles or HGVs, loaded or not, towing a trailer or not, etc.);
- ambient conditions: visibility and weather conditions.

It should also be pointed out that, sometimes, the capacity of a road is created by certain conspicuous (or critical) points. They may be generated by a local increase in demand around a built-up area or by a point where capacity is reduced (crossroads, interchange, narrowing, bridge, tunnel, etc.).

4.2 - Illustrations and statistics

A certain amount of quantitative data is proposed below to illustrate the above paragraph. This data is provided as an indication only. The figures given depend largely on the context in which they have been calculated (study context); the data must therefore be taken as orders of magnitude.

4.2.1 – Infrastructure capacity

The studies conducted by the Ministry (especially for motorways [43]) adopt the capacities shown in Figure 13 for each type of road (e is the coefficient of equivalence between light vehicles and HGVs).

	Extrapolated data						Data based on field values	
Type of road	6 m e=3	7 m e=3	3-lane 9 m e=3	3-lane 10.5 m e=3	Dual 2-lane at-grade junction e=3	Dual 2-lane urban express road e=3	Dual 2-lane motorway e=2.5	Dual 3-lane motorway e=2.5
Capacity (in PCUs/h/direction)	1220	1350	1650	1830	3100	4000	3460	5200

Figure 41. Capacities in PCUs/direction/hour for different types of road

These values are default values. Wherever possible, it is preferable to use the results of measurements.

4.2.2 - Impact of HGV traffic on road infrastructure capacity

From the flow/speed curves presented above (and detailed in Appendix 6), it is possible to make a brief assessment of the impact of HGVs on capacity: for each proportion of HGVs in the traffic, the number of PCUs per direction is calculated for speed at capacity (85 km/h on dual 2-lane or 3-lane motorways) from curves of the type shown in Figure 12. This gives the results in Figures 14 and 15, valid for dual 2-lane or 3-lane motorways.

Percentage of HGVs	0	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
Reduction in the capacity of the road (compared with 0% HGVs)	0	-7%	-13%	-19%	-23%	-28%	-31%	-35%	-38%	-41%	-43%

Figure 42. Reduction in road capacity w.r.t. percentage of HGVs

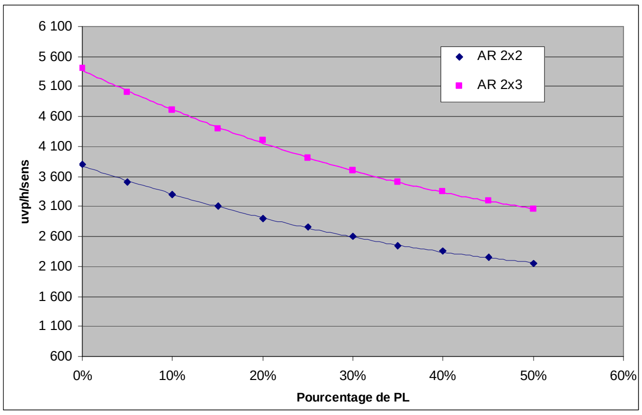


Figure 43. Hourly capacity w.r.t. percentage of HGVs (dual 2-lane and 3-lane motorways)

Uvp/h/sens	*PCUs/h/direction (axis y)*
Pourcentage de PL	*Percentage HGVs (axis x)*
AR 2x2	*Dual 2-lane m/way (rose)*
AR 2x3	*Dual 3-lane m/way (blue)*

The impact of the presence of HGVs on average daily speed can also be illustrated (*cf*. Figure 16).

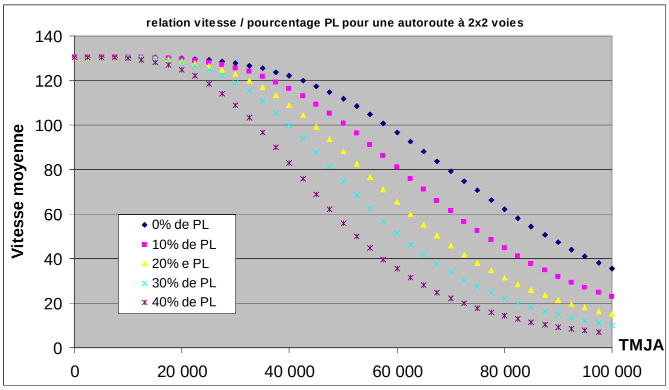


Figure 44. Speed in relation to percentage of HGVs for a dual 2-lane motorway

Vitesse moyenne	*Average speed*
0% de PL, 10% de PL, etc.	*0% HGVs, 10% HGVs, etc.*
TMJA	*AADT (average annual daily traffic)*

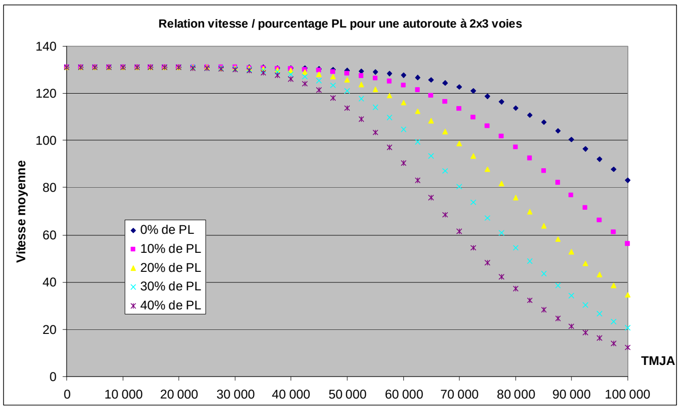


Figure 45. Speed in relation to percentage of HGVs for a dual 3-lane motorway

This graph shows, for example, that at constant AADT (60,000 veh/day, for example), on a dual 2-lane road on which 20% of the traffic are HGVs, the average speed over the day is 65 km/h, whereas it would be 80 km/h if this percentage were 10%.

An observation of the data and curves reveals that the presence of heavy goods vehicles clearly affects traffic conditions:

- with the same concentration of vehicles, a lower flow is achieved (or lower speed, which amounts to the same thing);
- the higher the percentage of HGVs in the traffic, the lower the capacity of the road: it is reduced by 13% if HGVs make up 10% of the traffic (compared with 0% HGVs); and by 28% with 25% HGVs.

It may also be added that the efficiency of traffic flow is reduced in the presence of HGVs, particularly by the direct inconvenience connected with the overtaking manoeuvres necessary for the fastest vehicles to progress.

4.3 - Road infrastructure and HGV geometry

4.3.1 – Main provisions to be made for HGVs in road design

The specific nature of HGVs, from the point of view of their size, weight and manoeuvres, occasionally calls for adaptations to the highway network. Certain parameters must be taken on board in the design of infrastructures, depending on the HGV traffic supported by the route (source: Sétra, 2006 [44]):

- **Carriageway width**: lateral safety margins must take account of the speeds travelled on the route and, as a result, values of 3 to 3.5 m are usually selected for main roads. The international standard is 3.5 m. Depending on topographic constraints and HGV traffic, narrower widths may be adopted. However, the interministerial order on road signing and marking advises against systematically marking the centre line of a carriageway less than 5.2 m wide (lanes compatible with the maximum width of a motor vehicle permitted by the French Highway Code);
- **Case of low-radius bends (hairpins and junction islands)**: when HGV traffic reaches a certain level, extra width must be

provided for bends with a radius of less than 200 m so articulated trucks can negotiate them without going outside their lane;

- **Descending and ascending gradients**: steep descending gradients may cause braking problems to HGVs and thus compromise the safety of road users. In particular, it is necessary to avoid locating a moderate descending gradient between two steep descending gradients (difficulties in reducing speeds to a suitable level) but also positioning conspicuous points in or immediately after zones with steep gradients.

Apart from the above-mentioned examples, other situations are notably to be avoided in project design:

- numerous and/or accentuated bends;
- presence of insufficiently large junctions or roundabouts;
- presence of critical points in the lower part of a descent (low-radius bend, intersection, built-up area entrance, etc.);
- absence of lane edge marking;
- soft shoulders, etc.

In design manuals for highway infrastructures and equipment[15], few specific provisions as a function of HGV traffic are made. The standards and provisions presented are deemed suitable for "normal" traffic, including HGVs. However, for pavement sizing, knowledge of HGV traffic is an important element.

The specific road planning measures most often used in favour of HGVs are:

- special slow-moving vehicle lanes (or "crawler" lanes), arrangements designed to ensure similar traffic conditions in relation to slow-moving vehicles on sections of motorway with moderate relief;
- emergency arrester beds, a complement to crawler lanes (although they also exist without crawler lanes) which are designed to stop vehicles in difficulty before a critical point (low-radius bend, interchange, etc.);
- diverging lanes (left or right drop);
- porous asphalt pavements which, in wet weather, prevent spraying especially from heavy goods vehicles;
- restraint systems: barriers, safety rails and anti-tip systems essentially for cargo restraint;
- dedicated lanes in motorway access ramps or interchanges;
- specific hydraulic arrangements to limit pollution risks in the event of a spillage from a HGV;
- special, secure HGV parks in rest and service areas, etc.

4.3.2 – HGV parking

HGVs are subject to restrictive legislation regarding driving time and stoppages are mandatory at fixed intervals. The issue of parking is therefore a major concern, notably on the main routes used by HGVs.

A distinction can be made between two categories of parking facility available near the main HGV traffic routes:

- service and rest areas, which are the responsibility of central government or concession holders;
- parking areas for private use: truck drivers' motels and restaurants (no check on the quality of the services provided or how long they have been in business).

The priority services demanded by truck drivers are toilet and shower facilities and a suitable restaurant. Specific security services are increasingly being requested for certain types of cargo.

The parking demand in rest areas is estimated, per route, on homogeneous traffic sections, on the basis of three criteria:

- the length of the route in question, which must be significant (L ~ 100 km);
- HGV through-traffic on each of the sections making up the route;
- a parking rate τ.

*[15] **In the national instructions on technical design requirements for motorways (ICTAAL (Sétra [45])), recommendations are given for motorways sections with a high grade difference. Other reference works include instructions on technical design requirements for urban express roads (ICTAVRU) and other roads (ARP).***

The number of places N is then determined by the formula:

$$N = \Sigma \frac{\text{section length} \times \tau \times \text{through traffic}}{10{,}000}$$

with a parking rate τ equal to:

- 8.5 for HGVs
- 5 for light vehicles.

The HGV rate has been validated over the entire network, however the light vehicle rate needs to be confirmed as the sample is still too limited.

The through traffic is obtained by deducting local traffic, which covers traffic within a district and flows between adjacent districts or over distances of less than 100 km. Taken annually, this does not fluctuate for HGVs, but can vary for light vehicles according to seasonal peaks which must be taken into consideration if they last a long time. As a result, different types of parking areas may be created although the capacity of these areas will always be assessed using a parking rate of “5”, applied respectively to out-of-season traffic and to the difference between out-of-season and seasonal traffic.

Figure 46 : Optimizing available space - credit P. BILLET-LEGROS - Sétra

Appendix 1. Additional Traffic Flow and Road Transport Statistics

Traffic, major corridors and percentage of HGVs

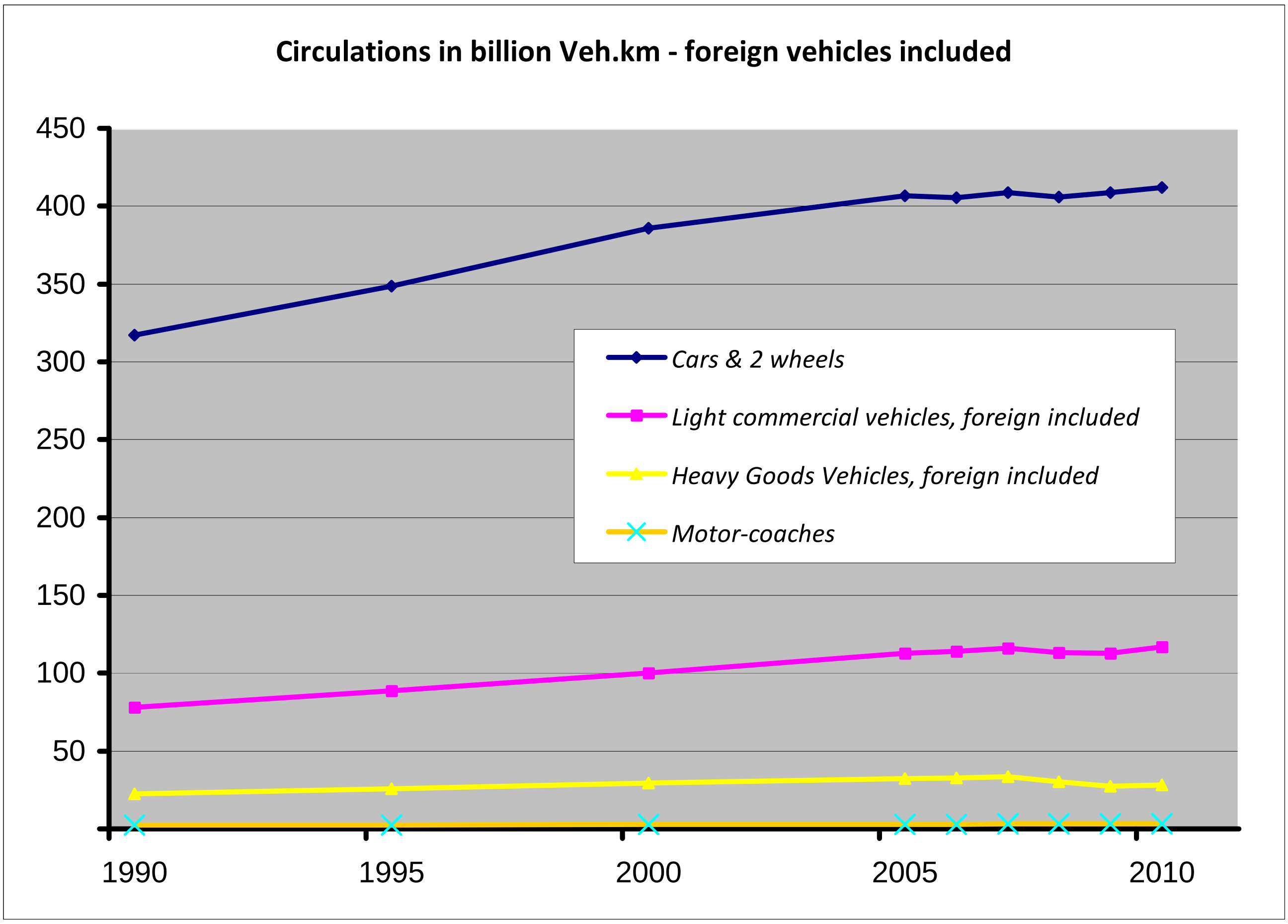
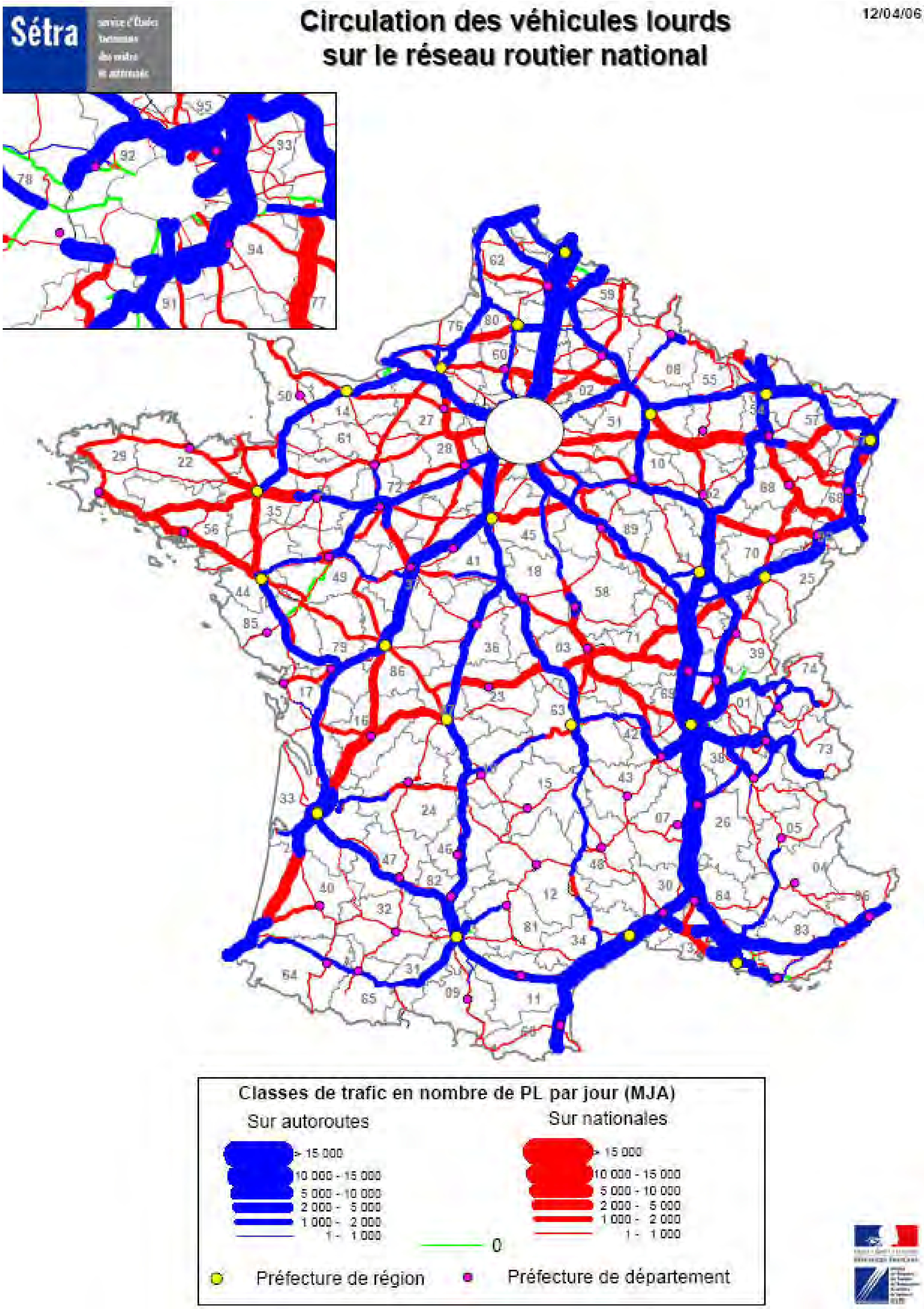


Figure 47. Annual traffic in billions of vehicle-km in France (datas : SoeS – Sétra)



Circulation des véhicules lourds sur le réseau routier national	***Heavy goods vehicle traffic on the national road network***	Sur nationales	*On State highways*
Classes de trafic en nombre de PL par jour (MJA)	*Classes of traffic in number of HGVs per day (AADT)*	Préfecture de region	*Regional capital*
Sur autoroutes	*On motorways*	Préfecture de département	*District capital*

Figure 48. HGV traffic on French national road network (2005)

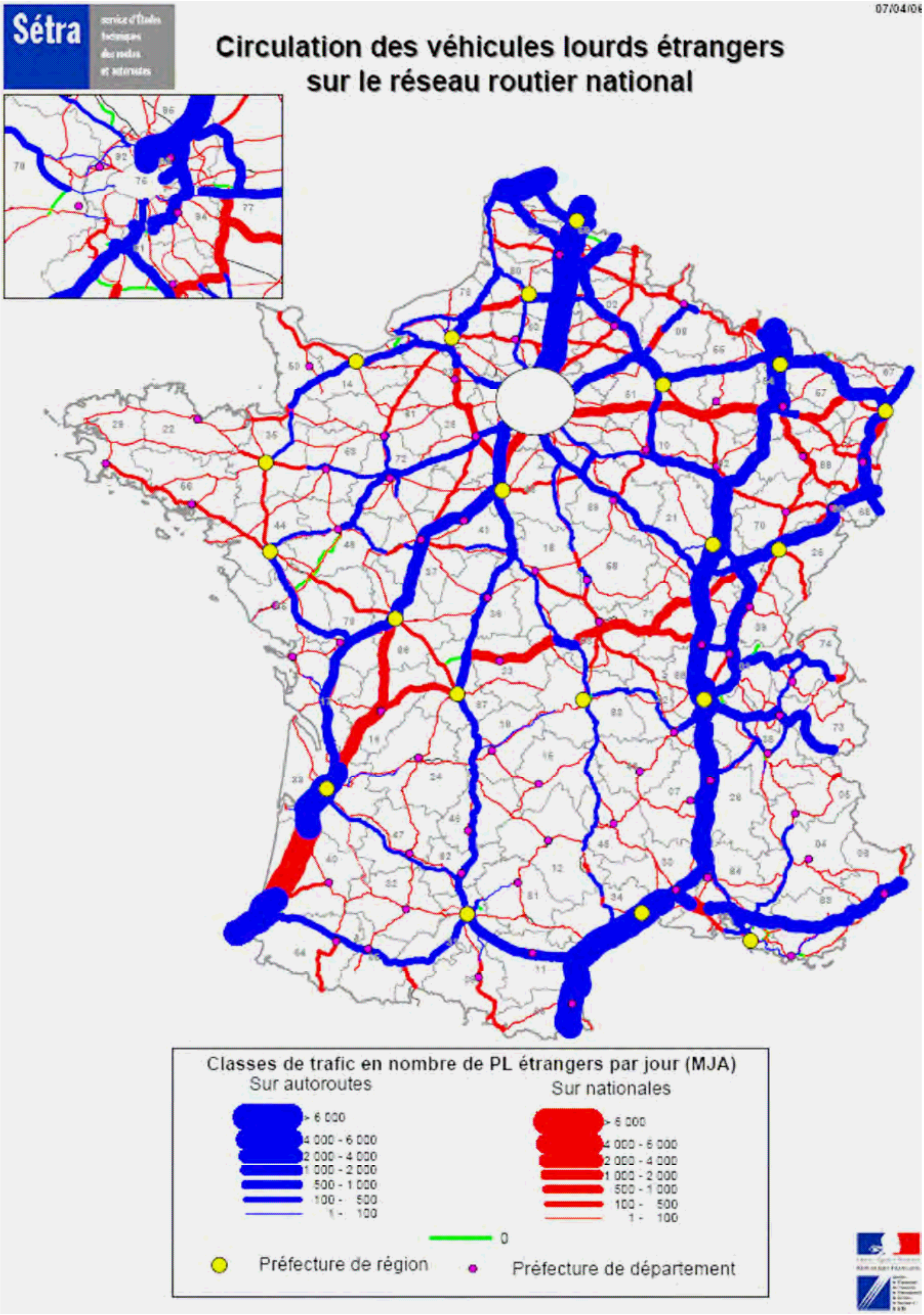
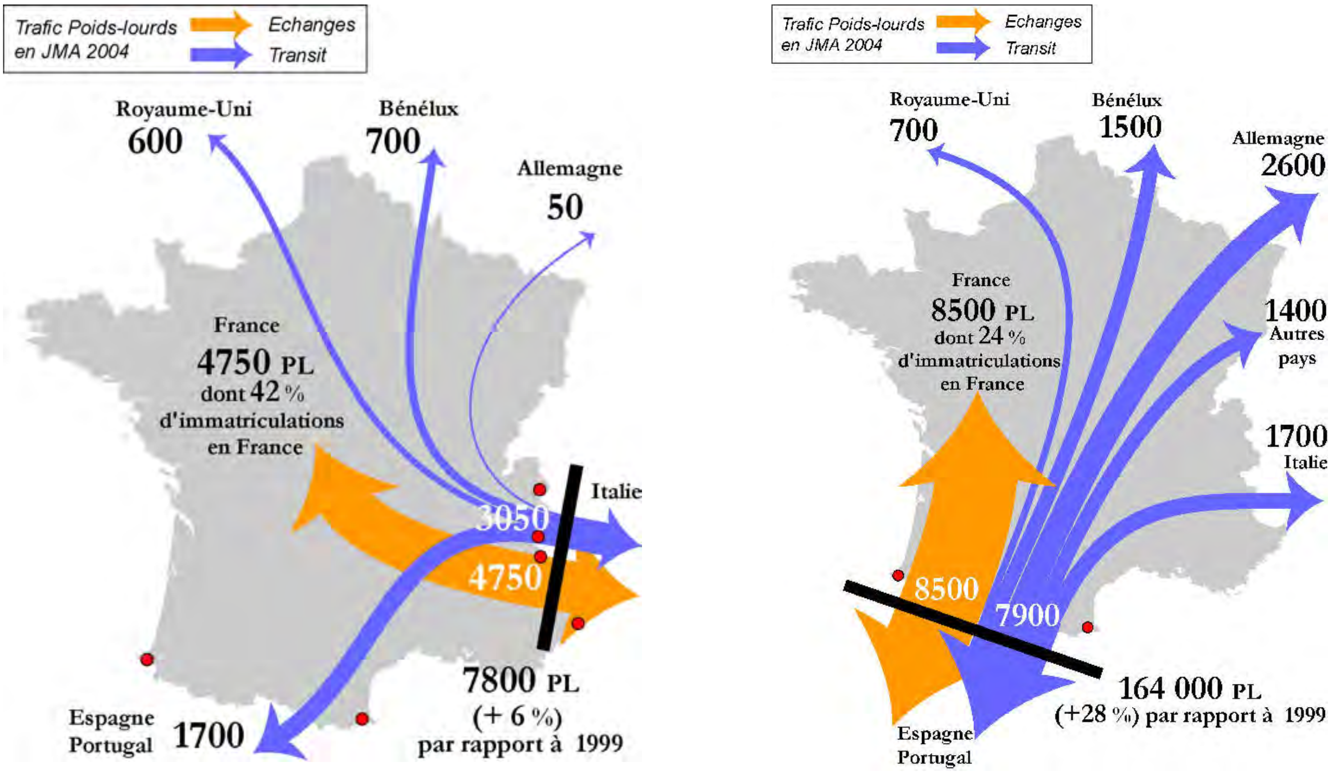


Figure 49. Foreign HGV traffic on French national road network (2005)

Circulation des véhicules lourds étrangers sur le réseau national	***Foreign HGV traffic on the national road network***	Sur nationales	*On State highways*
Classes de trafic en nombre de PL par jour (MJA)	*Classes of traffic in number of HGVs per day (AADT)*	Préfecture de region	*Regional capital*
Sur autoroutes	*On motorways*	Préfecture de département	*District capital*



Trafic poids-lourds en JMA 2004	*HGV traffic (AADT - Annual Average Daily Traffic, 2004)*
Echanges	*Exchanges*
Transit	*Transit*
Royaume-Uni, Bénélux, Allemagne,	*United Kingdom, Benelux,*

1750 PL dont 42% d'immatriculations en France	*4750 HGVs, of which 42% are registered in France*
PL	*HGVs – Heavy Goods*
par rapport à 1999	*compared with 1999*

Figure 50. HGV traffic at Alpine and Pyrenean borders in 2004 (Source: CETE Méditerranée) (2009 datas soon available)

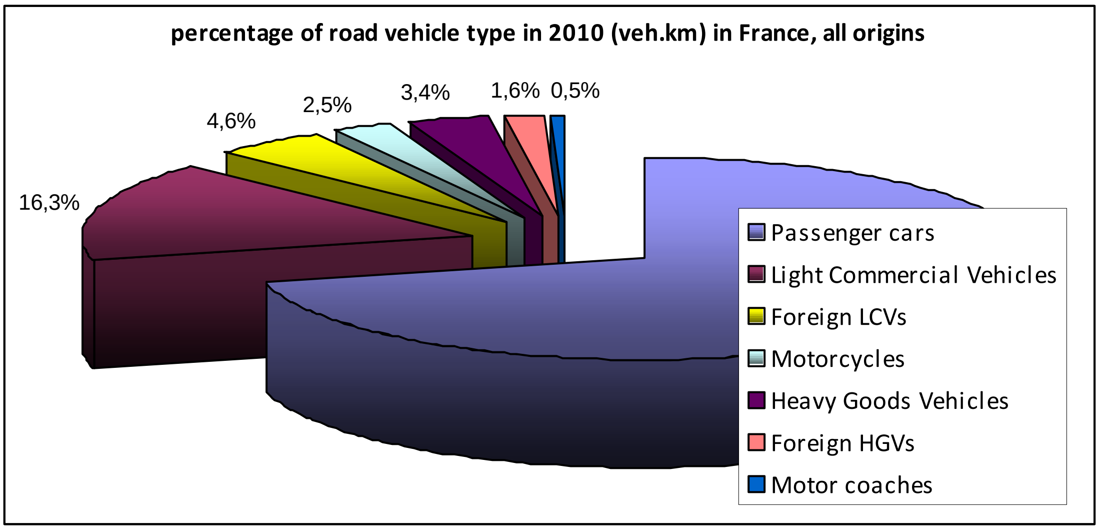


Figure 51 - Datas : SOeS, Sétra

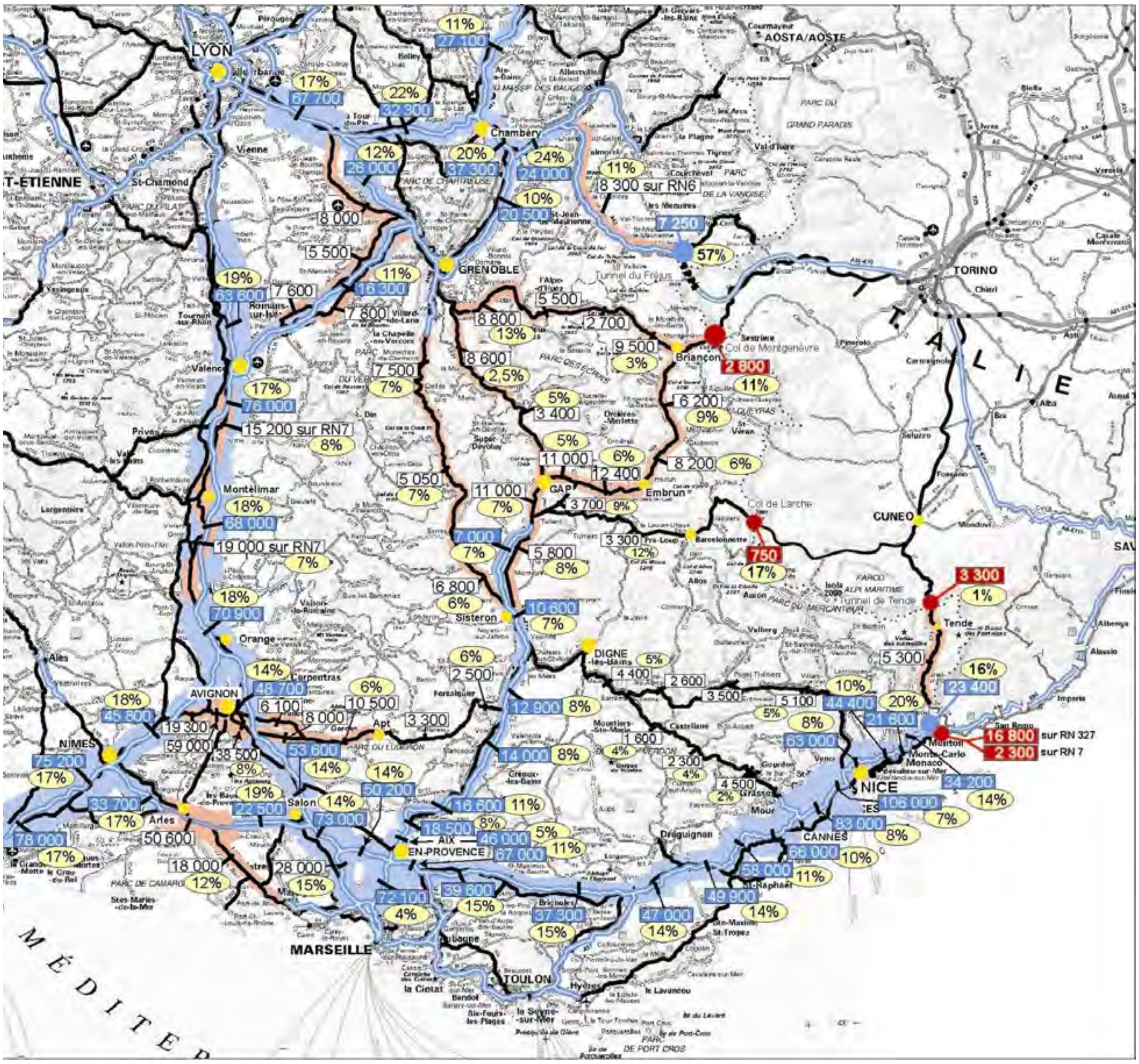


Figure 23. Road traffic and HGV percentages in French greater South-East area in 2002 (Source: CETE Méditerranée)

Average distances covered by HGVs

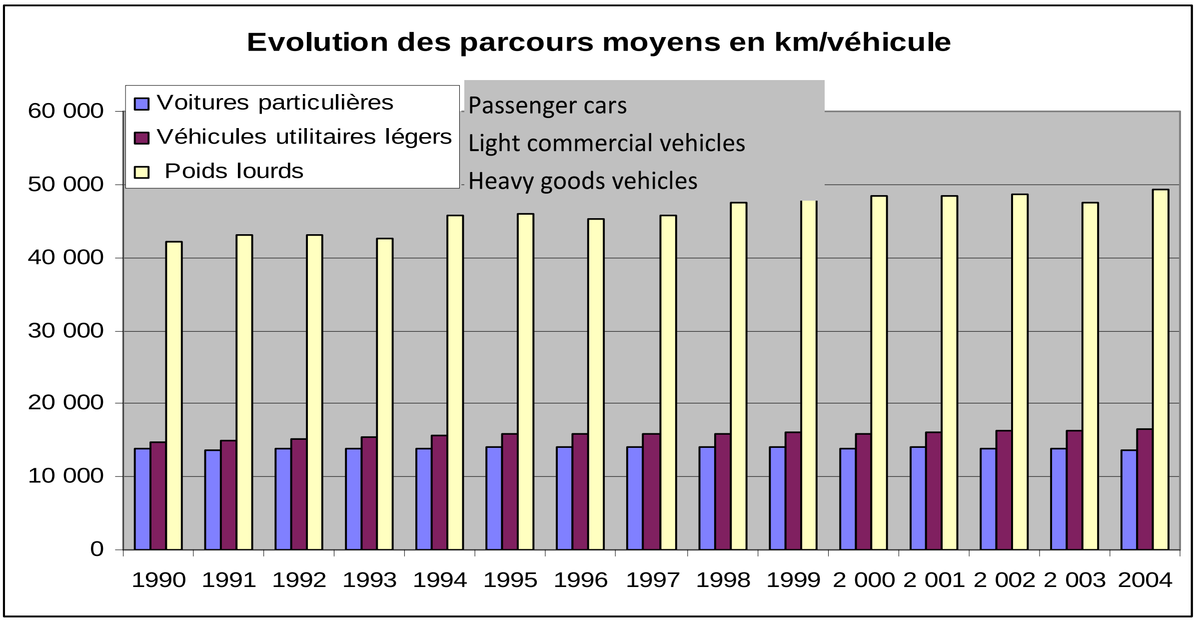
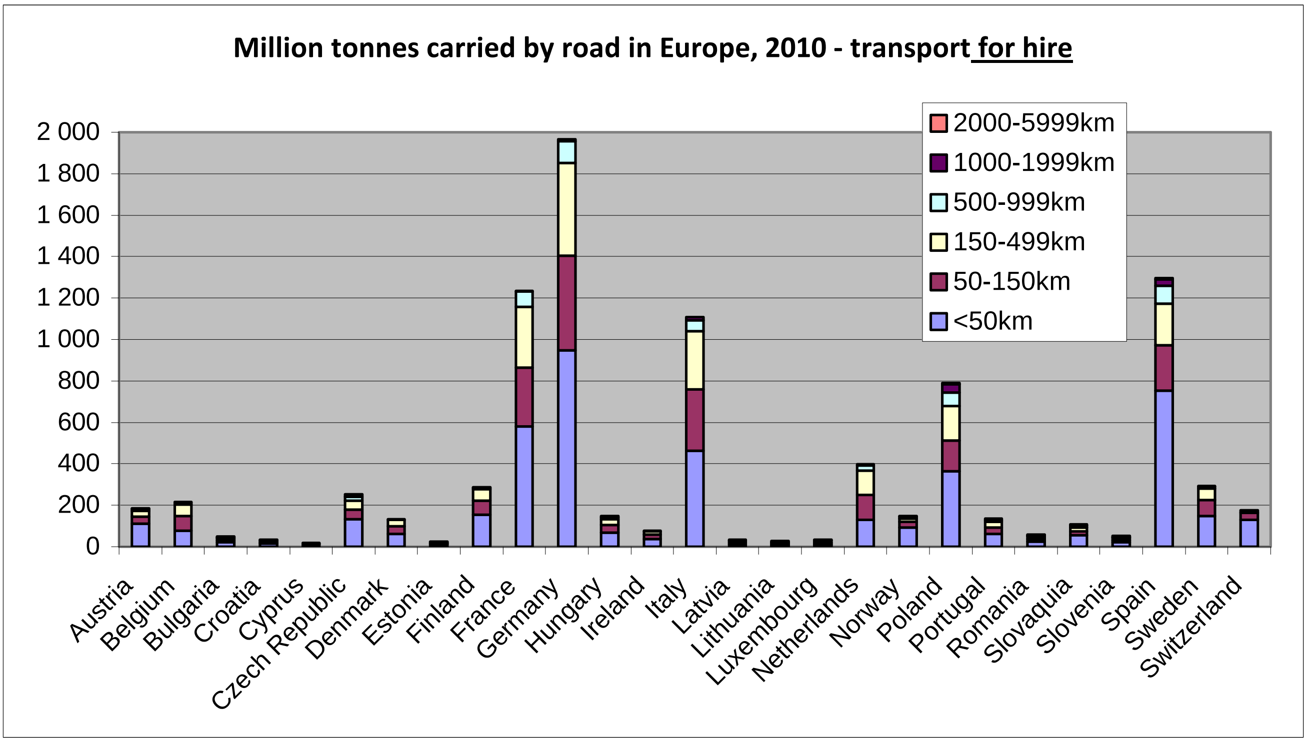


Figure 52. Growth in annual average distance travelled in France (Source: French road transport survey).



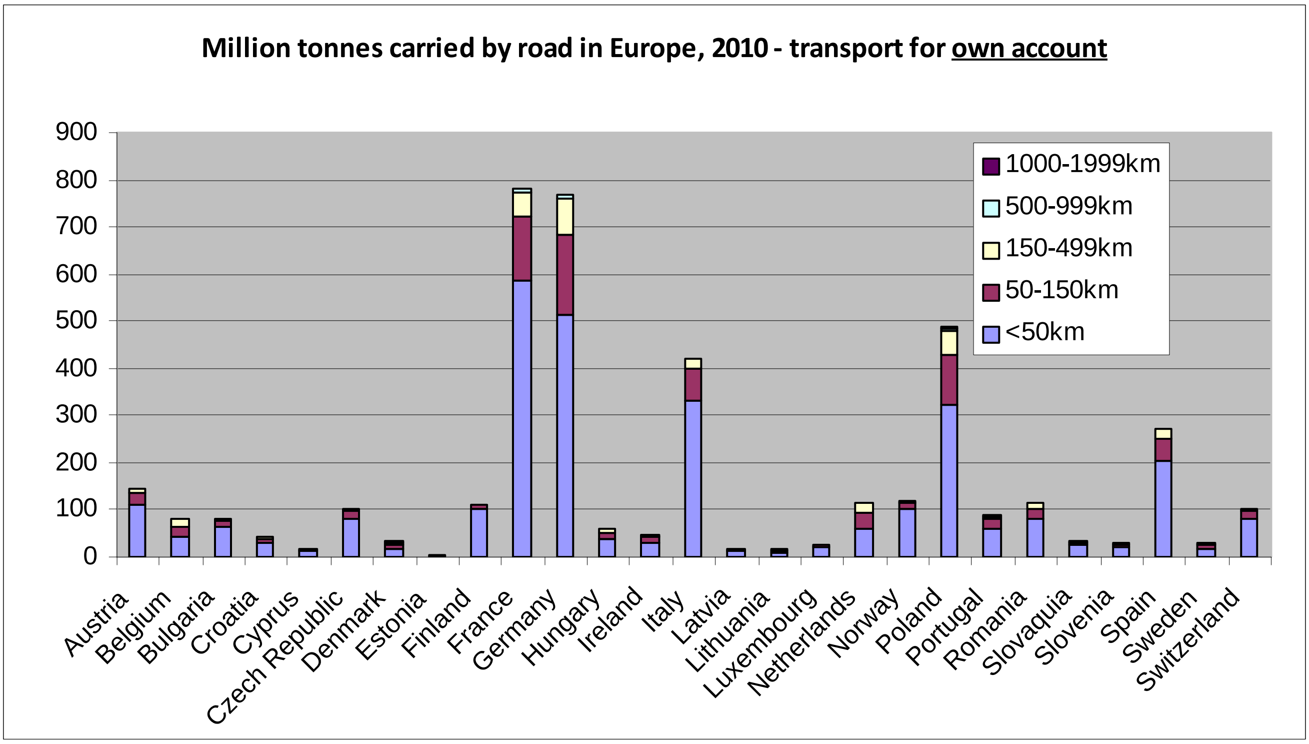


Figure 53 : Total road transport within each country (national, international, transit, cabotage), light vehicles not included. Note : Datas on long distance are not available for some countries (confidential). Datas for Greece, Turkey, Serbia, United Kingdom are not available.

Created with datas from European Union, 2011 (Eurostat).

Average loads and empty HGV levels

Year	Total journeys	% unladen journeys	Average load, excluding unladen journeys	Average load, including unladen journeys
1996	245,053,965	44%	12.5	7.1
1999	265,411,072	43%	12.4	7.1
2001	275,449,774	43%	12.8	7.2
2004	281,976,808	43%	12.9	7.4
2007	303,154,323	43%	13.1	7.4
2010	265,795,664	43%	13.4	7.6

Figure 54. Growth in unladen journeys and average tonnage in road transport (summary) - French-registered vehicles. Source : SITRAM data - road transport survey

For HGVs in transit and exchange traffic, the average loads are a little higher; the transit survey gives the following figures for 2004 (*2009 figures will be soon available – see at the end of this document for contact*) :

- the average tonnage of loaded HGVs in exchange traffic is similar at the Italian and Spanish borders (17.1 and 16.9 tonnes respectively), which corresponds to an increase over the Pyrenees (16.6 t in 1999) and a decrease over the Alps (18.1 t in 1999);
- loaded HGVs in international transit have an average tonnage of 16 tonnes as in 1999 (16.9 t in 1993) but a reduction in the percentage of empty HGVs from 3.8% in 1999 to 3.1% in 2004, leading to a slight increase in the average load for all vehicles, from 15.3 t in 1999 to 15.5 t in 2004.

Type of transport	% unladen journeys	Average load, excluding unladen journeys	Average load, including unladen journeys
Cabotage (1)	75% (2)	15.7	4.0
Export	28%	16.7	12.1
Import	30%	18.3	12.7
National	43%	13.3	7.5
Transit	3%	17.0	16.5
Total	**43%**	**13.4**	**7.6**

*Figure 55. Unladen journeys and average tonnage per type of transport in 2010, **French Flag** (French-registered vehicles). Total is largely influenced by the national transport, which is the most important in volume. Source: SITRAM data - road transport survey*

(1) : "Cabotage" includes the cabotage within one country, but also transport between several countries by a French-registered vehicles, without passing through France.

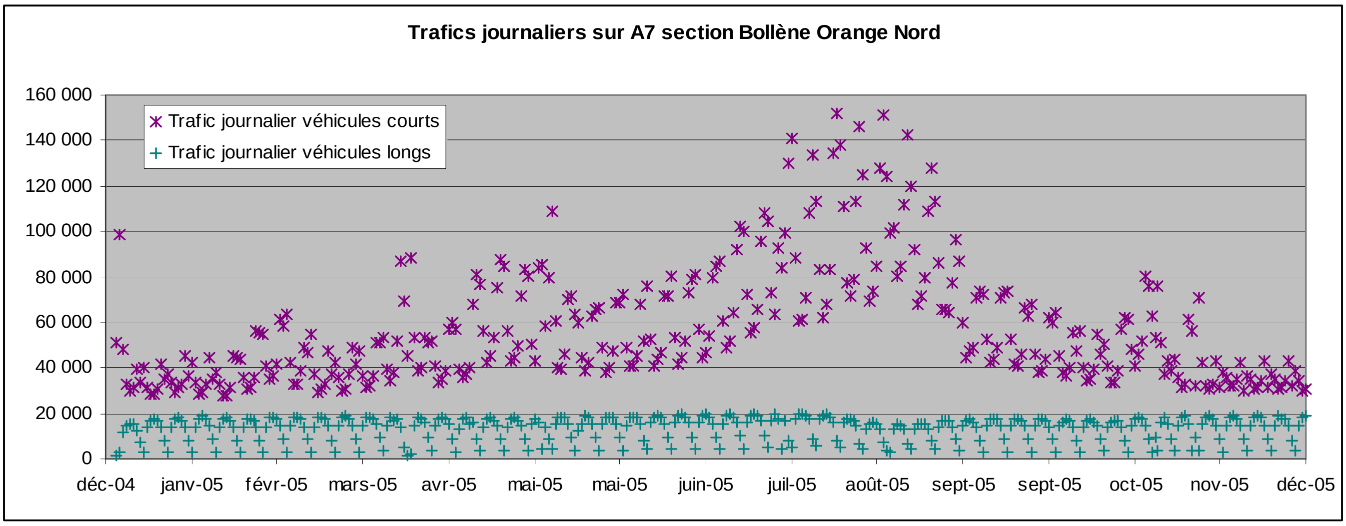
(2) The high percentage of unladen journeys for cabotage is due to repositioning between export or transit destination and import or transit departure points.

Note : these facts take only tonnages in account, figures in veh.km are different. Particularly percentages of unladen journeys, because of shorter repositioning journeys (optimised flows ; e.g. 500km laden journey, 50km repositioning lorry unladen, return 450km laden, 60 km repositioning unladen → 50% unladen journeys but only 110/950 = 11,6% unladen veh.km)

Year	Type of transport	Number of laden journeys	Number of unladen journeys	tons	% unladen journeys	Average load, excluding unladen journeys	Average load, including unladen journeys
2004	CCSC (1)	240 762	784 626	3 655 993	77%	15,2	3,6
2005	CCSC	175 698	675 679	2 913 568	79%	16,6	3,4
2006	CCSC	250 745	763 727	3 834 339	75%	15,3	3,8
2007	CCSC	180 275	667 980	3 010 610	79%	16,7	3,5
2008	CCSC	137 624	591 631	2 191 082	81%	15,9	3,0
2009	CCSC	146 061	449 823	2 402 191	75%	16,4	4,0
2010	CCSC	154 641	453 735	2 431 970	75%	15,7	4,0
2004	EXPORT	2 058 469	497 680	34 470 979	19%	16,7	13,5
2005	EXPORT	1 872 416	489 744	30 380 253	21%	16,2	12,9
2006	EXPORT	1 935 893	590 569	32 651 202	23%	16,9	12,9
2007	EXPORT	1 864 106	641 013	30 754 934	26%	16,5	12,3
2008	EXPORT	1 671 408	569 516	27 203 601	25%	16,3	12,1
2009	EXPORT	1 366 709	493 922	22 071 593	27%	16,1	11,9
2010	EXPORT	1 409 521	538 899	23 547 494	28%	16,7	12,1
2004	IMPORT	1 828 477	662 061	30 934 540	27%	16,9	12,4
2005	IMPORT	1 669 699	688 632	28 412 935	29%	17,0	12,0
2006	IMPORT	1 738 881	711 200	30 751 375	29%	17,7	12,6
2007	IMPORT	1 814 991	653 883	32 449 986	26%	17,9	13,1
2008	IMPORT	1 627 037	567 062	28 847 720	26%	17,7	13,1
2009	IMPORT	1 279 264	537 134	22 593 477	30%	17,7	12,4
2010	IMPORT	1 331 313	576 381	24 317 282	30%	18,3	12,7
2004	NATIONAL	156 194 848	119 666 064	2 006 724 631	43%	12,8	7,3
2005	NATIONAL	153 841 095	119 244 500	1 997 363 016	44%	13,0	7,3
2006	NATIONAL	162 810 799	126 694 812	2 113 748 427	44%	13,0	7,3
2007	NATIONAL	168 052 554	129 244 050	2 191 052 498	43%	13,0	7,4
2008	NATIONAL	162 483 160	124 933 677	2 144 288 512	43%	13,2	7,5
2009	NATIONAL	141 992 419	109 734 880	1 891 908 822	44%	13,3	7,5
2010	NATIONAL	147 984 664	113 336 218	1 964 845 167	43%	13,3	7,5
2004	TRANSIT	39 614	4 207	702 888	10%	17,7	16,0
2005	TRANSIT	28 637	2 847	481 919	9%	16,8	15,3
2006	TRANSIT	28 661	3 608	513 827	11%	17,9	15,9
2007	TRANSIT	30 910	4 561	574 837	13%	18,6	16,2
2008	TRANSIT	23 620	4 498	383 048	16%	16,2	13,6
2009	TRANSIT	16 431	710	308 904	4%	18,8	18,0
2010	TRANSIT	10 980	312	186 301	3%	17,0	16,5

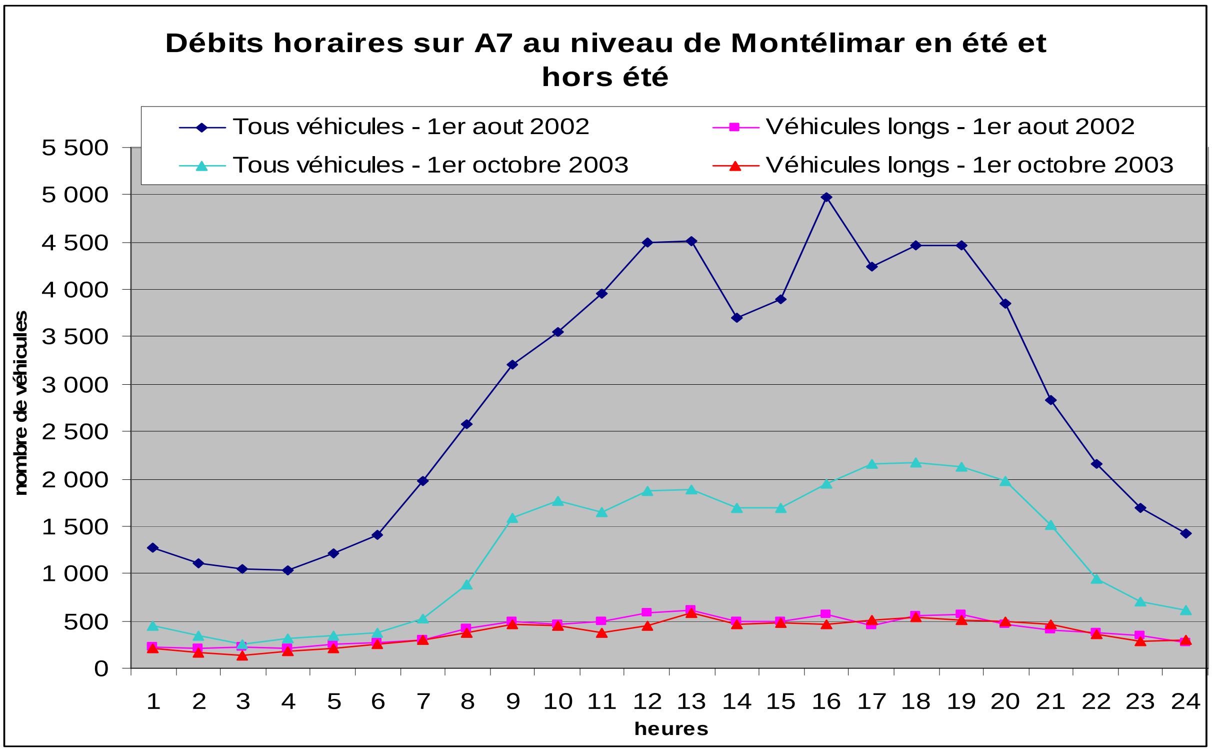
Figure 56. Unladen journeys and average tonnage in road transport – French-registered vehicles (SITRAM data)

HGV traffic distribution over time



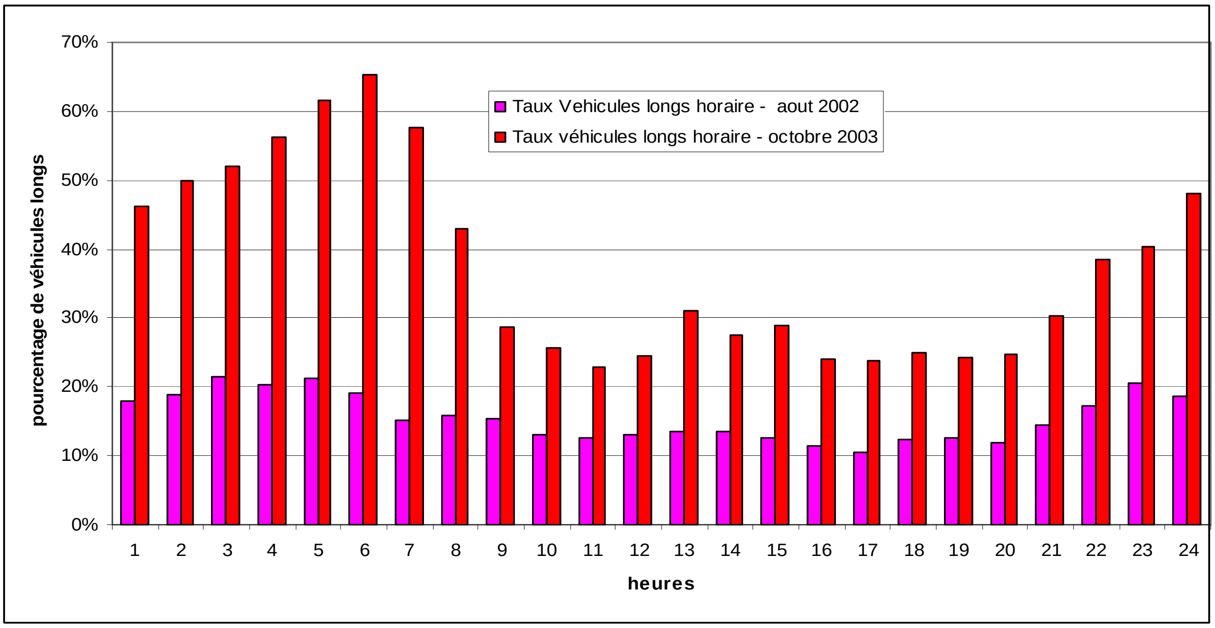
Trafics journaliers sur A7 section Bollène Orange Nord	*Daily traffic on Bollène-Orange Nord section of A7*	Trafic journalier véhicules longs	*Daily long vehicle traffic*
Trafic journalier véhicules courts	*Daily short vehicle traffic*		

Figure 29. Growth in annual daily traffic (during year 2005) (Source: CETE Méditerranée/Data: ASF)



Débits horaires sur A7 au niveau de Montélimar en été et hors été	*Hourly traffic flow on A7 at Montélimar in summer and out of summer*	Véhicules longs – 1^er^ octobre 2003	*Long vehicles – October 1, 2003*
Tous véhicules – 1^er^ août 2002	*All vehicles – August 1, 2002*	nombre de	*number of vehicles*
Véhicules longs – 1^er^ août 2002	*Long vehicles – August 1, 2002*	heures	*times*
Tous véhicules – 1^er^ octobre 2003	*All vehicles – October 1, 2003*		

Figure 57. Hourly traffic flow on A7 motorway at Montélimar according to season (Source: CETE Méditerranée/Data: ASF)



Taux véhicules longs horaire – août 2002	*Long vehicle rate per hour – August 2002*	pourcentage de véhicules longs	*long vehicle percentage*
Taux véhicules longs horaire – octobre 2003	*Long vehicle rate per hour – October 2003*	heures	*times*

Figure 58. Variation in hourly traffic flow (Source: CETE Méditerranée/Data: ASF)

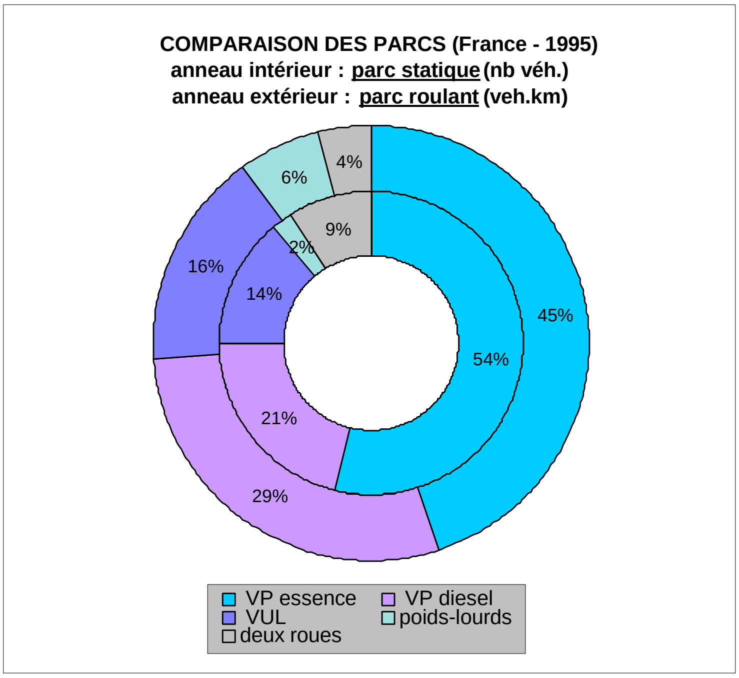
Appendix 2. Maximum Vehicle Dimensions in Europe

PERMISSIBLE MAXIMUM DIMENSIONS OF TRUCKS IN EUROPE					
COUNTRY	HEIGHT	WIDTH	LENGTH		
			Lorry or Trailer	Road Train	Articulated Vehicle
Albania	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Armenia	4 m	2.55 m	12 m	20 m	20 m
Austria	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Azerbaijan	4 m	2.55 m	12 m	20 m	
Belarus	4 m	2.55 m (3)	12 m	20 m	24 m
Belgium	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Bosnia-Herzegovina	4 m	2.55 m	12 m	18.75 m	16.50 m
Bulgaria	4 m	2.55 m	12 m	18.75 m	16.50 m
Croatia	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Czech Republic (4)	4 m	2.55 m (3)	16.50 m	18.75 m	18.75 m
Denmark	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Estonia	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Finland (1)	4.20 m	2.60 m (6)	12 m	25.25 m	16.50 m
France	not defined	2.55 m (3)	12 m	18.75 m	16.50 m
FYROM	4.10 m	2.60 m	12 m	18.75 m	16.50 m
Georgia	4 m	2.55 m (3)	12 m	20 m	20 m
Germany	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Greece	4 m	2.55 m	12 m	18.75 m	16.50 m
Hungary	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Iceland	4.20 m	2.55 m (3)	12 m	22 m	18.75 m
Ireland	4.65 m	2.55 m (3)	12 m	18.75 m (7)	16.50 m
Italy (2)	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Latvia	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Liechtenstein	4 m	2.55 m	12 m	18.75 m	16.50 m
Lithuania	4 m	2.55 m (3)	12 m	18.75 m (4)	16.50 m
Luxembourg	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Malta	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Moldova	4 m	2.50 m	12 m	20 m	16.50 m
Montenegro	4 m	2.50	12 m	18 m	16.50 m
Netherlands (8)	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Norway	not defined	2.55 m (3)	12 m	19.50 m	17.50 m
Poland	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Portugal (2)	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Romania	4 m	2.55 m	12 m	18.75 m	16.50 m
Russia	4 m	2.55 m (3)	12 m	20 m	20 m
Serbia	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Slovakia	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Slovenia	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Spain	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Sweden	not defined	2.55 m (3)	24 m (5)	24 m (5)	25.25m
Switzerland	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Turkey	4 m	2.55 m (3)	12 m	18.75 m	16.50 m
Ukraine	4 m (9)	2.60 m	22 m	22 m	22 m
United Kingdom	not defined	2.55 m (3)	12 m	18.75 m	16.50 m

1. For vehicles registered in an EEA member country
2. Increased values are applicable for certain types of transport (i.e. containers, motorcars, etc.)
3. Vehicles at controlled temperatures = 2.60 m
4. Road train specialised in the carriage of cars: height = 4.20 m; length = 20.75 m
5. Theoretically, but in practice: 25.25 m in conformity with Directive 96/53/EC, Article 4
6. Road train (total length over 22 m); width = 2.55 m as from 1 Jan 2010. Road train (>22m) units and coaches fitted with a new vehicle body on 1-Oct-2004 or later; width = 2.55 m. Vehicles at controlled temperatures
7. But may be allowed up to 22 m subject to certain restrictions
8. Under specific conditions EMS (European Modular System) combinations may have a max. length of 25.25 m and max. weight of 60 tons; Domestic transport of 45 ft containers is accepted with combinations of vehicles (tractor – trailer – container) of max. length of 17.30 m. The maximum overhang of the container to the (rear) underrun protection shall not exceed 0.60 m
9. Container trucks = 4.35 m

Figure 59. Permissible maximum dimensions for road vehicles in Europe - source: International Transport Forum – Oct 2011

Appendix 3. Additional Statistics on Vehicle Numbers



COMPARISON OF VEHICLE NUMBERS (France 1995)
Inner ring: vehicles registered (number of vehicles)
Outer ring: vehicle traffic (veh.km)

- Passenger cars, petrol
- Passenger cars, diesel
- LCVs
- HGVs
- Two-wheeled vehicles

Figure 60. Comparison of registered vehicle numbers and vehicle traffic

	1970	1980	1990	2000	2005	2009
Austria	:	:	:	326 784	338 888	370 907
Belgium	186 639	217 425	:	502 979	604 437	676 644
Bulgaria	:	:	:	237 655	311 038	290 784
Switzerland	:	:	246 191	270 325	297 088	317 047
Cyprus	:	:	74 018	113 581	116 797	121 935
Czech Republic	89 000	133 000	156 000	275 617	415 101	587 032
Germany (including former GDR from 1991)	1 028 116	1 277 167	1 388 505	2 610 885	2 573 077	2 385 099
Denmark	245 347	248 787	286 613	373 293	:	:
Estonia	:	51 100	67 700	82 119	86 201	73 594
Spain	1 100 000	1 338 258	2 332 928	3 780 221	4 655 413	5 136 214
Finland	:	:	264 157	304 318	376 092	443 912
France	1 504 100	2 514 595	:	5 194 817	5 417 502	5 405 456
Greece	105 032	400 940	743 176	1 043 018	:	:
Croatia	:	:	56 823	115 941	151 134	156 057
Hungary	:	:	208 302	328 357	375 236	419 416
Ireland	:	:	143 166	205 575	:	:
Iceland	:	:	13 122	18 662	24 477	:
Italy	1 260 560	1 600 354	:	3 377 573	4 179 659	4 584 210
Liechtenstein	:	:	:	2 166	:	2 446
Lithuania	47 386	65 683	83 035	88 346	106 247	126 519

Luxembourg	8 528	8 559	11 275	20 415	24 881	29 191
Latvia	:	:	53 692	86 853	100 151	106 376
Former Yugoslav Republic	:	:	15 489	20 763	14 702	14 160
Malta	:	:	21 870	41 983	:	:
Netherlands	286 000	345 400	506 617	839 194	938 898	945 723
Norway	:	152 545	304 327	70 652	458 772	514 984
Poland	:	:	1 010 143	1 783 008	2 177 901	2 595 485
Portugal	100 000	234 505	555 459	1 658 229	:	:
Romania	38 877	59 100	29 512	413 493	:	629 753
Sweden	31 962	70 797	309 520	367 515	454 005	506 571
Slovenia	15 946	28 455	30 767	50 232	60 234	74 749
Slovakia	:	:	149 902	149 902	:	265 614
Turkey	:	:	520 760	1 188 742	2 075 403	2 817 817
United Kingdom	1 624 480	1 852 000	2 705 566	2 861 463	3 373 441	3 564 489

Figure 61. Number of lorries (all sizes) in European countries, 1970-2009; Source – Eurostat . Europe 2009 : ***37 millions lorries***

	1970	1980	1990	2000	2005	2009
Austria	:	:	386 438	17 682	19 161	17 065
Belgium	11 730	17 376	:	45 452	47 646	47 418
Bulgaria	:	:	:	21 735	22 828	27 024
Switzerland	:	:	5 942	8 193	10 176	10 761
Cyprus	:	:	:	1 085	1 558	2 162
Czech Republic	:	:	:	22 669	24 060	14 735
Germany (including former GDR from 1991)	112 490	222 832	382 066	171 124	192 124	170 911
Denmark	6 787	10 324	15 227	11 557	:	:
Estonia	:	:	:	:	:	7 517
Spain	10 000	24 166	68 157	142 955	:	206 730
Finland	:	:	:	5 309	6 064	8 966
France	61 100	127 864	166 809	197 668	239 680	211 918
Greece	4	367	409	9 293	:	:
Croatia	:	:	:	5 748	8 164	8 906
Hungary	:	:	38 397	24 426	34 917	47 304
Ireland	:	:	:	:	:	:
Iceland	:	:	:	772	1 064	:
Italy	13 234	32 729	67 780	115 958	:	157 807
Liechtenstein	:	:	:	294	:	266
Lithuania	2 079	6 410	7 752	10 267	16 239	19 806
Luxembourg	380	892	6 697	4 228	4 724	5 550
Latvia	:	:	6 273	10 228	12 962	14 195
Former Yugoslav Republic	:	:	2 332	3 865	3 339	4 263
Malta	:	:	:	1 181	:	1 223
Netherlands	13 000	22 700	36 214	59 804	65 608	71 560
Norway	:	2 379	3 604	5 299	6 047	7 484
Poland	:	:	35 934	96 060	126 604	201 282
Portugal	106 882	14 275	19 509	49 879	:	:
Romania	:	:	:	31 923	:	32 106
Sweden	:	:	3 975	6 707	7 156	8 005
Slovenia	:	:	:	4 298	6 213	8 884
Slovakia	:	:	3 281	3 281	14 141	22 655
Turkey	:	:	:	40 658	76 583	114 436
United Kingdom	:	116 000	106 000	:	333 466	97 841

Figure 62 : growth in number of road tractors in European countries 1970 – 2009 : Source Eurostat. Europe 2009 : **1,5 million tractors**

Appendix 4. Map of French Road Network

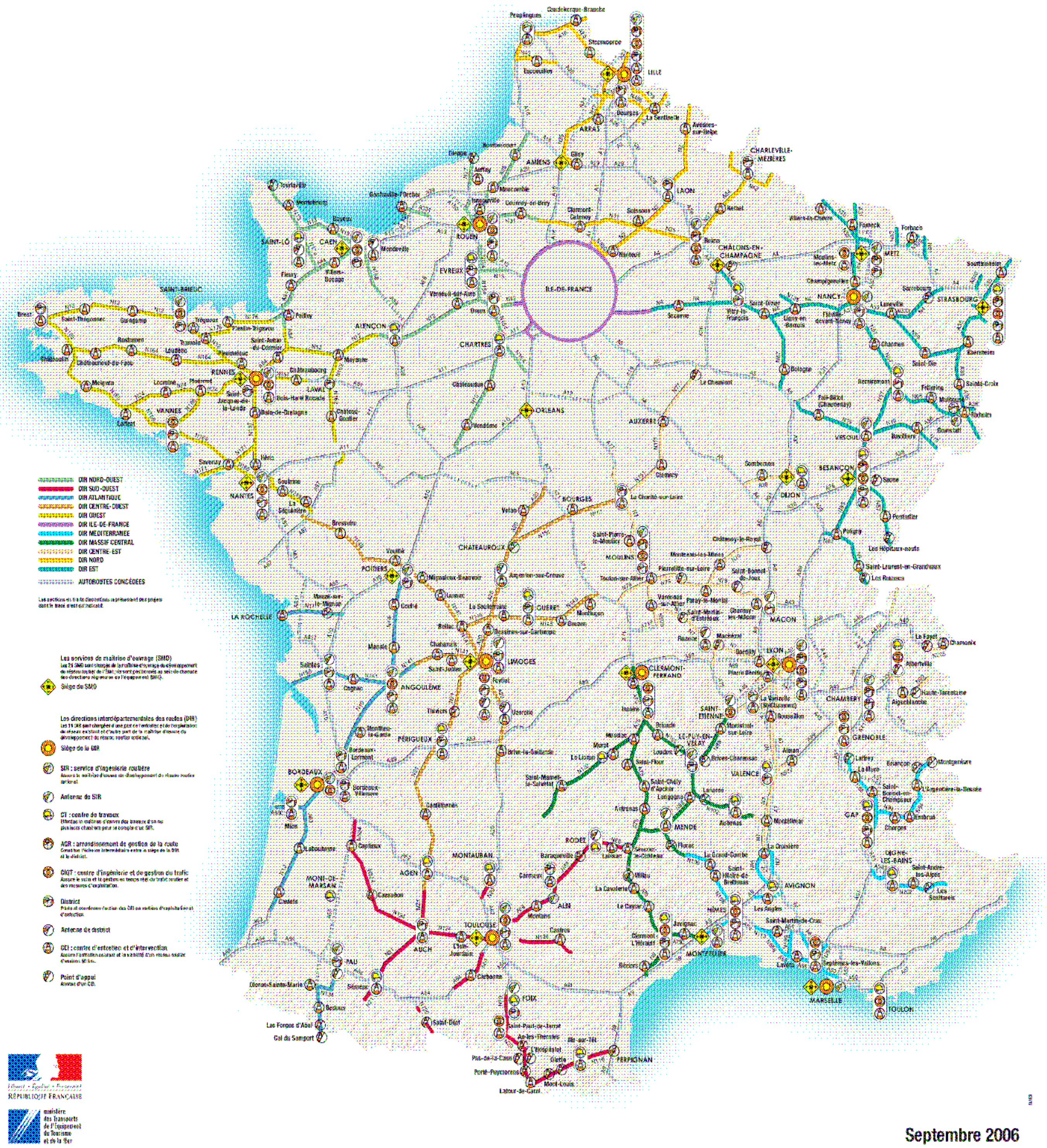


Figure 63. Map of French national road network (Source: General Highways Directorate)

Appendix 5. Additional Information on Notion of Inconvenience to Road Users

The inconvenience indicator summarises the average state of congestion for unsaturated periods. By calculation, it can be compared to the average annual daily traffic depending on a number of parameters relating to the motorway, and parameters of the time-flow function. As a result, four service levels with their corresponding inconvenience indicators – ranging from less than 10% to over 45% of time where traffic is disrupted – can be qualified.

For example, **for a 3-lane motorway with 15% HGVs**, the service level thresholds are presented in the table in Figure 37.

Characterisation of the situation	% time held up for light vehicles on annual average	AADT (veh/day) both directions	Average saturation frequency	% time lost for light vehicles on annual average
Free-flowing	**< 10%**	**< 62,000**	Slowdowns or short waiting periods are not to be excluded, but they are not localised	< 3%
Disrupted	**10 to 20%**	**62,000** to **70,000**	Outside the summer period, saturation occurs on an average of one day in 20, mainly at holiday periods and school holidays	3% to 7%
Highly disrupted	**20 to 45%**	**70,000** to **81,000**	Outside the summer period, saturation occurs on an average of two days per month, mainly at holiday periods and school holidays	7% to 16%
Extremely disrupted	**> 45%**	**>81,000**	Outside the summer period, saturation occurs on an average of three days per month at holiday periods and school holidays and certain working days	> 16%

Figure 64. Service level thresholds on A7 and A9 motorways

Appendix 6. Flow-Speed Curves

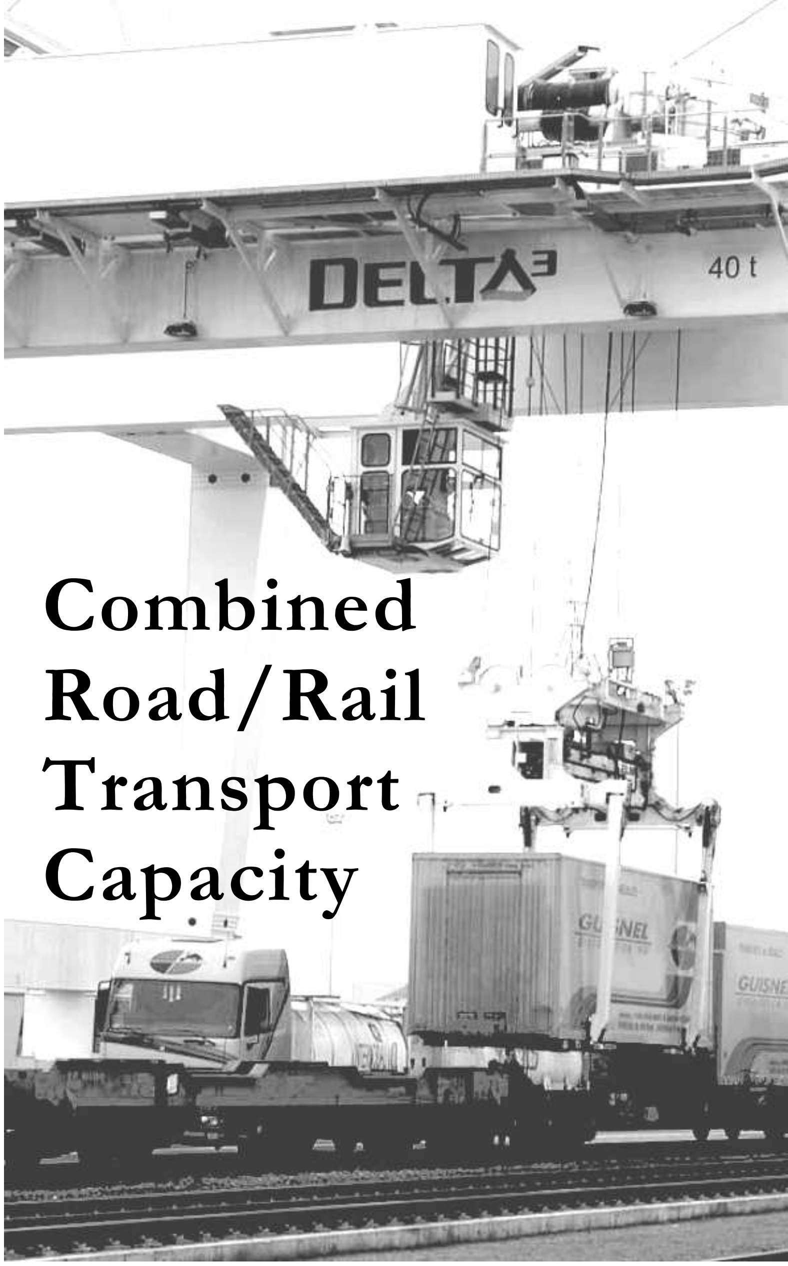
Traffic forecast models are based on flow/speed curves which, depending on a large number of indicators characterising the road and the traffic it carries, and **notably the percentage of HGVs**, enable correspondences between traffic flow and daily or hourly average vehicle speed to be obtained for each type of road. For a HGV percentage of 15%, the flow/speed curves resemble those illustrated in Figure 38.

If an average hourly speed of 80 km/h is achieved on a dual 2-lane motorway, the traffic flow can be estimated at 3200 PCUs/h/direction.

With AADT approaching 60,000 vehicles per day on a limited-access dual two-lane road, the average speeed over the day approaches 75 km/h.

For further information on the curves and the method of calculation, contact Sétra, CSTM division, DEOST (Transportation Systems Organisation). See contact at the end of the document.

Section 5 – Combined Road/Rail Transport Capacity



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Introduction

Very often referred to in national and European transport policy documents, intermodal transport is intrinsically international within the countries of the European Union: two-thirds of road/rail transport in Europe crosses borders and this proportion is continuing to grow at the expense of domestic transport.

While combined transport is tending to grow overall on a European scale, with ¼ of freight trains, the French combined transport sector is in a slump. In 2004, in European Union countries, combined transport traffic increased by 8% in national markets and 16% internationally; over the same period, French combined transport dropped by 10% in terms of domestic traffic and 20% in international traffic. Although France has made the most of its relatively flat geography to develop an efficient motorway network favourable to road transport, it cannot be said to be lacking in major point-to-point combined transport routes, although their potential is far from being exploited in view of the vast percentage occupied by road transit.

There is a multitude of reasons for this situation. First, as combined road/rail transport has an international vocation, border crossings must be optimised. European development of combined road/rail transport depends on the construction of the European railway space which depends on system interoperability. Furthermore, the combined road/rail transport technique calls on the involvement of several participants in clearly divided tasks. The transport service that road carriers sell to their customers therefore largely escapes from their control. Intermodal transport also comes up against operator-related issues. Operators generally show a deficit and are hardly in a position to invest and develop a profitable activity. Finally, the rules of railway operation, in terms of both pricing and assigning slots between the various types of traffic and operators, pose a further problem. Consignors often criticise the railways and road/rail transport for a lack of punctuality.

Yet combined road/rail transport is often presented as a sustainable transport solution. The results achieved in some countries or on certain lines shows that conditions favourable to the success of intermodal solutions can be found in Europe.

The purpose of this section is to highlight the stakes involved in the capacities of combined road/rail transport: certain particular aspects relating to the combined transport of sea containers are not developed here. Following a reminder of some general information relating to this mode of transport, the characteristics of the equipment used will be presented. Capacity matters will then be analysed, firstly by understanding the constraints placed on combined transport, and secondly by studying the design of intermodal terminals.

1 – General Information on Combined Road/Rail Transport

1.1 – Definitions

Combined road/rail transport is intermodal transport where the major part of the journey, in Europe, is by rail, and any initial and/or final legs carried out by road are as short as possible

source: UNECE [36].

Refer to the glossary for definitions of multimodal and intermodal transport.

1.2 – Advantages and drawbacks

1.2.1 – Advantages (according to the UIRR[16])

On a macro-economic level, for the community of businesses and citizens:

- respect for the environment;
- combination of the flexibility of road transport with the security of rail;
- contribution to the relief of congestion in the motorway and road network and improvement in road safety;
- development of the exchange of goods throughout France and Europe from the point of view of massification of flows between terminals.

On a micro-economic level, for road carriers:

[16] UIRR: International Union of combined Road/rail transport companies

- the possibility of maintaining control over the transport service and exclusive contact with customers (which is not the case when the consignor contacts a rail carrier directly, for example);
- savings on fuel and maintenance expenses;
- the possibility of promoting growth while minimising investments in tractive stock;
- contribution to improved staff management;
- exemptions, depending on the country : for example in France, allowing a 44-tonne load instead of 40 tonnes within a 150-kilometre radius around the combined transport terminal. This advantage is being discussed within debate on 44t GWTR generalization.

1.2.2 – Drawbacks

For the community: combined transport terminals are generally situated near built-up areas. In the train arrival/departure time slots at the beginning and end of the day, they generate additional HGV traffic on often congested suburban routes. As a train can load up to 35 Intermodal Transport Units (ITUs), it generates 35 HGVs, each one of which is to be counted twice (outward and return journeys), multiplied by the number of trains.

For carriers using combined road/rail transport services:

- lack of control over the rail leg of the journey with the risk of delays and strike action. According to the UIRR, since 1999, 15 to 30% of trains are delayed in Europe (over the 30-minute tolerance margin) – <15% for accompanied rolling motorway, <20% for national combined transport, >30% for international. Eighty percent of delays are ascribable to the lack of tractive stock and staff. Road carriers deliver on time in around 95% of cases;
- transport cost and profitability: traction prices have continually increased (by 5 to 8% per year since 2002 up to 2008) whereas road transport costs have remained unchanged. This is forcing consignors away from combined transport;
- additional cost involved in transhipments;
- the imbalance in traffic flows is difficult to manage; the return of empty swap bodies in the south-to-north direction hampers the profitability of the system.

These drawbacks borne by the carrier are passed on to consignors and influence their modal choice.

1.3 – Description of transport chain

Figure 1 describes the combined road/rail transport chain (illustration of the route followed by an ITU from origin to destination) and compares this to simple road transport.

The use of combined road/rail transport implies placing the goods in a sea container or swap body, transporting this by road to the departure terminal, and retrieving it at the destination terminal to transport it by road to its final destination. It can be seen in particular that combined transport generates a series of isolated actions (including handling operations) which road transport avoids and which are difficult to synchronise and make cost-effective.

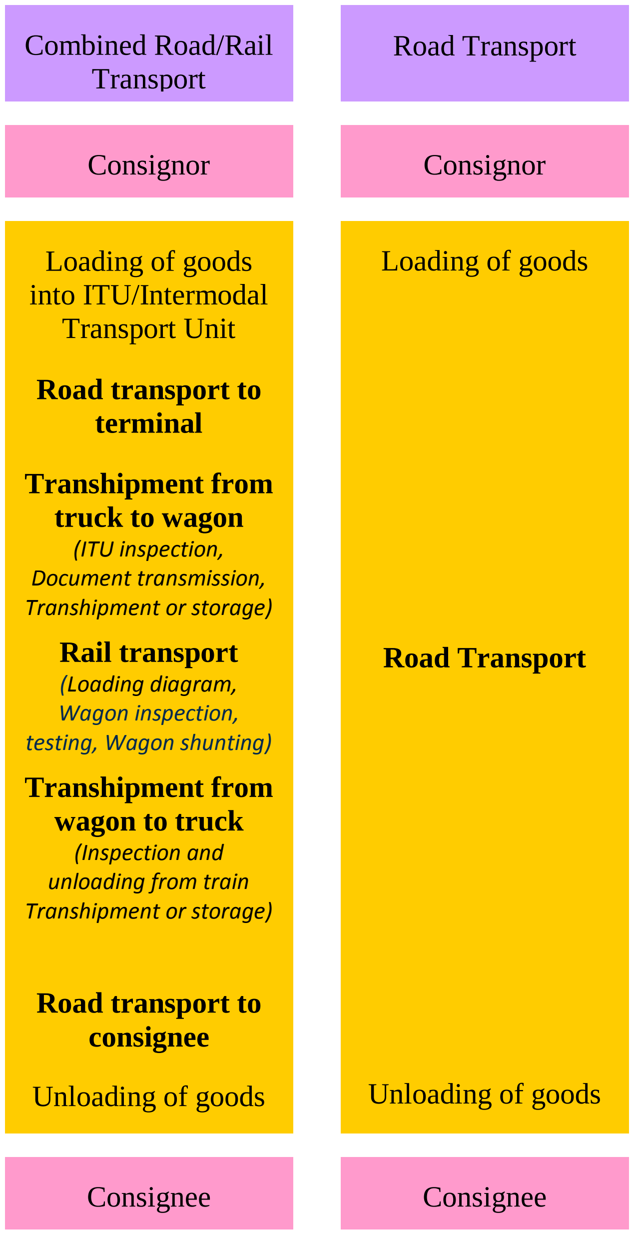


Figure 1. Description of the combined road/rail transport chain and comparison with road transport

2 – Equipment: swap bodies

2.1 – Definition

A swap body is a freight-carrying unit optimised to road vehicle dimensions and fitted with handling devices for transfer between modes, usually road/rail.

Detailed characteristics of sea containers can be found in the “Pallets and containers” section. Here, we shall refer only to swap bodies, equipment dedicated specifically to combined road/rail transport.

Swap bodies are available in various size categories and numerous versions adapted to the main types of consignment packaging. The data below is taken from the ADEME (French Energy Agency) report on combined transport [46].

Box bodies are the most widespread type and are available in all sizes. Large box body specifications:

- capacity: 33 Europallets or twenty-six 100x120 cm pallets;
- volume: approximately 80 m^3;
- tare weight: 3.5 – 4.5 tonnes;
- possible payload: 29 tonnes;
- price: from 7,000 to 12,000 euro;
- average lifetime: 15 years.

Curtainsider or tautliner bodies can be loaded from the rear and from the sides at the same time. Large body specifications:

- capacity: 33 Europallets or twenty-six 100x120 cm pallets;
- volume: approximately 80 m^3;
- tare weight: 5 tonnes;
- possible payload: 29 tonnes;
- price: average of 18,000 euro;
- average lifetime: 11 years.

Bulk bodies are used to transport bulk products that are unloaded through a rear tailgate, requiring the use of a tilting chassis:

- length: 6 to 13 metres;
- volume: 35 to 72 m^3;
- tare weight: 4 to 6 tonnes;
- price: 15,000 to 25,000 euro, net of VAT;
- average lifetime: 15 years.

Refrigerated bodies (reefers) are equipped with a refrigeration unit:

- length: up to 13.60 metres;
- capacity: payload of up to 28 tonnes;
- tare weight: 5 to 6 tonnes;
- price: 40,000 to 45,000 euro, net of VAT;
- average lifetime: 10 to 12 years.

Other types of swap body include silos, tanks, flat beds, etc.

2.2 – Dimensions

The main standardised swap body dimensions in Europe are contained in the table in Figure 2 (source: French National Transport Council [47])

Type	Length (m)	Width (m)	Height (m)	Gross mass (t)	Pallets		Reference
					Euro	UK	
Class A	12.20 to 13.60	2.5, 2.55 and 2.6	2.67	34	30 to 33	24 to 26	Standard EN 452
Class C	6.052 to 7.82	2.5, 2.55 and 2.6	2.67	16	17 to 18	12 to 14	Standard EN 284
ITF (Ex-ECMT)	7.45	2.5	2.67		18	14	Resolution ECMT/CM (91)24
Tank	6.058 to 12.192	2.5	2.67				Standard EN 1432:1997

Figure 2. Main standardised swap body dimensions in Europe. ITF = International Transport Forum

2.3 – Advantages

- The most commonplace swap bodies have equal dimensions to semi-trailers: an outside length of 13.60 m and an outside width of 2.55 m. The inside width of 2.44 m is sufficient to load two Europallets side by side and 25% capacity is gained over a 40-foot container (see figure p37).
- Swap bodies are lighter than containers due to their thinner walls.
- When they are equipped with legs, the carrier can leave them at the customer's premises and set off with another body without having to wait for them to be unloaded.

2.4 – Drawbacks

- They are confined to rail transport and the continuation by road because, being non-stackable, they cannot be used for sea cabotage or waterway transport.
- The diversity of designs, dimensions and technical characteristics can be a handicap to the carrier.

3 – Combined Transport Capacities: what Constraints?

3.1 – Combined transport terminal network

Combined road/rail transport implies the existence of equipped sites, also known as terminals, which are capable of handling ITUs/Intermodal Transport Units and which form a network. A terminal's capacity may be limited by that of the receiving terminals.

As stated above, combined road/rail transport implies the massification of flows. Road/rail terminals must be positioned in areas of high economic density providing a sufficient volume of freight. Combined road/rail transport must only be used where it can be cost-effective; covering the territory with a fine grid of road/rail sites is not economically viable. The network formed by the terminals cannot therefore be homogeneous, but must enable the massification of flows between origins/destinations that allow it.

3.2 – Terminal accessibility constraints

3.2.1 – Terminal location in suburban areas

Platforms are situated in proximity to large economic hubs. Road access to them is therefore threatened by congestion. This also applies to rail traffic. Rail congestion due to the suburban traffic (regional trains) of regional capitals requires a few precautions to be taken in choosing the site which may be created upstream of a freight passing connection of a large hub, for instance. The difficulty for the developer lies in finding a location at the limit of the two areas of congestion – road and rail – but not too far away from consignors' production or storage sites. The site must provide the greatest possible accessibility for a large part of the catchment area.

Furthermore, demand implies increased terminal activity at peak hours. Indeed, to meet the expectations of industrial manufacturers, combined transport proposes overnight trains[17]. Although this system enables combined transport trains to avoid the hours of intense regional trains traffic around large cities, the movements of heavy goods vehicles on the other hand coincide with the hours of major road traffic congestion. Road congestion, without limiting the activity or the capacity of a road/rail terminal, forces carriers to organise themselves to ensure that the swap bodies are delivered to the terminals on time.

3.2.2 – Terminal road service performance

The geographical positioning of terminals has an impact on the efficiency of terminal road services. The works conducted by Patrick Niérat in 1992 [48] produced two results in particular that illustrate the poor performance of initial and final road transport legs:

- on average, more than a third of the journeys made are unproductive, in that they are completed with the fifth-wheel tractor alone or with an empty swap body. This results from the mode of operation and the various constraints to which the company is subjected;

[17] ***Loading is performed at the end of the day, the rail leg of the transport is completed overnight and the swap body is collected in the morning at the destination terminal.***

- the number of swap bodies handled per day and per driver (swap bodies arriving and leaving by train) varies on average between 2 and 4, for an average number of operations (number of journeys completed) of 6.15.

The cost of these initial and final road legs represents 30 to 50% of combined transport cost. Poor terminal service performance linked to the economic environment and the constraints of the combined transport sector are an essential cause of this.

Figures 3 and 4 illustrate these elements with two examples of a circuit completed by a driver covering the initial and final road legs.

The example in Figure 3 illustrates an unfavourable scenario where the carrier unloads and then loads far from the road/rail terminal and where waiting times at firms are high. The total circuit time is nine hours (excluding the compulsory 45-minute rest period).

The example in Figure 4 illustrates a more favourable scenario where the carrier can make two deliveries and collect two loads during the day. The total circuit time is nine-and-a-half hours (excluding the compulsory 45-minute rest period).

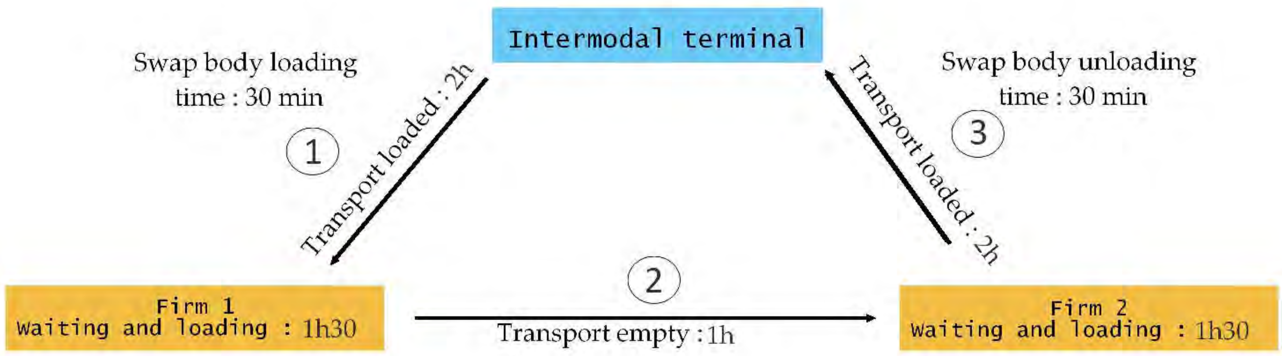


Figure 3. Example of initial and final road leg circuit

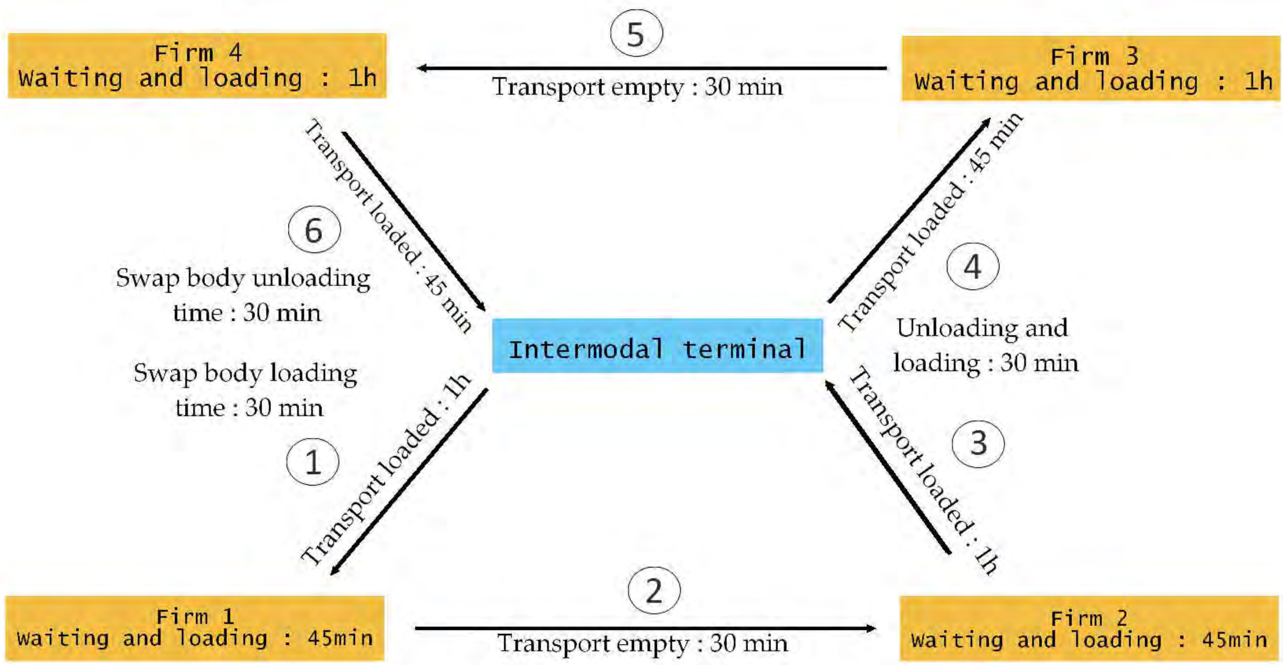


Figure 4. Example of initial and final road leg circuit

3.3 – Terminal market areas

We have already seen that road/rail terminals must therefore be positioned in areas of high economic density and providing a sufficient volume of freight. The market area of a combined road/rail transport terminal is a factor that influences the capacity of this terminal.

The works conducted by Patrick Niérat in 1992 [49] are based on the theory of market areas which, by comparing costs, can be used to determine the area linked to an intermodal terminal for which combined road/rail transport is less expensive than road transport alone.

The market area is the result of a theoretical construction. It is distorted by the conditions under which the firm operates (imbalance in terms of long-distance traffic, terminal service empty journey rate, drivers' wage level, etc.), by discounts granted by operators and by the productivity of the equipment used. The parameters conditioning the cost-effectiveness of combined transport can thus be defined.

3.3.1 – Impact of empty journeys

As we have already seen, the percentage of empty journeys has an impact on the effectiveness of terminal services and, consequently, the market area of a terminal. Figures 5 and 6 have been drawn up using the example of a Paris-Avignon link and comparing the market area of a terminal according to the percentage of empty terminal service journeys, all other values being equal.

If 50% of terminal journeys are completed empty, the combined transport market area shrinks considerably to a narrow zone around terminal B. Outside the shaded area, the least expensive transport solution for the firm is road transport throughout.

In cases where there are no empty terminal journeys, combined transport is less expensive than road transport alone for all points situated beyond terminal B in the extension of the rail leg. For locations requiring a "back-haul" journey (i.e. where the final leg involves heading back towards point A), combined transport remains a solution up to a certain point beyond which road transport would be the most cost-effective option.

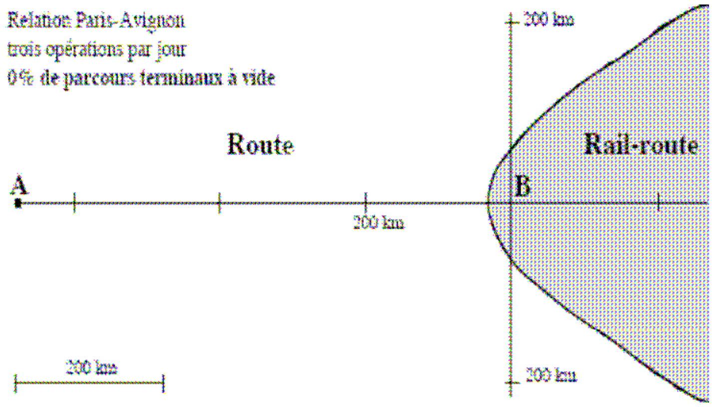


Figure 5. Combined transport market area – no empty terminal journeys (Source: P. Niérat)

*(Paris-Avignon link - three operations per day - **0% empty terminal journeys.** Route = road, rail-route = road/rail)*

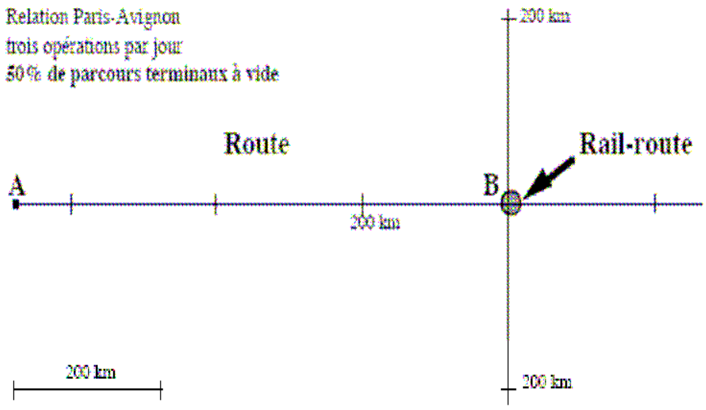


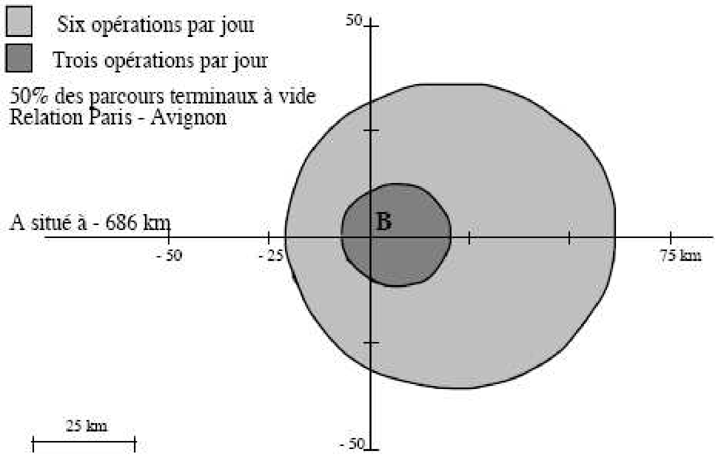
Figure 6. Combined transport market area – 50% empty terminal journeys (Source: P. Niérat)

*(Paris-Avignon link - three operations per day - **50% empty terminal journeys.** Route = road, rail-route = road/rail)*

The empty journey rate therefore appears to be one of the basic ingredients in the competitiveness of combined transport: the higher the rate, the more the combined transport solution is confined to a restricted area around the intermodal terminal.

3.3.2 – Impact of number of driver operations during initial and final legs

We have already seen that the higher the number of operations performed (journeys completed) by a driver during the day, the higher the number of swap bodies actually loaded and unloaded. Figure 7 shows that a rise in the number of operations leads to an increase in the combined transport market area, if all other values are equal.



Six opérations par jour	*Six operations per day*
Trois opérations par jour	*Three operations per day*
50% de parcours terminaux à vide Relation Paris-Avignon	*50% empty terminal journeys Paris-Avignon link*
A situé à -686 km	*A at a distance of -686 km*

Figure 7. Influence of the number of operations on the combined transport market area – Source: P. Niérat

The productivity of terminal services therefore conditions the market area of the intermodal centre.

Other parameters affect the competitiveness of combined transport and, consequently, the size of a terminal's market area: cargo weight and flow imbalance, for example, have repercussions on the size of the market area through the rail charging rate.

3.4 – Viable distance and cost effective traffic levels

The distance at which combined transport becomes a viable alternative to road transport is assessed in relation to the operating conditions for these two modes. Road transport alone involves relatively low fixed costs and variable costs proportional to the number of kilometres travelled. Combined transport, on the other hand, involves high fixed costs (relating firstly to rail transport and, secondly, to transhipment operations) and lower variable costs than road transport.

These considerations imply that, in terms of cost price, combined road/rail transport appears to be competitive in relation to road transport from end to end where the distance of the rail leg exceeds ~500 kilometres and where traffic flows are sufficiently "massified" (see also : ADEME/[46]). Thus, average course of rail leg was 632km for UIRR members, with greater distances for unaccompanied transport than for accompanied transport (source : UIRR annual report 2010)

Patrick Niérat [49] provides a different response. His approach shows that there is a link between rail distance and size of market area (all other values being equal): the further the distance, the greater the market area. Therefore, depending on whether demand is scattered or concentrated around the terminals, distance requirements vary accordingly.

There is no general rule however as the cost price of road transport varies according to several factors such as the type of truck used, the type of journey or the logistics set up by the carrier. Moreover, combined transport can, in certain favourable situations, be viable over shorter distances, and can also be uncompetitive over long distances.

When it is considered that 58% of the tonnage carried by road in France is transported over distances of less than 50 kilometres (2010, see p88, and p112 for European figures), it seems clear that the combined transport market is quite restricted. However, it may be reminded that journeys over 150km in France represent 70% of t.km, which is the unit used to invoice goods transport.

Furthermore, for the operation to be financially profitable for the rail carrier, a full train must be commissioned over a given link. This represents 350 to 400 tonnes net of goods in one direction.

If we assume that combined transport can at best (comparable price and delivery times to road transport) appropriate half of the possible volume of goods on a given axis, a total balanced volume per link of 700 to 800 tonnes would be required per day and per direction, or 1400 to 1600 tonnes/day over both directions. As few links can provide such a volume of traffic, the offer is bound to be restricted and limited to the major traffic streams.

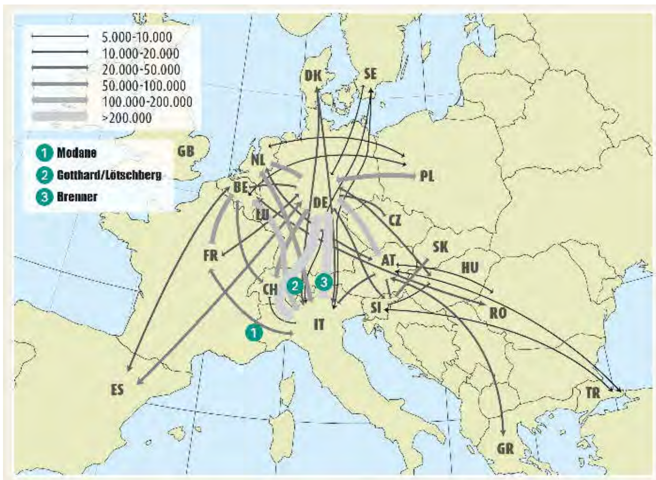


Figure 7 : UIRR unaccompanied international flows, which represent 50% of cross-border unaccompanied combined transport. Unaccompanied transport (16 millions TEUs in Europe) represent 85% of combined traffics.
– Source UIRR annual report 2010

4 – Design of Combined Transport Terminals

4.1 – Operation

Combined road/rail transport requires transhipment installations where the ITU is handled vertically in order to transfer it from the wagon to the HGV chassis and vice-versa. Road/rail terminals therefore comprise:

- railway lines;
- road traffic areas;
- ITU storage areas;
- ITU transhipment equipment (gantry cranes or self-propelled cranes)

For continental traffic, the main function of a road/rail terminal is to transfer ITUs in the shortest time between wagons and trucks on arrival/departure of the train, without long-term intermediate storage[18].

To enable combined transport to propose competitive routing times and to comply with the constraints of railway operation, terminal installations must be sized to accommodate and handle all of the trains arriving in the morning within a short window of around four hours (4.30–8.30 a.m.) and form the trains departing in the evening within a three-hour time slot (6.00–9.00 p.m.). The terminals therefore have an uneven working pattern over the day.

4.2 – Handling capacity of a road/rail terminal

This sub-section deals with the handling capacity of a road/rail terminal taken in isolation.

4.2.1 – Design of a road/rail terminal

Trainset reception sidings and handling yard

The capacity of a road/rail terminal depends first and foremost on its physical dimensions. A terminal must be capable of receiving trains, the length of which is adapted to the potential of the rail network to which it is connected. The maximum length of a train is 750 metres in France (1,000 metres in Europe in the near future on certain priority routes).

Electrified reception sidings can be used to accommodate trains, send wagons to the handling yard or, conversely, to reform a train (*cf.* Figure 11). They also enable an electric locomotive to be replaced by a diesel light rail motor tractor as the handling yard is not electrified; the catenary prevents handling operations beneath the gantry crane. Where the terminal is originally designed with reception sidings less than 750 metres in length, the land resources must permit a future extension of the site, if applicable, in order that complete trains of optimum length can be formed. For financial reasons or because of a lack of available land, some terminals are created with tracks capable of accommodating 450-metre long trains only. This length is sufficient today to dispatch certain trains (to Central Europe, for example). As an indication, a 750-metre long train has a capacity of approximately 55 swap bodies.

If the reception sidings can be installed parallel to the actual intermodal terminal, it is preferable for them to be positioned in line with the terminal to facilitate trainset make-up, and therefore a total terminal length of approximately 1500 metres may be required.

The storage area

In combined road/rail transport, ITUs are often loaded or unloaded directly between a train and a truck, but the handling yard does contain an area designed for temporary ITU storage. Contrary to port areas, ITUs are generally dealt with during the day, and 90% within a half-day.

In France, terminal capacity is not generally limited by the area of the area intended for ITU storage as the necessary space has usually been correctly estimated by the designers.

Examples

The surface area of a terminal is based on the available land and can vary from 2 hectares (Marseilles terminal) to 15 hectares (Dourges terminal):

- the Marseilles terminal measures 60 metres in width for the two handling yards by 300 metres in length. There is no storage capacity as the terminal only accepts continental traffic in transit;

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[18] For long-term storage, the "dry port" function has developed in the context of sea transport with the possibility of storing empty (buffer stock) or full containers on behalf of shipowners. Refer to Appendix 7 of the sea transport section for further details on dry ports.

- the Dourges terminal measures 150 metres in width by 1000 metres in length for the handling area. The terminal takes containers in transit and provides storage for sea containers. It is the largest terminal in France.

4.2.2 – Handling equipment

There are mainly two types of handling equipment for ITU transhipment at a road/rail terminal.

A travelling gantry crane (*cf.* Figure 8) is a 20 to 30-metre wide gantry crane capable of moving the load in three dimensions (height, width and length), as well as moving itself within its own craneway, either on rails or on tyres. In the case of a road/rail terminal, the gantry crane is assigned to a work area limited to a single direction (the track direction). These cranes permit storage under the gantry, insofar as the height and width of the gantry allow. The investment cost, net of VAT, is estimated at €1.3m or more – depending on size – for a rail-mounted gantry crane and €0.6 to 0.9m for a tyred model. This difference in investment is partly compensated by the higher running costs for a tyred gantry crane (fuel and tyres) which are economised with the rail-mounted version. But rail-mounted gantry crane cannot be displaced outside its track.

The “reach stacker” (*cf.* Figure 9) is a self-propelled crane equipped with a front lifting device enabling it to move and stack containers. This equipment offers flexible operation and can access the entire terminal whereas the gantry crane is most often captive to the track. It is used for access to medium and long-term storage areas and to stack empty containers. The investment cost, net of VAT, is approximately €400,000. The operator T3M used to run this type of equipment at its road/rail terminal when it was installed in Bonneuil-sur-Marne.

No ratios can be generalised regarding the use of one type of equipment or another: it depends on the geometry of the site. At terminals close to urban areas where land is rare and expensive, preference will generally be given to gantry cranes.

4.2.3 – Loading/Unloading times

The handling capacity of a combined transport terminal is determined by the least productive link in the terminal chain and therefore most often depends on the time to transfer ITUs between wagons and trucks.

Depending on whether the gantry crane is mounted on rails or tyres, wagon/truck transhipment varies from three to four minutes. For a 35-container domestic train, the average loading or unloading time is thus estimated at around two hours when there is just one gantry crane, although road/rail terminals in France are often equipped with two.

Figure 8. Rail-mounted gantry crane, Delta 3 terminal, Dourges (©MTETM/SG/SIC - 2004 Photo B. Suard)

If ITUs are to be routed from or to a storage area, transport time will depend on:

- the distance from the wagon to the storage hub. This distance may vary by ± 700 metres, the length of a train, depending on whether the container is on the leading wagon or tail wagon, corresponding to an average of ± 5 minutes for the return journey;
- traffic and congestion at the terminal;
- whether the containers are stacked two or three units high, or whether the container to be picked up is on the ground thereby requiring the removal of the container(s) on top.

Overall, the handling time of a container with storage is estimated at ten minutes. For a train with 25% of ITUs to be put into or taken out of storage, the overall unloading or loading time will be three hours, again where just one gantry crane is used.

The use of several tracks and handling cranes will help to reduce these times, but only up to certain limits linked to congestion in the parking areas and traffic lanes.

4.2.4 – Terminal capacity

In view of the various elements highlighted above, the handling capacity of a road/rail terminal is determined by the following factors:

- infrastructure and superstructure: number and length of the transhipment tracks, quantity and type of handling equipment, storage surface area;
- terminal organisation: road and rail access, performance of railway operations, information flows, etc.;
- customer behaviour (observance of collection or delivery timetables) and opening times;
- type of services proposed: domestic/international, hub function.

In the 2004 study into the reserve infrastructure capacity of combined transport up to 2015 ("*Étude sur les réserves de capacité d'infrastructure pour le transport combiné à échéance 2015*") [50] conducted by KombiConsult and Kessel&Partner, a calculation methodology is proposed. This methodology is presented in Appendix 1.

Figure 9 :. Reach Stacker, handling 45-foot containers in Antwerp docks (Source: Sétra)

4.3 – Financing

The terminal infrastructures installed on the land of the French rail network are financed and maintained, in France, by RFF (*Réseau Ferré de France*). The European Union or Regional Councils also contribute to the funding of the terminals. These infrastructures represent a very high burden (Valenton 1 cost FRF 200m (€30m) in 1985 and the Hourcade terminal, opened in 2001, cost around €40m plus an extra €7m for the superstructures specifically for the operators CNC and Novatrans).

Some terminals are installed on land that does not belong to the infrastructure manager (e.g. in France Dourges Freight Centre, Bayonne-Mouguerre European Freight Centre, etc.) which have been developed and funded by other authorities (e.g. CCIs/Industry and Commerce Chambers, regional councils, etc.). The handling equipment is funded by the various operators.

The high investment explains why a considerable amount of traffic needs to be handled to make the cost of ITU transfer acceptable to the market. It also explains why public authorities (Europe, central Government and local authorities) agree to grant financial support to these investments which contribute to the development of an environmentally-friendly system and help to bring land planning more into line with the organisation of the transport chains.

4.4 - Example of Bayonne intermodal terminal

The case of the Bayonne Intermodal terminal is given here purely for information purposes. This example is not intended to lay down rules or good practices for the design of combined transport terminals, but gives a few orders of magnitude and enables a better understanding of the organisation of a terminal.

The Bayonne Intermodal road/rail terminal is situated within the Bayonne-Mouguerre European Freight Centre which stretches over 100 hectares of land stock on the south bank of the river Adour. It is situated at the crossroads of the A63 Bordeaux-Hendaye-Spain and A64 Bayonne-Toulouse motorways and connected to the rail network by a branch line to the Paris-Bordeaux-Madrid line on the one hand, and to the Bayonne-Toulouse line on the other. These facilities are located 6 kilometres upstream of the sea port installations.

The terminal opened in May 2001 and is managed by Novatrans. The Italian operator Ambrogio has also been present at the site since September 2004 but, as it has yet to acquire its own equipment, it uses that belonging to Novatrans.

In 2006, the site covered an area of 4 hectares. The Novatrans terminal (four tracks) and Ambrogio terminal (two tracks) can be used to load 350 to 400 m long trains. Novatrans owns two tyred gantry cranes, three light rail motor tractors (to shunt wagons between the reception sidings and the handling yard), and a yard tractor (to move trailers).

The terminal provides parking space for 150 ITUs and can handle 95 wagons per day. In 2005, 28,000 ITUs were handled (arrivals and departures) with daily traffic amounting to two incoming trains and two outgoing trains. 38 000 were handled in 2010, close to the capacity planned in the first phase of the project – 40,000 ITUs per year, rising to 100,000 ITUs per year in the second phase.

By way of an example, Figures 10 and 11 show simplified diagrams (cross-sectional and longitudinal views) of the layout of the Bayonne Intermodal road/rail transport terminal. Figure 11 does not show the connections to the railway line or road access or traffic in the handling yard. HGV traffic can however pose occasional problems and must be organised.

Example of Valenton II

The new Valenton combined transport terminal, known as Valenton II, was officially opened on July 13, 2006, six months after it was effectively put into commercial operation. As a result, the Valenton site receives and dispatches an average of twenty trains every day. Valenton II has a yard with three tracks, each one 560 m long, and two transhipment gantry cranes, enabling the overall capacity of this site to be almost doubled. The investment for this facility, costing a total of €18m, was jointly funded by the central Government and the Ile-de-France region.

Source: Infrastructure & Mobilité, 2006 [51]

Conventional and combined freight trains in the USA. The "double-stack" system (possible thanks to the absence of tunnels) combined to long trains and long distances leads to another balance in the economy than in Europe (43% rail modal split in 2007, including domestic sea transport). – Image AAR (Association of American Railroads)

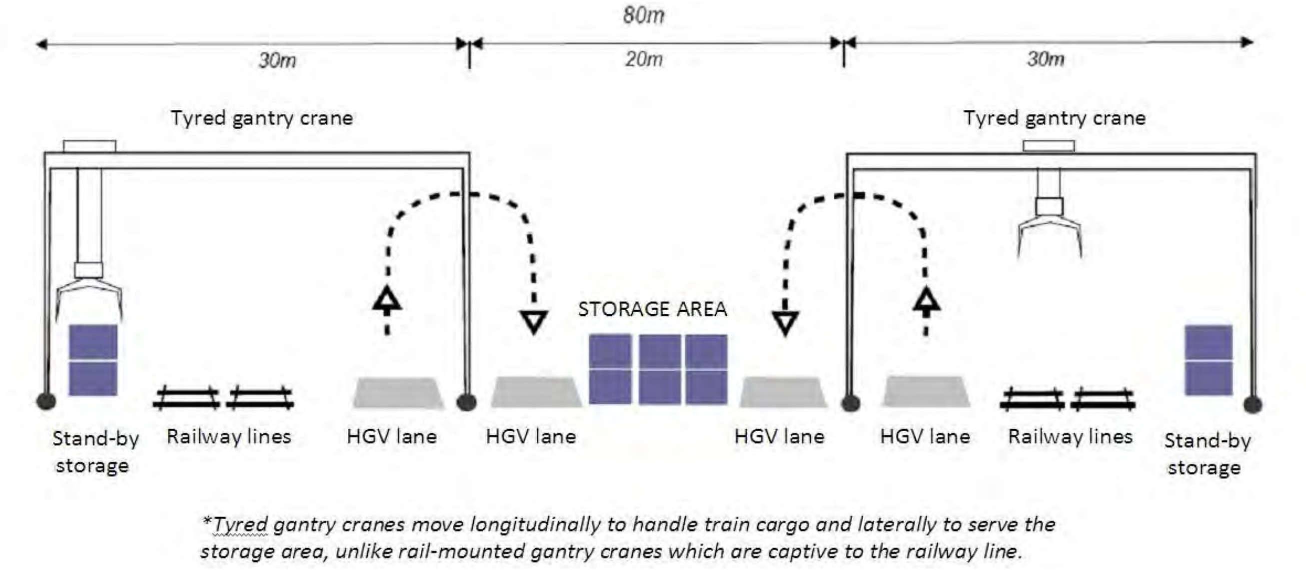


Figure 10. Cross-sectional view of handling yard at Bayonne intermodal road/rail terminal

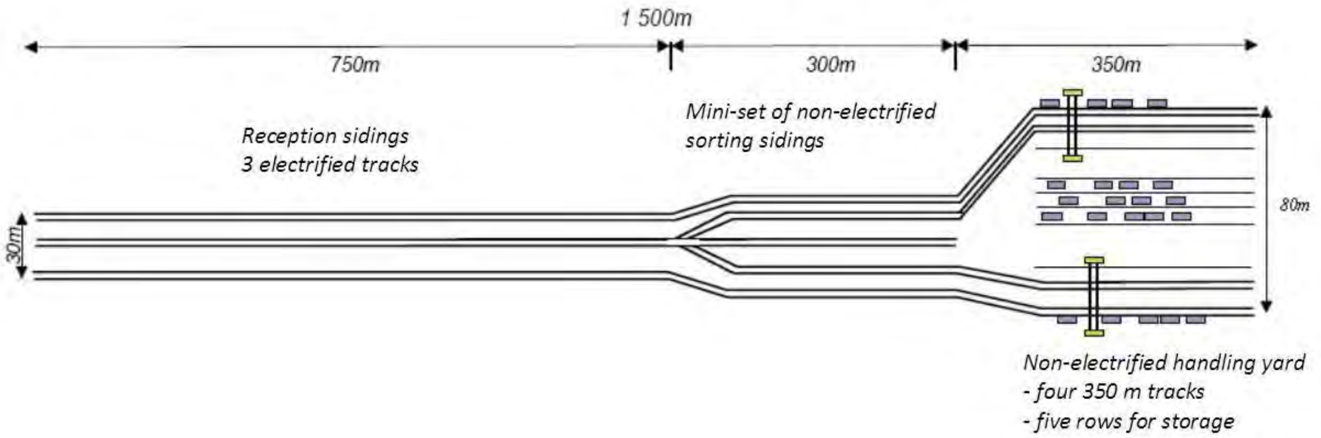


Figure 11. Longitudinal view of Bayonne intermodal road/rail terminal

Another terminal with gantry cranes : Dourges Delta 3, the most important road/rail/river terminal in France. Another crane to the right (not seeable) handles containers and swap bodies for inland waterway. Notice the reach stacker at the back, which handles intermodal units between storage area and gantry cranes. – © Bruno Meignien, Sétra.

Appendix 1. Methodology for calculating Road/Rail Terminal Capacity

This method is proposed by KombiConsult and Kessel&Partner in "*Étude sur les réserves de capacité d'infrastructure pour le transport combiné à échéance 2015*" (Study into the reserve infrastructure capacity for combined transport up to 2015), conducted on behalf of the Combined Transport Group (UIC/*Union Internationale des Chemins de fer/International Union of Railways*) in May 2004 [50]. Its purpose is to determine the capacity of the handling yard, without taking account of breaking and sorting operations that may be performed upstream of the yard.

The underlying hypothesis is that the capacity of the terminal is determined by the smaller of these two limiting factors: the capacity linked to the length of the transhipment tracks (C_{rail}) and the capacity of the handling equipment (C_{hand}).

Determining the capacity linked to the length of the tracks

The capacity C_{rail} linked to track length is determined using the following formula:

$$\mathrm{C}_{\mathrm{rail}} = \frac{L_{track}}{L_{wagon}} \times LF \times FF \times 2 \times N_{DT}$$, where:

> *L_{track} = the length of the transhipment tracks, in metres;*
>
> *L_{wagon} = the average wagon length, in metres;*
>
> *LF = the load factor, in number of ITUs per wagon;*
>
> *FF = the flow factor, corresponding to track use in the course of one day;*
>
> *N_{DT} = the number of days of traffic in the year.*

The formula takes account of the number of incoming and outgoing ITUs, hence the multiplicative factor "2". The limit of this method comes from the determination of the flow factor FF, which corresponds to the number of times per day that all tracks are occupied and therefore, finally, to the number of trains entering the handling yard every day. The study by KombiConsult and Kessel&Partner does not specify the method to be used to determine this factor. An evaluation of this figure by the terminal's managers will therefore enable this coefficient to be estimated.

Determining the capacity of handling equipment

The capacity C_{hand} of the handling equipment is determined using the following formula:

$$\mathrm{C}_{\mathrm{hand}} = C_{crane} + C_{mobile} \times U_{mobile}$$, where:

> *C_{crane} = the capacity of the gantry cranes;*
> *C_{mobile} = the capacity of self-propelled vehicles (i.e. reach stackers);*
> *U_{mobile} = the utilisation factor of self-propelled vehicles for transhipment.*

$$\mathrm{C}_{\mathrm{crane}} = N_{crane} \times \frac{P_{crane}}{MF_{crane}} \times D_{open} \times N_{DT} \text{ and } \mathrm{C}_{\mathrm{mobile}} = N_{mobile} \times \frac{P_{mobile}}{MF_{mobile}} \times D_{open} \times N_{DT}$$, where:

> *N = the number of gantry cranes or self-propelled vehicles at the terminal,*
> *P = the performance of gantry cranes or self-propelled vehicles, in number of ITUs per hour;*
> *MF = the management factor relating to gantry cranes or self-propelled vehicles, representing non-productive movements;*
> *D_{open} = the duration of daily opening times of the terminal, in hours;*
> *N_{DT} = the number of days of traffic in the year.*

Here too, the limit to the method is found in the determination of factor MF. These formulas can be used to enter the various parameters considered in determining capacity and are therefore provided as guidance, but their numerical application remains subject to the delicate estimation of certain coefficients.

Appendix 2. Rolling Motorways & Piggy-back systems

Definitions

Definitions of the different forms of road-rail transport are often subject to misunderstandings. To ensure correct use of terms, the *Terminology on combined transport* from the ITF/International Transport Forum (ex-ECMT) can be usefully consulted. A *rolling road*, more commonly said ***rolling motorway*** , is defined in the document as *Transport of **complete** road vehicles, using roll-on roll-off techniques, on trains comprising low-floor wagons throughout.*

Rolling motorway thus offer the possibility of *accompanied transport*, with a passenger coach being provided in the train to accommodate drivers, although *rolling motorway* is often used to design both accompanied and unaccompanied transport.

The other form of road-rail transport with the lorry onto the train is *unaccompanied transport* : the driver deposits the trailer at the terminal, and another driver collects the trailer at the destination terminal.

The term ***piggyback*** *does not refer to combined transport in general but specifically to the transport by rail of road semi-trailers* – with low-floor flatbed wagons, permitting roll-on roll-off operations from the ends of the train, or with pocket wagons, whose pocket receives the axles of the semi-trailer, permitting a gain on maximal height in cases where the railroad gauge is limited – but leading to stronger and then heavier structure for the wagon, in addition to the truck tare. Road-Railers wagons also permit piggy-back, with a very light system (only bogies) ; it implies however that trailers are specially equipped. We will here use the term in this sense : **action consisting to transport a lorry onto a train.**

Figure 12 : piggyback ("pick-a-back") ride. The concept was extended to the transport of one vehicle onto another – Image Roland Petrasch

The French term *autoroute ferroviaire* refers to the piggyback system in general, but is particularly used for a specific solution, which allow accompanied or (mostly) unaccompanied combined transport with pocket wagons – due to limited height clearance, and absence of legal height limit for trucks in France. Which wagons can pivot to allow roll-on roll-off operation, without gantry cranes or reach stackers.

Piggy-backing is a service aimed at road haulage contractors. It must offer relatively high throughput. The concept consisting of "driving a truck onto a train" requires the vehicle to be passed through specific installations (intermodal terminal) and therefore involves additional costs compared with a journey by road throughout. The transfer operated in this manner must therefore allow external transport costs (pollution, accidentology, energy consumption, etc.) to be reduced.

Due to the above-mentioned economic constraints, piggyback services are particularly suited to:

- the crossing of a physical barrier (sea, mountain, etc.) involving an additional road transport cost (boat, tunnel, special additional toll, etc.);
- long distances over level gradient.

Material resources and technical solutions – the "autoroute ferroviaire" example

Like all railway traffic, the implementation of a piggyback service requires the allocation of an available train path/ slot – i.e. a licence to run on the railway at precise times (refer to the section on rail transport for these matters).

Furthermore, the sizes and shapes of the trucks and wagons call for constraints with regard to gauges. The GB1 loading gauge shall apply to enable the circulation of trains carrying trucks up to 4 metres in height. Moreover, the wagons also require gauge width clearance thereby requiring work to be performed on the present-day lines (shifting of trackside signalling, track circuits, etc.).

"Autoroute ferroviaire" wagons and transfer terminals

The "autoroute ferroviaire" wagon is an articulated, low-floor wagon developed by Lohr Industrie (*Modalohr* wagon), specially designed to transport standard, non-specific road vehicles. It is characterised by:

- standard bogies and wheels to keep maintenance costs comparable to those of a conventional wagon;
- a very low loading floor to enable 4-metre high trucks to be conveyed within the limits of existing railway loading gauges (UIC GB1); 4.03, 4.05 or even 4.08m high trucks are currently being discussed. Some tests with few centimetres polystyrene on 4-m high trucks showed that these dimensions could be allowed without safety risks.
- lateral "herringbone" loading of trucks, directly with the fifth-wheel tractor (no handling equipment), for simultaneous, rapid truck transhipment. Operation of a 750m train at French Le Boulou terminal, between arrival (fully loaded) and departure (fully loaded) of the train takes ~1h20
- a simple intermodal terminal consisting of an asphalted area and a railway track (no platforms). Due to a great surface of asphalt, terminal costs can be consequent.

Figure 12. Modalohr pivoting wagon and Bourgneuf-Aiton hub (© Pascal Raud, Sétra)

Another technical solution

The Arbel Fauvet Rail (AFR) company has developed another wagon concept for the transportation of all types of semi-trailer. This concept had yet not been used.

The system operates as follows: the tractor positions the semi-trailer in a basket. Once the semi-trailer is secured, a self-propelled crane or gantry crane completes the transfer (vertical handling) and deposits the basket in the wagon. AFR wagons are also designed to carry containers or swap bodies. The wagon measures 20.08 metres and weighs 29.7 tonnes with the cradle and the removable devices for container transportation.

It is claimed that a 965-metre train can transport 58 to 60 semi-trailers. Terminal dimensions are estimated at 350 x 160 m with the semi-trailers arranged in a herringbone pattern. Various terminal layouts are possible depending on the required throughput.

A 20-wagon train would take three hours to be dealt with by three people. This corresponds to the handling of a 60-wagon train in one hour by 18 people.

Notion of capacity

Train capacity (where first solution is used)

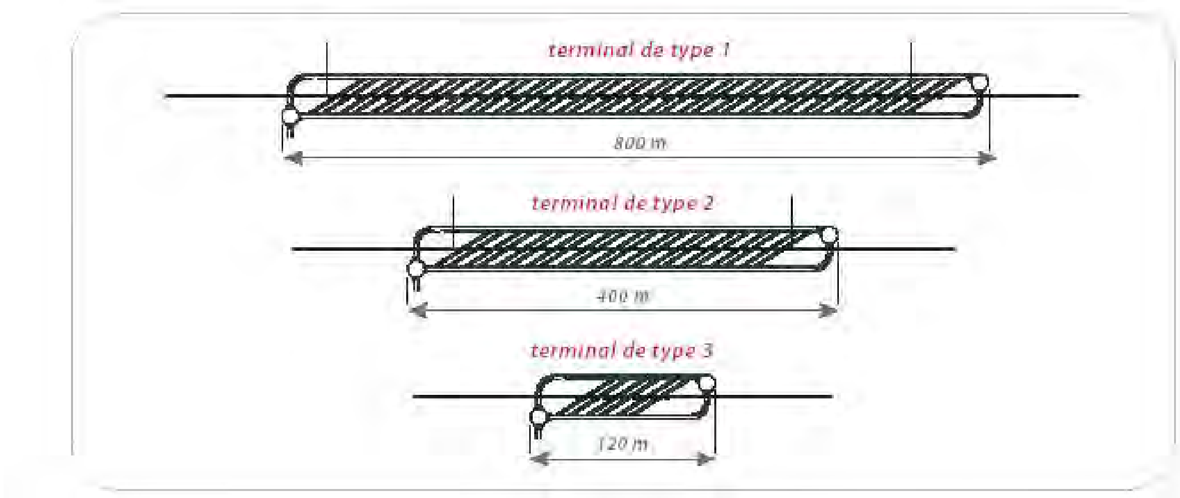
A Modalohr double wagon measures 33 metres and consists of two slots for the transportation of two semi-trailers or one semi-trailer and two tractors. At the end of 2006, the Autoroute Ferroviaire Alpine (AFA) train comprised 11 wagons and therefore 22 slots (for 14 full trucks or 22 trailers). Since 2007, the service between

Perpignan and Luxembourg is provided by 700-metre trains comprising 20 wagons (40 slots). RFF and SNCF are working on 62-slot trains (1000 metres/3000 tonnes).

Terminal capacity

The capacity of a terminal depends on the number of tracks, their length (if they are too short, the trains will have to be broken and shunted) and the quantity of transhipment equipment (ground installations for the Modalohr system or gantry cranes for the AFR system).

Figure 13 shows the accommodation capacities for various terminal sizes (source: Modalohr).



Type of terminal	Capacity	Frequency of trains	Length (750 m train)	Number of movements on terminal (750 m train)
Type 1	High	1 to 2 trains per hour	800 m	0
Type 2	Medium	From 1 train every two hours to 1 train every six hours	200 to 400 m	1 to 2
Type 3	Low	1 to 3 trains per day	120 to 200 m	3 to 6

Figure 13. Accommodation capacity for various terminal sizes (source: Modalohr)

The Boulou terminal (*cf.* Figure 14) could also be taken as an example. This terminal corresponds to a type 2 as defined in Figure 13, with its maximum capacity estimated at four or five trains in each direction per day.

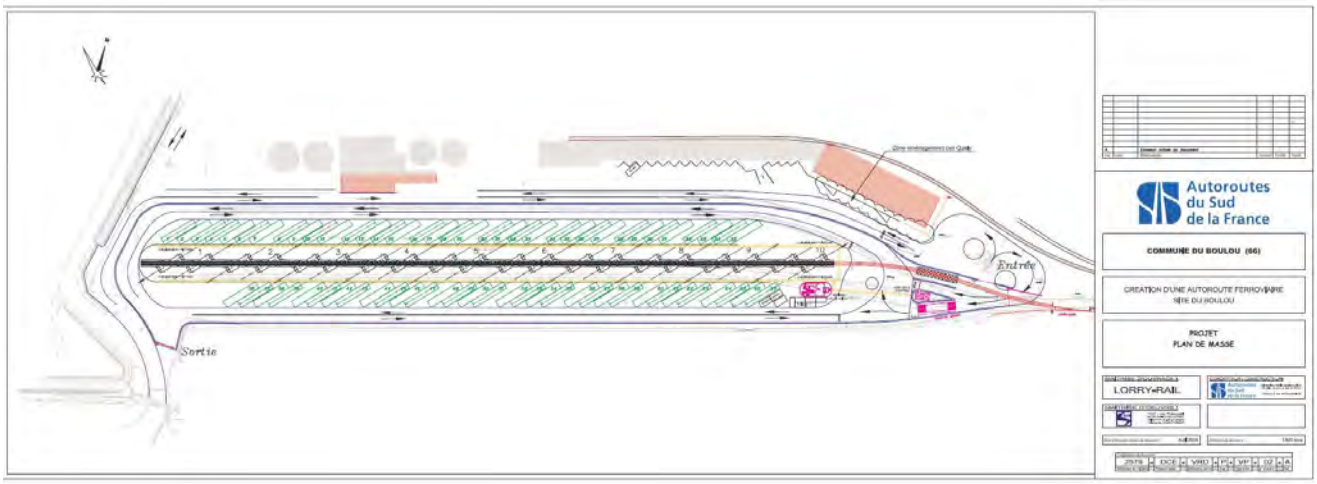


Figure 14: The Boulou terminal on the Perpignan-Bettembourg rolling motorway (source: MEEDTL/DGITM)

Service capacity

To obtain the capacity of the service, the capacities of the available slots (on the line and at the entrance to the intermodal terminal), the trains and the terminal will have to be cross-tabulated. It should also be remembered that demand can also be a determining factor of capacity.

The following formula can be taken as a benchmark:

Capacity = Number of trains per day x Number of days of traffic per year x Fill rate.

The number of days of traffic per year may be between 250 and 325.

The fill rate may be taken as 75%, once the service is up to speed.

Areas of development

The economic viability of the offer (grants included, if any) depends on the comparison with the costs and constraints of the “all-road” option. The solution to the economic equation either comes from an elongation of the distance or from a supplementary local road toll (tunnel). Only a few routes are therefore possible in France with the maximum throughput to be defined as a function of the penetration rate.

Development hypotheses in France concern:

- an Atlantic line from the Basque country to the Paris region, and possibly up to the Nord district;
- a link towards Italy by extending the current AFA with a new transhipment site near Lyons.

The Perpignan-Luxembourg rolling motorway was officially opened by the Minister in April 2007, and put into service in the summer 2007. It began with one train per day, consisting of twenty wagons capable of loading 40 semi-trailers (750-metre train). Today there are 4 trains in each directions, running every 6 hours. It costs road carriers around 900 euro per semi-trailer, compared with a figure of 850 to 1000 euro to cover the same distance of 1000 kilometres by road.

A long-distance – 2,000km – service between Perpignan (Le Boulou, close to the Spanish border) and Sweden was opened in 2011.

In 2010, the French "autoroutes ferroviaires" (Alpine one between Orbassano and Bourgneuf-Aiton, and Perpignan-Luxembourg) carried ~50 000 lorries (source – SNCF). It remains marginal compared to other countries as Austria or Switzerland, which adopted constraining measures for road freight transit (taxs) : 820 000 shipments passed through alpine corridors in 2010 according to UIRR, from which only 25 000 passed by Modane with the Alpine "autoroute ferroviaire".

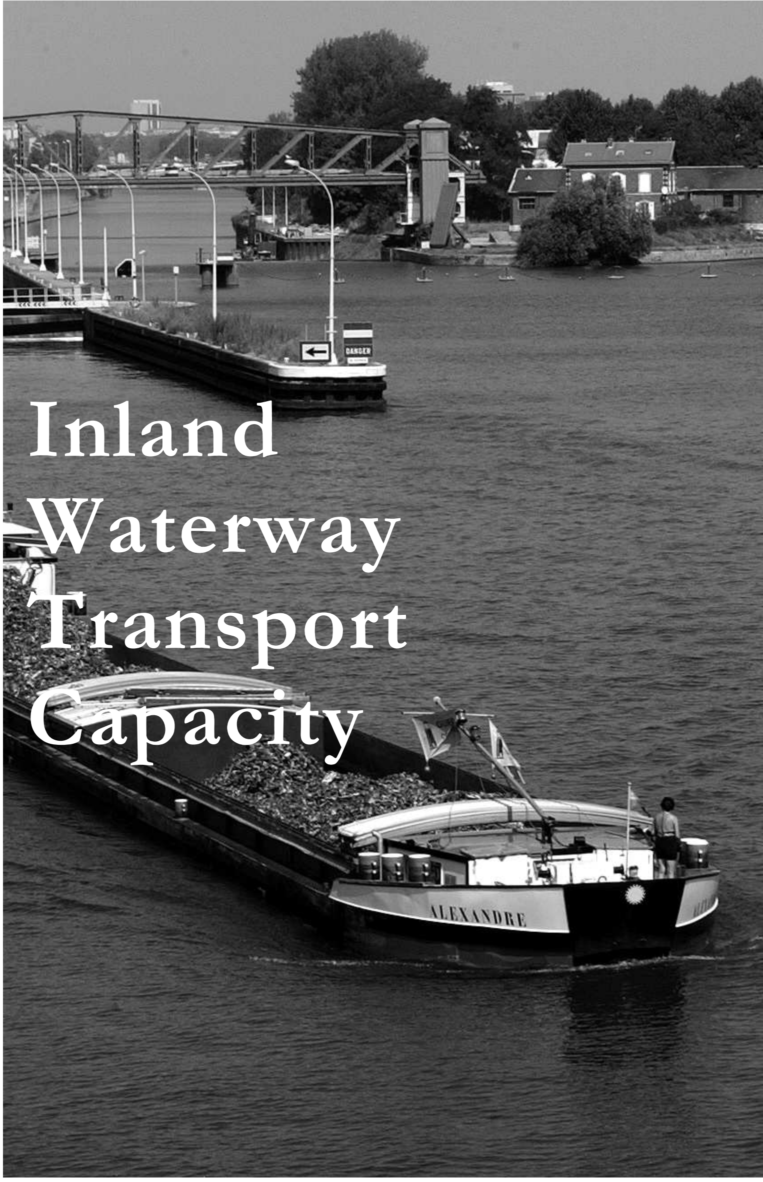
By 2020, it is envisaged that the unaccompanied transport traffic will theoretically reach 40 return journeys per day, with a fill rate of 75%. These hypotheses would result in the transfer of 2400 trailers per day (i.e. ~900 000 per year).

Other solutions

Many solutions exist to transport lorries onto trains. But not every solution is suitable for every railroad, because of a great variability of gauges and axle loads permitted around the world. For example, this type of rolling road can not be implemented in France, due to small gauges compared to Central Europe countries.

Figure 15: rolling road, stricto sensu, *with charging of lorries immediately following each other from the end of the train – source UIRR. This type of wagon is used by great companies as Ralpin (photo), which picked up in 2011 the rolling motorway activity of Hupac*

Section 6



Inland Waterway Transport Capacity

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Introduction

The purpose of this part is to evaluate the relevant parameters allowing the capacity of the inland waterway network as a mode of transport to be characterised and measured.

From the point of view of the network, the parameters influencing capacity stem from two different logics. Some constraints are related to demand: fleet distribution, tonnage carried and maximum tonnage per type of vessel, average load factor and empty return rate. Others are linked to the transport supply: characteristics of the network (gauge, discontinuities: locks and height clearances – *cf.* glossary and sub-section 2.2.1 – alternate one-way systems) and operation (current and future network opening times). These final parameters are essentially the ones that are studied here, but it is important to understand that, independently of the theoretical capacity of the waterway, some elements may prove to be limiting factors, such as slipway availability on a basin. Capacity may be expressed in tonnes for bulk and TEUs/*Twenty feet equivalent units* for containers.

The work presented focuses on three areas. The first part presents the existing fleet (types of vessel and performance levels) and the second part offers a general presentation of the network. Finally, the following parts deal with the issues of capacity: operation of the network and influence on capacity, method for calculating the capacity of a waterway (conventional method resulting from the circular of March 1, 1976 [52]) and highlighting of the inadequacies of this method. A summary of the capacity per basin will also be included, particularly in Appendix 4. This appendix must be used with caution as the characteristics presented are those corresponding to the network on the date of publication of this document. However, VNF is constantly looking at *ad hoc* improvements to capacity and this data is therefore liable to change.

Institutional framework

Founded in 1991, **Voies Navigable de France/ VNF** is responsible for managing, operating, modernising and developing the French navigable waterway network, comprising 6,700 kilometres of developed rivers and canals, over 2,000 permanent structures and 80,000 hectares of waterside public land. As a public body answerable to the Ministry, VNF acts in close cooperation with institutional partners and waterway users.

In a context of development of inland waterway transport, the French Government and VNF signed a "**contract of objectives and means**" on November 16, 2004, covering the 2005-2008 period. This contract represents a decisive step for the establishment and affirms Government priorities in terms of network safety and development of freight transport by waterways. This contract takes account of the new situation introduced by decentralisation by distinguishing the master network (*réseau magistral*), which is not open to decentralisation and on which freight transport is concentrated, from the decentralisable regional network which has a touristic vocation. Over the entire network of navigable waterways entrusted to VNF, the contract has the purpose of ensuring the safety of the structures and people and improving the management of its environment and heritage. On the master network, it implements measures aimed at reinforcing the availability of the waterway and developing traffic. To this end, it defines a work programme, levels of services and coordination and development actions in favour of the inland waterway sector.

VNF and non-sovereign navigation services are to be regrouped in a national agency of 4,500 persons: **ANVN**/*Agence Nationale des Voies Navigables*.

On a European scale, Inland Navigation Europe (INE) was created in 2000 by VNF and its Walloon, Flemish, Dutch and Austrian partners responsible for promoting waterway freight transport on a national level. INE has the ambition of contributing to an increase in the waterways' share of the goods transport market by emphasising the advantages and possibilities offered by waterway transport, by developing a common promotional strategy for this mode and by proposing the measures required for its development (www.inlandnavigation.org).

Carriers are represented in France by two bodies.

The *Comité des Armateurs Fluviaux* (CAF) is a professional organisation that represents the interests of waterway freight or passenger transport companies, covering various forms of small or medium-sized enterprises, shipping companies or cooperatives of self-employed operators. The *Comité* has 80 member companies representing 500 waterway units and around 1500 jobs (www.caf.asso.fr).

The *Chambre Nationale de la Batellerie Artisanale* (CNBA) is a public administrative body responsible for representing the small-scale inland water transport operators. It is represented on the VNF board.

Needs of various inland waterway network users

Source: François Nau, CGEDD (ex-CGPC) [53].

To fulfil their expectations for the transportation of their goods by inland waterways,

consignors demand:

- an improvement in the dependability of the logistics chain, which implies a guarantee on passing at the times scheduled within the framework of the opening hours announced by the services;
- reliability and regularity of transport times at all periods;
- enhancement of the waterway's advantages with regard to rival modes (guarantee of transport times possible due to non-saturation and opening of the network on Sundays and some public holidays);
- differentiation in service levels according to freight type: container traffic justifies a round-the-clock (24/7) service, whereas, for other types of traffic, consignors are more interested in the regularity and reliability of the transport times;

carriers demand:

- safety and a guaranteed passage and gauge as announced by the services;
- reliability and regularity of the service and a smooth passage through locks;
- broader amplitude in the opening of the network with standardised timetables fixed all year-round;
- additional safety facilities (lighting) and amenities (mooring, etc.);
- improved information on disruptions or interruptions to shipping.

1 – Fleet used for Inland Waterway Freight Transport

1.1 – Description of various types of vessel

Owing to their dimensions and their draught (itself linked to the tonnage carried), the various vessels used cannot all travel on every navigable waterway in the network. The fleet of vessels liable to sail on the navigable waterways of France can therefore be divided into six major categories: the "**Freycinet**" (length: 38.50 m, beam/width : 5.05 m). The normal draught of these barges is 2.20 m, but most of the units built over the last 50 years could navigate, without alterations, with a draught of 2.50 m. The deadweight (*cf*. glossary and sea transport section) is generally 320 tonnes with 2.20 m of draught, and 370 tonnes with 2.50 m;

- "**Canal du Nord**" barges and small convoys, capacity: 750 tonnes (length: 60 m + 30 m, beam: 5.70 m), draught: 2.50 to 3 metres;
- Seine and Rhône **barges**, capacity: 900 tonnes, length: 50 to 60 metres;
- self-propelled vessels with a larger size, both in length and in beam, simply called "**large self-propelled barges**" (***grands automoteurs***). The dimensions of these units are not standardised. The type known as the RHK[19], for example, is an 80-metre long self-propelled barge with a beam of 9.50 m, 2.50 m of draught and a deadweight of 1350 tonnes. All of these units have a beam of less than 11.30 m, a length of less than 90 metres and a draught of 2.50 to 3 metres. The RHK can transport 24 TEUs per layer;
- **self-propelled Rhine barges** with a capacity of 1000 to 3000 tonnes, a length of 95 to 110 metres, a beam of 11.40 m and a draught of 2.50 to 3 metres. This type of self-propelled barge can transport 42 TEUs per level;
- **pushed convoys**: for larger-sized barges, there is a clear trend towards a single type

[19] *RHK: Rhein-Herne-Kanal*

with a length of 76.50 m and a beam of 11.40 m, and with a deadweight of 1600 tonnes at a draught of 2.50 m, and 2200 tonnes at a draught of 3 metres. The length of pushed convoys (pusher + barges) varies from 143 to 185 metres and the capacity from 2500 to 5000 tonnes. The Europa II barge (76.50 m x 11.40 m) can transport 30 TEUs per level.

Self-propelled barges have a two-person crew. Pushed convoys have a crew of eight people, renewed every eight hours.

Inland waterway vessels are built according to the size of the locks that they pass through and the corresponding safety rules. On larger-sized self-propelled barges, such as the Rhine barge, or pushed convoys, three or four rows of 20-foot or 40-foot containers can optimally be loaded side by side.

It is worth recalling the following orders of magnitude:

- a Freycinet barge (from 250 to 400 tonnes) carries as much as fourteen 40-tonne heavy goods vehicles with a 25-tonne payload;
- a pushed convoy (with a 1500-tonne barge) carries as much as sixty 40-tonne heavy goods vehicles with a 25-tonne payload.

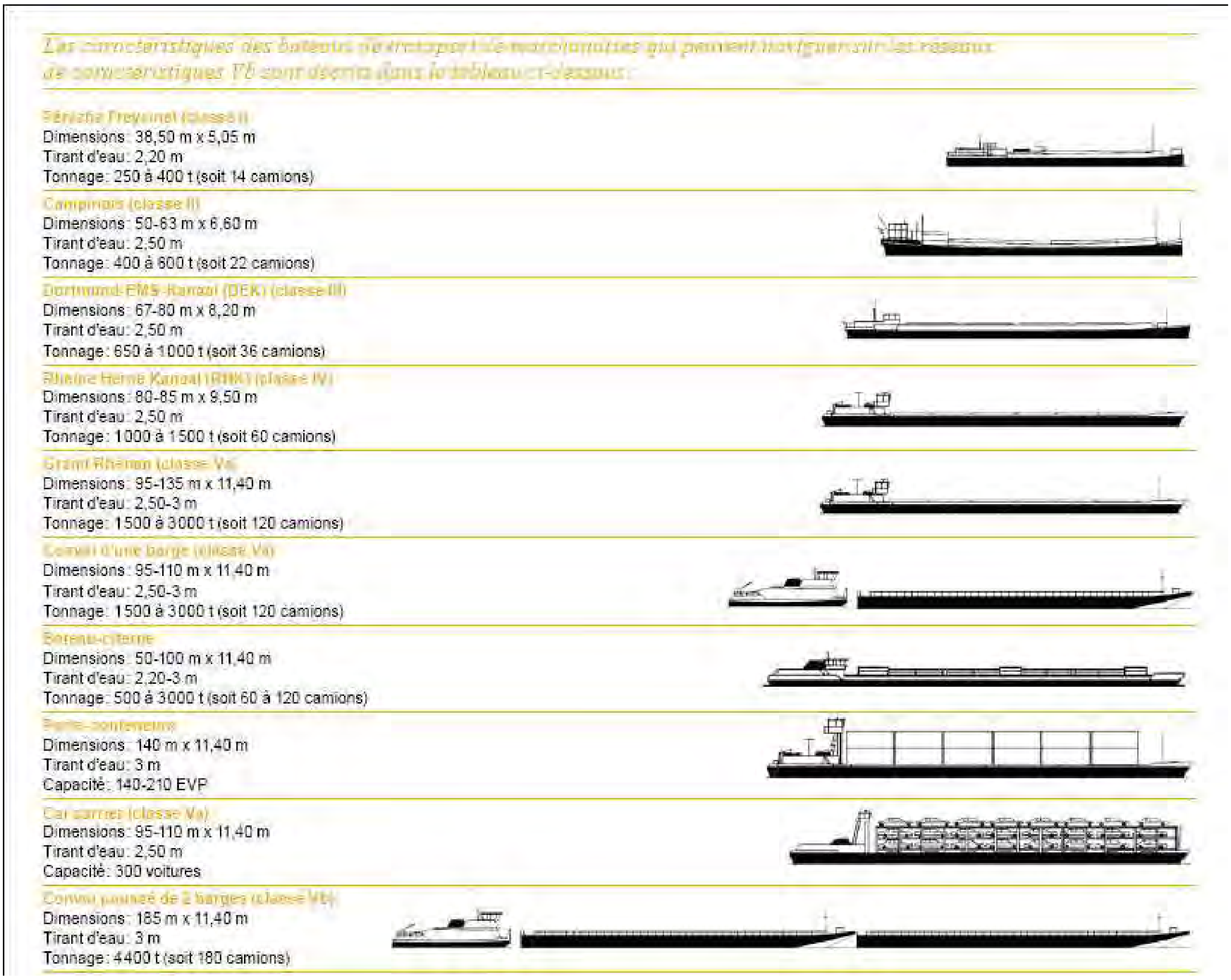


Figure 1. Characteristics of freight vessels travelling on inland waterway network (source: VNF)

Les caractéristiques des bateaux…	*The characteristics of freight vessels sailing on waterway networks with Vb characteristics are described in the table below:*
Péniche Freycinet	*Freycinet barge*
Classe	*Class*
Tirant d'eau	*Draught*
Tonnage : 250 à 400 t (soit	*Tonnage: 250 to 400 t (equivalent*
Grand Rhénan	*Large Rhine barge*
Convoi d'une barge	*Single-barge convoy*
Bateau-citerne	*Tanker*
(soit 60 à 120 camions)	*(equivalent to 60 to 120*
Porte-conteneurs	*Container vessel*
Capacité : 140-210 EVP	*Capacity: 140-210 TEU*
Capacité : 300 voitures	*Capacity: 300 cars*
Convoi poussé de 2 barges	*Double-barge pushed convoy*

Navigable waterways are classified according to their gauge, themselves standardised according to two classification systems: the 1976 French classification system and the one presented by the European Conference of Ministers of Transport (ECMT) in 1992. This point is detailed in sub-section 2 below.

Unités types	CEMT 1992	France 1976	Dimensions	Capacité en t	Capacité en E.V.P
Freycinet	1	1	38,50m x 5m	250 à 350	-
Canal du Nord		2	50m x 5m	550 à 750	-
Convois Freycinet			77m x 5m		
Campinois	2		50m x 6,60m	550	16 à 20
DEK	3	3	67m x 8,20m	950	36 à 42
RHK	4	4	80m x 9,50m	1350	54 à 81
Grand Rhénan	5a	5	110m x 11,40m	2 600	168 à 224
barge EUROPA 2 + pousseur				2 200	120 à 160
Grand Rhénan 2 barges + pousseur	5b	6	185m x 11,40m	4 500 à 5 000	288 à 384
convois EUROPA 2 : 4 barges + pousseur	6b		185m x 22,80m	9 000	480 à 640
automoteurs classe "Jowi"* (PC intégral)	6b		135m x 17m	4 800	398 à 498

* Le JOWI est le premier bateau XXL conçut pour le transport de conteneurs. Il a été depuis rejoint par de nombreux autres bateaux du même type. Ces bateaux peuvent emporter plus de 500 conteneurs, soit de 250 à 500 camions, en fonction de l'état des eaux et du poids du chargement.

Unités types	*Vessel type*
CEMT 1992	*ECMT 1992*
Capacité en t	*Capacity in t*
Capacité en EVP	*Capacity in TEU*
250 à 350	*250 to 350*
Convois Freycinet	*Freycinet convoys*
Grand Rhénan	*Large Rhine barge*
Barge EUROPA 2 +	*EUROPA 2 barge + pusher*
2 barges + pousseur	*2 barges + pusher*
Convois EUROPA 2 :	*EUROPA 2 convoys*
Automoteurs classe	*"Jowi" class self-propelled container vessel*
*Le JOWI...	**The JOWI is the first XXL vessel designed for container transport. It has since been joined by several other vessels of the same type. They can carry up to 500 containers, the equivalent of 250 to 500 trucks, depending on water conditions and cargo weight.*

Figure 2. Transport vessels and dimensions (Source: VNF)

1.2 - Fleet productivity

Source: VNF

	Hold size (L x W)	Volume (m³)
Freycinet	26 x 4.8 m	400
RHK	65 x 9.30 m	1900
Large Rhine barge	90 x 8.90 m	4000

Figure 3. Hold sizes of main inland waterway transport vessels

	km
Intra Rhône-Saône basin traffic	150
Intra Seine-Oise basin traffic	155
North-North/International traffic	203
Moselle-Moselle/International traffic	592
Rhine-Rhine/International traffic	557

Figure 4. Average distances per journey observed in five large navigation basins (1997)

The enclosed nature of the first two basins limits the possibility of increasing the transport distance, which does not act in favour of the mode.

The productivity of the French fleet (t-km carried/available deadweight) increased by 82% between 1995 and 2005.

In terms of energy efficiency, it must be remembered that one tonne-kilometre transported requires two times less energy by rail as by road, and five times less energy by waterway as by road. See more precise

1.3 – Description of French and European fleet (Source: VNF[54], CCNR)

The French fleet was reduced by a factor of 2.5 between 1975 and the end of the 1990s due to the Economic and Social Plan and the European "Old for New" plan; 1,765 scrapping applications (*cf.* glossary) were dealt with. There remained only 1,329 at 31th December 2010, but with increased capacity – 1.16 million tonnes, i.e. an average capacity increasing by 25%, from 668 tonnes in 2004 to 835 tons. The average tonnage of the European fleet, far greater, followed the same trend; +25% between 2003 – 1,084t – and 2008 – 1,321t

European perspective

In 2010 (31th December), according to the CCNR/ Central Commission for Navigation on the Rhine, the European waterway fleet – *main navigable countries : Poland, Germany, France, Romania, Holland, Ukraine, Belgium-Luxembourg Economic Union* – comprised more than 12,000 cargo vessels with a total Deadweight Tonnage (DWT) of 15.5 million tonnes, i.e. +25% compared to 2005. Almost half of the fleet was sailing under Dutch flag.

The European fleet is on average about 40 years old. The French fleet is even older, with an average of more than 60 years old. Thus, inland waterway transport suffers the same problem than rail transport in the competition with road transport, renewing its fleet much more frequently and this way benefiting high performances vehicles. This is directly linked to the important cost of a vessel, needed to be amortized on a long time, and to a relative technological stability (only motors are changed). However, a breakdown of numbers by age group shows a trend toward a younger active fleet – 130 new ships in 2010 in Europe, representing 365,000t, or 2,807t on average, after an exceptional 2009 year ; 203 vessels. A certain gap has grown between offer and demand, due to the 2008-2009 crisis; orders were placed before, a long time is needed to build a boat.

	Poland	Germany	France	Romania	Holland*	Ukraine	BLEU(*)	TOTAL
General cargo	540	1,698	1,240	907	4,555	497	1,112	10,549
Self-propelled barges	109	914	850	304	3,580	94	888	6,739
Pushed barges and lighters	431	784	390	603	975	403	224	3,810
Tankers	2	462	89	10	986	0	246	1,795
Self-propelled tankers	2	418	40	10	943	0	235	1,648
Pushed tankers	0	44	49	0	43	0	11	147
Total	**542**	**2,160**	**1,329**	**917**	**5,539**	**497**	**1,358**	**12,344**

(*) Belgium-Luxembourg Economic Union. Luxembourg owns only a few boats.
Figure 9. European inland waterway fleet of main navigable European countries, in terms of numbers of vessels (31th December 2010) – source CCNR/ Central Commission for Navigation on the Rhine; Indicative figures for Ukraine.

	Poland	Germany	France	Romania	Holland*	Ukraine	BLEU*	TOTAL
General cargo	280,016	2,035,164	1,028,815	1,445,131	5,729,642	756,263	1,512,176	12,787,000
Self-propelled barges	67,571	1,183,160	578,128	369,066	4,097,901	132,479	1,072,026	7,500,000
Pushed barges and lighters	212,445	852,004	450,687	1,076,065	1,631,714	623,784	440,150	5,287,000
Tankers	3,204	809,451	131,172	19,318	1,389,197	0	378,358	2,731,000
Self-propelled tankers	3,204	761,161	53,338	19,318	1,323,883	0	357,116	2,518,000
Pushed tankers	0	48,290	(est)77,834	0	65,314	0	21,242	213,000
Total	**283,220**	**2,844,615**	**1,160,000**	**1,464,449**	**7,158,460**	**756,263**	**1,890,534**	**15,518,000**

(*) Belgium-Luxembourg Economic Union. *Holland : registered fleet according to IVW Source: CCNR
Figure 10. European main navigable countries waterway fleet in terms of deadweight tonnage (31th December 2010)

2 – Description of European Inland Waterway Network

2.1 – Network functions

Out of the various functions of a network, indicated below, this part only deals with the goods transport activity. The other important waterway functions that can influence the organisation of goods transport are:

- River tourism, nautical and recreational activities and angling;
- Transfer of water by abstraction or discharge, playing a major role in water distribution in favour of agriculture, industry, power plants, etc.;
- Flood control;
- Hydroelectric power generation, especially on the Rhone and Rhine;
- Living environment: water is an important element in the structural design of a town from the points of view of landscaping and urban planning and on a social level.

2.2 – Network classification

2.2.1 – Navigation rectangle

The navigation rectangle is the zone through which the boat must pass. Its base is formed by the navigation channel, which ensures a sufficient draught under the hull. Similarly, under a bridge or in a tunnel, its height is given by the "height clearance", which ensures a sufficiently large gap for the boat to pass through.

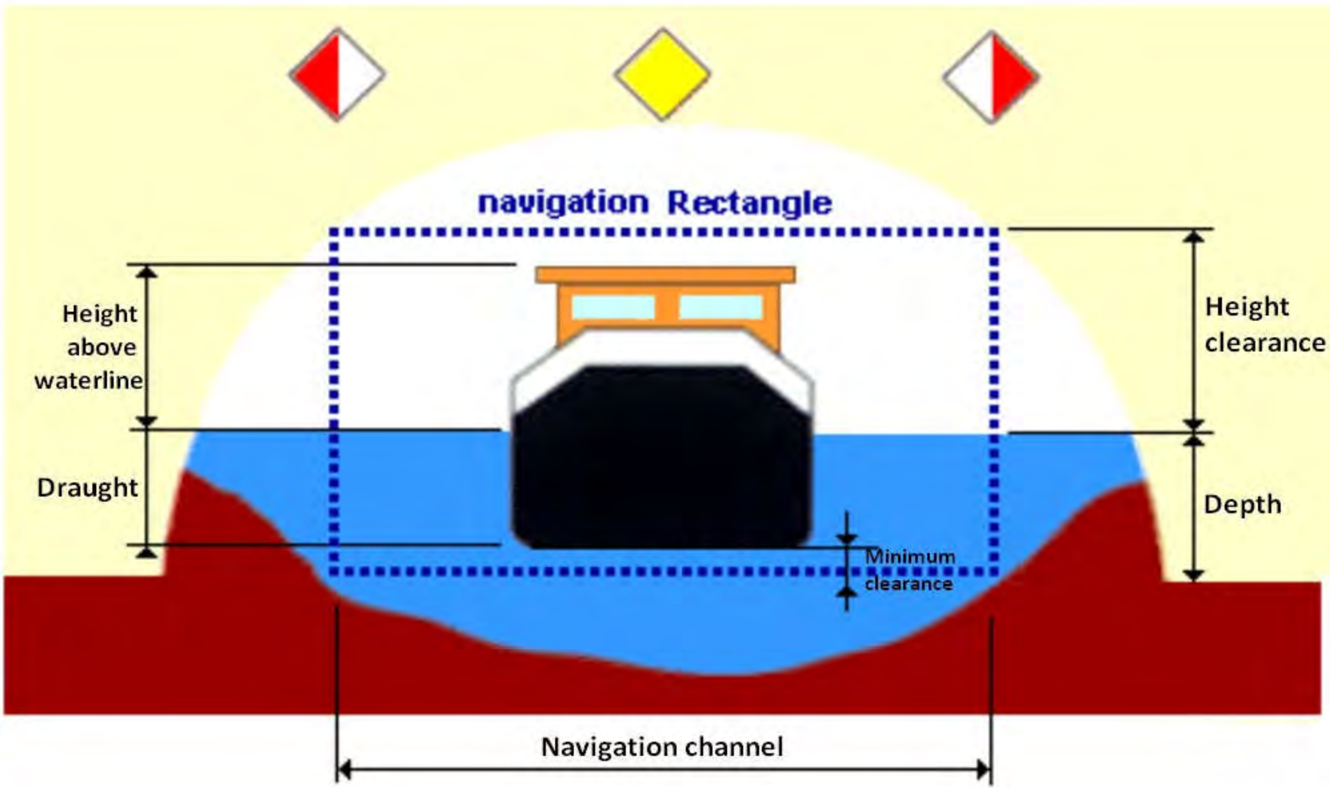


Figure 11. Navigation rectangle and associated vocabulary (Source: VNF). "depth" on the chart can be said "water clearance".

2.2.2 – Network classification

The waterway network in Europe represents 24,000 kilometres, 60% of which are in the "over 1000-tonne" category. For France, this proportion is just 25% whereas it represents 50% of waterways in the Netherlands, 70% in Germany and 80% in Belgium.

The table in Figure 15 presents the UNECE European navigable waterway classification (ECMT standards, source: United Nations [56]), which differs from the classification of the 1976 Circular.

LÉGENDE
Port
Port avec accès ferroviaire
Axe fluvio-maritime
Ville
Autoroute
Classes de voies navigables (CEMT)
Classe VI : convois de 3200 à 18000 tonnes
Classe V : bateaux de 1500 à 3000 tonnes convois de 1600 à 6000 tonnes
Classe IV : bateaux de 1000 à 1500 tonnes convois de 1250 à 1450 tonnes
Classe III : bateaux de 650 à 1000 tonnes
Classe II : bateaux de 400 à 650 tonnes
Classe I : bateaux de 250 à 400 tonnes
Voie non dédiée au transport ou non navigable
0 100kms
0 50kms
MER DU NORD
NEDERLAND NETHERLANDS
DEUTSCHLAND GERMANY
BELGIE BELGIQUE BELGIUM
FRANCE FRANCE
NORGE NORWAY
SVERIGE SWEDEN
DANMARK DENMARK
MER BALTIQUE
Golfe de Riga
Golfe de Gdansk
ROSSIJSKAJA FEDERACIJA RUSSIA
BELARUS BELARUS
POLSKA POLAND
UKRAJINA UKRAINE
GREAT BRITAIN
Manche
LUXEMBOURG LUXEMBOURG
ČESKÁ REPUBLIKA CZECH REP.
SLOVENSKA REPUBLIKA SLOVAKIA
REPUBLICA MOLDOVA MOLDOVA
ÖSTERREICH AUSTRIA
MAGYARORSZÁG HUNGARY
ROMÂNIA ROMANIA
SCHWEIZ SWITZERLAND
LIECHTENSTEIN
SLOVENIJA SLOVENIA
HRVATSKA CROATIA
BOSNA I HERCEGOVINA BOSNIA AND H.
SRBIJA SERBIA
BALGARIJA BULGARIA
ITALIA ITALY
ESPANA SPAIN
ANDORRA ANDORRA
Golfe de Gascogne
Golfe du Lion
MER MÉDITERRANÉE
MER LIGURIENNE
MER ADRIATIQUE
Amsterdam
Bruxelles
Luxembourg
Paris
London
København
Berlin
Warszawa
Praha
Wien
Bratislava
Budapest
Bern
Vaduz
Ljubljana
Zagreb
Sarajevo
Beograd
Bucuresti
Sofiya
Skopje
Roma
Réalisation : Études et Cartographie - LILLE

Navigable waterway classes (1992)	**Self-propelled barges** ("motor barges")				**Pushed convoys** ("push-tows")					Minimum height under bridges
	Vessel type: general characteristics				Convoy type: general characteristics					
	Max length	Max beam	Draught	Tonnage	Number of barges	Length	Beam	Draught	Tonnage	
I West of Elbe	38.5	5.05	1.8 – 2.2	250 – 400	Péniche					4.00
II	50 – 55	6.6	2.5	400 – 650	Campine barge					4.00 – 5.00
III	67 – 80	8.2	2.5	650 – 1000	Gustav Koenigs					4.00 – 5.00
I East of Elbe	41	4.7	1.4	180	Grosse Finow					3.00
II	57	7.5 – 9	1.6	500 – 630	Barka Motorowa 500					3.00
III	67-70	8.2 – 9	1.6 – 2	470 – 700		118 – 132	8.2 – 9	1.6 – 2	1000 – 1200	4.00
IV	80 – 85	9.5	2.5	1000 – 1500	Johan Welker	85	9.5	2.5 – 2.8	1250 – 1450	5.25 or 7.00
V a (V in France)	95 – 110	11.4	2.5 – 2.8	1500 – 3000	Large Rhine Barge	95 – 110	11.4	2.5 – 4.5	1600 – 3000	5.25 or 7.00 or 9.10
V b (VI in France)	Up to Class VII : Large Rhine Vessels					172 – 185	11.4	2.5 – 4.5	3200 – 6000	
VI a						95 – 110	22.8	2.5 – 4.5	3200 – 6000	7.00 or 9.10
VI b	140	15	3.9			185 – 195	22.8	2.5 – 4.5	6400 – 12000	7.00 or 9.10
VI c						270 – 280	22.8	2.5 – 4.5	9600 – 18000	9.10
						193 – 200	33 – 34.2	2.5 – 4.5	9600 – 18000	
VII						285	33 – 34.2	2.5 – 4.5	14500 – 27000	9.10

Figure 15: UNECE European navigable waterway classification (ITF/International Transport Forum standards)

Note that the Class VII is relatively rare, the main section in Europe being the Danube between Beograd and Black Sea. Traffics are relatively strongly linked to the size of the navigable waterway. Historically, many of the main cities grew up around a great river (Thames, Seine, Danube, Elbe, etc.) and are this way well connected to the navigable network. This is especially true for the North of Blue Banana (European Backbone).

In terms of the density of the wide-gauge network (number of kilometres of wide-gauge waterway per 1000 km² of territory), the Netherlands have the highest density with 71, followed by Belgium with 40 and Germany with 14. France has a density of 3.7.

Gauge	**0**	**I**	**II**	**III**	**IV**	**Va**	**Vb and over**	**Total**
France (ref. 2000)	64	3,177	210	225	31	232	1,445	**5,384**
Belgium (ref. 2002)	12	337	245	0	436	248	249	**1,527**
Netherlands (ref. 1999)	1,157	407	871	213	597	1,136	665	**5,046**
Germany (ref. 2000)	108	790	213	250	1,657	2,222	1,003	**6,243**

Figure 16. European navigable waterway network by gauge (km of regularly used waterway)

3 – Inland Waterway Network Operation

Section 4 will present the methodology of the March 1, 1976 Circular, which proposes to calculate the capacity of a waterway from the characteristics of its locks. However, certain elements ignored in the described method and linked essentially to network operation, can influence the capacity of the waterway network. They are:

- the impacts of the Master Plan for Navigable Waterway Operation (SDEVN = *Schéma Directeur d'Exploitation des Voies Navigables*);
- the maximum permissible draught on the waterway and the draught of the vessel;
- the speed limit;
- climatic conditions.

3.1 – Operation scheme and capacity: the example of SDEVN

The French Master Plan for Navigable Waterway Operation (SDEVN = *Schéma Directeur d'Exploitation des Voies Navigables*) [57] defines the levels of service that VNF – soon "ANVN", *Agence Nationale des Voies Navigables* – has implemented since 2009 over the entire network for which it is responsible. There are two issues at stake: firstly, meeting the demand in terms of network operating hours and, secondly, setting timetables that enable a clear basic offer to be established and a stable work organisation to be created for employees.

Note that the low amount of night-time traffic in general is linked to both supply (social problems relating to night work for operating employees in particular) and demand (problem of daily night-time rest for the self-employed fleet). Changes in demand, the fleet and labour organisation are likely to modify the current situation with a view to a wider range of operating times.

SDEVN network classification

In order to define the level of services to be attained on the network, VNF has split the network into four categories (below).

Tonnage	Type of waterways	Category	
> 650 t	All waterways	1	Wide gauge
< 650 t	Significant goods traffic	2	Related wide-gauge waterways
	Waterway currently or potentially supporting a particular type of traffic		
	Inter-basin connection		
	Insignificant goods traffic	3	Multi-purpose waterways
	No goods traffic	4	Tourist waterways

Figure 17. SDEVN network classification

Network operating times

The SDEVN sets the seasonal operating times for each category of the network. A distinction is made between three levels of service for sailing timetables: minimum (commitment to be observed), target (commitment sought within a maximum five-year period) and maximum (level which it is possible to surpass if a demand exists and if the services – locking – have the means). In the rest of

<table>
<tr><th colspan="2" rowspan="2">Waterway category</th><th rowspan="2">Users</th><th rowspan="2">Objectives</th><th colspan="2">Number of hours of navigation</th><th colspan="2">Operating hours</th></tr>
<tr><th>Low season (11/11 –16/03)</th><th>High season (17/03 – 10/11)</th><th>Low season (11/11 – 16/03)</th><th>High season (17/03 – 10/11)</th></tr>
<tr><td rowspan="8">Wide-gauge</td><td rowspan="4">1A</td><td rowspan="3">Commerce</td><td>Max</td><td colspan="2">24h</td><td colspan="2">0:00 – 24:00</td></tr>
<tr><td>Min</td><td colspan="2">18h</td><td colspan="2">5:00 – 23:00</td></tr>
<tr><td>Target</td><td colspan="2">24h</td><td colspan="2">0:00 – 24:00</td></tr>
<tr><td>Pleasure</td><td colspan="5">Open to pleasure craft in daytime periods</td></tr>
<tr><td rowspan="4">1B</td><td rowspan="3">Commerce</td><td>Max</td><td colspan="2">18h</td><td colspan="2">5:00 – 23:00</td></tr>
<tr><td>Min</td><td colspan="2">14h
except Sundays: 9h</td><td colspan="2">6:30 – 20:30
9:00 – 18:00</td></tr>
<tr><td>Target</td><td colspan="2">14h
except Sundays: 9h</td><td colspan="2">6:30 – 20:30
9:00 – 18:00</td></tr>
<tr><td>Pleasure</td><td colspan="5">Open to pleasure craft in daytime periods,
limited to operating hours scheduled for commerce</td></tr>
</table>

Figure 18. Ranges and opening hours of Category 1 network

the document, SDEVN target values are used to estimate capacities. As an example, the table in Figure 18 gives the ranges and operating hours for the Category 1 network. Category 1 waterways come under Category 1A, except for seven waterways classified as 1B.

Network operation

The SDEVN provides full details in relation to network operation: ice breakage, closures (*cf.* lexicon), structure availability, guaranteed clearance of the navigation rectangle, services to users (mooring in the locks, etc.).

As far as wide-gauge navigable waterways are concerned:

- the range of operating hours is tending to increase towards the generalisation of 24-hour navigation over the next five years for a large proportion of category 1 waterways. For the others, the range will be 14 to 18 hours per day;
- the SDEVN also agrees to limit the number of days' closure for maintenance and for ice breakage, which will increase the average number of days' navigation in the year and, therefore, the capacity of the waterway;
- the SDEVN provides for the centralisation of structure control facilities with a remote management system which will lead to the optimisation of work stations and improved handling of traffic peaks, which should also increase the capacity of the waterway.

3.2 - Draught

Large vessels are characterised by a draught in excess of 2.5 metres, whereas medium-sized and small vessels have a draught of less than 2.5 metres.

Vessel draught is proportional to the tonnage carried. The block coefficient is a characteristic parameter of a type of vessel, and is the ratio of the volume of water displaced by the boat to the product of its length x beam x draught. For most waterway boats, it is considered equal to 0.85 but is closer to 1 for very flat-bottomed barges or less than 0.85 for streamlined boats.

Thus, for a vessel of length L, beam l, draught (unladen) Eo and block coefficient Cb, the total draught is equal to:

$$E = E_0 + \frac{T_t}{\rho \times \mathrm{C_b} \times L \times l},$$

where T_t is the tonnage carried and ρ the density of the water.

Numerical applications:

For a Freycinet, the draught when unladen is approximately 40 centimetres, the length 38.50 metres and the beam 5.05 metres. With a block coefficient of 0.85 and a tonnage of 350 tonnes, we obtain:

*E = 0.4 + 350 000 / (1000*0.85*38.50*5.05) or a draught of approximately 2.50 metres.*

Conversely, where the maximum permissible draught on a waterway is known, the maximum tonnage carried can be deduced. If the draught of a Freycinet barge cannot exceed 2.20 metres, either because of the depth of the navigation channel or due to the boat design (some Freycinet barges would be submerged if their draught exceeded 2.20 metres), the maximum tonnage that it can transport can be deduced as follows:

t = 1000 x 0.85 x 38.50 x 5.05 x (2.20-0.40), or approximately 300 tonnes.

3.3 – Speed limit

The maximum speed limit is set on each waterway within the framework of a particular regulation. Exceptions aside, for laden vessels, it must be 6 km/h for classes I, II and III, and a minimum of 8.5 km/h for higher classes. For empty vessels, these figures are to be increased by 40%.

Theoretical justification for these figures is provided in appendix.

3.4 – Climatic conditions

During low water periods (for example, the prolonged low water period in the summer of 2003), larger units can no longer circulate due to a lack of water (draught problem). Small units, such as self-propelled Freycinet barges, are sought-after in such circumstances, hence the importance of having a varied fleet to maintain the capacity of a waterway.

The figures below illustrate the variability of water height and its consequences for navigation.

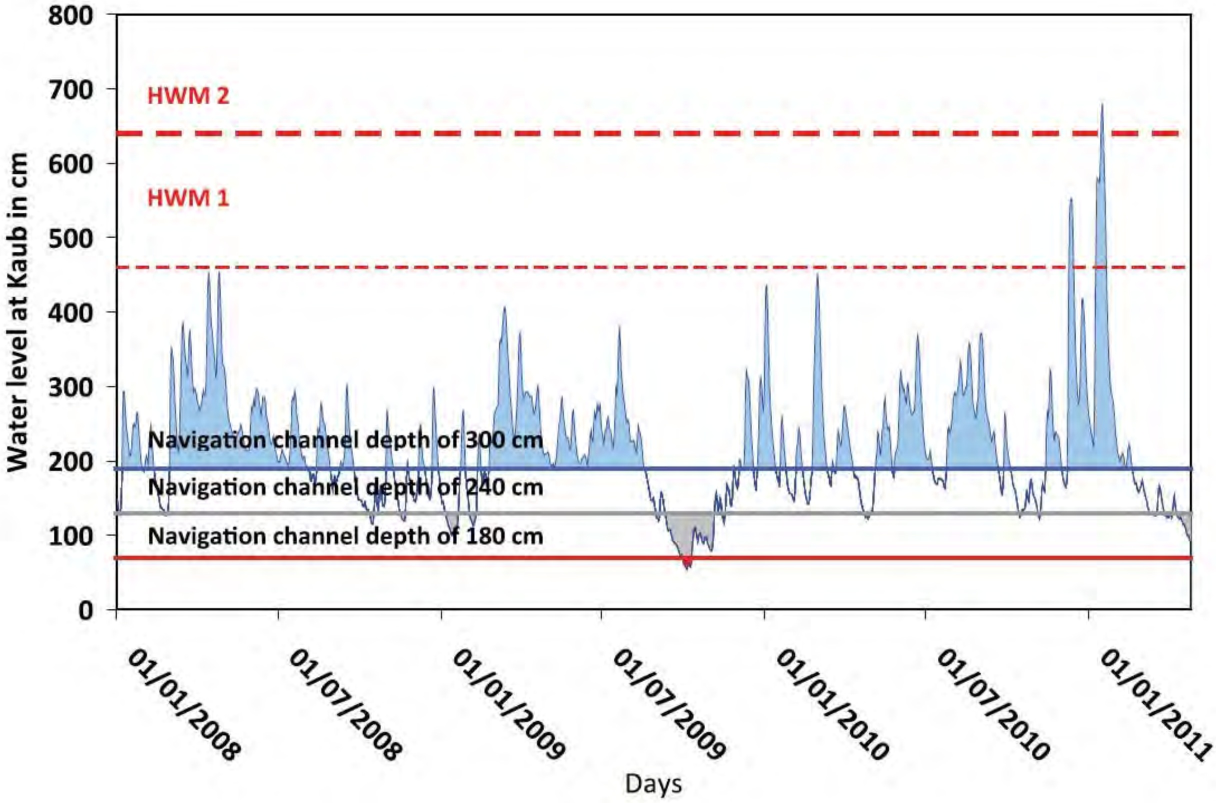


Figure 19 : Rhine water levels between 2008 and 2011 at Kaub – source BfG (Bundesanstalt für Gewässerkunde)

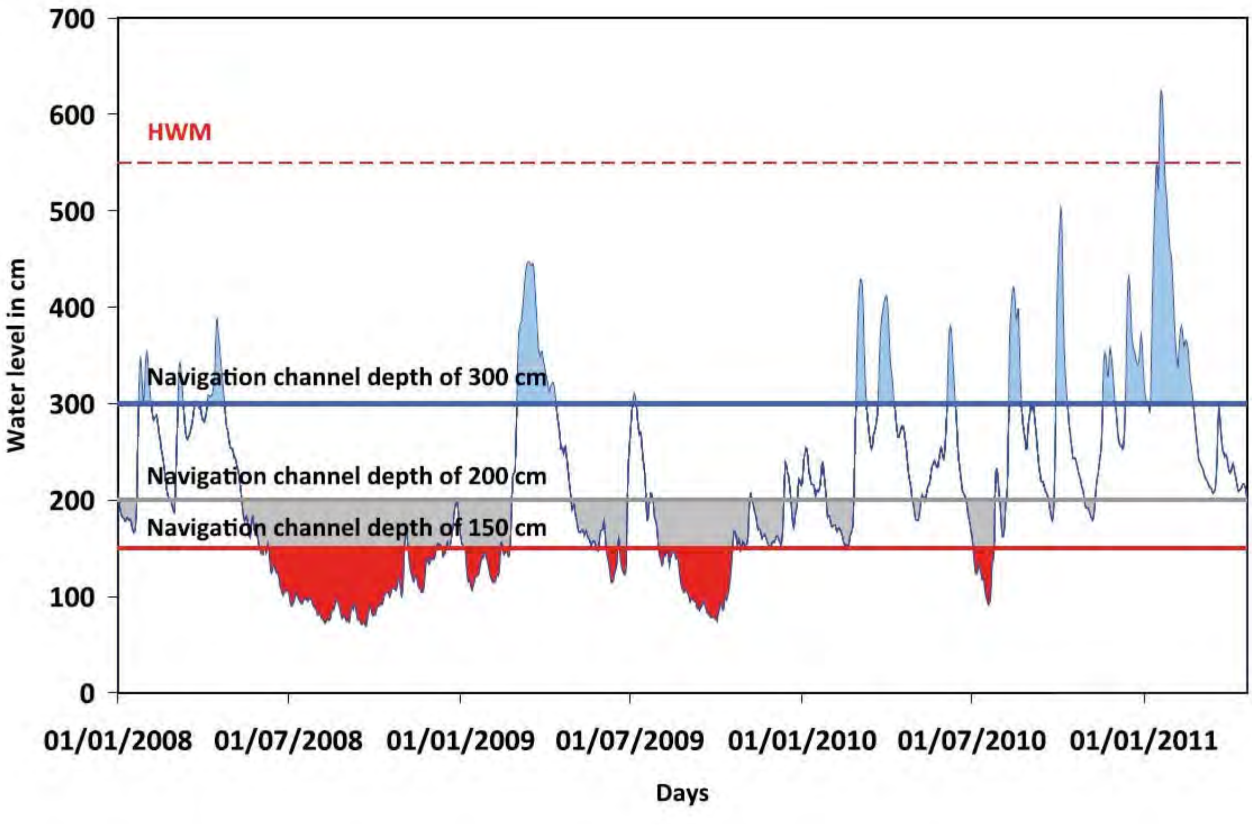


Figure 20 : Elbe water levels between 2008 and 2011 at Magdeburg – source BfG (Bundesanstalt für Gewässerkunde)

4 – Inland Waterway Network Capacity

4.1 – Lock capacity

The capacity of navigable waterways (source: Federal Ministry of Transport, Germany, 1993 [58]) is largely determined by its locks. Apart from its dimensions, the capacity of a lock is defined by its specific flow rate linked to three factors:

- distribution of boat arrivals which is influenced by the proportion of empty and laden traffic, the distance between the locks and differences between the capacity of the locks;
- lock occupancy: this occupancy rate is defined by the structure of the vessels using the lock (proportion of the various tonnage categories and average vessel length);
- duration of the locking operation: this includes the time required by the vessels to enter and leave the lock chamber and the time required to fill and empty the chamber and open and close the gates.

A cycle breaks down into three steps: boat entry manoeuvre and gate opening/closing; filling/emptying; gate opening and exit manoeuvre.

Figure 21. Suresnes lock (©MTETM/SG/SIC - 2003 Photo B.Suard)

Filling/emptying rates, lock topology (location and presence or absence of a guide wall facilitating entry and exit manoeuvres) and hydraulic conditions (currents) influence the manoeuvrability of the vessel and therefore the duration of the locking cycle.

Lock accessibility times also have an obvious effect on their capacity: staff presence during night-time periods, whether or not the locks are doubled to enable transit all year round, even if limited, during major maintenance operations, etc.

It is evident that major investments are necessary to ensure a permanent freight flow rate on a river or canal:

- presence of dams and reservoirs to regulate the water course;
- doubling of locks for maintenance purposes (and to increase capacity);
- rapid systems for lock chambers (rapid upstream/downstream transfers);
- capacity developments: sufficient length and/or width for locks, the ideal situation being where several barges can enter the lock chamber simultaneously (otherwise, possibility of dividing convoys, hence longer locking time…);
- sufficiently stable and solid banks and wayside structures to increase navigation speeds.

4.2 - Capacity evaluation based on 1st March 1976 circular

The French March 1, 1976 Circular defined a method of evaluating the capacity of locks which is described in detail below. It is therefore assumed that the capacity of a waterway route is entirely determined by the lock with the smallest capacity.

The maximum theoretical capacity C of a lock, for a year and for navigation established over 12 hours, depends on:

- the duration of the complete lock cycle[20] – D in minutes;
- the number of days' navigation per year – N;

[20] ***This complete cycle allows transit against the current and then in the direction of the current, or vice-versa***

- the maximum tonnage permitted by the waterway – T in tonnes (T is a function of the permissible draught and the capacity of the vessels able to use the waterway).

On average, N is equal to 340 days per year, 340 being the normal duration on a modern, wide-gauge waterway which takes account of public holidays, freezing conditions and closure. The theoretical capacity C, in millions of tonnes, is derived from the formula:

$$\boxed{C = 2 * \frac{12*60}{D} * N * T}$$

12*60 = 12 hours * 60 minutes. It corresponds to the opening time during the day, in minutes. The complete lock cycle permit passage of 2 vessels (one in each direction)

This calculation assumes that the chamber is always fully occupied and that the vessels are carrying maximum tonnage. To take account of the fact that this maximum can never be reached, the 1976 Circular proposes a table of reduction coefficients (*cf.* Figure 20 – Source: March 1, 1976 Circular) depending on the class of waterway.

Class of waterway	*VI*	*V*	*IV*	*III*	*II*	*I*
C-1, regarding average vessel load	0.75	0.83	0.75	0.83	0.83	0.83
C-2, regarding average lock occupancy	0.6	0.6	0.68	0.68	0.7	0.75
C-3 = C-1 x C-2, resulting coefficient	0.45	0.50	0.51	0.56	0.58	0.62

Figure 22. Reduction coefficients for calculating maximum annual capacity

Lock category	***VI***	***V***	***IV***	***III***	***II***	***I***
Duration of complete locking cycle in min (or double locking)	60	60	50	35	-	25

Figure 23. Lock cycle duration (D) for different waterway gauges

These coefficients are valid for 12 hours' navigation per day. With continuous navigation, account must be taken of the fact that traffic is much lighter at night than during the day. It is estimated that night traffic represents just 40% of daytime traffic. Consequently, the capacity with continuous navigation (over 24 hours) is 1.4 times the capacity with a 12-hour navigation period[21].

It is therefore considered that all hours of navigation over the 12 hours are night-time hours. To calculate one hour's night traffic, divide the daytime traffic by 12 to obtain the hourly traffic figure, and then multiply this figure by 0.4.

In particular, we obtain:
$T_{14\,h}$=1.06 x $T_{day(12h)}$ and T_{18h} = 1.2 x $T_{day(12h)}$

These are only average values. In practice, the duration of lock cycles on the same route can differ. During the cycle, two boats (or groups of boats **proceeding downstream**) pass. In the case of a double chamber (double width) or a double lock (two parallel locks), four boats pass, but better use can be made of the chambers in this case, such that the capacity of two parallel locks is slightly higher than the sum of the capacities (approximately 5%).

4.3 – Parameters affecting capacity based on 1st March 1976 circular

The parameters considered in this evaluation are:

- Supply-related parameters:

- lock cycle time: capacity is inversely proportional to lock cycle time. Cycle time is proportional to drop height. Recent locks are quicker than old locks with an equivalent drop height. If the lock is well positioned and has systems such as guide walls, the boat entry manoeuvre can only be quicker and safer, thereby naturally reducing the cycle time;

[21] Note. At present, French navigable waterways are not saturated and, therefore, night traffic represents just 10% of daytime traffic. However, as saturation is approached, a part of the daytime traffic will naturally be transferred to the night, thereby resulting in a higher proportion.

- lock dimensions which determine the maximum size of waterway vessel able to enter the lock chamber;
- mode of operation: two elements linked to operation can be used to increase the capacity of a waterway: increasing the range of operating time (by switching from 12 to 24 hours per day, for example) and increasing the average number of days of navigation during the year.

- Demand-related parameters:

- tonnage carried per vessel type: capacity is directly proportional to the tonnage carried per vessel type. Consequently, the more the traffic is "massified", the more the tonnage carried per vessel type increases and the greater the capacity will be. For example, the average cargo load of a self-propelled Freycinet barge is 275 tonnes which corresponds to 73% of its possibilities (source: Anteor, 2005 [59]);
- maximum load per vessel type: occasionally, the draught allowed on a canal is insufficient for vessels to carry their maximum tonnage, resulting in reduced capacity. This is the case, for instance, on the Canal du Nord, where draught is limited to 2.40 metres and where *Canal du Nord*-type barges cannot carry their maximum tonnage;
- average load factor of vessels: this depends on socio-economic conditions and therefore necessarily on the route in question. The value indicated in the 1976 Circular is to be used with care as, since then, the economics of waterway transport have changed considerably. In all cases, it is strongly recommended to collect field data from local waterway managers to determine the value of this factor;
- lock occupancy rate: this depends on two parameters: seasonal traffic fluctuations and the percentage of empty vessels. Here too, this coefficient must be linked to the economic conditions of waterway transport. Over the last thirty years or so, as the percentage of light vessels has fallen, a reasonable increase in the occupancy rate of around 5% is possible.

These elements have already been developed. In particular, the consequences of the implementation of the new SDEVN master plan are of major importance.

Numerical application

On a route where all locks are of the same size, the capacity will be determined by the lock with the longest cycle time. The first stage in the calculation consists of determining the maximum tonnage able to enter the lock chamber.
For a class VI (or Vb) waterway, locks are 185 metres long, 12 metres wide and 4.50 metres deep and allow the transit of pushed convoys with a length of 180 metres, a beam of 11.40 metres and a draught of 3 metres. Where no other size restrictions apply (insufficient depth on the route preventing the passage of units with 3 metres of draught), the maximum tonnage transported by such a pushed convoy is approximately 4400 tonnes.
With a cycle time of 60 minutes and under usual operating conditions (open 12 hours per day and 340 days per year), the capacity of the route will therefore be, with the reduction coefficient C-3 = 0.45:

$$C = 0.45 \times 2 \times (12 \times 60)/60 \times 340 \times 4400 = 16.2 \text{ Mt}$$

If the locks on the route in question do not have the same dimensions, it becomes more complicated to identify the lock determining the capacity. A comparison between the maximum tonnages that the lock chambers can accommodate and the cycle times is necessary. Furthermore, a draught restriction due to limited depth over all or part of the route impacts on the maximum tonnage of the waterway units and can cause the route's capacity to fall significantly.
Taking the above data and considering the case of a double lock of the same size (5% increase), then the capacity is:

$$C = 16.2 \times 2 \times 105/100 = 34 \text{ Mt approximately}$$

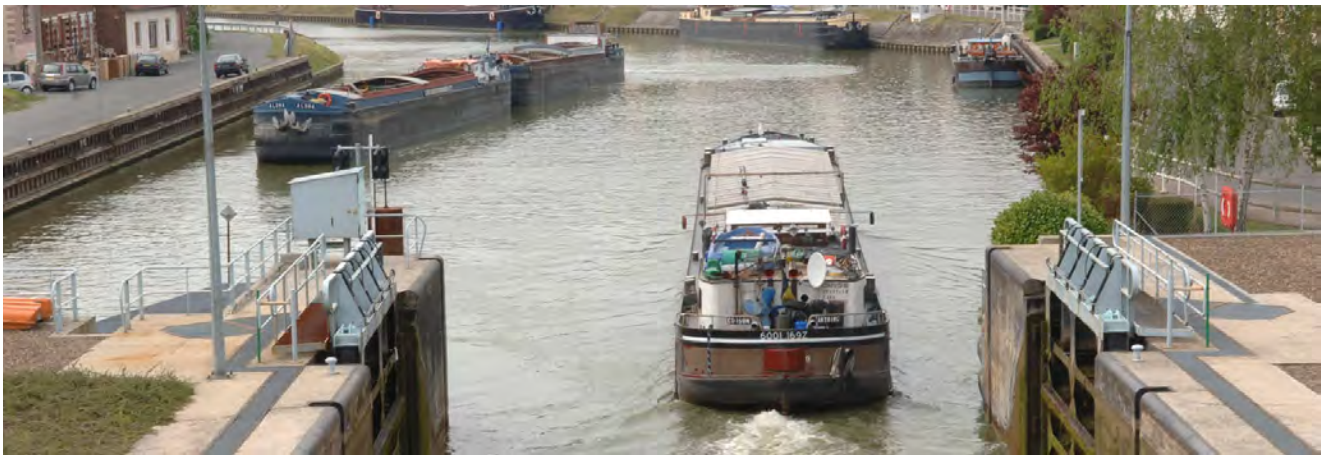


Figure 22. Transit through a lock in Margny-les-Compiègne – source B.Suard (MTETM/SG/SIC – 2006)

4.4 – Advantages and limits of method

4.4.1 – Advantages of method

This method is simple to apply. It can be used to make a quick, approximate calculation of the capacity of a route.

4.4.2 – Limits of method

The duration of the double-locking cycle corresponds to an average which is rarely reached; in reality, each cycle has a different duration according to the composition of the locking (*cf.* glossary), the position of the vessels already waiting or approaching, the water level, etc.

The loaded vessel chamber occupancy coefficient C-2 (*cf.* Figure 20) is just an average value: chamber occupancy differs on each locking operation and depends on:

- arrival laws, i.e. intervals between successive arrivals of the various types of vessels;
- the dimensions of the various types of vessel.
- In addition, coefficient C-2 is supposed to integrate traffic irregularity phenomena consisting of two components:
- fluctuations according to season, day of the week and time of day;
- random fluctuations of which only statistical laws are known.

Finally, **the method is based on the strong assumption that the capacity of a waterway route is determined by the capacity of the lock with the lowest capacity.** However, we saw in sub-section 3 that other parameters can influence the capacity of the waterway.

4.5 – Application to main waterway transport routes

4.5.1 – Gauge-based capacity calculation.

	Duration of the cycle (in mins)	Maximum tonnage (in t)	Theoretical capacity (in millions of t/year)	Reduction coefficient	12-hour practical capacity (in millions of t/year)	24-hour practical capacity (in millions of t/year)
I	25	250	4.9	0.62	3.04	4.25
I	25	400	7.83	0.62	4.86	6.8
III	35	650	9.09	0.56	5.09	7.13
III	35	1000	13.99	0.56	7.83	10.97
IV	50	1000	9.79	0.51	4.99	6.99
IV	50	1500	14.69	0.51	7.49	10.49
V	60	1500	12.24	0.5	6.12	8.57
V	60	3000	24.48	0.5	12.24	17.14
VI	60	3000	24.48	0.45	11.02	15.42
VI	60	5000	40.8	0.45	18.36	25.7

Figure 23. Gauge-based waterway capacity

Application of the formula produces the results shown in Figure 23
Calculating according to European standards produces the results in Figure 24.

	Duration of the cycle (in mins)	Tonnage per vessel (in t)	Theoretical capacity (in		Reduction coefficient	Practical capacity (in millions of t/year)			
			Minimum	Maximum		Minimum		Maximum	
						12 h	24 h	12 h	24 h
Va	50	1500-3000	14.69	29.38	0.51	7.49	10.49	14.98	20.98
Va	50	1600-3000	15.67	29.38	0.50	7.48	10.97	14.69	20.57
Vb	60	3200-6000	31.33	48.96	0.50	15.67	21.93	24.48	34.27
VIa	60	3200-6000	31.33	48.96	0.45	14.10	19.74	22.03	30.84
VIb	60	6400-	62.67	97.92	0.45	28.20	39.48	44.06	61.69
VIc	60	9600-	94.00	146.88	0.45	42.30	59.22	66.10	92.53

Figure 24. Gauge-based waterway capacity (European standards)

4.5.2 – Capacity calculation applied to French network

The table in Figure 25 shows the capacity (by applying the method described above), 2005 traffic and the average cargo of a vessel using the various navigable routes in France.

Capacity of the waterway	Capacity (in millions of tonnes)			Traffic (in millions of tonnes)	Average cargo of (in tonnes)
	Values defined in the SDEVN				
	Max	Min	Target	(2005)	(2005)
RHINE	**24h**	**18h**	**24h**		
French part	51	43.7	51	21.2	838
MOSELLE	**24h**	**18h**	**24h**		
Metz – Border	22	18.8	22	9.101	1343
South of Metz – Frouard	22	18.8	22	3.189	979
Access to the port of Frouard	10.2	8.8	10.2	1.2	
Frouard – Neuves-Maisons	22	18.8	22	0.846	668
SEINE	**24h**	**18h**	**24h**		
Le Havre – Tancarville canal				4.02	743
Tancarville – Rouen				6.608	699
Upstream of Paris	25.6	22	25.6	4.388	430
Downstream of Paris	20.6	17.6	20.6	9.629	580
Seine – Oise	**24h**	**18h**	**24h**		
Conflans Saint-Honorine / Nogent/Oise	20.6	17.6	20.6	4.816	435
Nogent/Oise – Compiègne	11.5	9.8	11.5	4.816	435
Seine – Marne	**24h**	**18h**	**24h**		
Charenton – Bonneuil/Marne	12.9	11	12.9	1.732	338
NORD	**18h**	**14h**	**14h**		
Dunkirk – Lille	13.2	11.7	11.7	4.36	335
Dunkirk – Valenciennes	13.2	11.7	11.7	5.786	452
Lille – Belgium route (French part)	8	7.1	7.1	3.875	331
Valenciennes – Belgium route (French part)	8	7.1	7.1	5.223	461
RHÔNE / SAÔNE	**24h**	**18h**	**24h**		
St Jean-de-Losne – Chalon	14	12	14	0.725	692
Chalon - Lyons	22.7	19.4	22.7	3.164	496
Lyons – Fos	22.7	19.4	22.7	4.162	757
Arles – Sète	10.9	9.4	10.9	0.441	660

Figure 25. Capacity and traffic of navigable waterways in France

It can be seen that saturation of the waterways is not a subject for concern at the moment. Undoubtedly for several years to come, consignors will be complaining more about other infrastructure-related issues (insufficient gauge, depth or height clearance, etc.) rather than excessively heavy traffic.

However, the method of estimating traffic capacity in relation to locks does not take account of specific issues relating to crossing conditions in the reaches: it is not necessarily easy for two large convoys to pass each other, hence the need to develop waiting and crossing areas, etc..

Moreover, the CETMEF has developed the simulation tool SINAVI (*Simulation de l'Impact sur la Navigation des Aménagements des Voies Intérieures*) to assess the impact of changes to the facilities, traffic and operation of a waterway on navigation.

4.5.3 – Traffics and evolution

See appendix 8 for more figures (European main ports traffics, French traffics). Existence of large capacities rivers or canals often implies important traffics, as can be seen on the Danube (largest and longest navigable corridor in Europe, see map upon, p 148) :

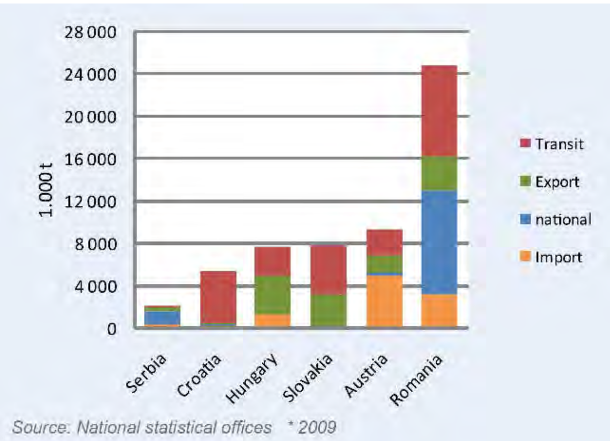


Figure 26 (source IVW) : Transport of goods on the Danube. Figures were higher before the crisis. To compare with 20Mt handled at Paris ports in 2010. Other point explaining traffic is the attendance of a great maritime port at the mouth of the River, as Rotterdam (greatest inland waterway port in Europe, handling 165Mt for inland waterway in 2008) or Antwerp (79 Mt in 2009).

4.6 – Container transport

On a European level, the transport of containerised items via inland waterways is developing strongly. Sea ports are increasingly using inland waterways to serve their hinterland.

For container transport via inland waterways, the most pertinent unit for measuring capacity is the number of containers. Expressing the capacity of inland waterways for container transport only in terms of tonnes has no real meaning.

The limiting factor is often the height clearance (for definitions of height clearance and "height above waterline", refer to the glossary and to { 2.2 or this section) under bridges. *Voies Navigables de France* (VNF, soon "ANVN") is in fact planning to raise a number of structures to open the way to increased container traffic. It is worth noting here in particular that the raising of bridges underway or planned in the Nord Pas-de-Calais basin is boosting accessibility to the European fleet, with wider gauges than the French one.

The capacity of a boat for container transport depends on several parameters: boat type, loading method (number of levels of containers and number of rows of containers able to be stacked side by side) and the loading percentage.

The height above waterline of a vessel can thus be determined according to the number of levels in which containers can be stacked. For a large-sized self-propelled barge (110 m x 11.40 m), the results are shown below (variations enabled by ballasting are not taken into account). The results obtained with other types of vessel (pushed convoys, etc.) are of the same order of magnitude:

Number of levels of containers	Number of rows	Height above waterline (m)		
		Empty	50% load	100% load
2	3	5.09	4.61	4.13
	4	5.05	4.43	3.81
3	3	7.61	6.9	6.19
	4	7.55	6.62	5.69
4	3	10.14	9.21	8.28
	4	10.05	8.81	7.57

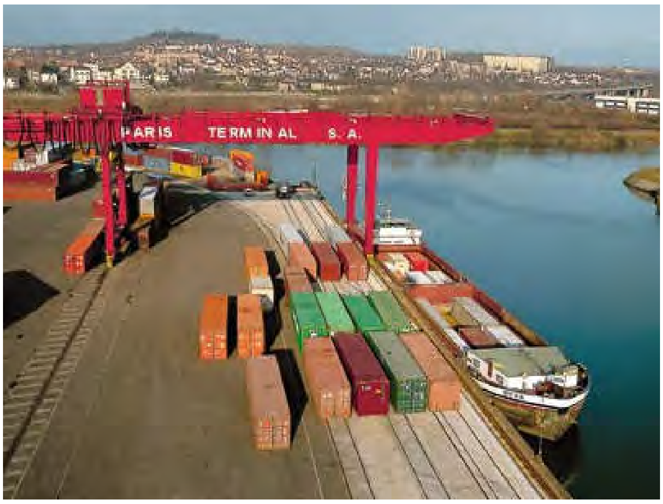
Figure 27. Number of containers on a barge and corresponding height above waterline (Source: STCPMVN, 1992 [60]). Heights depend on draught of vessel (few differences) and are slightly higher for high-cube containers.

For the transport of containers stacked three or four-high, the European classification adopted in 1992 (ECMT) set height clearances under bridges of 7 metres and 9.10 metres respectively. These values should enable vessels carrying containers loaded to 50% of their capacity to pass under bridges without ballasting, with a safety margin of 30 centimetres.

Finally, as described in the section of this guide relating to containers, recent years have seen the development of “high-cube” containers, offering increased capacity particularly as a result of their height of 9'6" (2,895 millimetres), compared with 8'6" for ISO containers. This can cause problems for inland waterway transport: for example, if the height clearance is 5.25 metres, ISO containers can be stacked two-high whereas only one level of high-cube containers will be possible.

Refer to appendix 2 for further details on inland waterway/sea transport.

Refer to VNF (soon ANVN) for conducting studies of navigable waterway routes (methodological note)



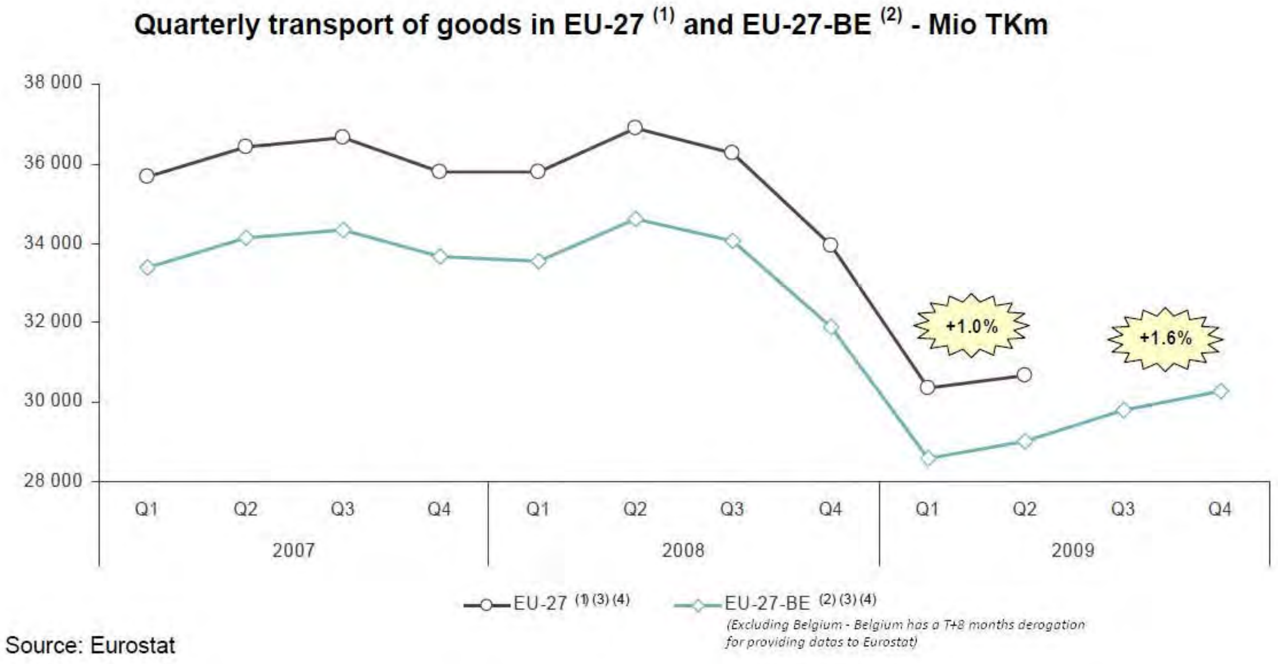


Figure 28 : Transport of goods in European Union. Inland waterway suffered the same falling than other modes at the end of 2008, due to the crisis. Modal split remains low in average (EU-27 : 5,2% in 2009, 3,3% including sea and air transport), with strong variations depending on the countries and their equipment (wide-gauge rivers and canals, ports) ; almost half of Netherlands' cargo is thus transported by waterway.

Such variations are noticeable in the world : for example, inland waterway represents only 1% of inland freight transport in India (planning a great equipment program), but ~30% in Bangladesh and – according to the European commission, DG-MOVE – 8% in the USA (2008), and 23% in China 2008, with 1,740 billion t.km on a 123 000 km navigable network (doubling capacity is aimed by the 2007-2020 water plan, concentrating on connecting major Chinese cities and ports).

5 – Inland Waterway Port Capacity

5.1 – General information on inland waterway ports

The waterway network is served by numerous ports which form mandatory connection points between waterway services and their customers. The main function of the port is the transhipment function between the waterway and an overland road or rail network. This is generally accompanied by a cargo storage function which requires at least a wharf hardstanding area or other facilities specific to the goods transported (grain silos, hydrocarbon tanks, etc.). It is worth noting that a significant part of the traffic is conveyed through private ports or quays, directly adjacent to industries or silos. In comparison with sea ports, inland waterway ports do not require any defence structures against the actions of the sea and can therefore be limited to a simple quay and a wharf hardstanding area for the handling equipment, and the storage and removal of cargo.

The administrative organisation of French inland waterway ports is similar to that of sea ports with two ports having autonomous port (*port autonome*) status (Paris and Strasbourg), and the majority of the other ports being assigned to Chambers of Commerce and Industry. Appendix 7 contains statistics regarding inland waterway port traffic.

5.1.1 – Types of inland waterway port

There are two possible scenarios for the installation of inland waterway ports:

- either the port installations are dedicated to a specific clientele (iron and steel industry, aeronautics industry, etc.), in which case the port will be located in proximity to the industry in question and privately managed. This is the case of river spurs which are generally funded by the consignors using them. They represent relatively high investments and constitute a strategic element in the logistics of consignors. Since 1987, in France, a funding support policy has been conducted firstly by the *Office National de la Navigation* and then by *Voies Navigables de France (soon ANVN – Agence Nationale des Voies Navigables)*;
- or the port installations are designed to serve large built-up areas, in which case the port will be managed by a public stakeholder and will be located at a suitable site for serving the area in question.

These two types of installation can be combined to form large inland port complexes. The port of Paris, for example, comprises a series of wharfs along the waterway (public wharfs managed by the autonomous port or private wharfs) which are quite close or even adjacent to one another, but with different characteristics and operated independently of each other. This set-up can also be found in other European ports such as Liège or Duisburg and more generally in industrial regions and large cities. This type of complex is known as a "linear port".

For the construction of a new installation, the planner must take account of economic data such that the new port fulfils the functions for which it is designed (i.e. serving an industrial company or a built-up area) as close as possible to the economic optimum. When located in a dense area, existing ports or ports to be created pose problems regarding integration into their environment as their development will result in concentrating heavy goods vehicle flows in these sectors.

5.1.2 - Functions of inland waterway ports

The construction and/or operation of an inland waterway port may comprise:

- mooring areas to prevent waiting boats from hindering the waterway traffic flow;
- loading/unloading areas;
- cargo packing and processing functions such as palletising, container make/break-bulk, labelling, etc.;
- certain manufacturing functions (for example, concrete batching plant processing the sand and gravel received);
- industrial annexes through which a company receives raw materials or sends processed products;
- administrative functions (customs clearance of goods, etc.).

5.1.3 – Adaptability in line with diversity of transhipped goods

Inland waterway ports take care of the loading/unloading of all types of goods: dry bulk (ore, grain, etc.), bulk liquids (hydrocarbons, etc.), conventional goods, vehicles and containers. In addition to becoming hot spots of intermodal transport, some ports are also developing their logistics service offer. This is particularly the case of the port of Lille which, with Delta 3 (www.delta-3.com), has a 30-hectare zone devoted to logistics warehouses, in addition to an inland waterway terminal and a combined transport terminal.

Port typology depends on the type of goods to be handled. Two cases are presented below: the description of a grain silo and a container terminal.

Grain silo

(source: www.invivo-group.com)

Let us take the example of a new grain loading wharf on the Seine: the InVivo silo at La Grande Paroisse. This terminal benefits from a total capacity of 170,000 tonnes: 110,000 tonnes of horizontal storage and 60,000 tonnes in vertical cells. Until now, loading operations were conducted in a dock but, due to its shallow draught, this could only accommodate inland waterway units of up to 800 tonnes; access was also made difficult when the strength of the current in the Seine increased. InVivo therefore created a direct grain loading wharf, where vessels can come alongside a 190-metre section. As a result of this investment, 1500-tonne barges can now be loaded in particular. It corresponds to the installation of a conveyor linking a 1300-tonne vertical silo comprising 22 cells (storage compartment) to the Seine. The loading rate has increased by 50% (600 tonnes/hour). Convoys of two or three 1500-tonne units can be loaded and set up in a single day. The increase in transit volume envisaged is of the order of 80,000 to 100,000 tonnes per year.

Container terminal, example of Lyon Terminal *(source: www.lyon-terminal.fr)*

Lyon Terminal, a subsidiary of the Compagnie Nationale du Rhône created in 1993, is in charge of container activities at the Edouard Herriot harbour in Lyons. For this purpose, it has a terminal with the following characteristics (also found in other inland waterway terminals): a 10-hectare storage area, 300 metres of quay, a fixed travelift with a 250-tonne capacity, a mobile crane, five reach-stackers for full containers (the reach-stacker is the most commonly used container handling equipment on the hardstanding areas of inland wharfs), seven trucks for empty containers and 1200 metres of railway line. The travelift is used to handle containers arriving via the river and heavy packages. In case of a problem and/or emergency, the mobile crane (33 tonnes at 18 metres) completes the work performed with the travelift to prevent a break in the service.

Note that a second container terminal of 10-hectares and 2,000 meter of railway line, with mobile travelift, was brought into service in 2007 for 16.5 Mio Euros, permitting the first one to be specialized in river/rail handlings, heavy packages and miscellaneous goods.

5.1.4 – Multimodal hub network

As a point of concentration of traffic flows, uncoordinated development of this type of terminal would inevitably result in dispersion in the flows of goods. Conversely, greater coherence in the hub network is likely to reinforce the position of domestic terminals within the logistics chain and make a greater contribution to mode transfer. Planners should notably pay attention to HGV flows generated by the infrastructure for the initial and final legs via road, which cause a nuisance to local residents. This is why multimodal hubs and their development must be included in a concerted, global land use planning procedure. A more coherent network requires better coordination of the facilities; better coordination can come from a single stakeholder involved in the management of several hubs. The port of Lille therefore manages several hubs in the Nord-Pas-de-Calais, including Lille, Prouvy and Delta3.

Certain inland waterway ports act as “dry” ports for large commercial sea ports. For further details on this subject, refer to Appendix 7 of the Sea section.

5.2 – Factors determining inland waterway port capacity

The notion of capacity of an inland waterway port must be approached in a similar way to the notion of capacity of a sea port, by making a distinction between three components: quayside or transhipment capacity, storage capacity and goods reception/hinterland servicing capacity. Each one of these components depends on a variety of factors, and notably:

- the number of quayside berths and the equipment used for the transhipment capacity;
- intrinsic storage (storage specific to the infrastructure, in area or volume depending on the type of terminal, and which does not depend on the technical or human resources devoted to goods handling) for the storage capacity;
- modal split for the goods reception/forwarding 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. Furthermore, a port's traffic depends on the capacity of the waterway which is itself dependent on climatic variations (floods and drought). Some carriers propose alternative solutions via rail or road when meteorological constraints are affecting its capacity.

. 5.2.1 – Quayside capacity

Quayside capacity represents the volume of goods that can be transhipped per unit of time. It depends on the number of berths, their length and the stevedoring equipment used. Quayside capacity also depends on the deadweight of the barges travelling on the waterway. For example, in the case of the old InVivo grain silo at La Grande Paroisse, barge deadweight was limited to 800 tonnes due to the silting-up of the dock.

Quayside berth configuration

The number of berths and their length must be suited to the quantity of traffic expected. If not, and in the absence of moorings, the vessels to be loaded or unloaded will encroach on the waterway which may lead to a blockage. This problem disappears in cases where the port is installed in a dock. This configuration also has the advantage of limiting the hindrance caused to handling operations by vessel traffic (wave effects). The drawback is that docks take up a large area which may be detrimental in urbanised zones.

Equipment

The stevedoring equipment used depends on the type of goods. A multipurpose crane can however be used to handle most products, load and unload a truck, build a stockpile, etc., but is less effective than specialised equipment. If quayside railway lines are present, the crane must necessarily be mounted on a travelift striding over the tracks. Reach-stackers (Refer to subsection 4.2. of the Combined road/rail transport part for further details) are also regularly used for quayside handling, especially for containers.

Figure 29. A reach-stacker at Paris container terminal (©MTETM/SG/SIC - 2006 Photo G. Crossay)

Specific equipment can increase vessel loading/unloading rates: container travelift, conveyor belt, etc.

Stevedoring equipment must be adapted to the capacity of the barges using the waterway and the frequency with which they arrive at the port. There is no point in having a high-performance but expensive container travelift to load barges with around ten TEUs. The equipment must be reliable in the case of high logistic constraints (as for container barge rotations). In the event of equipment failure, the port operator has to set up a downgraded mode of operation which reduces capacity. In Lyons, for example, a mobile crane can step in to cover a container travelift failure.

5.2.2 – Storage capacity

The type of storage to be set up depends on the type of goods received. Specific storage structures – such as grain silos or hydrocarbon tanks – may be required. As a general rule, however, goods are stored on a wharf hardstanding area for certain bulk solids, containers, vehicles, etc. In all cases, the storage infrastructures and their capacity must be suited to the expected traffic.

Grain silos

The grain silo at La Grande Paroisse comprises twenty-two 1300-tonne cells, making an intrinsic storage capacity of 28,600 tonnes, directly connected to the transhipment conveyor. The annual storage capacity represents the volume (or mass) handled per year. It is equal to the product of the intrinsic storage capacity (the infrastructure's actual storage capacity, expressed here in volume) by a factor called the annual rotation rate of the silo (e.g in Rouen, average annual rotation rate : 4 to 6):

Annual capacity = (rotation rate) x (intrinsic storage capacity)

Container terminals

The storage capacity of a container terminal is more difficult to determine. It depends mainly on the average number of days that a container spends at the terminal and the container stack height. The possible stack height depends on the type of reach-stacker used. It is however not uncommon to see full containers stacked four-high and some reach-stackers can stack empty containers six-high. The average number of days that a container spends at the port can vary greatly from one terminal to another. Storage periods may be long when the inland waterway port is used as a buffer storage area as shown in the example in the panel below.

Figure 30. Paris container terminal (©MTETM/SG/SIC - 2006 Photo G. Crossay)

Service to the Toyota Onnaing plant (Valenciennes)

The plant receives large quantities of parts by sea from Japan. Around twenty-five 40' containers arrive in Rotterdam every week. Toyota's strategy is aimed at reducing stocks and receiving "just in time" (cf. glossary). However, a period of 45 days is required between initiating the order and entry into the plant, and this transport period is too long for the assembly plant's forecast to be extremely reliable. The plant holds barely one day's stock, and this time is in a downward trend. A buffer storage area is therefore required: this is the role of the dedicated Toyota terminal at the port of Prouvy, a few kilometres from Valenciennes.

The logistics system set up is as follows: some of the containers are transhipped in Rotterdam and are sent to Dunkirk via a regular feeder line and then carried along the waterway by a regular Dunkirk-Béthune-Lille-Prouvy service. Other containers are directly conveyed along a regular line between Rotterdam and Prouvy set up by CCES (Combined Container Escaut Service), the Prouvy terminal operator. Conversely, in an emergency, the barges can be unloaded upstream of Prouvy and then transported by road. Note that this logistics system offers other advantages; especially customs processing of the cargo in Rotterdam in grouped batches, which is more economical than in separate batches.

5.2.3 – Hinterland servicing capacity

The goods reception/forwarding capacity may be a decisive factor depending on the split of import/export traffic, the modal split of the traffic and the size of the port's hinterland.

Note that the depth of this hinterland (which can vary from 30 to 150 or even 200 kilometres around the port) depends on:

- the distance between the sea port and the inland port;
- the economic fabric near to the port;
- the proximity and success of neighbouring terminals.

The goods reception/forwarding capacity by rail is similar to that of a combined transport terminal. Roads access routes must be carefully thought out to avoid congestion at the entrance to the port at certain times. This matter of road access is however less of an issue than in certain sea terminals as the traffic is obviously lower in this case.

The size of the hinterland has strong repercussions and determines, for example, the possibility of setting up a container shuttle system. Indeed, the hinterland must be large enough to guarantee a satisfactory vessel fill rate on each rotation. The geographical layout of the port is therefore important and the installation of effective technical resources (high-performance equipment, sufficiently large quay, large storage area, etc.) will not be sufficient to ensure the theoretical traffic if the port's hinterland is restricted.

5.3 – Overview diagram

The diagram in Figure 31 shows:

- the interdependence of goods transhipment, storage and reception/forwarding;
- the parameters to be considered in assessing each of the three capacities;
- the capacity of the waterway and the size of the hinterland as the main elements of port design.

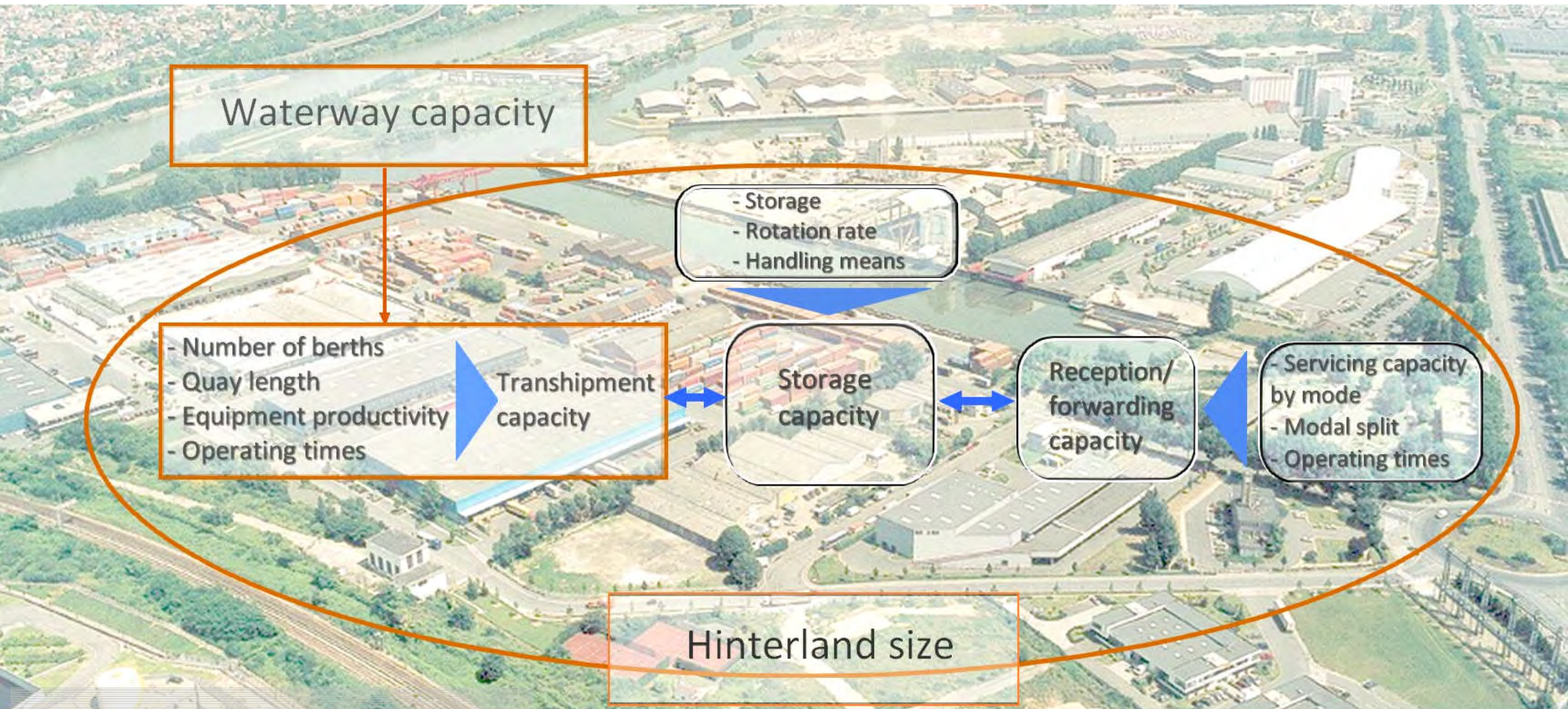


Figure 31 : Overview – Determining port capacity

Appendix 1. Vessel Speed and Draught

Source: ENPC, 1978 [61]

In addition to the so-called static draught which can limit the tonnage carried, vessels are also subject to a further “dynamic” draught (squat) which is dependent on speed. Indeed, the passage of a boat is notably accompanied by a lowering of the water level, compared with the situation at rest, which is fairly constant along the hull, thereby producing the squat phenomenon. The theory put forward by Schijf, a Dutch engineer, at the 1949 PIANC / Permanent International Association of Navigation Congress, enables this phenomenon to be understood with the following simplifying assumptions:

- homogeneous speed in the various sections of the canal;
- head losses (energy losses) disregarded along the walls of the canal and the boat;
- water level dropping homogeneously along the boat.

Schijf then showed that the speed V of the boat (in relation to the water) must be less than a limit speed V_l, a function of h, the average height of the canal, and n, ratio of the wetted cross-section of the canal to the midships cross-section of the boat.

The table in Figure 32 below gives the value of the ratio $\frac{V_l}{\sqrt{g \times h}}$, as a function of n (g: gravity).

n	2	3	4	5	7	10	∞
$\frac{V_l}{\sqrt{g \times h}}$	0.205	0.33	0.42	0.47	0.55	0.62	1

Figure 32. Limit speed in a canal

The case of infinite "n" represents a sheet of water with a very large cross-section compared with that of the boat (an extremely wide canal, for example, over 100 times the beam of the vessel). In this case, Vl = √(g*h). For a canal of depth h = 4 metres, it can therefore be deduced, where g = 10 m/s^2, that Vl = 6.3 m/s or approximately 22 km/h.

Conversely, where "n" tends towards 1, the cross-section of the canal is reduced to approach that of the boat and the limit speed tends towards 0; this is the case when a boat enters a lock of the same size as itself. This explains in part why the entry manoeuvres into a lock must be completed at low speed.

Schijf deduced the lowering of the water level Z_l, also a function of "h" and "n", for a boat progressing at limit speed (*cf.* Figure 33).

n	2	3	4	5	7	10	∞
Z_l / h	0.15	0.18	0.19	0.19	0.18	0.17	0

Figure 33. Vessel draught at limit speed in a canal

In theory, squat can therefore reach a value of approximately one-fifth of the depth. In reality, it is always lower as boats rarely exceed 90% of the limit speed.

Appendix 2. Combined Inland Waterway/Sea Transport

Combined sea/river-going vessels are sea-going vessels designed to sail on wide-gauge inland waterways (with up to 3.50 metres of draught). They are equipped with folding masts and stacks, a retractable hydraulic bridge and a double hull with ballast tanks. These units are generally manned by a five to seven-strong crew.

Without intermediate unloading or transhipment in a sea port, they can reach inland ports which are occasionally located a long way from the coast. Combined inland waterway/sea transport offers the following advantages:

- elimination of a break-bulk operation: handling costs limited, less risk of lost or broken goods and time saved;
- less congestion in the sea port.

Combined inland waterway/sea or River-sea transport in France is restricted to three basins:

The Seine basin: from Rouen to Montereau and on the Oise as far as Compiègne

The Seine allows access to combined sea/river-going units with a length of 85 metres, a beam of 15 metres, a draught of 3.35 metres and a height above waterline of 7.15 metres. In theory, it enables units with a 6000 m² hold capacity and 2400 tonne deadweight to reach the Paris region. In 2004, River-sea traffic in the Seine basin amounted to 480,000 tonnes. This is essentially Community traffic and is mainly composed of grain in the downward direction and iron and steel products, industrial sand, etc., in the upward direction.

Figure 34 contains a table of the restrictions for the three main inland waterway ports of Ile-de-France accommodating sea/river-going vessels, according to www.paris-ports.fr.

Port	Bonnières	Limay	Gennevilliers
Length (metres)	120	120	120
Beam (metres)	15.5	15.5	15.5
Draught (metres)	3.5	3.5	3.5
Height above waterline (metres)	8.75	8.75	8.75
One-way journey time from Le Havre (hours)	14	17	24
Distance from port to Paris (km)	60	45	5

Figure 34. Restrictions at main Ile-de-France ports receiving combined sea/river-going vessels

Here are a few examples of trip times including sea transport and the river journey from the Le Havre roadstead:

- Paris - Southampton: one-and-a-half days;
- Paris - Dublin: three days;
- Paris - Bilbao: three-and-a-half days;
- Paris - Lisbon: five days;
- Paris - Seville: six days;
- Paris - Helsinki: six days;
- Paris - Casablanca: six-and-a-half days.

North basin (Dunkirk – Valenciennes canal)

In 2003, 12 river/sea-going vessels carrying around 15,300 tonnes used the Nord-Pas-de-Calais network.

Rhône-Saône waterway from Fos to Chalon-sur-Saône

In 2004, combined river/sea traffic in the Rhône-Saône basin amounted to 870,000 tonnes.

The inland ports on the Rhône are accessible to river/sea-going vessels up to Chalon-sur-Saône with the limitations shown in Figure 35 below.

Ports on the waterway	Maximum draught (m)	Maximum height above waterline (m)
Arles	4.25	9.5
Le Pontet – Porte les Valance – Salaise – Lyon	3.1	6.2
Villefranche – Macon – Pagny	3.1	6

Figure 35. Access limitations to river/sea-going vessels in Rhône-Saône basin

Appendix 3. French and European Inland Waterway Port Traffic

Inland waterway port traffic has evolved favourably in recent years, particularly due to the growth in container traffic

Waterway traffic at French inland ports in 2010

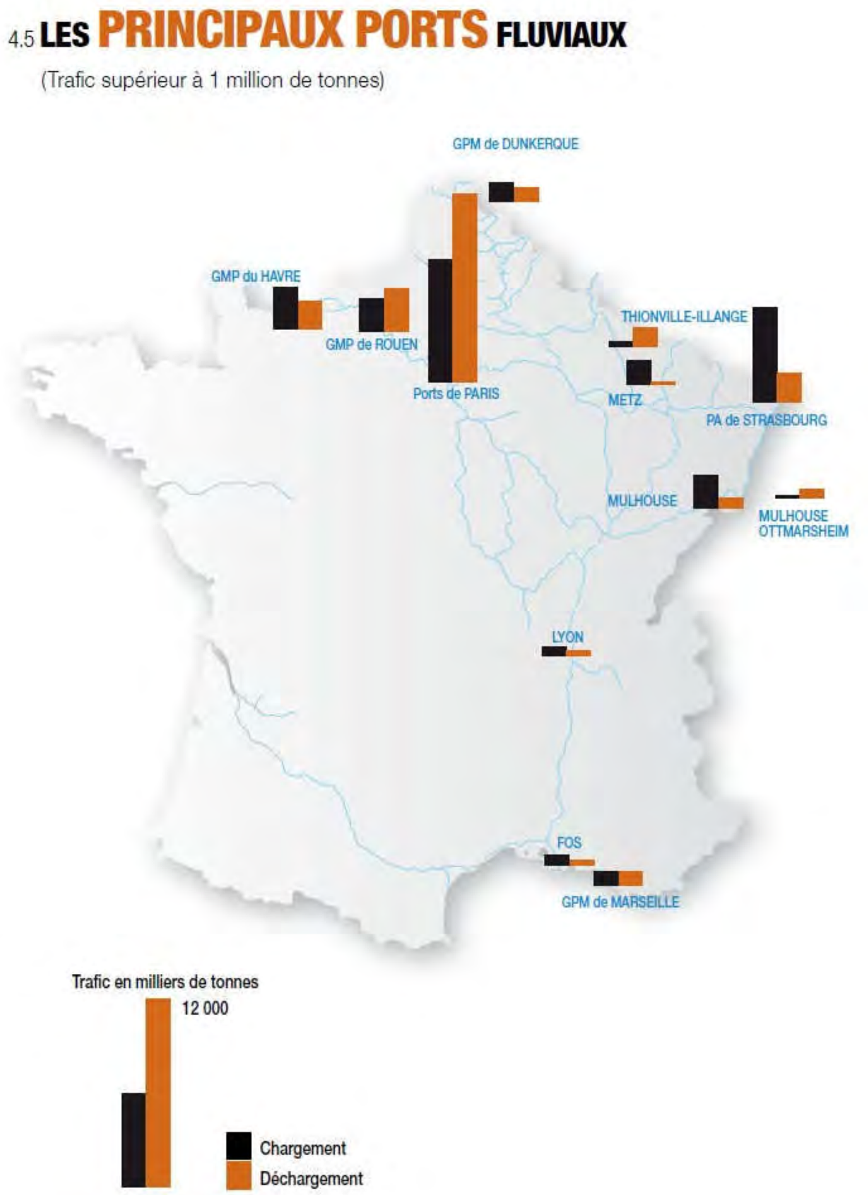


Figure 36: main French inland ports and traffics handled. Black: loading. Orange: unloading. Paris port handled (total) 20Mt in 2010

Waterway traffic at main European inland ports (Million tons)

Rotterdam	Antwerp	Duisburg	Paris Ports	Liège	Cologne
165.6*	78.58	51*	20.0	13.0	10.2*

*Figure 37. Waterway traffic of main European inland ports (2009, *2008) – source VNF*

Although inland waterway transport often represents a small part of total transport at maritime ports, at some ports as Antwerp or Rotterdam, inland waterway traffic count for a significant amount in the modal split (~30%)

Appendix 4. Some Cost Factors

Cost price of transport

The cost structure of a tonne of freight transported by inland waterways is traditionally composed of fixed costs and variable costs.

Fixed costs include labour expenses, insurance, various costs (canal fees, pilotage and harbour dues) as well as impairment loss on the boat (repair and maintenance expenses, depreciation provisions, interest charges and returns on capital).

Variable costs include diesel and lubricants, small equipment expenditure and other sundry costs.

According to VNF, in 2007, the cost to transport 1000 tonnes over one kilometre on inland waterways vary between 8 and 38 euros, depending on the vessel and distance of journey. This is in average lower than rail (23 to 46) and road (23 to 53) transport, thanks to greater tonnages by motor unit and relative simple operation. The table in Figure 38 below presents the cost price structure of a boat according to the type of boat considered (source: Eurostat).

in %	Cost components			
	Labour	Capital	Fuel	Other
Dry cargo				
Self-propelled barges, < 450 t	57	10	9	25
Self-propelled barges, 450 – 1200 t	46	11	15	30
Self-propelled barges, > 1200 t	37	18	15	29
Pushed convoys, < 5000 t	21	14	23	42
Pushed convoys, > 5000 t	10	14	29	48
Tankers				
Self-propelled, < 1200 t	47	13	14	27
Self-propelled, > 1200 t	46	16	12	26
Containers				
Container vessels	41	17	19	23

Figure 38. Cost price structure of an inland waterway vessel (in %) in 2000

It is noted that, logically, for dry cargo, the greater the vessel's capacity, the lower the percentage of labour costs in the total cost of transport will be. This component drops from 57% for a self-propelled barge of less than 450 tonnes to 10% for a pushed convoy of over 5000 tonnes. For tankers, the split is practically identical irrespective of the capacity of the self-propelled vessel.

The cost of the service is influenced by the unit capacity of the transport units. This phenomenon is traditional in terms of transport and concerns all modes.

The costs calculated by ADEME are of the same order as those given by VNF, but ADEME works according to a scale (it can indeed be assumed that the higher the tonnage to be transported, the cheaper the cost per tonne will be as the fixed costs will be spread more).

The table in Figure 39 shows the number of navigating personnel for the various types of inland waterway unit in addition to unit consumption (source: VNF [63]).

	Navigating personnel	Unit consumption[1] - GOE[2]/t-km
Freycinet (350 t)	2	7.7
RHK (1350 t)	3	5.8
GR (2500 t)	4 to 5	5.7
Convoys (4400 t)	5	3.6

[1] *Estimate on a typical journey from Gennevilliers – Le Havre*

[2] *Grams of Oil Equivalent*

Figure 39. Navigating personnel and unit consumption for various inland waterway units

Cost of vessel building

Source: ONTF, 2004 [64]

Building a two-barge convoy (38.5 metres) costs around one million euro in France and half as much in Poland or the Far East. However, an average of a further 15,000 euro per unit must be added to this cost to transport it; a figure that generally puts them out-of-reach of self-employed operators. They may however be able to afford a second-hand convoy costing from 90,000 to 120,000 euro.

Appendix 5 – French fleet and network

Source: VNF [54]

	Self-propelled barges			Pushed barges and lighters		
	number	million t-km	share t-km	number	million t-km	share t-km
< 400 t	590	889.8	36%	51	38.3	2%
400 – 649 t	140	332.5	13%	165	218.3	12%
650 – 999 t	104	589.5	24%	92	251.6	14%
1000 – 1499 t	68	449.1	18%	19	66.6	4%
1500 – 2999 t	15	234.7	9%	133	1188.1	67%
> 3000 t	0	0	0%	1	1.8	0%
Total	**917**	**2495.6**	**100%**	**461**	**1764.7**	**100%**

Figure 6. Capacity and volume of activity of French general cargo vessels (2005)

The Rhône-Saône basin

The Rhône fleet increased in number and capacity between 2002 and 2005, rising from 74 to 135 units, for a capacity of 180,700 tonnes (*cf.* Fig 7).

	Self-propelled barges		**Pushed barges**		**All vessels**	
	number	deadweight	number	deadweight	number	deadweight
<1000 t	18	11,783	50	26,167	68	37,950
1000 to 1499 t	12	14,945	1	1,230	13	16,175
1500 t and over	13	28,300	41	98,275	54	126,575
Total	43	55,028	92	125,672	135	180,700

Criteria: beam > 5.05 m or DW > 380 t

Figure 7: Waterway fleet in the Rhône–Saône basin in 2005

The Seine basin

The captive fleet of the Seine basin dropped slightly in capacity between 2002 and 2005, falling from 446 to 416 units, and from 500,000 to 484 700 tonnes in terms of deadweight capacity (*cf.* Figure 8).

	Self-propelled barges		**Pushed barges**		**All vessels**	
	number	deadweight	number	deadweight	number	deadweight
<1000 t	91	70,393	180	114,339	271	184,732
1000 to 1499 t	31	38,638	16	19,393	47	58,031
1500 t and over	9	19,308	89	222,620	98	241,928
Total	131	128,339	285	356,352	416	484,691

Criteria: beam > 5.70 m or DW > 600 t

Figure 8: Waterway fleet in the Seine basin in 2005

French navigable network

France has an 8,500 km network of navigable waterways. The characteristic dimensions of French navigable waterways are laid down in Circular 76-38 of March 1, 1976 [52] which defines classes of navigable waterways according to the dimensions of the largest vessels or pushed convoys which can normally navigate on them. This circular was amended by Circular 95-86 of November 6, 1995 [55] in order to take account of the recommendations of the 1992 European Conference of Ministers of Transport regarding height clearance under bridges on wide-gauge waterways.

The navigable waterway classification is conditioned by the working dimensions of the locks, allowing certain types of vessel to navigate on the network (source: [55]). The working dimensions of a lock are respectively the maximum length, width and depth that must remain clear throughout the locking operations (cf. glossary), and in particular during gate manoeuvres.

In compliance with the recommendations of the European Conference of Ministers of Transport of March 1992, the March 1, 1976 French Circular was amended with regard to height clearance under bridges crossing wide-gauge class V or VI navigable waterways – *Note that there is a class VII, which concerns few rivers in Europe, as the Danube between Beograd and Black Sea (longest section of class VII in Europe) or the Seine from Gennevilliers to Rouen.* Bridges over class V and VI canals shall have a minimum height clearance of 7 metres above the normal water level or the base line for rivers. For navigable rivers, the bridge shall have a height clearance of 5.25 metres above the highest navigable water level (HNWL). This standard is applied with a view to developing container transport to enable containers to be stacked three-high.

Class	Deadweight (in t)	Locks			Standard vessels or convoys			Bridge – height clearance (m)
		Working length (m)	Working width (m)	Depth (m)	Length (m)	Beam (m)	Draught (m)	(built or to be adopted)
0	< 250							
I	250 to 400	40	6	3/3.50	38.5	5.05	2.20/2.50	3.7
II	400 to 650							4.1
III	650 to 1000	92	6	3/3.30	90	5.7	2.20/2.50	4.1
IV	1000 to 1500	110	12	3.50/4.50	105	11.4	2.50/3	5.3
V	1500 to 3000	185	12	3.50	180	11.4	2.50	7.0
VI	> 3000	185	12	4.50	180	11.4	3	7.0

Figure 12: Classification of navigable waterways in France, according to the working dimensions of the locks

Description of French network by gauge

The 1976 Circular classified the network from 0 to VI (*cf.* above note regarding class VII) on the basis of the deadweight tonnage of the vessels that can be accommodated. These classes are then grouped by gauge (*cf.* Figures 13 and 14). Wide gauge (GG = *grand gabarit*) relates to classes IV to VI waterways (vessels over 1000 tonnes), medium gauge (MG = *moyen gabarit*) to classes II and III (vessels from 400 to 999 tonnes) and narrow gauge (PG = *petit gabarit*) to classes 0 and I (vessels under 400 tonnes).

The term "length used" refers to the number of kilometres of waterways actually navigated for goods transport. Less than a quarter of the network is wide-gauge and can therefore accommodate vessels in excess of 1000 tonnes. The medium gauge is the least common with 800 kilometres. Two-thirds of the network is narrow-gauge, 1600 kilometres of which are below Freycinet standards. Moreover, these class O waterways are practically no longer used (except for tourism). Only 5,400 kilometres (on 8,500) are regularly used.

	Gauge	Class	Length (in km)	Weight of each class by length	Length used (in km)	Weight of each class by length used
50 to 250 t	Narrow	O	1660	20%	64	1%
250 to 400 t	Narrow	I	4002	47%	3177	59%
400 to 650 t	Medium	II	266	3%	210	4%
650 to 1000 t	Medium	III	568	7%	225	4%
1000 to 1500 t	Wide	IV	137	1%	31	1%
1500 to 3000 t	Wide	V	247	3%	232	4%
> 3000 t	Wide	VI	1621	19%	1445	27%
Total (in km)			**8500**	**100%**	**5384**	**100%**

Figure 13. Length of French navigable waterway network (2003) – Source: Transport statistics memo, 2003 results, DAEI, July 2005

Figure 14. Map of navigable waterway network gauges (Source: VNF)

Evolution of French traffics per basin

In the memo updating the document on transport demand in 2025 [12 bis, 2007], it is estimated that waterway transport will average 10 billion t-km by 2025, with a 90% probability of being between 8.8 and 11.3 billion t-km, which represents an annual growth rate of 1.1 to 2.2% from 2002 to 2025). This memo states that, as the waterway networks are not connected, there will be great differences in traffic growth between them. Furthermore, considering the importance of the break in supply that the building of the Seine-North Europe canal will constitute, and which would mask the other effects, the estimates do not include it in the basic projections. The Seine-North Europe project is due to bring in an extra 4.3 billion t-km (refer to Appendices for further details on this project). High degrees of uncertainty centre on the development of Freycinet gauge transport on the one hand and container transport on the other. For Freycinet barges, the scope of variation ranges from 50 to 100% of the current level of traffic. For containers, a low-end hypothesis of multiplication by two in phase with the forecasts for sea ports has been adopted in addition to a high-end hypothesis of multiplication by four to take account of a stronger dynamic in inland navigation.

The national waterway transport observatory (ONTF = *Observatoire National des Transports Fluviaux*) has forecast growth in traffic in millions of t-km, per basin, between 1998 and 2020 based on 1985 – 1998 traffic data, and the hypothesis of infrastructure rehabilitation (*cf.* table in Figure 26, Source: VNF and ACT).

To compare with these previsions of 2007, French inland navigation represented 8,1 billions t.km in 2010 – g60.5 Mio T, i.e. 134km average distance. ~45% of this traffic was supported by foreign vessels.

	AAGR 1998/1985[1]	1998	2010	2020	AAGR 2020/1998
Wide-gauge infrastructures					
Seine Oise	-1.60%	1965.7[2]	2752.6	3114.5	2.10%
Rhône Saône	3.00%	617.0[3]	1214.2	1491.1	4.10%
Rhine	2.70%	1171.1	1424.1	1593.8	1.50%
Moselle	1.50%	460.8	608.1	669.6	1.70%
Nord-Pas de Calais	Not communicated	376.1	425.5	526.8	1.50%
Wide gauge total	0.10%	4590.7	6424.1	7395.8	2.20%
Freycinet					
North-south route	Not communicated	562.8	824.6	1056.8	2.90%
Other Freycinet gauges	Not communicated	1122.2	1128.9	1137.2	0.00%
Freycinet gauge total	-3.60%	1685	1953.5	2194	1.20%
TOTAL	-1.50%	6275.7	8377.6	9589.8	1.90%

[1] Average annual growth rate
[2] 1996 coal traffic is taken as the benchmark
[3] 1997 coal traffic is taken as the benchmark

Figure 26. Evolution in traffic from 1998 to 2020 in Mt-km (including combined inland waterway/sea traffic)

Appendix 6. French Network Characteristics and Capacity by Basin

Moselle basin

The traffic in the Moselle basin is essentially international traffic to Germany, the Benelux countries (especially the ports of Rotterdam and Antwerp), and Eastern Europe. The main products transported are:

- imported solid mineral fuels (coal): 3.6 Mt in 2005;
- exported agricultural produce (grain), where the two ports of Metz and Nancy act as hubs, centralising a part of the flows originating from the Lorraine, Champagne-Ardenne and even the Burgundy regions and shipping them to Germany and the Benelux (2.5 Mt). The various Lorraine ports also import fertilisers (200,000 tonnes);
- imported metallurgical products and ores and waste for metallurgy in terms of procurement (1.3 Mt) and exported metallurgical products or semifinished goods: 0.95 Mt.

Development also relies on the dynamics of the Rhine, both from the point of view of accessibility to the Benelux ports and integration of inland waterway logistics into industrial processes.

The characteristics of the Moselle are established by the international Moselle convention. The authorised height above the waterline limits the loading capacity of self-propelled Rhine barges to 112 TEU upstream of Thionville compared with 168 TEU downstream. The work to raise bridges in progress on the French part of the river will significantly increase its capacity in the coming years.

Map of Moselle basin – Source: VNF

Operations to the north of Metz are conducted around the clock. To the south, on the other hand, operations are only conducted for 12 hours per day with service on request outside the operating times. The SDEVN plans 24-hour operation over the entire network within a five-year time frame.

Wide gauge:

- over 3000 tonnes
- 1500 to 3000 tonnes
- 1000 to 1500 tonnes

Medium gauge:

- 650 to 1000 tonnes
- 400 to 650 tonnes

Narrow gauge:

- 250 to 400 tonnes
- under 250 tonnes

ECMT class: VIb

Duration of locking cycle: 60 min

Tonnage: 3600 t / 4100 t

Number of days' navigation: 340

Reduction coefficient: 0.45

Theoretical depth: 3 m

Height clearance: 5.04 m, increased to 5.25 m in 2007

SDEVN category: 1A

Capacity

Present capacity (target value: 24-hour op.): 21 Mt.

Daytime capacity (12 h/day operation): 15 Mt

Traffic in 2005: 9.10 Mt

Average vessel load in 2005: 1343 t

Limiting factors for container transport:

In France: Thionville bridge: 5.04 m (sufficient height clearance for three levels of containers 300 days/year)

In Germany: the Koblenz bridge providing access to the Rhine: 3.60 m above the reference waterline, but 3.10 m for 290 days/year

The Moselle between Metz and Frouard

ECMT class: VIb

Duration of locking cycle: 60 min

Tonnage: 3600 t / 4100 t

Number of days' navigation: 340

Reduction coefficient: 0.45

Draught: 2.50 m

Height clearance: 5.65 m

SDEVN category: 1A

Capacity (tonnage 4100 t)

Present capacity (target value: 24-hour op.): 21 Mt

Daytime capacity (12 h/day operation): 15 Mt

Night-time service by request

Traffic in 2005: 3.2 Mt

Average vessel load in 2005: 979 t

Limiting factors for container transport:

Height clearance of 5.65 m

Access to port of Frouard

Capacity (tonnage: 2000 t)

Present capacity (12 h/day operation): 7.3 Mt

Target capacity (24-hour operation): 10.22 Mt

Traffic in 2005: 1.2 Mt

The Moselle between Frouard and Neuves-Maisons

ECMT class: VIb

Duration of locking cycle: 60 min

Tonnage: 3600 t / 4100 t

Number of days' navigation: 340

Reduction coefficient: 0.45

Draught: 2.80 m

Height clearance: 5.07 m

SDEVN category: 1A

Capacity (tonnage 4100 t)

Present capacity (target value: 24-hour op.): 21 Mt

Daytime capacity (12 h/day operation): 15 Mt

(Night-time service by request)

Traffic in 2005: 0.8 Mt

Average vessel load in 2005: 668 t

Limiting factors for container transport:

Height clearance of 5.07 m

Rhine basin

In Alsace, the Rhine occupies a central position in the goods transport network. Inland waterway transport accounts for 42% of the market in terms of the region's exchanges with Germany and the Benelux countries, and especially the ports of Rotterdam and Antwerp. In 2004, total traffic at the Gambsheim locks was 21.4 Mt, of which approximately 6 to 8 Mt involved international transit.

Inland waterway activity is varied (agri-foods, chemicals, hydrocarbons, materials, containers, metallurgy, etc.) and in constant development: over a third of traffic (excluding transit) concerns raw or manufactured minerals and construction materials (NST 6), followed by oil (24%), agricultural produce and foodstuffs (18%) and machines and manufactured items (12%).

The gauge permits the transportation of 10,000-tonne units but thus varies with the hydrologic regimen of the river. In terms of containers, a theoretical capacity per river unit of 288 TEU is possible upstream of Kehl bridge (containers stacked three-high) and 470 TEU downstream (four-high). On the lower Rhine, the capacity reaches 538 TEU.

Map of Rhine basin - Source: VNF

Wide gauge:

- over 3000 tonnes
- 1500 to 3000 tonnes
- 1000 to 1500 tonnes

Medium gauge:

- 650 to 1000 tonnes
- 400 to 650 tonnes

Narrow gauge:

- 250 to 400 tonnes
- under 250 tonnes

Class: VI – VIb

Duration of cycle: 60 min

Tonnage: 6,400 to 12,000 t

Number of days' navigation: 340

Reduction coefficient: 0.45

Draught: 3.50 m (max 3.90 m)

Vessel tonnage: 10,000 t

SDEVN category: 1A

Capacity (considering a deadweight of 10,000 t)

Present capacity (target value: 24-hour op.): 51 Mt

Daytime capacity (12 h/day operation): 36.4 Mt

Traffic in 2004 (Gambsheim): 21.2 Mt

of which vessels in transit: 6 Mt

of which container traffic (2005): 160,472 TEU

Limiting factor for container transport:

Kehl bridge (Strasbourg) limits container stack height to 3 upstream of the bridge, versus 4 downstream.

The number of days' navigation can theoretically reach 365 days.

Traffic can therefore be doubled on the Rhine.

Nord-Pas-de-Calais basin

This basin in the far north of France relies on a traditionally important industrial fabric and trade currents with the Benelux and other countries by sea. The inland waterway network has several functions:

- North-South transit;
- service to Lille (containers, household refuse, construction materials, etc.) and the main built-up areas in the region;
- service to the port of Dunkirk;
- integration of the region with the Benelux countries within a "Euro region", with which commercial and cultural ties are predominant.

The Nord-Pas-de-Calais basin is structured around the Dunkirk–Scheldt wide-gauge canal, which covers the majority of commercial traffic, and the main canalised waterways flowing towards the north-east or the north (Scheldt, Scarpe, Deûle, Lys and Aa). The most important links extend the wide-gauge canal for the purpose of communications with the Belgian network, which itself wide-gauge (the Scheldt and the Lys) and the Seine (Canal du Nord and Canal de Saint-Quentin). In spite of the antiquated infrastructure, the present-day Canal du Nord fulfils two requirements:

- North-South exchanges based on the one hand on supplies to Paris, particularly of building materials, and, on the other hand, on supplies to the grain processing industries in the Benelux countries and the large-scale export of these same products via Dunkirk or Ghent from the Centre and Champagne-Ardenne regions of France;
- grain logistics marking the Picardy region, traversed by the route.

Work (recalibration and bridge raising, *cf.* Appendix 6) is underway to make the Dunkirk-Scheldt wide-gauge link accessible to the European wide-gauge fleet. In 2006, relations with Belgium were still limited to the use of self-propelled RHK vessels (1350 tonnes). The Canal du Nord helps to lighten the traffic on the through-road links and access to the two major urban areas of Paris and Lille. The link with the Seine basin should be considerably reinforced with the opening of the Seine-North Europe wide-gauge link.

Map of the Nord – Pas-de-Calais basin

Wide gauge:
- over 3000 tonnes
- 1500 to 3000 tonnes
- 1000 to 1500 tonnes

Medium gauge:
- 650 to 1000 tonnes
- 400 to 650 tonnes

Narrow gauge:
- 250 to 400 tonnes
- under 250 tonnes

Dunkirk-Lille Link

Class: V – Va (circular 76/ECMT)

Duration of locking cycle: 60 min

Maximum tonnage: 3000 t

Number of days' navigation: 340

Reduction coefficient: 0.45

Draught: 3 m

Height above waterline: 4.54 m

SDEVN classification: 1B

Capacity (considering a deadweight of 3000 t)

Target capacity (14 h/day operation): 11.7 Mt

Daytime capacity (12 h/day operation): 11 Mt

Traffic in 2005: 4.36 Mt

Limiting factor: Essars bridge: 4.54 m height clearance (under reconstruction to raise to 7 m) – Opening of the entire link to 5.25 m by mid-2009

Dunkirk-Valenciennes (Prouvy) link

Class: V – Va

Duration of locking cycle: 60 min

Maximum tonnage: 3000 t

Number of days' navigation: 340

Reduction coefficient: 0.45

Draught: 3 m

Height above waterline: 4.76 m

SDEVN classification: 1B

Capacity (considering a deadweight of 3000 t)

Target capacity (14 h/day operation): 11.7 Mt

Daytime capacity (12 h/day operation): 11 Mt

Traffic in 2005: 5.78 Mt

Container traffic in 2005: 8400 TEU

Limiting factor: Prouvy bridge: 4.76 m height clearance - Opening of the link to 5.25 m by mid-2011 - Under reconstruction to raise to 7 m

Lille-Belgium link

Class: IV

Duration of locking cycle: 50 min

Maximum tonnage: 1350 t

Reduction coefficient: 0.51

Draught: 2.5 m

Height above waterline: 4.72 m

SDEVN classification: 1B

Capacity (considering a deadweight of 1350 t)

Target capacity (14 h/day operation): 7.1 Mt

Daytime capacity (12 h/day operation): 6.7 Mt

Traffic in 2005: 3.87 Mt

Container traffic in 2005: 21,000 TEU

Limiting factor: Werwicq bridge: 4.72 m height clearance - Opening of the link to 5.25 m by mid-2009

Valenciennes-Belgium link

Class IV (Scheldt canalised from Bruay to Mortagne)

Maximum tonnage: 1350 t

Duration of locking cycle: 50 min

Reduction coefficient: 0.51

Draught: 2.5 m

Height above waterline: 5.78 m

SDEVN classification: 1B

Capacity (considering a deadweight of 1350 t)

Target capacity (14 h/day operation): 7.1 Mt

Daytime capacity (12 h/day operation): 6.7 Mt

Traffic in 2005: 5.22 Mt

Container traffic in 2005: 21,600 TEU

Limiting factor: Marais Escautpont bridge: 5.78 m height clearance

Example of the Canal du Nord (Source: VNF)

- Locks: 90 m x 5.70 m
- Draught: 2.40 m
- Cycle time: 30 min for one vessel / 40 min for two vessels
- Maximum transport unit (TU) load: 350 t

Practical capacity calculation (excluding tourism):

Number of cycles: 18 (= 72 TUs) per 12-hour day
18 + 14 (reduction for works and maintenance), = 128 TUs per 24-hour day

In terms of tonnage, per 12-hour day: 72 TUs, of which 30% are empty, = 50 loaded TUs/day

=> capacity of 6.35 Mt

- Seasonality coefficient: 0.9
- Lock occupancy coefficient: 0.85
- Average load coefficient: 0.9

=> capacity of 4.37 Mt

In terms of tonnage, per 24-hour day: 14 additional cycles, = 56 TUs of which 30% are empty, = additional 5.08 Mt. After applying the coefficients:

=> 7.87 Mt at the locks
=> 6.41 Mt at the locks, with a weekend reduction

Maximum traffic (in 1981): 4.86 Mt; traffic in 1997: 2.7 Mt; traffic in 2005: 3.75 Mt

Seine basin

Source: National Waterway Transport Observatory (ONTF)/"Infrastructures and fleets" working party report

Today, the waterway commonly referred to as Seine-Oise combines to serve three requirements:

- the Paris Region: supplies of construction materials (13.4 Mt in 2005), energy products (over 0.5 Mt) and containers, and removal of spoils and excavated residues (2.5 Mt). Paris Autonomous Port figures estimated traffic at 20.8 Mt in 2005, a 6% increase over 2004, three-quarters of which were devoted to construction materials (13.4 Mt). Container traffic has also increased, to around 52,000 TEU in 2004 and 73,500 TEU in 2005. More detailed figures are provided on the Paris Autonomous Port's website (http://www.paris-ports.fr);
- waterside industrial sites installed particularly in the Val-d'Oise and Yvelines districts (agri-food, automotive, metallurgy and energy industries, etc.) as well as large hub ports (Gennevilliers, Bonneuil, etc.);
- a link between the ports of Rouen and Le Havre with their hinterlands (the Ile-de-France, Picardy, Champagne-Ardenne and Centre regions).

Along this waterway, the infrastructure authorises unit loads of 5000 tonnes (or 352 TEU - 2 x 176 TEU) downstream of Paris.

In the upper Seine, the height above the waterline between Charenton (at the confluence with the Marne) and Paris (at the outer ring-road, upstream) is 10 metres, which indeed allows a high number of containers to be transported. But it must be emphasised that such boats cannot cross Paris, as the height above the waterline is limited here especially by the Invalides bridge to around 6.50 metres.

The Oise can accommodate loads of 3000 tonnes up to Creil and 2000 tonnes up to Compiègne. The Marne is accessible to 2500-tonne units as far as Bonneuil.

Map of Seine basin – source VNF

Wide gauge:

- over 3000 tonnes
- 1500 to 3000 tonnes
- 1000 to 1500 tonnes

Medium gauge:

- 650 to 1000 tonnes
- 400 to 650 tonnes

Narrow gauge:

- 250 to 400 tonnes
- under 250 tonnes

Seine: Rouen - Gennevilliers

Class: Vb – VII (as per circular 76)

Maximum tonnage: 5000 t

Duration of locking cycle: 60 min

Reduction coefficient: 0.45

Draught: 3.50 m

Height above waterline: 7.50 m (8.75 m after Amfreville)

Tidal influence downstream of Amfreville

SDEVN classification: 1A

Present capacity

Present capacity (target value: 24-hour operation): 20.6 Mt

Daytime capacity (12 h/day operation): 14.7 Mt

Traffic in 2005: 9.6 Mt

Seine – Oise: Conflans-Sainte-Honorine - Nogent

Class Vb (VI)

Maximum tonnage: from 3000 to 5000 t

Duration of locking cycle: 60 min

Reduction coefficient: 0.45

Draught: 3 m

Height above waterline: 5.20 m

SDEVN classification: 1A

Present capacity

Present capacity (target value: 24-hour operation): 20.6 Mt

Daytime capacity (12 h/day operation): 14.7 Mt

Traffic in 2005: 4.8 Mt

Average vessel load: 435 t

Limiting factor: Mours railway bridge, with a 5.20 m height clearance

Seine - Oise: Nogent - Compiègne

Class V

Maximum tonnage: 2000 t.

Duration of locking cycle: 60 min

Reduction coefficient: 0.45

Draught: 2.50 m

The draught is just 2.50 m between Nogent-sur-Oise (upstream of Creil) and Compiègne, therefore limiting the deadweight and ultimately the capacity of the waterway.

SDEVN classification: 1A

Present capacity

Present capacity (target value: 24-hour op.): 11.4 Mt

Daytime capacity (12 h/day operation): 8.16 Mt

Traffic in 2005: 4.8 Mt

Average vessel load: 435 t

Limiting factor: Compiègne bridge, with a 5.76 m height clearance

Seine - Marne: Rouen - Paris - Bonneuil-sur-Marne

Class IV

Maximum tonnage: 1350 t.

Duration of locking cycle: 50 min

Reduction coefficient: 0.51

Draught: 3 m (upstream of Paris)

SDEVN classification: 1A

Present capacity (considering a deadweight of 1350 t)

Present capacity (target value: 24-hour op.): 12.9 Mt

Daytime capacity (12 h/day operation): 9.2 Mt

Traffic in 2005: 1.732 Mt

Average vessel load: 338 t

Limiting factors:

- lock between Bonneuil/Marne and the Paris confluence

- Invalides bridge: 6.50 m height clearance

Rhône basin

In addition to the river Rhône, canalised to form a wide-gauge waterway down to the sea, with many locks (Lyons : 235m above sea level), the basin includes extensions towards the port sites and the Marseilles and Sète regions (Rhône to Sète canal) and upstream towards Burgundy (Lyons, Mâcon and Chalon) via the wide-gauge Saône (*cf.* Figure 40). This is where the majority of goods traffic is concentrated.

The so-called Rhône-Saône waterway opens the Rhône industrial area to the Mediterranean via the two sea ports of Fos-sur-Mer and Sète, as well as via river/sea services. Traffic is essentially supported by the industry in the Lyons area (especially petrochemicals) and, to a lesser extent, further north in Chalon-sur-Saône. More recent times have seen the development of grain logistics, creating an export flow.

The infrastructure allows 4400-tonne (or 240 TEU) convoys to sail from Chalon-sur-Saône to Fos-sur-Mer. Sète is accessible to units of around 1000 tonnes and Saint-Jean-de-Losne to 2200-tonne units.

Map of Rhône–Saône basin - Source: VNF

Wide gauge:

- over 3000 tonnes
- 1500 to 3000 tonnes
- 1000 to 1500 tonnes

Medium gauge:

- 650 to 1000 tonnes
- 400 to 650 tonnes

Narrow gauge:

- 250 to 400 tonnes
- under 250 tonnes

SDEVN category: 1A

Saint-Jean-de-Losne - Chalon-sur-Saône

Class Va / Deadweight: 2200 t

Duration of locking cycle: 60 min

Reduction coefficient: 0.45

Draught: 2.0 m

Height above waterline: 4.80 m

Present capacity (considering a deadweight of 2200 t)

Present capacity (target value: 24-hour op.): 14 Mt

Daytime capacity (12 h/day operation): 10 Mt

Traffic in 2005: 0.725 Mt

Average vessel load: 692 t

Chalon-sur-Saône - Lyons

Class Vb / Deadweight: 4400 t

Duration of locking cycle: 60 min

Reduction coefficient: 0.45

Containers: 264 TEU

Draught: 3 m

Height above waterline: 4.90 m

Present capacity (considering a deadweight of 4400 t)

Present capacity (target value: 24-hour op.): 22.6 Mt

Daytime capacity (12 h/day operation): 16.2 Mt

Traffic in 2005: 3.2 Mt

Average vessel load: 496 t

Lyons - Fos

Class Vb / Deadweight: 4400 t

Duration of locking cycle: 60 min

Reduction coefficient: 0.45

Containers: 264 TEU

Draught: 3 m

Height above waterline: 6.30 m

Present capacity (considering a deadweight of 4400 t)

Present capacity (target value: 24-hour op.): 22.6 Mt

Daytime capacity (12 h/day operation): 16.2 Mt

Traffic in 2005: 3.9 Mt

Average vessel load: 757 t

The *Service de la Navigation du Rhône* can be contacted for the specific issue of crossing Lyons.

Rhône - Sète

Class IV / Deadweight: 1000 t

Duration of locking cycle: 35 min

Reduction coefficient: 0.56

Draught: 2.50 m

Height above waterline: 4.95 m

Present capacity (considering a deadweight of 1000 t)

Present capacity (target value: 24-hour op.): 11 Mt

Daytime capacity (12 h/day operation): 7.8 Mt

Traffic in 2005: 0.4 Mt

Average vessel load: 660 t

Appendix 7. The Seine-Northern Europe project

Source: Preliminary inquiry to the public utility declaration regarding the Seine-Northern Europe canal and related developments from Compiègne to Aubencheul-au-Bac, VNF, December 2006 [62]. (No change in 2011)

The Seine-Northern Europe wide-gauge canal to be built between Compiègne and Aubencheul-au-Bac (Nord) is the central link of the Seine-Scheldt European waterway, selected in April 2004 among the thirty priority projects of the Trans-European Transport Network (cf map of TEN-T p69).

Figure 27. Map of Seine-Northern Europe link

Seine-Northern Europe consists of building a 106-kilometer long, Vb-gauge canal in the regions of Picardy and Nord-Pas-de-Calais, to allow the passage of convoys of up to 4400 tonnes. The height clearance under the bridges will allow containers to be stacked three-high. In particular, it comprises:

- eight reaches connected by seven locks with a drop height ranging from 6.4 to 30 metres;
- two reservoir basins to supply water during low-water periods;
- three canal bridges, one of which is 1330 metres long to cross the Somme;
- four multimodal terminals and seven transhipment quays for exchanges with other modes of transport (road and rail).

The Seine-Northern Europe canal project forms part of a global land planning and regional competitiveness strategy, aimed at reducing the environmental impacts of transport and promoting the versatility of waterways. It fulfils several public policy objectives:

- eliminating the major bottleneck in the European wide-gauge waterway network;
- improving the competitiveness of companies by placing the benefits of inland waterway transport (reduced costs, reliability, safety, etc.) at their disposal;
- reinforcing the integration of the Greater Paris Basin and the Nord-Pas-de-Calais region into the European economy and contributing to land planning;
- supporting the development of French sea ports by developing their hinterland;
- firmly setting the stakes of sustainable development in transport policies;
- promoting the hydraulic and touristic advantages offered by waterways.

Its transport capacity will be 19 Mt per year with single locks (solution adopted in the framework of the current project), and 38 Mt per year with double locks. In 2020, with the Seine-North Europe canal, the traffic anticipated on this route will equate to between 13 and 15 Mt of goods, a fourfold increase on 2000.

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Introduction

The purpose of this section is to understand issues relating to sea freight capacity within a complex international economic context.

Economic growth on Asian countries, China in particular, represents an essential driving force for current growth in sea transport, which is apparent from the explosion in sea traffic during the last fifteen years or so. Whilst the boom in sea transport and, more specifically, the explosion in container traffic have represented powerful prime movers in the development of the main European markets, French ports have not taken full advantage of these favourable conditions to extend their market share. A share that has indeed decreased to the benefit of their competitors. This can be partly explained by the fact that French ports are located significantly to one side of the major backbone of European trade. The immediate hinterland for the ports of Rotterdam, Antwerp and, increasingly, Hamburg is therefore a determining factor in port competition. Furthermore, insufficient competitiveness of French ports may cause them to lose ground in relation to their close hinterland. Quality of service and capacity criteria are therefore of prime importance.

Following a brief introduction to sea transport organisation of, the characteristics of the merchant fleet will be described. Capacity issues are approached by both a description of the different types of terminal and an understanding of the criteria governing port competitiveness.

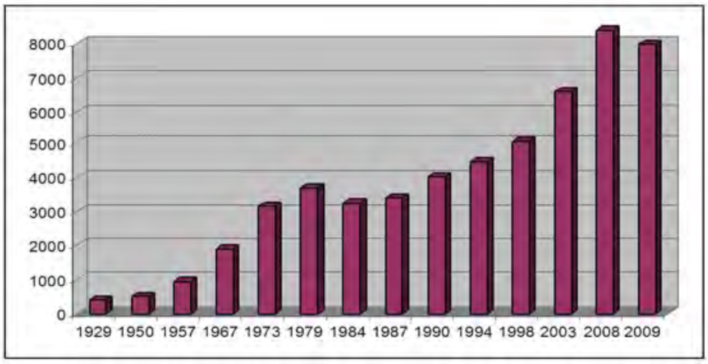


Figure 2. Growth in world shipping since 1929 in million tonnes – source: E. Musso, IML. Figures 2003, 2008 and 2009 added from review of maritime transport, UNCTAD

1 - Organisational Framework of Sea Freight

Sea freight is the main goods transport mode, it handles three-quarters of the total volume of international trade. Annually, the volume of sea freight had been growing by 4% for ten years, up to September 2008 crisis.

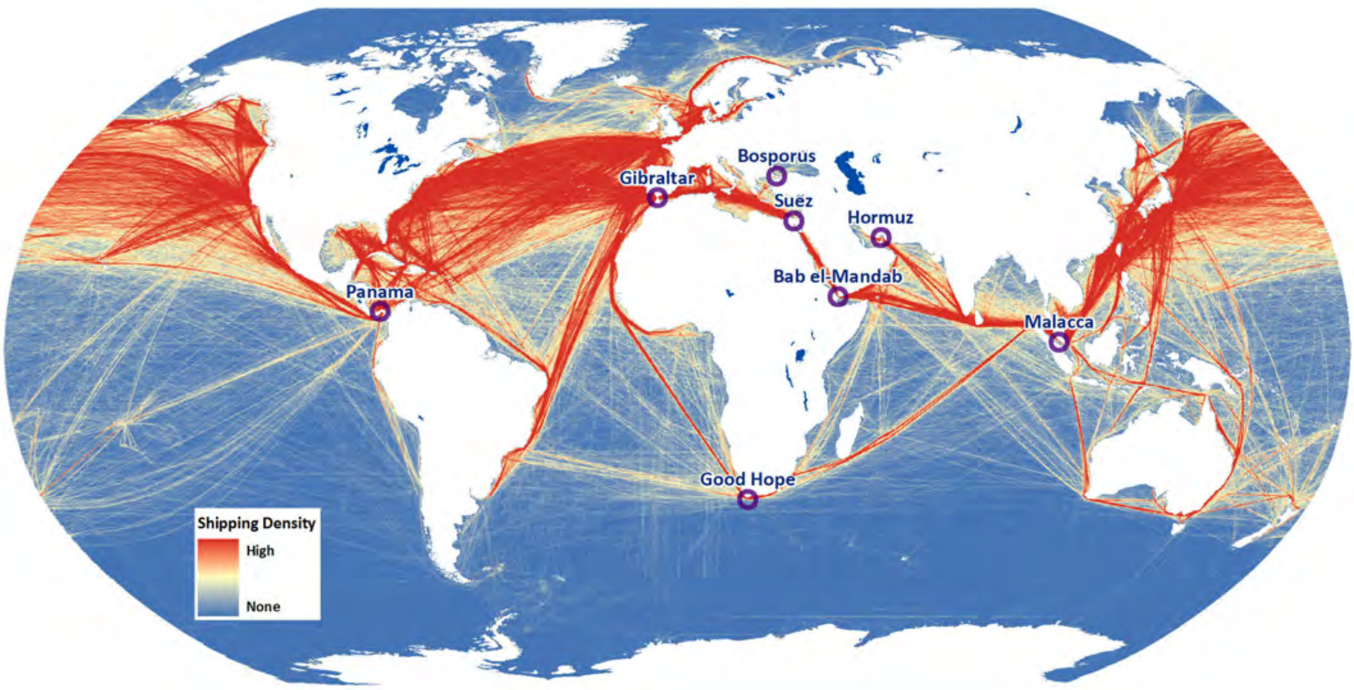


Figure 1 : Maritime shipping routes and strategic locations
– Source Dr. Jean-Paul Rodrigue, Université Paris Est / IFFSTAR / UR Splott & Dept of Global Studies & Geography, Hofstra University

The sea transport mode has been subjected to major transformation associated with efforts to achieve unitisation and standardisation, prompted by a need for industrialisation and massification. Whilst solid (iron ore, coal, cereals) and liquid (crude oil, refined products, gaseous hydrocarbons, chemicals) bulk consignments are invariably transported by special ships, miscellaneous goods are increasingly transported in containers. Container traffic has grown from approximately 30 million TEU/Twenty feet equivalent unit (see lexicon) in 1990 to more than 150 million TEU in 2010 (*Source – Annual review of maritime transport 2010, UNCTAD*).

1.1 - Advantages of sea transport

1.1.1 - Transport massification

Growth in worldwide trade has been facilitated by the massification possibilities offered by sea freight. Geographical concentration of production areas with respect to consumption areas has accelerated the demand massification process and the transport offer.

1.1.2 – Low transport cost

Sea transport is a relatively cheap means of transport per unit of weight (it is reckoned to cost approximately 30 times less than land transport).

Sea transport requires major infrastructures, but the shipping environment is freely available so infrastructure costs are limited to the port interface and are therefore lower than for other transport modes.

1.1.3 – Other advantages

- Safety and security: sea transport offers excellent guarantees with respect to both personal accidents and goods loading
- Sea transport consumes little energy on a t-km basis
- Reliability: shipping routes are not congested, so sea transport offer guarantees of reliability; only port congestion and meteorological risks can hamper this regularity
- Sea transport is also an appropriate means for short distances, but its financial conditions are optimum for long distances.

1.2 - A variety of goods transported

1.2.1 – Bulk consignments

“Bulk consignments” comprise goods transported directly in the ship’s hold. Bulk transport markets are subject to great instability and major fluctuations in freight rates (transport prices). Liquid bulk consignments represent nearly half the goods tonnage transiting through French ports:

- Liquid bulk consignments include hydrocarbons (oils and petroleum products), chemicals and certain liquid food products
- Solid bulk consignments include coal, ferrous and non-ferrous ores, fertilizers, certain foodstuffs (cereals, cattle food, flours, etc.) and other products (cement, bauxite, etc.).

1.2.2 – Miscellaneous goods

Most miscellaneous merchant shipping is concentrated in three sea routes or seaways: North America ⇔ Europe, North America ⇔ Far East, Europe ⇔ Far East. The different types of miscellaneous goods are:

- **Conventional goods**: miscellaneous goods transported conventionally, i.e. neither containerised nor handled horizontally (industrial equipment, many intermediate products, tubes, timber, vehicles, fruit not transported in refrigerated containers...) and they can be packed on pallets, "big bags" (a large volume, high-strength bag for packing bulk good), etc.
- **Containerised goods**: containerisation involves transporting goods in standard containers (see lexicon, sub-section 1.4 and sub-section on containers). The level of miscellaneous goods containerisation exceeds 50% and continues to rise. However, there can be quite high variations in this level, ranging from 40% for North African ports to 95% for Asian ports
- **Roll-on/Roll-off traffic**: this involves transporting tractor-trailer combinations, unaccompanied trailers (e.g. in Europe, Ro-Ro traffic between the Continent and the British Isles) or new cars by sea.

Appendix 1 includes statistical data on the growth in world sea trade since 1970.

1.3 - Different types of shipping service

1.3.1 - Tramping[1]

The shipper rents (charters) the services of a ship for the purpose of performing one or several, usually mass, transport operations on his own behalf. The shipper bears all the costs of chartering the ship charter, its navigation and all incumbent port charges. This transport mode is mainly implemented for bulk consignments. The four major goods categories prevalent on the tramping market are oil, ferrous ores, coal and cereals.

1.3.2 – Regular lines

The service is organised according to an established itinerary on regular shipping lines and a number of identified ports are served at a predetermined frequency, even at fixed days and times. A carrier sets up a service, while assuming the resulting risk and costs. In return, the carrier is remunerated by the user of the shipping line based on a negotiated freight tariff and a "fee" covering all or part of the handling costs in accordance with the transport contract conditions.

- Containerised services are regular lines dominated by East-West oceanic relations between highly industrialised countries. They are usually organised according to pre-established itineraries and schedules and are possessed by large worldwide shipowners (*cf.* Appendix 2 table of leading worldwide shipowners).

1.3.3 - Coasting

Coasting is sea transport over a short distance along continental coasts or between islands. It can be national or international. Under the name of feedering, coasting specifically enables smaller ports to be served from large ports receiving major transoceanic lines. Coasting also covers "motorway of the sea"-type services (*cf.* Appendix 3 for further details on this subject).

[1] ***Tramping means the vessel travels from destination to destination in compliance with its charter contracts.***

1.4 - Sea containerisation

1.4.1 - Background

1956 saw the start of modern and massive containerisation, when Malcolm Mac Lean, an American road transporter (*Mc Lean Trucking*), purchased the *Pan-Atlantic Steamship Company* and converted some of its vessels into the first containerised sea carriers. The company became *Sea-Land services, Inc.* in 1960 and Mc Lean's operation was profitable by 1961, according to Wikipedia.

The idea of avoiding breakdown constraints was not new. According to the World Shipping Council, some boxes similar to modern ones had been used in England for combined rail- and horse-drawn transport in… 1792. And *Seatrains Lines* had carried directly railroad boxcars on its vessels, to transport goods between New York and Cuba, from 1929. This last system is still used today, for example to operate the passenger night train between Berlin and Malmö (Sweden).

In 1965, the International Standards Organisation (ISO) recommended standards and this facilitated containerisation development. These first containers built in the United States were unloaded onto French quays in 1966. They were designated Category 20 or 40, depending on their length in imperial feet: 20' (20 feet, or more exactly 19 feet and 10.5 inches), or 6.05 metres, long for 30 m^3 containers and 40' (forty feet), or 12.19 metres, long for 65 m^3 containers. Many forms of container have been designed, based on these 20- and 40-foot standard lengths, to meet specific needs.

Figure 3 : Containers are only ~15% of volumes transported by sea, but contains relatively high-value goods – graph World Shipping Council 2011

1.4.2 – Advantages and drawbacks[2]

The main advantage of the container is its capacity to create economies of scale at every stage of the logistical chain. In sea transport, it specifically allows:

- Reduction of load breaking during trans-shipment, achieved with small tare.
- Quickness of handling operations leading to both time and financial saving; vessels can thus ensure more rotations
- Equipment standardisation insofar as all ports in the world can handle the different containers sizes
- Security of the goods, which travel anonymously so that losses, breakages or thefts are curtailed.

Compared with conventional sea transport, as operated in the 1960s, the container has allowed transport times to be halved and transport costs to be divided by three.

Container drawbacks are:

- High investment and expensive maintenance.
- Difficulty of adapting equipment in developing countries.
- Unbalanced flow of goods due to macro-economic imbalances cause logistical management problems and transport of empty containers.

1.4.3 – Growth in traffic

Container traffic has experienced the greatest growth within a context of overall increase in sea transport. Up to 2008, this development was attended to continue at an estimated annual rate of 7% - 10%. It is now far more uncertain, and at the end of 2011 there is no obvious trend. But the current volumes of exchanges, even without strong growth prospects, raise the problem of port congestion and dictate development of container handling capacities.

Most European traffic (three-quarters) is composed of intra-European trade, but a quarter results from inter-continental trade, especially with Asia. Growth in Asian economies, particularly that of China, therefore represents an essential driving force of current development in sea transport. This is apparent from the boom in its traffic, highlighted by the growth of major Chinese ports, trusting the first places within world competition. Thus, Shanghai port became the world largest port in 2011, ahead Singapore.

Figure 4 : Port of Barcelona, which is a medium-size one. Storage of containers needs huge surfaces.

Containerised sea transport services to Northern Europe by regular lines appears to be organised around three calling areas: the "Le Havre - Zeebrugge" area to the west, the ARA (Amsterdam - Rotterdam - Antwerp) cluster in the centre and the HBW (Hamburg - Bremmerhaven - Wilhelmshaven) cluster to the east.

North-South lines served by medium size container vessels (carrying 1,500 – 2,000 units) ensure links between Europe and less developed countries (West Africa, South America, Indian Ocean, etc.).

Figure 5 features a map of European container ports in 2005 and Appendix 3 includes a classification of the 20 largest container ports in the world and in Europe in 2010.

Container operating cost
Depending on the source, daily operating cost (maintenance, depreciation) is 1 - 3 USD for a 20' container and 5 - 25 USD for a tank container.
Cost of container annual replacement worldwide is estimated at 30 billion USD (Source: DTMPL, 2000 [65]).

Note on traffic figures : *capacities and traffics handled by ports are often different, depending on the source. The reason for that is the way of counting. Some figures take into account each cargo movement. Thus, a container can be counted 4 times in a port : Arrival, to storage, from storage, departure. Even with one movement = one unit, it must be reminded that there is twice as much port traffic that actual sea traffic.*

[2] ***Refer to the sub-section on containers for further information on the equipment itself.***

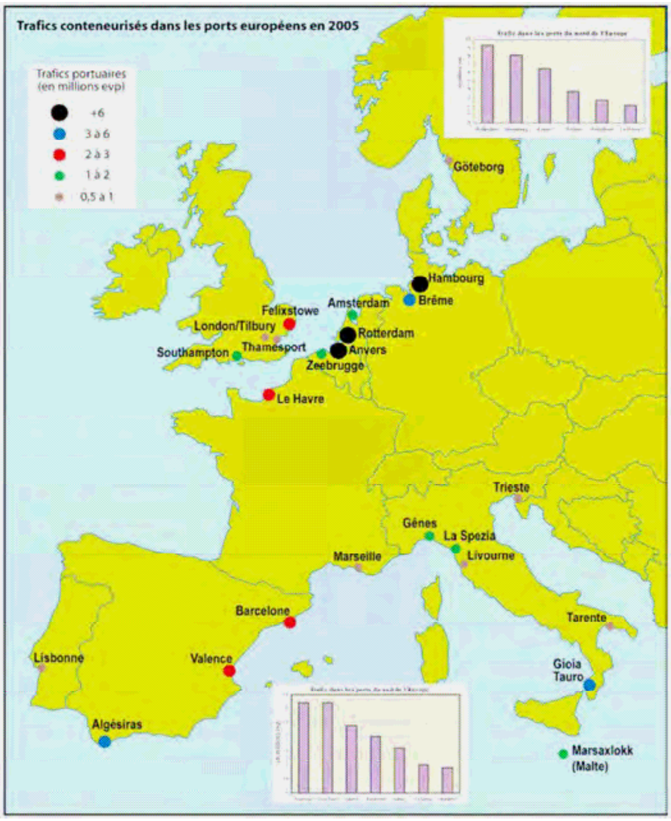


Figure 5. Major European container ports in 2005 (source : Cour des Comptes, 2006)

The worldwide pool of containers has also experienced very strong growth, especially in recent years. As an example, the TEU pool owned by the 20 largest world shipping companies has increased from 1.84 million units in 1994 to 5.66 million units in 2004 (source: A. Frémont). It should be noted that approximately twice the number of units represented by the relevant container vessel's capacity is required for proper management of the container pool and rotations.

The increase in transported container volumes and vessel size have the following consequences:

- Not all ports can receive these ships; good accessibility conditions, sufficiently long quays and efficient handling equipment are required to allow docking and minimise port time
- These ships are only profitable when they are full. The shipowner goes to ports, at which the abundance of freight ensures a satisfactory ship load factor
- The shipowner is present at ports visited by other shipowners to prevent giving the competition a free hand. A major shipowner deciding to call at a port very often leads to the arrival of other shipping companies and a port chosen by many companies therefore becomes more competitive
- The shipper moves his goods through ports with a high frequency of services offered by the sea transport carrier. This frequency may determine the choice of port. For example, if a container "misses" a ship departure for a given destination because of unforeseen events during preliminary transport, it is better to know that the next ship to call at this port is scheduled in 1 to 2 days rather than in 15 days.

Launching of "around-the-world" lines and of the new generation of high capacity container ships impose high fixed costs that require shipowners to reduce their number of ports of call. Given the costs of port time and vessel downtime, a call is only financially justifiable if a large enough proportion of the cargo is handled at the port (estimated at 10%).

The example shown in Figure 6 illustrates the economies of scale achieved by increasing the size of container ships and the ensuing reduction in the unit cost of slots.

Ship size in TEU	1,200	2,600	4,000	6,500
Operating cost	154	187	240	267
Capital cost	250	420	580	800
Fuel	103	133	164	195
Ports	154	203	245	301
Ship fixed costs	661	943	1,229	1,563
Slot costs (USD)	551	363	307	240

*Figure 6. Slot costs on North Atlantic line (**x1000** USD) (Source : INRETS, September 2006, Stopford)*

1.4.4 - Competition between ports

Competition between ports is a recent phenomenon. Ships formerly called at any port where there was a cargo to pick up or deliver. Miscellaneous goods traffic is the most affected by port competition: it is unstable because of the flexibility and reactivity of international logistical chains. Conversely, competition affects bulk transport less and its traffic is often captive: it frequently comprises raw materials with transformation locations close to ports (oil refineries, wharf side steelmaking, etc.).

These are low added value materials and their land transport cost is important in deciding on a location for their related industries. Moreover, investments made in the port chosen for transferring these bulk materials are usually very high so there is little incentive to change port.

Competition between ports can only be fully understood by highlighting the concept of a global logistical chain. Stakeholders, shipowners, port service companies and/or shippers manage worldwide logistical chains through mergers/acquisitions and vertical or horizontal integrations. Yet, these chains no longer depend exclusively on the presence of a close hinterland (refer to § 4.3 for more precisions about this notion), which is becoming an additional (necessary, even historical) condition, but is in fact insufficient for port development. Overall, three competitiveness factors are referred to: geographical location, port services (operational cost and reliability) and hinterland (existence of a market and land transport link). These factors concerning port competitiveness criteria are explained in the introduction to Section 4.

Further details of sea transport characteristics in general are provided in the booklet entitled "Transport shipping" [sea transport] published under the Techniques de l'Ingénieur [66].

2 - Fleet Used for Sea Transport

2.1 - Transport of dry products

A type of vessel and specific handling method can be associated with each goods category. In some cases (especially if the port does not possess suitable mechanical equipment), ships equipped with cranes allow handling of the goods carried on board without the need for port facilities.

2.1.1 – Bulk cargo vessels

This term covers any ship carrying grain, ore, etc; There are also bulk cargo vessels that transport liquid goods (oil). Their deadweight varies between 50,000 and 300,000 tonnes. They are sometimes more specifically classified as ore, bulk or oil (*cf.* Summary table of different bulk cargo vessel types shown in Figure 7.

2.1.2 – Container vessels

These are fast, powerful ships (travelling at 18 to 25 knots). Containers are retained by barriers in the ship's cargo hold. On deck, they are solidly fastened to the ship and interconnected by multiple attachments. Container vessel size is evaluated based on the number of 20' containers that can be stowed, although ~half of containers are 40' units nowadays. Figure 7 gives the characteristics of the main types of container vessel.

The different categories refer to limits or constraints imposed by the main maritime transport routes. For example, "Post-Panamax", also called "Over-Panamax", vessels are larger than the maximum allowable dimensions for entering the Panama canal locks. Huge works began to enlarge this strategic passage. 12,000 EVP vessels will thus be allowed by 2014 – 386m length, 49m width and 15m draught, to compare with current maximal size.

Type of vessel	Capacity (TEU)	Length (m)	Width (m)	Draught (m)
Panamax	4,500	294	33	12
Post Panamax	6,000	348	42	14
Suez Max New Panamax	12,000	400	50	17
Malacca Max	18,000	400	60	21

Figure 7. Characteristics of main container vessels. ***Knowing exact capacities is complex*** *; these widely used TEU figures must then be cautiously used. Nevertheless, dimensions limits are exact, as driven by canal size – Source : Armateurs de France*

Vessels are ever larger. As an example, at 1st January 2010, the 20 largest carriers cumulated 67.5% of world container ship fleet (15 million TEUs), or a capacity of 10.09 million TEU, with 2,673 vessels, i.e. an average vessel size of 3,774 TEUs! (source UNCTAD).

Many very large ships were ordered before the 2008-2009 crisis and are currently being delivered, creating an over-capacity in container transport. This effect was partly compensated by "slow-steaming", readily adaptable mechanism which consists to reduce speed of boats, implying longer trip times, but permitting both use of more ships for the same amount of containers to transport and fuel (and CO2) savings ; a very sensitive point, fuel share being between 30 and 50% of transport cost on regular lines (source P. Cariou).

Figure 8. Container vessel in the Port of Le Havre (©MTETM/SG/SIC – 2004 photo B. Suard)

In November 2011, the largest container ships in the world were the *Emma Maersk* and the following ones of the series : the *Eleonora, Estelle, Evelyn, Ebba, Elly, Eugen* and *Edith Maersk*, owned by A.P. Moller-Maersk since 2006-2007. With a length of 397 m, a width of 56 m and a draught of 16 m, they have a capacity of 13,500 to 14,500 TEUs, according to specialists, including empty containers ; official capacity – 14t loaded TEUs – is 11,000. Each ship has a crew of 13.

Second largest ships are CMA CGM ones : *Christophe Colomb, Amerigo Vespucci, Corte Real, Lapérouse* and *Magellan* have a capacity of 13,880 TEUs, empty containers included.

Ten Malacca Max vessels were ordered by the Danish A.P. Moller-Maersk Group to DSME South-Korean shipyards in 2011, creating surprise in a context of over-capacity. Each unit costs 190 millions US$. According to Maersk, 50% fuel and CO2 savings per container moved are made possible, compared to industry average on Asia-Europe trade ; thanks to increase in size (18,000 TEUs, empty containers included), but also improvements in motorisation (twin propulsion, waste heat recovery system), space optimisation, better design of hull and lower speed (17 to 23 knots). CO2 emitted will be 3g/t.km

Such current and future dimensions raise the issue of quays size and ports capacity, to handle and evacuate several thousands containers by one time. Not many ports are able to accept these sea giants.

Figure 9 : Maersk "Triple-E" Class : Efficiency, Economy of scale and the Environment – © Maersk

Figure 10 : Using all space available – © Maersk

2.1.3 – Vessels for transporting conventional goods

These vessels are intended for transporting miscellaneous goods, which do not fit into containers or whose loading with containers is uneconomical (pallets, bags, bulk grain, timber, steelmaking materials, heavy vehicles). There are many types of these general cargo vessels, including:

- **"Conventional" all-freight vessels** are usually composed of 4 or 5 main holds, each featuring 1 or 2 tweendecks. These vessels have integrated handling equipment (cargo derricks, cranes) and are fitted with large hatch covers
- **"Compact" all-freight vessels** differ from those above because they have large parallelepiped-shaped "box" holds flanked by a double hull. They are very suitable for transporting containers or large goods consignments (timber, bags, sheet metal rolls, etc.).

2.1.4 – Specific vessels

Log carriers

Log carriers are all-freight or bulk cargo vessels used to transport timber logs. They feature fixed or removable uprights along their sides for holding the many timber logs in place on the deck.

Roll-on/Roll-off (Ro-Ro) vessels

These vessels are fitted with different types of draw-bridge ramp for loading or unloading vehicles, both trucks and cars. Their capacity is measured not only in tonnes, but also in total loaded vehicle length. For example, on the Toulon – Rome line, the "Eurostar Valencia" operated by Grimaldi - Louis Dreyfus offers 2,250 m of HGV storage or a capacity of 150 tractor-trailer combinations; moreover, the ship can receive 160 cars and 800 passengers (*cf.* Figure 11)

Car transport vessels

These are Ro-Ro vessels specifically designed for transporting new cars. They feature very high superstructures and multiple low height tweendecks; their transport capacities vary widely (from several 100 to 5,000 vehicles).

Figure 11. "Eurostar Valencia" Ro-Ro vessel in the Port of Toulon (source : CETE Méditerranée)

Refrigerated vessels

These ships are usually fast (20 -22 knots) and fairly small. They transport fresh produce (bananas, frozen fish or meat, etc.) at temperatures between -25 °C and +14 °C. Their capacity can reach 16,000 m^3. The most common polythermal cargo ships with capacities between 9,000 and 12,000 m^3 have 4 or 5 holds, each divided into two independent cold sections.

2.2 - Transport of liquids

2.2.1 – Crude oil

Oil tankers are the largest ships ever built. They are classified as Aframax (Average Freight Rate Assessment measuring system) Very Large Crude Carriers (VLCC) or Ultra large Crude carriers (ULCC) and their capacities vary between 80,000 and more than 300,000 tonnes. 4 of the 5 largest ships, all scrapped today, were built in the St-Nazaire shipyards, in France, between 1976-1979. These tankers of the *Batillus Class* were 414m long and their full load draft of 28.5m was notably reducing their trips possibilities (Panama and Suez canal or even the Channel were not navigable) and port choices. The *Pierre Guillaumat*, the largest one, had a fully loaded deadweight of 555,000 tons.

Measuring ship's capacity :

The capacity of a ship is often expressed in DWT/Deadweight tonnes. Deadweight tonnage corresponds to total displacement of a ship (or total weight in tons, at given load, which can be measured according to Archimedes' famous formula with the volume of water displaced, i.e. the volume of ship immerged, multiplied by specific gravity of water (~1,000kg/m^3 slightly depending on temperature and proportion of salt), minus lightweight or lightship (i.e. weight of the ship alone, without cargo, load, fuel, water, crew, etc.)

It is thus possible to calculate the deadweight from its draught gauge, knowing geometrical characteristics of the hull. This particular calculation method, not giving the tons of cargo transported, is due to the impossibility to weight the ship by other means, as can be done with trucks or trains.

***Deadweight Tonnage**, expressed in tonnes**,** must not be mistook for Gross Tonnage, which is a measurement of ship's enclosed spaces (from keel to funnel) volume – GT = Total Volume V x (0.2 + 0.02 $\log_{10}(V)$), calculated in m^3 – or for Net Tonnage (NT), designating the commercially useful volume. These are used to define fees and taxes. Some complex calculations of volume are also used for specific fees, such as Suez Canal Net Tonnage or Panama Canal Universal Measurement System.*

There were up to 2009 an even larger tanker sailing, the *knock Nevis*, (firstly *Jahre Viking*), built in Japanese Oppama shipyard in 1979 and enlarged in1980, reaching 458m and 565,000 DWT.

These tankers were the greatest mobile structures ever built by humanity.

Figure 12 : the Knock Nevis, ex-Seawise Giant, Happy Giant and Jahre Viking, is today waiting for scrapping. Longest ships are know Maersk Line's Suez Max containerships, with 397m. Note the difference of draught between empty and fully loaded. – source ships-info.info

The French oil tanker fleet comprises 57 ships under French flag and, each year, French companies transport nearly 40 million tonnes of oil including 2/3rds between foreign countries.

2.2.2 – Refined petroleum products and chemicals

Refined petroleum products and chemicals are carried on board smaller ships fitted out to transport different products. This market spans a wider range than the crude oil market because of the very wide variety of products transported (asphalt, bitumen, kerosene, solvents, alcohols, etc.).

The French fleet comprises 54 vessels and, for the last 10 years, its renewal continues with the inclusion of all-freight vessels built to the most advanced safety standards (double hull).

Petroleum product ships transport 3 or 4 types of refined products at the same time (petrol, diesel, kerosene, domestic fuel). These vessels are relatively small, they scarcely exceed 30,000 – 40,000 tonnes deadweight.

Multipurpose chemical carriers are sophisticated vessels transporting almost any liquid at atmospheric pressure. Each tank is fitted with an independent pump and piping, allowing the vessel to transport as different chemicals as there are tanks (30 or 40).

Special chemical carriers are vessels dedicated to transporting a single chemical: phosphoric acid, methanol, etc. They usually ply a given route throughout their service lives.

Gas carriers built to various designs transport gases at normal pressure but more or less refrigerated: butane, methane, liquid natural gas (LNG), liquid petroleum gas (LPG). LNG is carried in liquid form at -163 °C by large capacity vessels (new buildings are often 160,000 m^3, for an average cost of 210 millions US$ - 2010 price), whilst smaller capacity ships (86,000 m^3 maximum) are used for transporting LPG under pressure or refrigerated (-50 °C).

LNG transport has strongly increased in recent years. The world fleet reached fast 50 millions m^3 in 2010 (49.3 million m^3 in April 2010, to compare with 44.4 millions m^3 only fifteen months before, according to UNCTAD – Review of maritime transport 2010). These vessels are ever larger to reduce the unit cost of transport. French owners operate approximately 15 ships at international level.

Figure 13 provides a summary table of different types of bulk cargo vessels and their capacities (in deadweight tonnage – DWT).

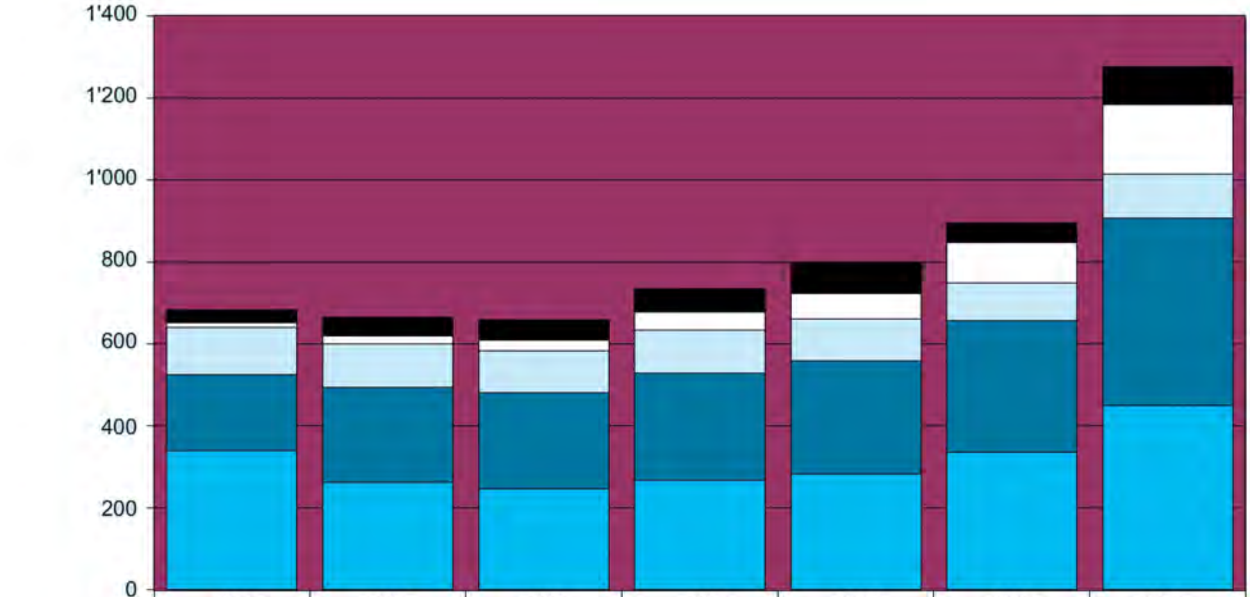
Oil-tankers				Types of vessel	Bulk cargo vessels				
Crude oil	**Petroleum products**	**Other liquid products**	**DWT Deadweight tonnage**		**DWT**	**Secondary bulk**	**Cereals**	**Coal**	**Iron ore**
	⚜	⚜	10 – 30 000	**Handysize**	10 – 30 000	⚜	⚜		
	⚜	⚜	30 – 80 000	**Handy max**	30 – 50 000	⚜	⚜	⚜	
				Panamax	50 – 80 000		⚜	⚜	
				Overpanamax	80 – 100 000			⚜	⚜
⚜	⚜		80 – 125 000	**Aframax**					
				Capesize	100 - 160 000				⚜
⚜			125 - 160 000	**Suez max**					
⚜			> 160 000	**VLCC – VLBC**	> 160 000				⚜
⚜			> 300 000	**ULCC - VLOC**	> 300 000				⚜

Figure 13. Different types of bulk cargo vessel (Source : ISEMAR)

2.3 - Growth in world fleet per type of vessel

Figure 14 shows the strong growth in the container vessel fleet, which is related to production globalisation. The fleet of all-freight cargo ships has remained stable, proving a certain demand for shipments in non-containerisable full batches. Following a drop in the oil tanker fleet between 1980 and 1995, the trend has since been upward in line with greater oil consumption in emerging countries.

A remarkable booming of vessel fleets capacity happened this lasts years, in line with growth of traffics, but with a gap of some years between economic climate and capacity of fleet, due to building times.



	1980	1985	1990	1995	2000	2005	2010
Other	31	45	49	58	75	49	92
Container	11	20	26	44	64	98	169
General cargo	116	106	103	104	101	92	108
Dry bulk	186	232	235	262	276	321	457
Oil tanker	339	261	246	268	282	336	450

Figure 14 : Growth of world fleet per type of vessel since 1980, in millions Deadweight Tons. Cargo-carrying vessels of 100 gross tons and above – source UNCTAD, on the basis of IHS fairplay data (beginning of years data).

3 - Port Terminal Characteristics

3.1 - Port terminal issues

The port constitutes a transit hub integrating logistical services and its terminals must fulfil the following functions:

- Accept traffic characterised by type, volume and scheduling (e.g. seasonal nature of some traffic associated with agricultural production)
- Optimise implemented facilities in relation to operational organisation, human resources mobilised and physical resources deployed
- Provide storage for not only empty and full containers awaiting transfer, but also for batched (e.g. timber logs, papermaking pulp) and bulk (e.g. coal, cereals) goods.

More generally, a port must:

- Provide for inland transport services: port terminals must be readily accessible by road, rail and inland waterway transport modes and, for land transporters, the port must provide adequate parking space for HGVs. The length of railway tracks within the port boundary must permit train storage (750 m lengths available for French full trains, even 1,000 m soon or 1,500m in the future, 650m in Belgium, 550 in Belgium and more than 2,5km in major North-American ports). Refer to Section 4 for further information on these issues
- Ensure a level of service for shipowners, forwarding agents and land transporters. The port must ensure limited ship waiting time prior to docking and that there are storage capacities suitable for the type of goods and length of storage, which can vary from 1 or 2 days to several months.

We should note the existence of “Conventions d’Exploitation de Terminal” [terminal operating agreements] (French Decree of 19th July 2000 [67]): an operator enjoys the advantage of priority usage of infrastructures in exchange for undertakings on traffic volumes and quality of service. These undertakings demand major private investments in superstructures (overhead gantry cranes, hardstanding, tooling). The operator usually owns container overhead gantry cranes.

3.2 - Liquid bulk terminals

3.2.1 – Onboard pumping capacities of different types of ship

- Large oil tankers (VLCC, up to 350,000 tonnes): 15,000 to 20,000 m^3/hour
- "North Sea" oil tankers (150,000 to 200,000 tonnes): 10,000 to 12,000 m^3/hour
- Coasters (approx. 50,000 tons): 4,500 m^3/h
- Multipurpose chemical tankers (7,500 to 45,000 tonnes): 2,000 to 5,000 m^3/hour.

Bulk carriers generally only remain on station at a terminal for less than 24 hours[3]. As an example, a terminal receiving 150,000 tonne ships could unload approximately 32 million tonnes of crude oil annually. Assumptions include 45% occupancy of a berth (i.e. 4,000 hours/year), an average pumping capacity of 10,000 m^3/hour and a crude oil density of 0.8.

3.2.2 – Main installations at a terminal

Traditionally, liquid bulk terminals offer the following facilities:

- A wharf several tens of metres long and a few metres behind the docking line (equipped with suitable defences)
- One or more articulated loading arms supported by the wharf and connected to pipework from the land-based storage tanks or depots.

The pumping installation does not form part of the terminal. It is on board the ship for unloading and forms part of the land industrial facility for loading.

For information, the order of magnitude investment cost for a VLCC berth is at least 12 million USD.

3.3 - Dry bulk terminals

Traditionally, dry bulk terminals offer the following facilities:

- A berthing structure or quayside area
- Overhead travelling or gantry cranes for skip handling or suction pump(s) for lightweight products
- A storage or silo transfer installation (conveyor belts, spreader conveyors)
- A pick-up installation at storage locations (bucket wheels) or in silos (suction pumps)
- An installation for land reloading (into trucks, trains or barges through hoppers).

At a grain terminal, an average transfer rate of 200 t/h allows a million tonnes to be processed annually. For coal, average transfer rates are 1,500 to 1,700 t/h for unloading and 3,000 to 4,000 t/h for loading. For ore, average transfer rates are 2,000 to 3,000 t/h for unloading and 5,000 to 7,000 t/h for loading.

For a berth receiving large ore carriers, featuring two overhead gantry skip cranes and a 6 million tonne processing capacity (60% optimum berth occupancy), the cost order of magnitude is 40 million USD.

3.4 - Container terminals

A modern berth must have the following characteristics:

- A length of between 300 and 350 m for a berth with a quay depth of 300 to 500 m
- A berthing structure suitable for the ships to be handled
- An approximately 50 m wide quayside area or hardstanding, on which the overhead gantry cranes travel (35 m distance between legs of large gantry cranes)
- One or more container storage areas (1 to 2 levels for full units; 6 to 7 for empty units), in which straddle carriers, road tractors, etc. circulate
- A rail or inland waterway transport loading area
- Ancillary services in sheds (container stuffing or stripping) or at a special area (container repacking).

Figure 16 shows an example of container terminal organisation.

[3] ***Port calling times are sometimes longer, especially for hydrocarbons. Standby at anchorage required by the refinery for conditioning products (heating) is a major factor in port calling time. The port has really very few levers for action in this case.***

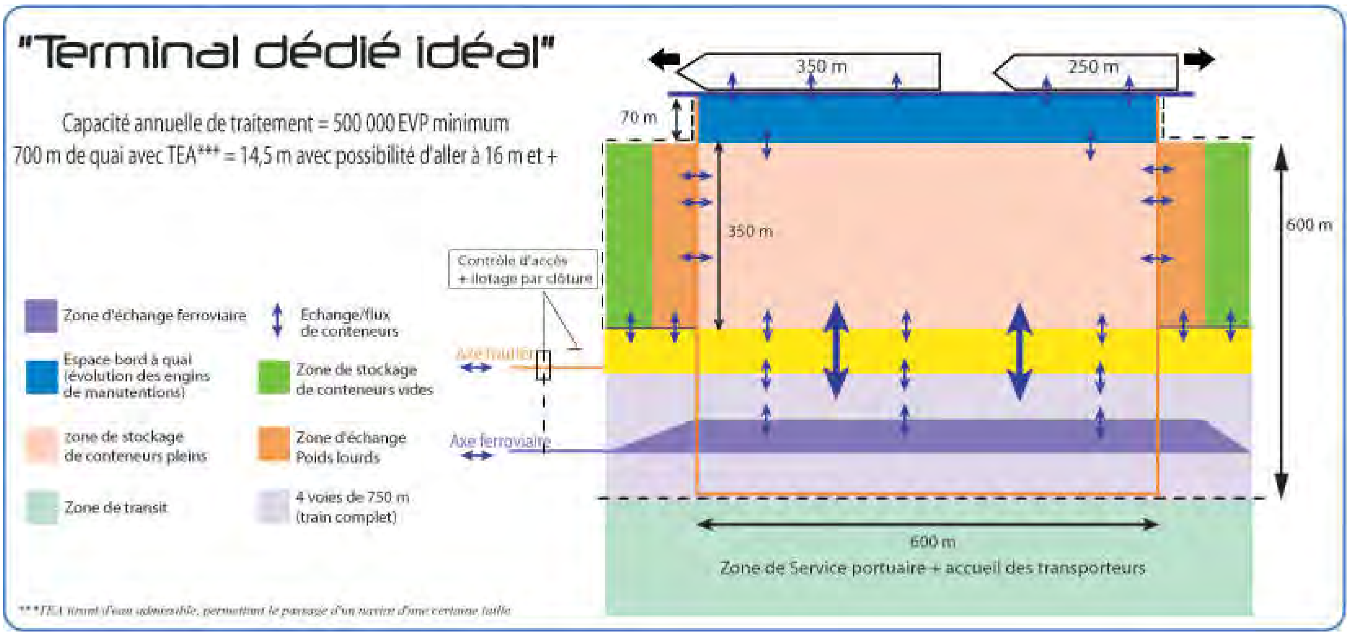


Figure 15. Container terminal configuration (Source : Fos 2XL public discussion summary document [68])

Conventional performance of a container berth is approximately 30 container movements per hour and per overhead gantry crane. Performance depends particularly on the terminal massification level and can vary between 20 movements/hour at niche terminals and 50 movements/hour at some Chinese terminals.

As specialised port components, **modern container terminals** require complex construction and organisation: easy nautical access; 1 to 2 km of straight quays to be equipped by contractors; extensive hardstanding for container storage; 10 or more overhead gantry cranes and container transport vehicles; roads and railways; high-performance IT systems for monitoring and allocating containers.

Commissioning of large size container ships has an impact on the expected performance (and land transport links) of container terminals:

- Size and depth of access channel and open water must be appropriate
- Quay length, storage and hardstanding areas, mechanical equipment must all be suited to the vessel width (up to 50 m). operators must invest in ever larger overhead gantry cranes called post-panamax and super post-panamax)
- Handling productivity: terminals must handle large volumes in minimal time to reduce costs per transported container. This requires not only competitive equipment, but also contractor productivity.

In France, only the ports of Le Havre and Marseille are equipped to receive the largest container ships because the current generation of these vessels require a minimum traffic of 1,200 to 1,500 units for a port call to be profitable.

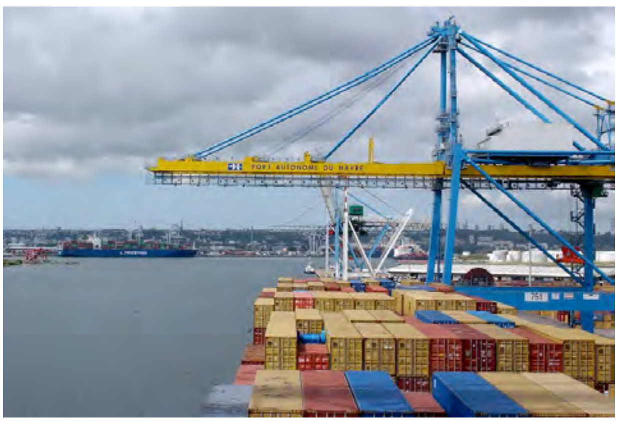


Figure 16. Container terminals at Port of Le Havre (©MTETM/SG/SIC - 2004 Photo B.Suard)

3.4.1 – Example of Port 2000 operation at Le Havre

The first phase (March 2006) of the Port 2000 operation at Le Havre provides 4 x 350 m long container berths (potentially 12 berths over a total length of approximately 4 km), 500 m wide hardstanding equivalent to a 17.5 ha area per berth. The allowable draught is 14.50 m under all tide conditions and no locks need to be passed; this is suitable for 8,000 TEU container ships. The next 6 berths (project second phase), achieved in 2010, can receive container ships with a 17 m draught (Suez canal maximum).

The aim is to handle 3 million TEUs (compared with 2 million TEUs handled in 2005 and 2.5 million in 2010). This investment amounts to 1.1 billion Euros. Ultimately, the 12 berths will allow a tripling of the volumes handled in 2005 to reach 6 million TEUs.

3.4.2 – Example of Fos 2XL at Marseille

Fos 2XL is a Port of Marseille – Fos development project involving construction of two new container terminals. These provide an additional annual container handling capacity of 1.5 million TEUs. Their characteristics are given in Figure 18 below. The first ship operating at Fos 2XL was the CMA CGM *Cendrillon*, in May 2011.

	Terminal A	Terminal B
Allowable draught	14.5 to 16m	14.5 to 16m
Quay length	600m	800m, separated from Terminal A by a 300m joint
Area	Approx. 52 hectares	Approx. 52 hectares
Rail installation	4*750m tracks	4*750m tracks
Overhead gantry cranes	4-5 overpanamax cranes, 47-52m reach	6-8 overpanamax cranes, 47-52m reach
Handling capacity	Approx 660,000 TEU	Approx 800,000 TEU
Entering service	2011	2011

Figure 17. Technical characteristics of Fos 2XL terminals

3.5 - Roll-on / Roll-off terminals

A Roll-on / Roll-off (Ro-Ro) terminal usually features the following components:

- A conventional quay with lightweight surfacing except at doors (50 t/m²) and sometimes a low gradient (3 – 5%) fixed ramp
- If the tidal range (*cf.* lexicon) exceeds 2 m, the berth is provided with a mobile linkspan actuated by hydraulic cylinders; the linkspan may bear on a floating pontoon (gradient less than 13 or 14% and slip-resistant surfacing)
- Storage hardstanding for 500 trucks, equivalent to 5 hectares.

Vehicle handling at a Ro-Ro terminal is based on so-called jockeying techniques (vehicles driven by a handler). Vehicles are then loaded onto or unloaded from the ship over rear or side ramps. Based on a typical productivity ratios, a team of 7-8 dockers will handle 300 vehicles in 2 hours (source : NOSICA [69]).

3.6 - Conventional goods terminals

Conventional goods are packed in different ways (pallets, big-bags, etc.) and possibly under controlled temperature. They can be handled using ship cargo derricks or mobile cranes on the quay.

A berth usually features the following components:

- A conventional quay, on which mobile cranes can travel
- An approximately 30 m wide quayside
- An approximately 5,000 m² shed or hardstanding area
- An area behind the quay for road traffic or rail loading (level lower than the shed floor).

4 - Port Competitiveness Criteria and Capacity Issues

For forwarding agents and shipowners, a port is competitive because of:

- Geographical location and physical characteristics, on the one hand, and location with respect to existence of a market, on the other hand
- Services offered to a ship (see Appendix 5) and/or the goods, including their quality and reliability
- Cost of port calling (see Appendix 6)
- Land transport links.

More generally, port competitiveness depends on positioning on global logistical chains and capacity to ensure reliable, quick and safe calling for ships. The problem of port calling time is not of its duration but rather of its "predictability"; Overrunning of calling time beyond a forecast duration causes delays, lost windows and demurrage (cf. lexicon). This is a determining factor for stakeholders in the logistical chain. The actual cost of port calling is important but is overshadowed by the major criteria of reliability, positioning and service quality.

4.1 - Port location

For a port, this is dependent on:

- Geographical location on the one hand. Port physical characteristics (draught, port calling time, etc.) and its network positioning. Its extension possibilities (need for ever larger sites in the face of growing property prices and increasingly strong ecological constraints in coastal areas). Its land transport possibilities. Port capacity partly depends on these factors.
- Location with respect to the market on the other hand. Port location within the transport chain is characterised not only by positioning with respect to direct shipping lines or within a port network framework (e.g. for a trans-shipment port), but also by the size of both the hinterland and the industrial and logistical area.

4.2 - Quality of port services

Quality of service is a major factor in all transport markets. In the port area, quality plays a very important part in shipowner and shipper decision-making:

- Speed. Everything that contributes to reducing "transit time" enhances service quality. Efficiency of handling and other port operations, unloading onto land outward transport modes, etc. Efficiency is partly dependent on technology (mechanisation and automation of handling operations, computerisation of tasks)
- Service frequency and flexibility (reactivity to unforeseen events)
- Reliability. Assurance of adherence to completion times; port efficiency is particularly dependent on work social organisation
- Goods security (damage, loss, theft, etc.).

4.2.1 – Time spent at port

The notion of time spent at the port relates to issues involving congestion and waiting, in which productive time must be distinguished from unproductive time. The latter is high in tidal estuary ports or those requiring shipping to pass through locks to access constant level basins and at congested ports. However, the least congested ports are not necessarily the most efficient because the price of efficiency may have prompted over-investment in structures and this inevitably leads to higher tariffs. Growth in productivity may result from seemingly marginal investments, thus, installation of radar control in the River Gironde estuary in 1986 saved 2,000 to 4,000 waiting hours prior to entering the Port of Bordeaux, representing 16 to 32 million USD (source : H. Gramboulan [70]).

Sea port capacity must be considered by taking into account three components, namely trans-shipment capacity, storage capacity and goods reception/forwarding capacity.

Trans-shipment capacity

Trans-shipment capacity reflects the port potential for receiving and handling ships in terms of arrival frequency and forwarding time. A ideal situation for the port operator would be totally regular ship arrival at the port and a constant loading-unloading time. It would then be easy to evaluate the port's trans-shipment capacity and this would ensure optimum berth usage and elimination of waiting times. But, these ideal conditions are never encountered in practice because ships can arrive randomly and loading-unloading time can vary.

One way of ensuring optimum berth usage would be to create a long waiting queue, but this would be unacceptable to shipowners! Conversely, eliminating totally waiting times would require over-designing terminal infrastructures and operating equipment; a financially unacceptable situation for the port operator. Trans-shipment capacity therefore calls for a compromise between these two extreme situations.

The purpose of calculating trans-shipment capacity is to relate ship waiting times (included in the service quality parameters) with to the demand to which the port is subjected (traffic), to the number of berths and their usage and to handling efficiency (particularly dependent on performance of the equipment used).

A ship's port time is therefore the sum of:

- Anchorage time
- Piloting to quayside
- Quay time (also called service time), itself the sum of the time effectively spent on handling and the downtime during which the ship is not processed
- Time between end of operations and time at which the vessel leaves the port.

Waiting queue time theory shows that the anchorage waiting time is directly related to the service time based on a parameter called berth utilisation rate.

For a quay exclusively allocated to one well-defined type of ship (e.g. container terminal quay), the berth utilisation rate ρ is given by:

$$\rho = \frac{Ts}{S \times Ta}$$

in which Ts is the average quay time, S is the number of equivalent berths and Ta is the average time between two ship arrivals.

Figure 18 gives the ship average waiting time expressed as unit service time with respect to berth utilisation rate.

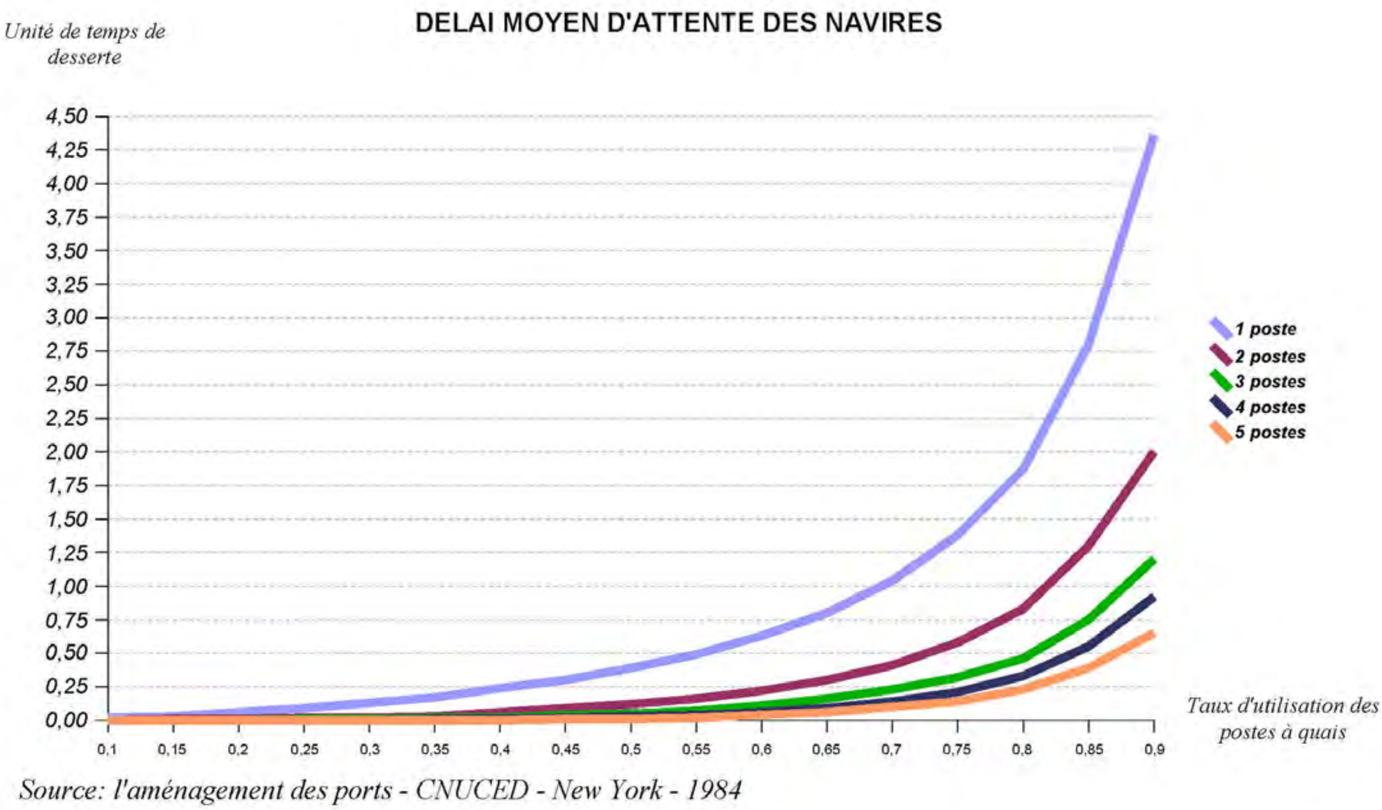


Figure 18. Ship average waiting time Vertical axis : Unit service time; Horizontal axis : Berth utilisation rate. "1, 2… postes" = *berths*

This analytical method of determining ship waiting time is not described in more detail here. It should be applied with caution because it requires the following simplifying assumption, which are far from always encountered under real conditions:

- Ship arrivals and service times must comply with particular statistical distributions
- The theory does not consider possible waiting due to weather conditions, which can disrupt handling operations (wind and/or swell), and tides that can prevent ships entering port, etc.
- The ease with which the port meets occasional higher demand, the operator can indeed increase his handling resources (by installing an additional gantry crane, adding a team of dockers) to reduce loading/unloading time.

It is an easy way for estimating waiting times and their variation subject to modifications in efficiency, traffic, etc. Simulation methods are essential to generating more accurate results.

However, the following conclusions can be reached:

- The greater the number of berths, the shorter the waiting times for a constant utilisation rate. The probability of a ship waiting for a vacant berth is effectively lower as the number of berths increases.

Figure 19. Overhead gantry cranes at Port of Marseille container terminal

It is usually considered that waiting time must not exceed 50% of the time take for port service operations but this percentage is variable because it depends on the type of ship and the volume of its cargo:

- Regular lines must comply with deadlines, especially in container transport
- A ship carrying relatively few goods cannot be allowed to wait as long as a ship carrying a large cargo.

The report entitled "Indicateurs de suivi des axes et pôles stratégiques de la politique de transport" [indicators for monitoring transport policy strategic axioms and principles] [30] suggests two indicators for port service quality and capacity utilisation. For the Port of Marseille, the first indicator gives the ship waiting time at terminals or at sea. This average waiting time is computed based on the total number of port calls sustaining a delay. The second indicator gives the occupancy time at certain container berths at the Ports of Dunkirk, Le Havre, Marseille - Mourpiane, Fos and Nantes. This indicator is defined as the ratio of the number of TEUs handled to the number of linear metres of container quay.

Container ship calling time

As an example, Figure 15 highlights the disparities in calling, waiting and manoeuvring times at European ports in 1995.

Port	Calling time (hours)	Waiting and manoeuvring time (hours)	Proportion of dead time (%)
Antwerp	21.0	11.0	52%
Dunkirk	18.0	4.2	23%
Felixstowe	22.0	3.7	17%
Hamburg	21.5	13.1	61%
Le Havre	30.5	5.7	19%
Lisbonne	27.0	4.1	15%
Rotterdam	22.0	5.1	23%
Average	**23.1**	**6.7**	**30%**

Figure 20. Container ship calling times at main European ports in 1995 (source : J. Grosdidier de Matons [71])

These figures have certainly changed, but they do allow us to observe that the Ports of Antwerp and Hamburg are heavily penalised by their "waiting and manoeuvring time" (52.3% and 60.9% of the calling time respectively), which may be explained by their upper estuary locations whilst other ports on the coast are directly accessible.

4.2.2 - Storage capacity

Storage capacity is mainly dependent on two parameters:

- Intrinsic storage available at the terminal (ground area, silo or tank volume, etc.)
- Human and technical resources on site (working hours, handling system used).

Quantitative determination of storage capacity depends on the type of terminal analysed.

The method below is a simple dimensioning method for container storage areas. There are more accurate, but more complex, methods. The following parameters must be taken into account:

- Containers are divided into 5 categories: full and empty export, full and empty import, containers for transfer;
- Each type of container is allocated a holding time: the average time for which the container is stored within the terminal enclosure. The holding time is usually longer for full import containers than for full export containers and longer for empty containers than for full containers. Figure 16 gives estimated container holding times
- A peak traffic coefficient is applied and taken as 1.2 except for transfer traffic, for which the peak traffic coefficient is taken as 1.3.

Container		Holding time (days)
Import	Full	7
	Empty	15 – 20
Export	Full	5
	Empty	20

Figure 21. Container holding time at a terminal (Source : CETMEF)

The previous data allow us to determine the storage requirement expressed in TEU for each type of container:

$$B_i = \frac{T_i \times D_i \times 1.2}{365}$$

In which *i* is the type of container, *Di* is the average holding time in days and *Ti* is the annual traffic expressed in TEU.

The handling system used at the container terminal has to be considered for determining the required storage area. We take into account the average storage height, which depends on the type of container (and the handling system) as well as a ratio giving the number of TEUs that can be stored per hectare. It should be noted that the stacking height can depend also on the climatic conditions (wind). Common figures are given in Figure 22 for two different storage area handling systems[4].

Container		Reach stackers		Rubber tyred Gantry cranes	
		Average storage height	Ratio TEU /ha	Average storage height	Ratio TEU /ha
Import	Full	1.8	245	2	300
	Empty	3.5	360	3.5	300
Export	Full	2.5	245	2.5	300
	Empty	3.5	360	3.5	300
Transshipment		2.5		2.5	

Figure 22. Storage ratios based on container type and handling system used (Source : CETMEF)

We can then deduce the required storage area from:

$$A = \sum_i \frac{B_i}{h_i \times r_i}$$

in which h_i is the average storage height and r_i is the TEU/ha ratio.

The reverse process, which involves working back from the storage area to the total traffic and thus the capacity, assumes that the import – export – empty traffic distribution is known. These data can be extrapolated from a known situation (case of a port extension) or they can be determined from socio-economic studies.

[4] ***Remark.*** ***Similar type handling machines can have different capacities. Thus, some reach-stackers (cf. lexicon) can store containers on four levels and/or two rows, whilst others are limited to one row. The Figure 17 figures should therefore be used with caution and must be suited to the situation encountered, whenever possible.***

4.2.3 - Reliability

This is an essential concern for port users. A ship that remains blocked at a port because of a strike, for example, is extremely expensive for an owner[5].

Social organisation of the port handling or stevedoring sector

In France, port handling companies employ nearly 5,000 staff including rather more than 4,000 dockers distributed as follows:

- approximately 2,500 dockers from the old casual worker contract system and still holders of the professional docker's "G" card of whom less than 500 have kept or regained casual worker contract docker status, mainly at the Port of Marseille
- approximately 1,500 monthly paid dockers (not casual worker contract personnel).

For several years, this activity sector has experienced strong growth, reflected by the concentration of companies and increased intervention of international groups with high investment capacities, such as *Sea-Invest* (Belgian group subsidiary) or *PortSynergy*.

The French law of 9th June 1992 [72] put an end to the contract docker system, which will gradually disappear, and opened up the way to stevedoring work being subject to employment common law (signature of a collective agreement). This reform was the opportunity for launching a significant restructuring effort, reflected by major restructuring programmes in the following years.

The current port handling organisation, which distinguishes between crane and gantry operators employed by port authorities or "chambers of commerce and industry", on the one hand, and dockers employed by port handling contractors, on the other hand, has apparently caused malfunctions and is not totally satisfactory at large container terminals. Integration of the two professions led to significant advances in 2006, with the establishment of operating agreements at the Le Havre container terminal. Five terminal operating agreements are currently in force: two at Dunkirk (one for bulk cargo, one for containers), one at Bordeaux for bulk cargo and, since January 2006, three at Le Havre (GMP, TPO, MSC), and one soon at Guadalupe Port. These agreements have allowed operational grouping to take place within the more general framework of private investment growth.

4.3 - Land transport to/from ports

4.3.1 – The notion of hinterland

This is the geographical and economic land area, in which the port receives and delivers the goods that supply its business. The definition of hinterland raises many issues related to:

- Availability of a suitable statistical tool and adoption of delimiting standards
- Existence of an import and export hinterland and by type of product in each case.

Two methods are applied to hinterland definition: the deductive method and the inductive method.

Deductive method

The deductive method uses absolute traffic figures; e.g. regions from which the port generates more than 300,000 or 400,000 tonnes of its traffic. Based on this definition, most French ports, except Le Havre and Marseille, have mainly regional hinterlands. These ports effectively handle low-value bulk traffic (cereals, cattle-cakes, timber, oils), which cannot sustain forwarding costs and are therefore captive with respect to ports near to their production/transformation locations. The deductive method enables us to know a region's (import and export) proportion of the port traffic, i.e. the port's traffic capturing capacity.

During the 2000 to 2004 period, approximately 50% of the export, and 70% of the import, container traffic at the Port of Le Havre was with the Haute-Normandie region and its four adjacent regions (Basse-Normandie, Picardie, Ile-de-France and Centre).

Similarly, the Port of Marseille's area of influence mainly comprises the Provence-Alpes-Côte-d'Azur, Languedoc-Roussillon, Rhône-Alpes and Midi-Pyrénées regions, for which the port enjoys approximately 2/3rds of the market. In relation to the

[5] The cost of chatering a 2000 TEU container ship is 15,000 to 17,000 USD/day. To this must be added the cargo cost (1.5 USD/day/ container) based on the fact that two containers are required on land for one container trnasported at sea. This represents and average total cost of 28,000 USD/day (2002 estimate).

latter region, Marseille is subjected to growing competition from Barcelona, which ensures road and rail links with Lyons – the so-called *Barcelyon* rail link – and other French cities close to Marseille. Further north, Marseille now only has 16% share of the Ile-de-France (Paris region) regional market and only 6% of the French North-East regional market.

The Port of Dunkirk's area of influence is even more limited. Apart from the steel industry traffic with Lorraine, it's area is effectively concentrated within a 150 km radius.

The inductive method

The inductive method is intended to establish a general law and this cost-based method is indeed the most commonly used. The cost of transport is assumed to be the essential hinterland determinant. Moreover, this approach presupposes that the travelling distance and speed determine a hinterland. However, tariffs are not always rigid because shipowner decisions in relation to port selection take into account many factors (ship frequency, cost of port transit, reliability, etc. and possibility of return freight for limiting empty transport movements), which makes any mechanistic approach unreliable.

Development of inland or dry ports (refer to appendix 7 for further details of advance and dry ports) is a way to extent hinterland in the port struggle to increase traffic and meet shipping requirements. For example, the Gennevilliers and Bonneuil-sur-Marne hubs (managed by the Paris port authority) represent advance ports for Le Havre.

4.3.2 – Modal distribution of land transport

Analysis of modal share development for rail and inland waterway transport in pre- and post-forwarding at French ports shows that, so far, these modes have not been able to challenge the supremacy of road transport (*cf.* Figure 23). On the contrary, rail and inland waterway transport modes, whose area of economic relevance depends on massified traffic flows, have to date been more competitors than complementary. Thus, the traffic shares currently won by inland waterway transport partly result from business transferred from rail transport.

	Total traffic	Trans-shipment	Inland Traffic	Road	Rail	Barge
Antwerp	7.4	37%	4.7	56%	10%	34%
Rotterdam	6.75	27%	4.4	57%	10%	33%
Le Havre	2.6	30%	1,9	87%	6.3%	7%
Marseille	1.0	3%	0.9	85%	9%	6%

Figure 23. Modal percentages for container transport services to/from 4 European ports. Traffics in million TEU – based on port authority data, 2010)

The report entitled "*Indicateurs de suivi des axes et pôles stratégiques de la politique de transport*" [indicators for monitoring transport policy strategic axioms and principles] [30] suggest two indicators for sea port accessibility. One the one hand, maps showing the road, rail and inland waterway transport forwarding times for 5 French ports and, on the other hand, a detailed description of the number of regular rail and inland waterway transport services to and from the ports of Dunkirk, Le Havre, Marseille and Nantes.

Comparisons of both forwarding times and costs show that the road transport mode is not always the most advantageous on some links or for massified flows. Figure 24 illustrates this observation for the Rhône valley axis.

	Time (hours)	Transport cost (€)
Road	6	400 to 500
Rail	12	250 to 300
Barge	36	150 to 200

Figure 24. Transport time and cost from Fos to Lyon for 20' containers (2006) (Source : PAM)

However, the intrinsic competitiveness of rail and inland waterway transport modes is distorted by the cost of trans-shipment operations within port areas. In this connection, costs of port internal transport and handling can reach 100 – 120 euro per container. Inland waterway transport is the most heavily penalised mode because of the additional load breaking sustained by it. Moreover, the river mode is subjected to possible competition from ships during barge loading/unloading at a sea terminal.

For information and irrespective of the transport mode used for pre- and post-forwarding operations, the average cost distribution for transporting a container is as shown in Figure 25 below.

Costs	%
Ship operation	23
Port services and handling	21
Pre- and post-forwarding	25
Container fleet	18
Others (including container repositioning)	13
Total	100

Figure 25. Cost distribution for door-to-door container transport (Source : INRETS, according to Stopford, 2002)

Situation at large Northern European ports

Quality of inland transport services (pre- and post-forwarding) was a determining factor in establishing the predominant position of the Northern European ports. These have a dense hinterland served by different transport modes (interconnected, dense wide gauge navigable network and massified traffic allowing optimisation of rail transport operations). Today however, growth of these ports is ensured by organisational innovations, dynamism and collective awareness (public and private) of the importance of inland transport services for draining the largest possible hinterland. For example, the Port of Marseille has a theoretical land transport offer that is essentially as extensive as that of certain Northern European ports, but it is the general organisation of these inland transport services that makes a difference.

The Port of Rotterdam is relying on growth in the rail transport modal share for ensuring its continued development by avoiding greater road congestion. The Betuwe line in the Netherlands – 112km of new line, 50 km refurbished – ensures since 2007 circulation of long, heavy, eventually twin level (double stack) container trains. Other projects have been launched in Belgium, in particular reopening of the "*Rhin d'acier*" [steel Rhine] between Antwerp and the Ruhr, as well as major rail infrastructure investments. The Belgian national railway company is banking on port traffic and has taken a 1/3 share in container terminals at both Antwerp and Zeebrugge, dedicated to steel products. Pre- and post-forwarding operations to and from Hamburg and Bremen therefore use almost exclusively combined rail-road transport for distances of 500 km and over. To the west of a line between Stuttgart and Ulm, container traffic is directed towards the ports of Antwerp and Rotterdam based on massive implementation of the inland waterway transport mode (nearly 70%).

Foreign examples reveal that river and rail transport modes are likely to be used complementarily, as shown by rail shuttles, which combine to massify river traffic on the River Rhine by feeder rail services to the river terminals at Basel and the Port of Duisburg. The initiative of the partnering charter signed by France's VNF (inland waterway transport authority, soon ANVN) and SNCF (national rail company) in October 2003 was aimed at this system by encouraging combination of these two modes and offering alternative inland waterway transport-based solutions to by-passing the Ile-de-France and Lyon rail congestion locations. However, this has not yet prompted concrete measures.

4.3.3 – Road transport: the dominant mode

Certain road network development projects involve opening up peripheral areas to link a number of European ports to their hinterlands; these ports would more than likely help to develop Europe's sea trade.

Development of the French motorway network from the 1960s to recently has not always coincided with the specific needs of French ports. Land transport services to French ports and adjoining port industrial areas were only effectively taken into account through the Schéma Directeur Routier National [national road master plan] in 1992 [73] (e.g. by scheduling west-east crosswise services linking Atlantic coast ports with their hinterland or by the major axis project ensuring motorway continuity near the coast from Dunkirk to Bayonne).

Local road transport services

Quality of port road transport services is not only related to the quality of the national motorway and road network. Road transport local to the port is also very important. Even if a port is properly fed by a motorway, the time saved by the HGV driver on the main journey is lost in traffic jams near the port entrance, if the road link from the port terminals to the motorway is poor. Signalling quality near a port and within the port area can also save time and create fluidity for road transport of port traffic.

The report entitled "Indicateurs de suivi des axes et pôles stratégiques de la politique de transport" [indicators for monitoring transport policy strategic axioms and principles] [30] suggests an indicator that measures the variation in truck waiting time and processing at the entrance and within the Port of Le Havre's container terminal between 1996 and 2003.

Regulations

European road transport regulations are not yet fully harmonised and this is particularly the case of truck total weight limitation, in which some countries are more severe than others.

French decree of 7th January 2004 [39] authorises, subject to dispensation, an increase in the total weight of road vehicles under maximum load from 40 to 44 tonnes for transport services to/from sea ports within a 100 km radius, and exceptionally within a 150 km radius. Road transporters are requesting that this dispensation be generalised to all port pre- and post-forwarding operations. They point out that 55 tonne HGVs travel on Belgian motorways (free), which contributes in favour of the ports of Antwerp and Rotterdam. However, this advantage could disappear ; debates are currently on-going in French Senate to generalize 44t transport on French roads, without technological change (5 axles trucks), after agreement by the Parliament.

4.3.4 - Rail transport service

Rail transport is an ideal massification mode. European ports devote considerable efforts to extending their rail transport hinterland. Their strategy is based on:

- Improving the port interface to transform port terminals into truly multimodal terminals offering efficient rail connections
- Developing rail infrastructures and quality of service offered to freight transport on the rail network.

The report entitled "Indicateurs de suivi des axes et pôles stratégiques de la politique de transport" [indicators for monitoring transport policy strategic axioms and principles] [30] suggests two indicators for sea port rail transport services: the first involves punctuality of combined transport trains leaving the SNCF (*Société Nationale des Chemins de fer Français,* national rail operator*)* region, to which each port belongs; the second describes the variation in the number of rail freight slots across a geographic line for port departure and arrival between 2003 and 2005.

Rail/Sea interface at ports

There is little point in a sea port being connected to a main European rail route allowing high-performance trains, in terms of cost and quality of service, to circulate, if the "local" rail transport service is poor. For example, at some ports with a poor quality local rail service (network saturation, problems of organisation between different operators, etc.) several hours can be wasted between a container being loaded onto a wagon at the port terminal and the train leaving the port industrial area on the main rail network.

Rail corridors and shuttles in Europe

In rail corridors, certain slots are allocated traffic priorities for freight trains and commercial speeds are there higher. The first corridors involved the North-South axis and services to the Benelux ports: Rotterdam - Gioia Tauro, Hamburg/Bremmerhaven – Brindisi, Rotterdam - Vienna, Muizen (hub for the ports of Antwerp, Zeebrugge and Rotterdam) - Lyon, extended since 1998 to Italy, Marseille and Barcelona.

European ports are linked to so-called "nodal point" systems, which concentrate and de-concentrate rail traffic for multiple destinations (star system). But, "shuttle train" systems have also been set up. Based on trains that cannot be split up, fixed cycle services connect ports to major European destinations. As in sea transport, these services are based on a massification principle and therefore require high load factors.

4.3.5 – Inland waterway transport service

The river mode represents a chance to optimise transport services to and from port hinterlands. Yet, a number of factors explain the minor contribution of this mode to French port transport services: the small volumes handled, lack of reference stakeholders at the ports of Le Havre and Marseille, the limited scale of the river network and the small size of the inland water fleet (source IFFSTAR).

However, certain data would enable us to foresee a change in this situation: firstly, there is considerable growth in container traffic on the River Seine and River Rhône, where reference stakeholders are now located (Logiseine, MSC, CMA-CGM). New infrastructure development (Port 2000 at Le Havre, Fos 2XL at Marseille, the Seine - Northern Europe canal) should also prompt development of inland waterway transport services to sea ports.

A first issue involves optimising inland waterway transport services and, more specifically, optimising port handling in relation to them: is it better to have windows and locations set aside for processing barges at the sea terminal or should a dedicated inland waterway transport terminal with port internal transport (*cf.* glossary) be favoured? There is no unique answer to this question because the solution depends on the case under consideration.

A second issue involves cooperation amongst stakeholders (shipowner, stevedoring company, inland waterway shipowner, inland waterway handler, road transporter). This cooperation, even integration within the transport chain, is necessary to ensuring high transport efficiency. Integration makes it possible to industrialise inland waterway transport and increase competitiveness.

Figure 26 : fast everything can be transported on boats. This vessel of the first world fleet (Greece) is carrying fresh water for a little Island, near Athens. Nevertheless, gauges and especially draught remains a main issue ; anchoring and then loading and unloading of goods is not possible for every ship in every harbor – © Bruno Meignien

Appendix 1. Growth in Worldwide Sea Trade

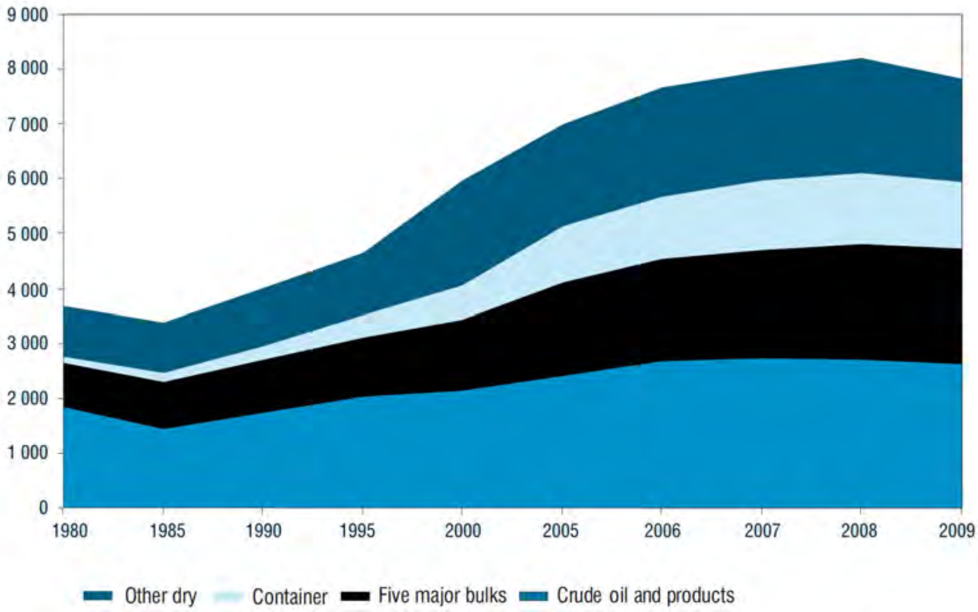


Figure 27. Worldwide sea trade from 1980 to 2009, selected years ***(million tonnes)*** *– Source : Review of Maritime Transport, UNCTAD*

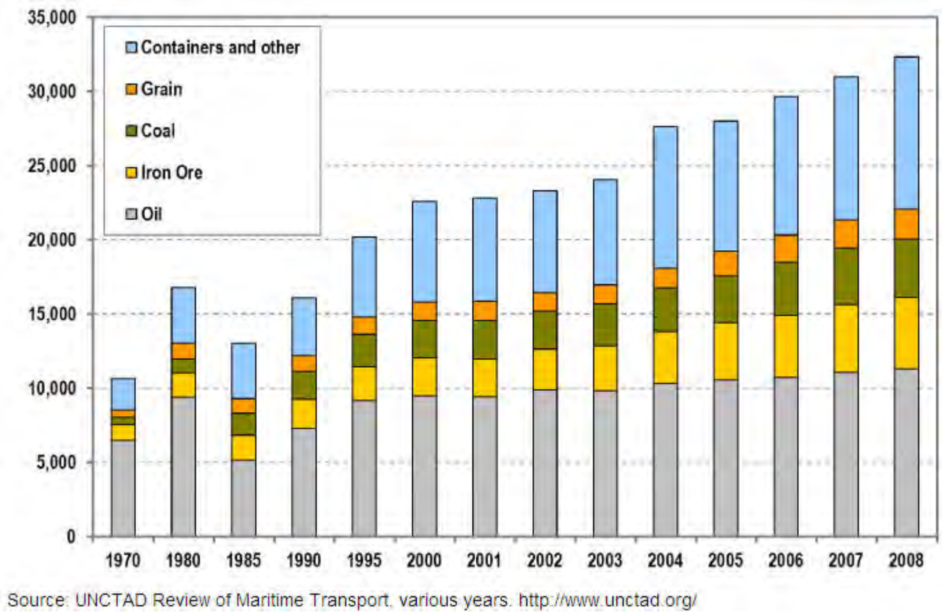


*Figure 28. Worldwide sea trade from 1970 to 2008 (**billion tonnes x miles**). Grain includes wheat, maize, barley, oats, rye, sorghum and soya – graph Dr. Jean-Paul Rodrigue, Hofstra University. More recent data not available in UNCTAD's reviews of maritime transport.*

Comparison of traffic variations expressed in tonnes and tonnes x miles (*cf*. figures above) reveal that average distance of sea freight is approx. 4,000 miles or 7,500 km. This leads to an immense supremacy of sea transport in terms of t.km. Total trade (32.7 trillion t.km or 32,746,000,000,000 t.km) may be compared with inland traffic. For example, France's total inland traffic reaches approx. 350 billion t.km, or only 1% of world maritime traffic. Fortunately, sea transport is the better mode in terms of fuel consumption and then CO2 emissions. The latter are estimated to 1 billion tons or 3% of world emissions. And other pollutions are noticeable : SOx (10% of world total) and Nox for example, due to utilisation of mediocre quality fuel by many old ships.

Many improvements are possible to reduce fossil fuels needs ; slow steaming (see appendix 3), motorisation, waste heat recovery system, hull design, optimisation of capacities (e.g. avoiding empty returns from Europe to Asia), etc.

Appendix 2. Main European and world ports

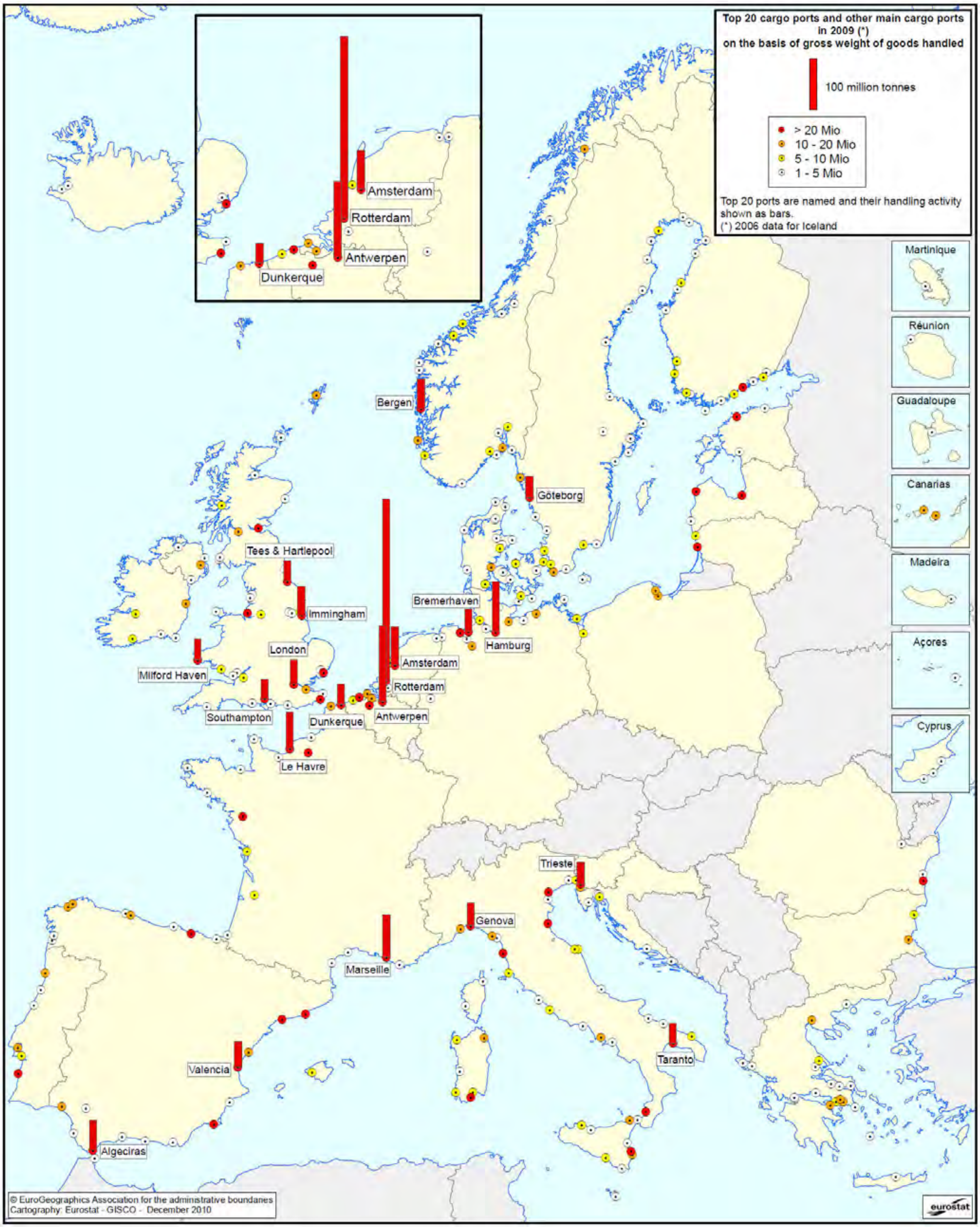
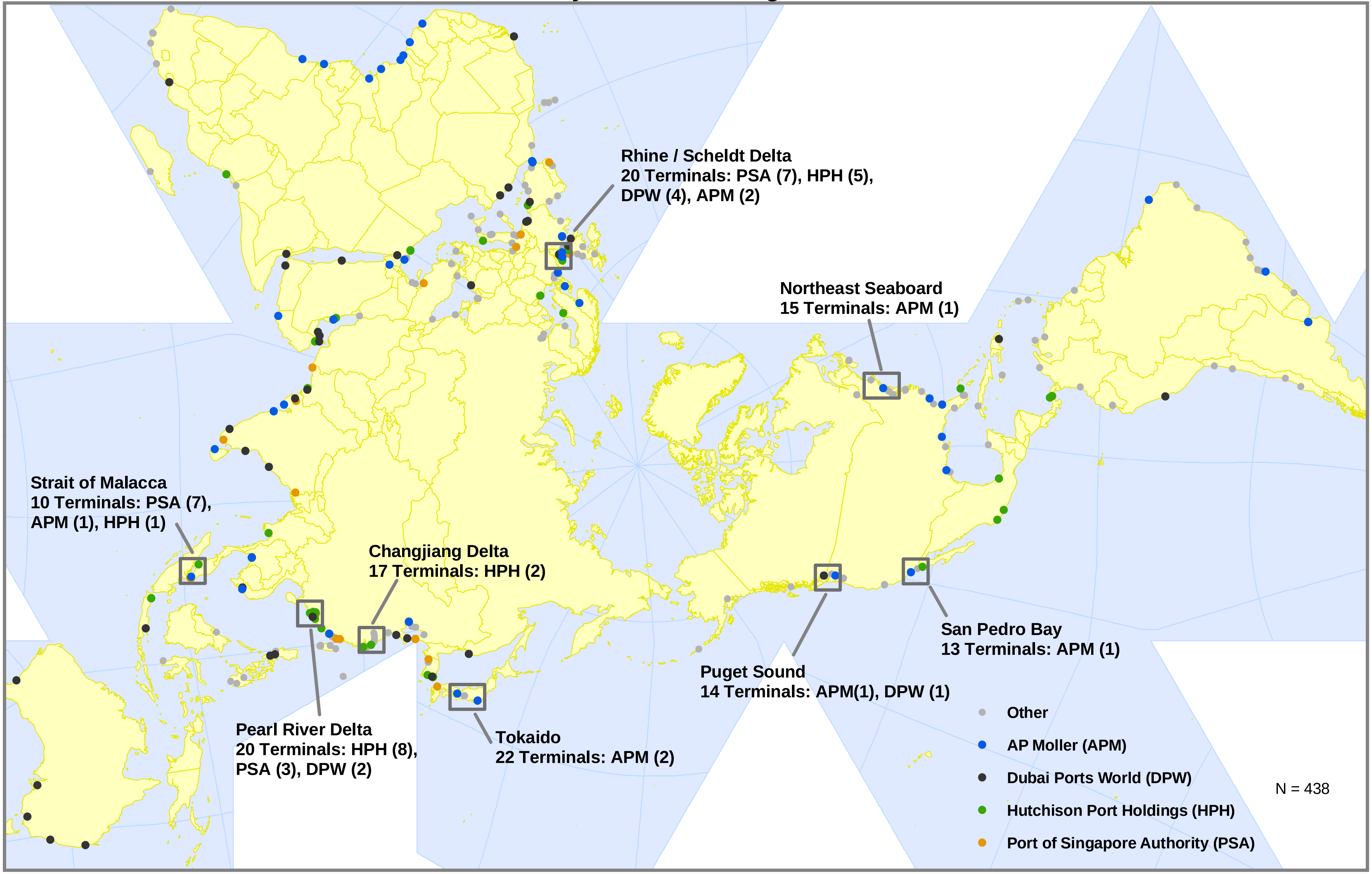


Figure 29 : Main EU-27 cargo ports (all cargo). Traffics of The 20 largest ports are indicated (scale upright) – source Eurostat

Container Terminals of the World's Four Major Port Holdings, 2010



Source: Web Sites of Port Holdings

Note: Terminal where the holding has a dominant share

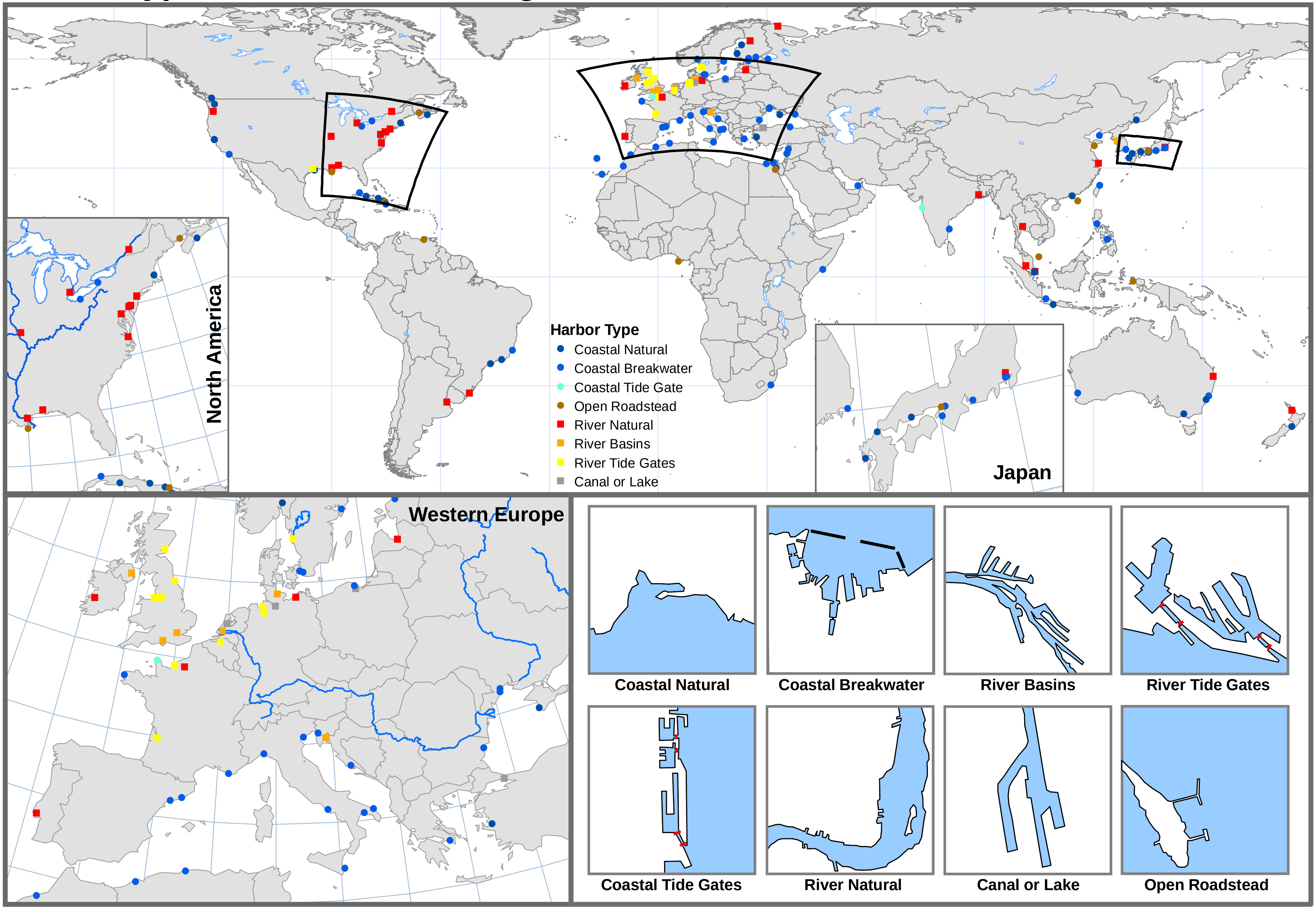
Dr. Jean-Paul Rodrigue, Dept. of Global Studies & Geography, Hofstra University

WORLD PORT RANKINGS - 2009								
TOTAL CARGO VOLUME					CONTAINER TRAFFIC			
THOUSANDS OF TONS					TEUs - Twenty-Foot Equivalent Units			
RANK	PORT	COUNTRY	MEASURE	TONS	RANK	PORT	COUNTRY	TEUS
1	Shanghai	China	Metric Tons	505,715	1	Singapore	Singapore	25,866,600
2	Singapore	Singapore	Freight Tons	472,300	2	Shanghai	China	25,002,000
3	Rotterdam	Netherlands	Metric Tons	386,957	3	Hong Kong	China	21,040,096
4	Tianjin	China	Metric Tons	381,110	4	Shenzhen	China	18,250,100
5	Ningbo	China	Metric Tons	371,540	5	Busan	South Korea	11,954,861
6	Guangzhou	China	Metric Tons	364,000	6	Guangzhou	China	11,190,000
7	Qingdao	China	Metric Tons	274,304	7	Dubai Ports	United Arab Emirates	11,124,082
8	Qinhuangdao	China	Metric Tons	243,850	8	Ningbo	China	10,502,800
9	Hong Kong	China	Metric Tons	242,967	9	Qingdao	China	10,280,000
10	Busan	South Korea	Revenue Tons	226,182	10	Rotterdam	Netherlands	9,743,290
11	Dalian	China	Metric Tons	204,000	11	Tianjin	China	8,700,000
12	South Louisiana	United States	Metric Tons	192,853	12	Kaohsiung	Taiwan	8,581,273
13	Houston	United States	Metric Tons	191,729	13	Port Kelang	Malasyia	7,309,779
14	Shenzhen	China	Metric Tons	187,045	14	Antwerp	Belgium	7,309,639
15	Port Hedland	Australia	Metric Tons	178,625	15	Hamburg	Germany	7,007,704
16	Kwangyang	South Korea	Revenue Tons	176,546	16	Los Angeles	United States	6,748,994
17	Ulsan	South Korea	Revenue Tons	170,314	17	Tanjung Pelepas	Malasyia	5,835,085
18	Nagoya	Japan	Freight Tons	165,101	18	Long Beach	United States	5,067,597
19	Antwerp	Belgium	Metric Tons	157,807	19	Xiamen	China	4,680,355
20	Chiba	Japan	Metric Tons	144,904	20	Bremen/Bremerhaven	Germany	4,578,642
21	Port Kelang	Malaysia	Metric Tons	137,615	21	New York/New Jersey	United States	4,561,528
22	Kaohsiung	Taiwan	Metric Tons	133,570	22	Dalian	China	4,552,000
23	New York/New Jersey	United States	Metric Tons	131,262	23	Laem Chabang	Thailand	4,537,833
24	Inchon	South Korea	Revenue Tons	122,128	24	Jawaharlal Nehru (Nhava Sheva)	India	4,061,343
25	Yokohama	Japan	Freight Tons	115,529	25	Tokyo	Japan	3,810,769
26	Xiamen	China	Metric Tons	110,963	26	Tanjung Priok	Indonesia	3,800,000
27	Hamburg	Germany	Metric Tons	110,381	27	Valencia	Spain	3,653,890
28	Yantian	China	Metric Tons	107,563	28	Ho Chi Minh	Viet Nam	3,563,246
29	Itaqui	Brazil	Metric Tons	105,026	29	Mina Raysut (Salalah)	Oman	3,493,459
30	Newcastle	Australia	Metric Tons	103,027	30	Colombo	Sri Lanka	3,464,297
31	Port Metro Vancouver	Canada	Metric Tons	101,888	31	Port Said	Egypt	3,300,951
32	Hay Point	Australia	Metric Tons	99,475	32	Felixstowe	United Kingdom	3,100,000
33	Tanjung Pelepas	Malaysia	Metric Tons	90,447	33	Jeddah	Saudi Arabia	3,091,312
34	Amsterdam Ports	Netherlands	Metric Tons	86,678	34	Algeciras - La Linea	Spain	3,043,268
35	Novorossisk	Russia	Metric Tons	86,519	35	Lianyunggang	China	3,020,800
36	Sepetiba	Brazil	Metric Tons	86,420	36	Gioia Tauro	Italy	2,857,438
37	Kitakyushu	Japan	Freight Tons	84,941	37	Manila	Philippines	2,815,004
38	Tubarâo	Brazil	Metric Tons	83,835	38	Khor Fakkan	United Arab Emirates	2,750,285
39	Santos	Brazil	Metric Tons	83,194	39	Yokohama	Japan	2,555,000
40	Marseilles	France	Metric Tons	83,194	40	Yingkou	China	2,537,000
41	Osaka	Japan	Freight Tons	80,944	41	Durban	South Africa	2,523,105
42	Primorsk	Russia	Metric Tons	79,138	42	Savannah	United States	2,356,511
43	Richards Bay	South Africa	Metric Tons	77,631	43	Zeebrugge	Belgium	2,328,198
44	Kobe	Japan	Freight Tons	77,027	44	Marsaxlokk	Malta	2,260,000
45	Le Havre	France	Metric Tons	73,768	45	Santos	Brazil	2,255,862
46	Tokyo	Japan	Freight Tons	72,259	46	Kobe	Japan	2,247,024
47	Algeciras - La Linea	Spain	Metric Tons	69,911	47	Le Havre	France	2,240,714
48	Long Beach	United States	Metric Tons	65,772	48	Melbourne	Australia	2,236,633
49	Daesan	South Korea	Revenue Tons	64,716	49	Bandar Abbas	Iran	2,206,476
50	Bandar Abbas	Iran	Metric Tons	64,454	50	Shahid Rajaee	Iran	2,206,476
51	Bremen/Bremerhaven	Germany	Metric Tons	63,106	51	Port Metro Vancouver	Canada	2,152,468
52	Corpus Christi	United States	Metric Tons	61,907	52	Nagoya	Japan	2,112,738
53	New Orleans, LA	United States	Metric Tons	61,804	53	Oakland	United States	2,045,211
54	Beaumont	United States	Metric Tons	61,431	54	Balboa	Panama	2,011,778
55	Madras	India	Metric Tons	61,057	55	Sydney Ports	Australia	1,927,507
56	Jawaharlal Nehru (Nhava Sheva)	India	Metric Tons	60,746	56	Osaka	Japan	1,843,067
57	Pohang	South Korea	Revenue	58,687	57	Ambarli	Turkey	1,836,030
58	Valencia	Spain	Metric Tons	57,502	58	Kwangyang	South Korea	1,810,438
59	Paradip	India	Metric Tons	57,011	59	Barcelona	Spain	1,800,214
60	Saldanha Bay	South Africa	Metric Tons	56,476	60	Houston	United States	1,797,198
61	Bergen	Norway	Metric Tons	56,138	61	Hampton Roads	United States	1,745,228
62	Grimsby and Immingham	United Kingdom	Metric Tons	54,708	62	Kingston	Jamaica	1,692,811
63	Mumbai	India	Metric Tons	54,540	63	San Juan	United States	1,673,745

Figure 30 : World port ranking in 2009. Ranking ports, even without considering productivity or service, is a delicate task, because of numerous measurement units. Note : Remember that there is more than twice as much port traffic as actual exchanges by sea (Each port traffic includes import, export and transshipment)

– source American Association of Port Authorities

Harbor Types of the World's Large Sized Ports



Source: adapted from National Geospatial-intelligence Agency (2010) World Port Index.

Dr. Jean-Paul Rodrigue, Dept. of Global Studies & Geography, Hofstra University.

Appendix 4. Top 20 container ship operators in the World

Ranking	Operator	Country/ territory	Number of vessels	Average vessel size	TEU	Share of world total, TEU	Cumulated share, TEU	Percentage of growth in TEU over 1 Jan. 2009
1	Maersk Line	Denmark	427	4 090	1 746 639	11.7%	11.7%	0.3%
2	MSC	Switzerland	394	3 827	1 507 843	10.1%	21.8%	-0.2%
3	CMA CGM Group	France	289	3 269	944 690	6.3%	28.1%	9.2%
4	Evergreen Line	China, Taiwan Province of	167	3 549	592 732	4.0%	32.0%	-5.9%
5	APL	Singapore	129	4 068	524 710	3.5%	35.6%	11.4%
6	COSCON	Singapore	143	3 468	495 936	3.3%	38.9%	0.9%
7	Hapag-Lloyd Group	Germany	116	4 053	470 171	3.1%	42.0%	-5.3%
8	CSCL	China	120	3 809	457 126	3.1%	45.1%	5.9%
9	Hanjin	Republic of Korea	89	4 495	400 033	2.7%	47.8%	9.4%
10	NYK	Japan	77	4 670	359 608	2.4%	50.2%	0.4%
11	MOL	Japan	90	3 871	348 353	2.3%	52.5%	-10.0%
12	K Line	Japan	89	3 655	325 280	2.2%	54.7%	5.1%
13	Yang Ming	China, Taiwan Province of	80	3 966	317 304	2.1%	56.8%	-0.1%
14	OOCL	China, Hong Kong	63	4 609	290 350	1.9%	58.7%	-20.3%
15	Hamburg Sud	Germany	88	3 226	283 897	1.9%	60.6%	10.7%
16	HMM	Republic of Korea	53	4 905	259 941	1.7%	62.4%	0.5%
17	Zim	Israel	64	3 371	215 726	1.4%	63.8%	-14.3%
18	CSAV	Chile	66	2 968	195 884	1.3%	65.1%	38.0%
19	UASC	Kuwait	45	3 924	176 578	1.2%	66.3%	13.6%
20	PIL	Singapore	84	2 071	173 989	1.2%	67.5%	17.6%
Total top 20 carriers			2 673	3 774	10 086 790	67.5%	67.5%	1.4%
Others			6 862	709	4 864 981	32.5%	32.5%	8.6%
World container ship fleet			9 535	1 568	14 951 771	100.0%	100.0%	3.6%

Figure 31 : main container ship operators in the World, ***2010*** *(beginning of the year) – source Review of Maritime Transport, UNCTAD*

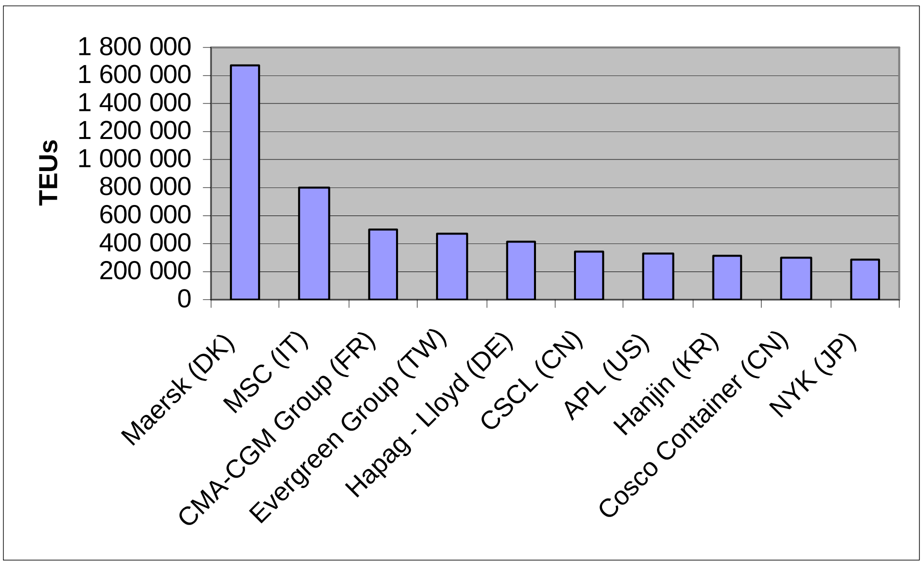


Figure 32. For reference, ten largest container ship-owners in the world ***2006***

Appendix 5. Slow steaming, CO2 emissions and economic climate

Many vessels ordered during the preceding years of great increase in international seaborne traffic were delivered after September 2008, during or after the worldwide recession. 2009 was indeed a record year for new buildings deliveries in the Republic of Korea, China and Japan shipyards (90% of vessels of 100 Gross Tons and above are bought in these three countries), although new orders were limited. It created a general surplus capacity, which was compensated by scrapings of old ships and slow steaming. Freight rates (see next page for definition) have been remaining however very low. Thus, "*Shipping one ton of dry bulk cargo over 1,000 nautical miles by sea in early 2010 cost between $4 and $7, as compared to between $10 and $16 in 2008*".(UNCTAD, review of maritime transport 2010)

Slow steaming consists in reducing sailing speed, from 24-25knots, container ships design speed, (~45 km/h ; 1 knot = 1 nautical mile / hour = 1.852 km/h) to 17-22 knots (31.5 - 40.7 km/h), or even less (extra slow steaming)

Sailing speed is basically a balance between three factors : fleet capacity, transport demand and bunker (maritime fuel) price. It is the main parameter to adjust supply to demand, with a given fleet. It leads to lesser productivity. As can be seen in Figure 33, over-capacity was even more marked during 80's and 90's. Detailed figures show that tankers were particularly in overcapacity.

Shipowners have been using this mechanism since crisis beginning and it could continue, relying on the current economic circumstances. It would permit significant savings in CO2 emissions ; according to P. CARIOU (see below), it allowed them to be reduced by 11% between 2008 and 2010, for containerships.

Table 3.1. Cargo carried per deadweight ton (dwt) of the total world fleet, selected years

Year	World fleet (millions of dwt, beginning of year)	Total cargo (millions of tons)	Tons carried per dwt
1970	326	2 566	7.9
1980	683	3 704	5.4
1990	658	4 008	6.1
2000	799	5 983	7.5
2006	960	7 682	8.0
2007	1 042	7 984	7.7
2008	1 118	8 210	7.3
2009	1 192	7 874	6.6

Figure 33 : Productivity of the world fleet, expressed in tons carried per deadweight ton during one year
- source UNCTAD, Review of maritime transport 2010

Not any traffic nor any route was concerned by slow steaming, because parameters are not the same (supply – demand parameters, consumptions facts depending on the type and size of vessel). Between 16-17% (South / East Africa related, Australasia / Oceania related) and 87% (Mid-East / South Asia related) of services were sailing under slow-steaming in January 2010 (Source Alphaliner, information on 2,051 containerships over 1,000 TEU / Twenty feet Equivalent Units). Larger vessels are more sailing slow-steaming than small ones.

For example, Applying a relatively simple calculation method to container traffics, P. CARIOU (*Is slow steaming a sustainable means for reducing CO2 emissions ?*, Euromed Management Forum, 2010) find an average bunker break-even price of 350-400$. It means that if the price of 1,000 tons IFO (Intermediate Fuel Oil) increases to more than 350-400$, slow-steaming becomes economically interesting.

Main assumptions for this calculation are :

- Ships over 1,000 TEU
- Daily operational cost of $7,000 for 1,000-2,000 TEU vessels, $8,000 for 2,000-3,000 TEU vessels, $9,000$ for more than 3,000 TEUs vessels (figure HSH Nordbank et al., 2008)
- Inventory cost for shipowners : average value of $27,370 per TEU (Eefsen and Cerup Simonsen, 2010), with 35% interest rate *pro anno*. (means that one TEU costs 35% of $27.370 a year)
- Assumptions on rate of empty containers.
- Assumptions on ship consumptions (too long to describe here, refer to the above-mentioned reference for further details)

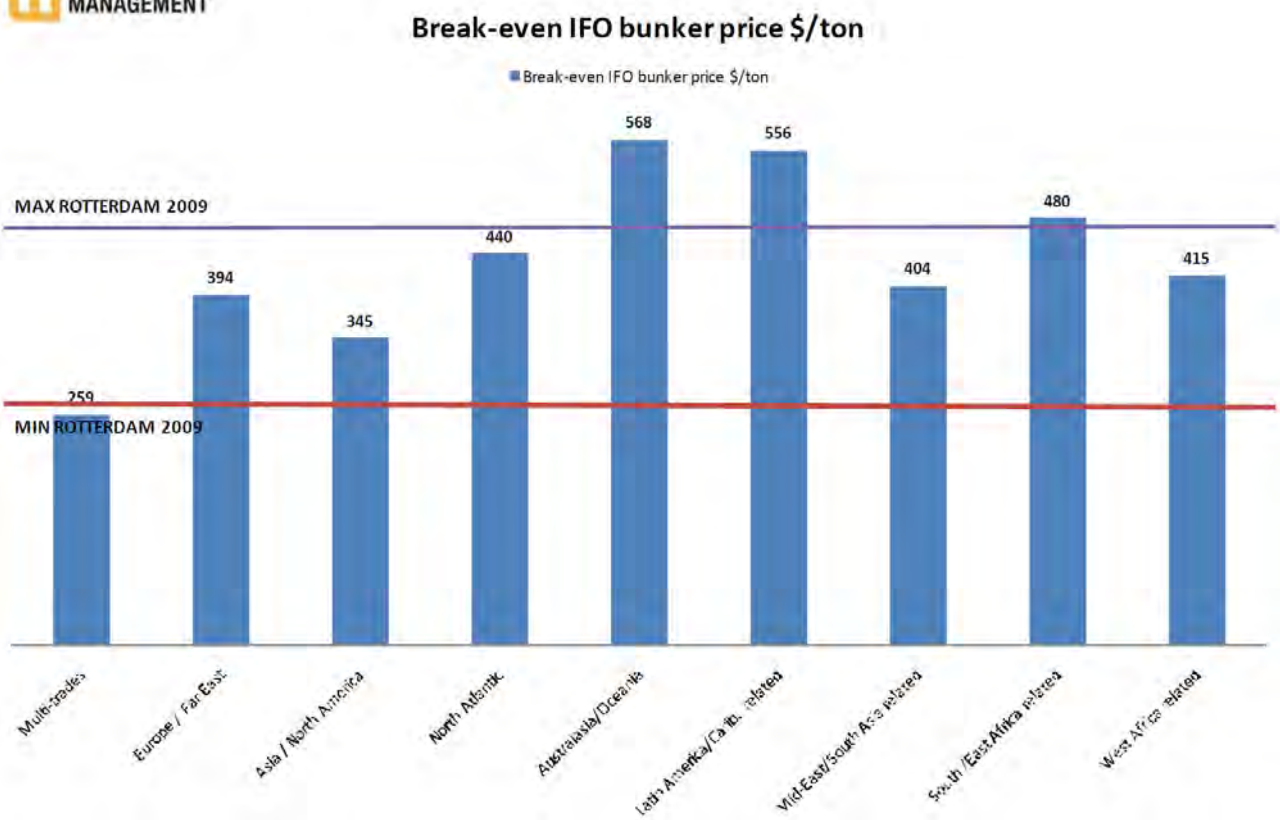


Figure 34 : Level of Fuel price needed to make slow steaming economically interesting, at 2009 economic conditions (freight rates, etc.) – Source P. Cariou, op.cit., 2010

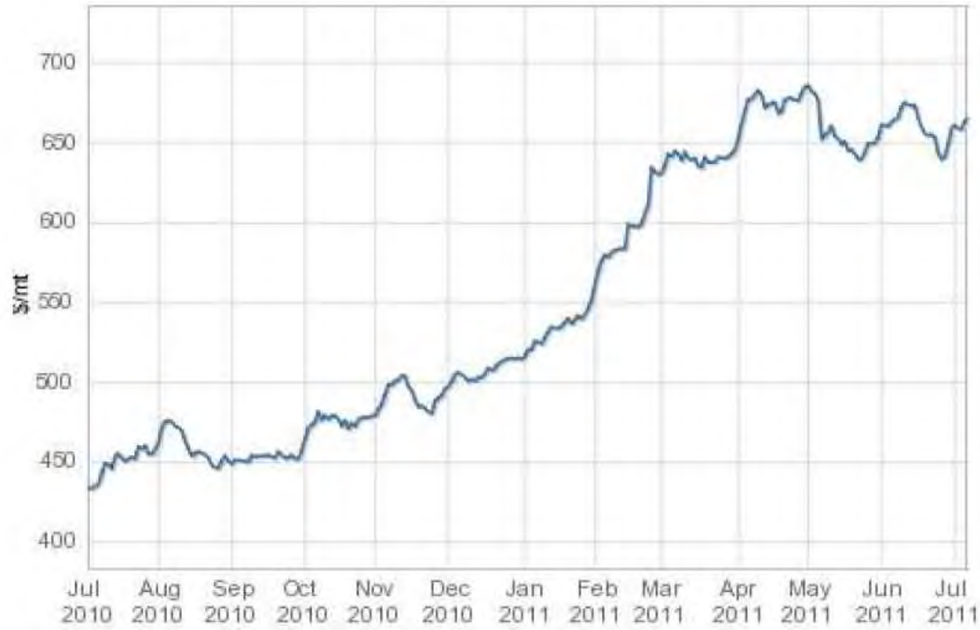
According to these assumptions and using 2010 effective data, the author then calculates **annual savings on consumptions**, **additional costs added for vessels operation** due to (or thanks to…) slow-steaming, **and in-transit inventory costs for containers** – which are several days longer on sea, then shipper is paid by his client only several days after and these containers are not useable for another transport or storage.

Dividing sum of added operation costs and in-transit inventory costs by savings on consumption gives a price per ton of fuel saved. If the effective price of fuel is higher, slow-steaming permits a gain equal to the difference between money earned by not paying the amount of fuel saved and price of additional costs to save this amount of fuel.

Main results are reported in figure 34. above. Although using assumptions and then to use carefully (change in freight rates, for examples, would change the results), they show that economic climate is quite favourable to slow-steaming, but that the latter is highly subjected to bunker price fluctuations (see red and purple lines on graph). To maintain slow-steaming, for environmental reasons, world coordinated policies should ensure a high level of bunker prices : limiting fuel production (very difficult, mining-claims being within states sovereignty), tax-levy or cap-and-trade system.

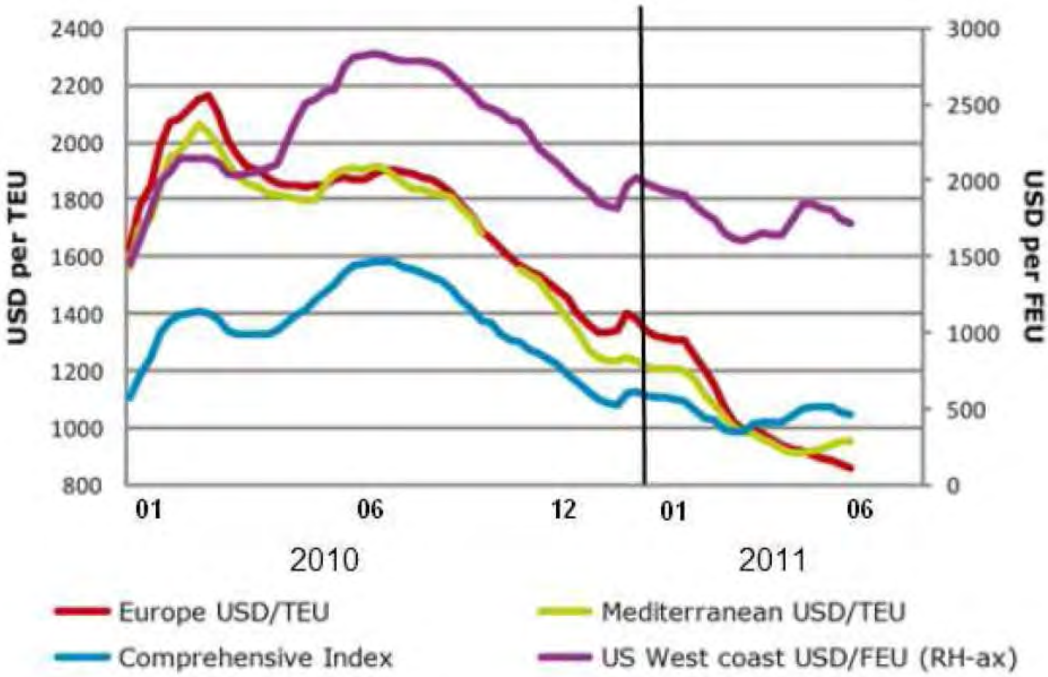
Transport price

*The **freight rate** is the amount of money charged by the carrier for transporting cargo overseas. Some fees and other charges come in addition to the freight rate : BAF/Bunker Adjustment Factor; CAF/Currency Adjustment Factor; THC/Terminal Handling Charges, piracy surcharges (e.g. for passing Eden Gulf), war risk premium (depending on countries on journey and period), fee for electronic release of cargo, container sealing fee and late fees as late collection of a bill of lading. Freight rates are known by various means, depending on type of cargo (newspaper, internet, shipbrokers). They can be highly volatile (containers, see figure 36) or contracted for several years (specialized markets as LNG)*



Source : Bunkerworld

Figure 35 : Bunker prices ($/ton IFO 380, world average). These are highly volatile, but seem to be high enough since two or three years to permit sustainable slow-steaming. Extracted from Economic conditions, sea transport, 1st semester 2011 analysis, (Mission de la Flotte de Commerce *of French ministry in charge of transports*).



Source : BIMCO, Shangai Shipping Exchange

Figure 36 : freight rates for containers, 2010 – 2011. FEU = Forty feet Equivalent Unit. Container carriage by sea is a strongly competitive sector, subject to high prices variations, depending on economic climate. When demand falls, overcapacity leads to some carriers using their container ships for other cargo than containers. Nevertheless, every cargo cannot be transported in every ship. For example, gaz or oil needs specific vessels (tankers).

Appendix 6. Motorways of the Sea

Short-distance sea transport

Short-distance sea transport represents a chance to meet the needs of growing trade within a European Union extended to 27 Member States and to reduce increasing road traffic. Public authorities and the European Union present short-distance sea transport as a direct alternative that will relieve road network congestion (mountainous sections, metropolitan areas, frontiers, etc.). However, short-distance sea transport at present raises difficult economic issues, mainly because the relationship between demand (shippers) and offer (operators) remains uncertain. Whilst the sea transport mode has development capacities, it nevertheless suffers from insufficient competitiveness in relation to road transport competition (regulations, limited charging of costs, load breaking at ports).

Several problems continue to hamper accelerated development of short-distance sea transport:

- It is not yet fully integrated into the door-to-door procurement chain based multimodal transport
- It is subject to complex administrative procedures
- It requires greater efficiency of port services and easy access to the hinterland.

Motorways of the sea: definition and factors affecting success

Motorways of the sea are an example and a major instrument for promoting short-distance sea transport. A motorway of the sea is a high-frequency link that offers door-to-door intermodal transport and allows modal transfer of HGVs from the road to the sea by concentrating goods flows on sea routes.

In 2001, the European Commission White paper on European transport policy [1] stated that developing motorways of the sea represents a true alternative to land routes and that some of these links, particularly those enabling Alpine and Pyrenean bottlenecks to be by-passed, should belong to the trans-European Network. In awareness of the limit to spontaneous creation of coasting services, the White Paper suggested granting them a “seal of approval” and assisting their establishment through European funding.

In April 2003, a report by French Senator Henri de Richemont [74] highlighted the reasons for the failure of several coasting services (insufficient capital, unsuitable offer, lack of dedicated industrial traffic, diffuse road transport demand) and, as a consequence, proposed a keener political willingness and public authority intervention (State and local authorities). This commitment should allow organisation of a credible transport offer based on three principles: durability, regularity and frequency. The report also proposes that the ship be “likened to an infrastructure"[6]. Finally, the de Richemont report suggests that the State should be the organising authority, specifically through setting up of semi-public companies owning the roll-on/roll-off ships[7] put into service. These semi-public companies will combine not only the State and local authorities, but also the port retained, road haulage contractors, transport logistical companies, handling contractors, motorway concessionary companies and the private company operating the line.

The Van Miert report (2003 [75]) maintains that successful launching motorways of the sea depends on a number of preliminary conditions or parallel measures, such as freight concentration, support of road haulage contractors, shippers and transport agents, removal of customs inspections and administrative procedures, development of electronic declaration for port authorities and availability of suitable facilities. The Van Miert project is not directive in terms of transport corridors and therefore ports, but it nevertheless admits that the most difficult stage for Member step is to select ports capable of participating in the motorway of the sea. If selection proves to be too difficult at national level, a global call for tenders could be extended to ports and shipping companies and let candidate consortia select suitable ports.

6 The report author thus considers the ship to be "a long service life infrastructure justifiable to future generations, who will have to participate financially (repayment of public debt)".

7 Ships would be coasters providing high frequency services. Estimated costs are 30 million euros for a coaster (equivalent to 5 km of motorway in the plain), 70 to75 million euros for a ro-pax (50 cabins). According to the report, investment in acquiring – or chartering – a ship is cheaper and quicker than construction of road-, rail- or inland water-type infrastructure.

Resorting to motorways of the sea implies adopting a multimodal outlook, in which load breaking and partial subcontracting of transport (sea transit) must represent a financial advantage. The question is therefore whether there is a price and transit offer that is effectively competitive compared with the all-road solution. The motorway of the sea should also be viewed as a new transport concept within the more general framework of commercialising the multimodal logistics offer (by transport or logistical companies), in which the most important parameter is efficiency (schedule compliance).

Example of the Toulon – Livorno line

The service concept implemented was similar to that of a motorway of the sea designed to by-pass a natural obstacle (Alpine crossing) but involving a sea distance that only allowed one rotation every 48 hours (whilst the motorway of the sea concept would require a high-frequency service). The Port of Marseille was unanimously decided against for cost and rigidity reasons; The two ports retained made efforts to reduce their tariffs and adapt their facilities for operating the service. The shipping agent considered that the rotation must be long enough to stimulate the interest of road transporters and prompt a substantial saving in road transport costs.

The service launched in October 2000 offered 3 rotations per week using a Ro-Ro ship with a capacity of 117 trailers, including 80 tractor-trailer combinations and cabin capacity for 38 drivers. The ship left alternately the ports of Toulon and Livorno at 1900 h and the night crossing took 11 hours. The invoiced price was 2,800 French francs (427€) for a single journey and 5,100 French francs (777€) for a return journey. Unfortunately, the service was halted after only 15 days when the bank stopped backing the operator.

Traffic flows concerned by motorways of the sea are usually of the same order of magnitude as those described above for the Toulon-Livorno line. For example, the ship used for the Nantes (West France) - Gijon (North Spain) line – which was initially foreseen in a projected motorway of the sea between Norway, Boulogne in France and Santander in Spain, never achieved – has a capacity of 85 unaccompanied trailers and represented an investment of 60 million Euros. Its full operating capacity is 25,000 unaccompanied trailers/year, i.e. some 500,000 tonnes. Today, an average of 35 trailers are transported by trip, with three rotations a week.

The intended aim of the operator was to achieve 100% load factor from the 3rd month of operation onwards and to then move quickly to a 2-ship service offering a daytime departure in both directions each day. Failure in this case would appear to be associated with an identifiable combination of factors:

- Insufficient capital: only 250,000 French francs (38,000 €) equity capital for 5 million French francs (0.76 M€) of loan-based investments and for a 6 million French franc (0.91M€) cash flow requirement (load increase, payment times, etc.) financed through bank cooperation. Losses can quickly become considerable with a ship chartering cost rising to 10,500 USD/day at the time
- Excessive optimism of the service promoter in terms of market and forecast load factor: 12 to 18 months are required for service load increase
- Cost identical or just less than that of an all-road journey: a road haulage contractor must be offered substantially greater advantages than the former situation for it to accept a logistical change
- Ignorance of the market (no real market study), error of judgement based on vague promises made by transport company managers
- Questionable rotation: Marseille shipowners were in favour of a shorter rotation (Toulon - Savona) allowing one departure per day in each direction from the start and penetrating the heart of the market (Turin / Milan).

More generally, the problems encountered when launching motorways of the sea can be related to:

- Ignorance of the market and the road transport organisation
- The difficulty in evaluating the market share likely to be acquired
- Excessive traffic imbalance
- Insufficient preliminary commercial action
- Insufficiently dense hinterlands near the ports concerned
- A very limited service offer: departure frequency, departure and arrival times, port waiting times, reliability, port services and facilities
- Over-complex customs and administrative formalities and procedures
- An insufficiently competitive price compared with road transport; it is considered that a motorway of the sea service must propose a tariff 10 – 20% less than the road transport tariff.

Combined Passenger and Ro-Ro ferry in Patras, Greece. It sails between Patras and Italy (Bari, Brindisi, Ancona, Venezia), a "natural" sea link - © Bruno Meignien

Appendix 7. Container Traffic

In 2009, as in 2005, the six main container ports were located in Asia (see appendix 2). In Europe, only Rotterdam (10th position), Hamburg (14th position), Antwerp (15th position) and Bremehaven (20th) were among the 20 largest ports.

Figure 37 provides forecasts of container activity for each market in 2006 and 2007. Actual figures were in the trend forecasted. Forecasts must be however cautiously used. They often misestimate long-term growth and abrupt changes-over. For example, the world container trade suffered a lot during recession (more than other cargos) ; forecasts were totally out.

It is particularly apparent that Asia – America traffic prevails strongly. Moreover, trade growth on this market is balanced. On the other hand, there is a major imbalance in traffic growth for Europe – Asia trade (+4.9% in the Europe – Asia direction and +10.3% in the opposite direction) and for Asia – Mediterranean trade (+6.8% in the Mediterranean – Asia direction and +21.4% in the opposite direction).

These movements result in the transport of large volumes of empty containers, which adversely affect the profitability of the most imbalanced links.

Note. Abbreviations EB and WB correspond to East Bound (trade in West to East direction) and West Bound (trade in East to West direction) respectively.

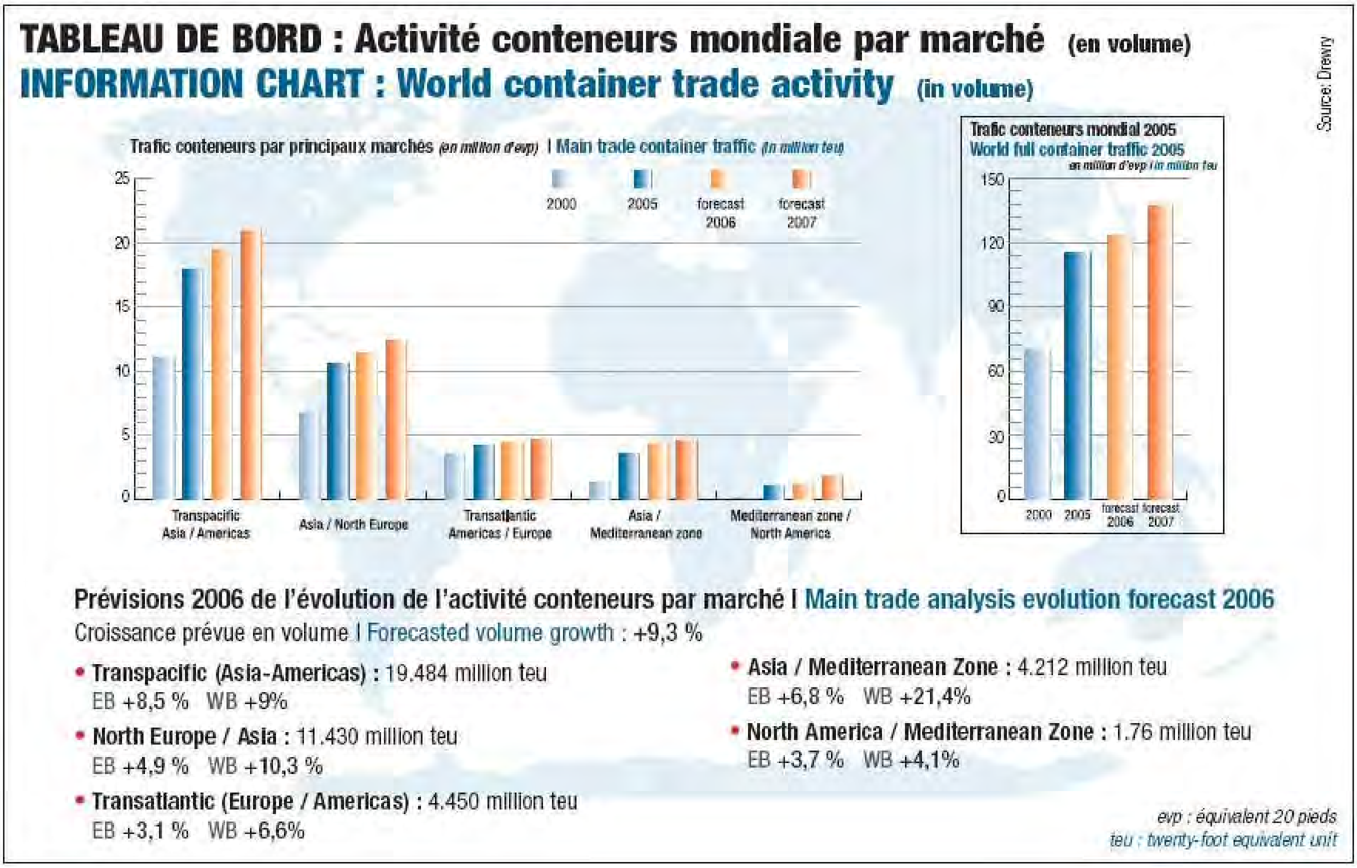


Figure 37. Container traffic current and forecast activity per market – source Drewry

Appendix 8. Port Services offered to Ships

Services offered to ships involve two types of company:

- Those that intervene in ship docking operations and contribute to their safety: piloting, towage, boatage
- Those that intervene on land: maintenance and repairs, miscellaneous services.

Piloting

Port pilots advise a ship's captain and provide him all information required for navigating in the approaches to, and inside, ports.

Piloting is compulsory, but the regulations grant an exemption to small ships or a captain-pilot's licence to the captain of a ship satisfying specific conditions. This is the case when ships call very regularly at a port.

The piloting tariff is fixed by prefectural order.

Towage

The high-powered marine engines of port tugs assist in manoeuvring and docking ships at the port.

Towing is not compulsory; companies performing this operation are private and are free to set their tariffs after Advisory opinion of a user commission. Greater ship autonomy explains the gradual decrease not only in towing needs, but also in the number of employees and in the fleet performing this operation.

Boatage

Boatage companies ensure mooring, warping and mooring release. Boatage is not compulsory.

In addition to this activity, boatage companies perform various services: preventing and combating port pollution, anchorage transport, crew additions. In common with pilots and tug crews, these professionals ensure the permanency of their activity.

Other stakeholders in shipping services

- Ship's supply and bunkering companies provide provisions, equipment, fuel, etc.
- Naval repair companies offer services associated with port facilities, ranging from winch repair to ship "jumboing" (heavy operation to lengthen the ship after having cut it in two!). Container repair, rental and maintenance companies also offer their services to container ships
- Ship's waste collection companies deal with disposal of domestic and specialised waste products.

Appendix 9. Port Calling Costs

Source : DAEI / SES, Charles Bergano, July/August 2002 [76]

Port calling costs result from the port make available its structures, facilities and services to ships in relation to transported goods. These costs are directly covered by the port and transferred to their users based on port tariffs. They are composed of fixed costs independent of the tonnage loaded and unloaded and variable costs dependent on the operational scale of the call.

Fixed costs

Fixed costs are composed of the cost of deviating the ship to enter port, the costs of piloting, towing and boatage and the port dues applied to ships, to which vessel identification and vessel traffic service (VTS) may be added at some ports (*cf.* lexicon).

For the ports of Nantes, Le Havre and Rouen, the report entitled "Indicateurs de suivi des axes et pôles stratégiques de la politique de transport" [indicators for monitoring transport policy strategic axioms and principles] [30] provides examples of port dues and technical services costs charged to different types of ships.

Variable costs

Variable costs are mainly composed of handling costs, to which vessel costs incurred during loading and unloading operations are added.

Depending on the transport contract, all or part of the handling costs incurred by the ship for loading or unloading the goods is reimbursed by the shipper. This "contribution" of the shipper to the handling costs often takes the form of a lump sum (fixed by the shipowner), so-called "Terminal Handling Charges" (THC) for containers and "Port Liner Terms Charges" (PLTC) for conventional goods. However, a proportion of the handling costs remains fully charged to the ship, for example the empty container loading and unloading costs.

Parameters that can influence port calling costs are:

- The type of ship
- The volume handled during the call
- The geographical location of the port and terminal (high on an estuary or on sea coast with waiting or no waiting for tides, locking to access a basin at constant level, etc.)
- Number of tugs used, frequency and duration of operations, etc.
- tariff structure, incentives introduced by various forms of cost reduction, etc.

Port calling costs also depend on waiting times.

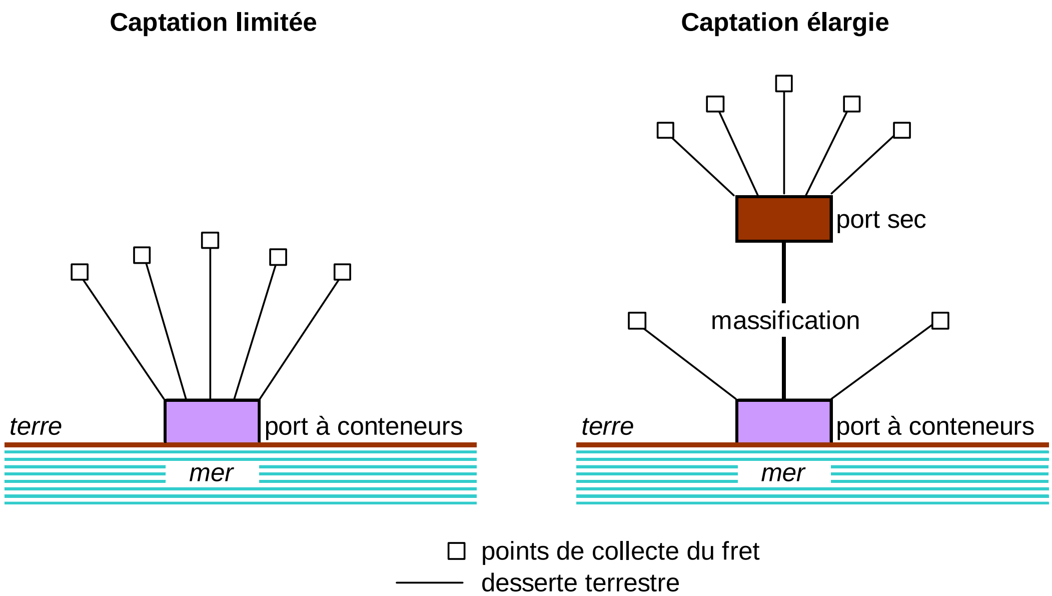
Appendix 10. Dry and Inland Ports

The notion of a dry port originated in the development of container sea transport in the 1970s and the problems of inland transport services to and from these ports. The need to accelerate rotations of ever more gigantic container ships (11,000 TEU ships – or 13-15,000 depending on the way to use its capacity – at present and 18,000 forecast) leads to concentration of port calls at a small number of central port hubs likely to generate enough traffic (1,500 to 2,000 TEU per port call) and at strategic locations offering sufficient draught and suitable trans-shipment facilities and efficient inland transport services. These multiple factors cause an increase in distribution needs and encourage development of projects involving sea/rail, sea/river transport and sea/sea (feedering) combinations.

The containerisation, intermodality and logistical system surrounding these projects have led to spatial and functional adaptations of port systems and inland transport services.

On land, the pressure exerted by evolving port hierarchy on collection and distribution networks has led to **creation of inland break-down hubs**. These inland trans-shipment centres enable the land transport network to be extended far beyond sea ports, thereby reducing the load on collection and distribution networks. Shipowners establish operational centres at inland hubs, which then become true container management facilities nearer to client industries. Formerly, containers were “repositioned” at sea ports near the port area itself. Development of inland ports, such as Gennevilliers for the Port of Le Havre and Lyon for the Port of Marseille, are contributing to this transport development.

Traffic flow concentration within a few major routes or high-flow intermodal corridors linking sea ports to large inland hubs is the most tangible outcome of this spatial and functional development. In this connection, appearance of break-down hubs and land corridors is essential to large scale concentration within the port system and to preventing asphyxiation of not only collection and distribution networks, but also trans-shipment centres (*cf.* Figure 27).



Captation limitée = *Limited intake;* Captation élargie = *Extended intake;* terre = *land,* port à conteneurs = *container port;*mer = *sea;* port sec = *dry port;* massification = *massification;* point de collecte du fret = *freight collection points;* desserte terrestre = *inland transport service*

Figure 38. Sea port hinterland and Dry port

Dry ports or inland ports?

The distinguishing factor between these two characterising terms is based on the legal and statutory system to which the goods belong:

- The "dry port" will be a hub intended for logistics, receiving mainly sea containers for storage or repair, which is not necessarily based on accurately identifiable maritime commercial and legal logic; everyone can undertake transport and logistics operations at dry ports
- In addition to the functions of a dry port, the “inland port” embraces the commercial and statutory dynamic (shipowners, chamber of commerce) of an accurately identified port, which ensures its financing.

The inland port is often linked to a navigable waterway and, in this case, it is obviously not “dry”! It is, above all, an extension of the original port in respect of the goods cycle, goods handling and infrastructure management. A container conveyed to the inland port is then transferred administratively and legally such that it becomes subject to international sea transport regulations. Moreover, the transport contract and customs clearance system under which a container is transported may not be interrupted; passing through an inland port is then "transparent".

Finally, transport agency (freight forwarding agents), expediting (shippers) and handling operations (handling agents) are compulsory at an inland port.

Examples

The **Port of Le Havre** wishes to take advantage of and optimise the transport infrastructure represented by the River Seine for transporting containers. In 1996, the Port Autonome du Havre [Le Havre port authority] invested in Paris Terminal S.A., the container terminal management company at the Gennevilliers and Bonneuil-sur-Marne (Port Autonome de Paris) hubs connected to the Port of Le Havre by the rivers Seine and Marne. The **Gennevilliers** hub is today considered an inland port for Le Havre. Other river-based hubs will soon complement this system in the Paris basin to the east and south of the River Seine as well as to the north on the River Oise. Their development is fundamental to flow massification, which will ensure rapid growth in river traffic.

On a smaller scale, the **Bordeaux International Freight** terminal, located at the Bruges area near the Bordeaux urban area and connected to the rail network, operates as an inland port for the **Port of Verdon** at the far end of the River Gironde estuary. Shipowners perform operations in the terminal bonded area involving container filling and emptying, storage of goods and empty containers awaiting usage as well as maintenance and repair of the latter containers. Two combined transport sites are also operated at this terminal.

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Air Transport Capacity

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Introduction

The purpose of this section is to describe the key components in understanding air transport capacity.

Over a number of decades (Source: "Le fret aérien: une importance méconnue" [*Air freight: an unknown significance*], DGAC [77]), air freight has developed widely based on technical advances in the aircraft industry, particularly during the Second World War. One of the most famous exploits was the 'Berlin Airlift' between 1948 and 1949, during which over 3.5 million tonnes of freight were transported into West Berlin by air in just one year. The second 'air freight revolution' took place at the end of the 1950s with the first generation of commercial jet aircraft and subsequently in 1970 with the so-called "jumbo jet" aircraft, which prompted greater capacity and speed. Between 1960 and 2010, air freight traffic (at both national and international levels) increased from 2.5 to approx. 200 billion tonne-kilometres carried (Source: IATA / International Air Transport Association. Traffic values over the same period are ~20% less based on the ICAO / International Civil Aviation Organisation definition) and has therefore been multiplied by 80. Air transport is a sector in which progress is rapid in terms of both airport operation and air navigation techniques.

Freight tonnages transported by air (46 million tons expected in 2011 – source IATA) remain low compared to the billion tons transported each year by sea (>7 billion tons), rail and road. The significant increase in tonne-kilometres carried is because of the greater distances being covered resulting from rapid development of Asian economies. However, the current economic importance of air freight relates to the value of the goods shipped. According to the different studies conducted by the Organisation for Economic Cooperation and Development (OECD) and by IATA, international air freight traffic only represents 0.5% of the world tonnage in terms of international traffic, but it also represents around 1/3 in terms of value. Finally, air transport is around 5 times more expensive than road transport and 50 times more expensive than sea transport, based on direct transport costs.

Air freight represents approximately 1.3 million tons per year of French international trade (note ; some figures on the internet can be higher, but counting several times a ton of freight handled several times). It has never been a major concern in relation to infrastructure because it is a marginal activity in terms of volume. Airports are primarily designed for passenger traffic and freight is only considered as a secondary activity.

Following a brief presentation of the air transport organisation, we will describe the characteristics of the handling equipment and systems implemented. Capacity issues are addressed not only through understanding the principles governing airport runway and air corridor operation, but also by describing a cargo terminal and the impact of its design on capacity.

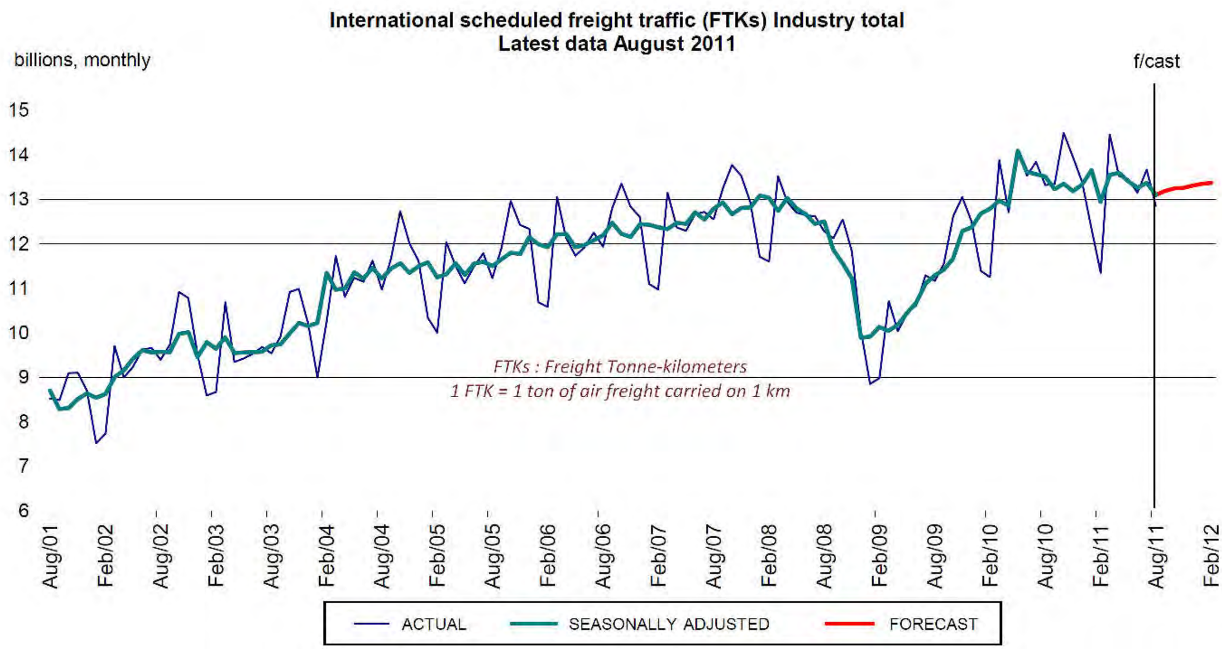

Figure 39 : International air freight traffic, which growth is following global world traffic trends, should represent in 2011 approx. 160 billion FTKs To compare with sea transport (32,500 billion t.km in 2008, or 200 times more) – source IATA economics 2011.

1 - Organisational Framework of Air Freight Transport

1.1 - Two types of air freight

Comparison of the different forms of offer and demand in the air freight sector leads to identification of two types of air freight – standard freight (referred as ‘general cargo’) and express freight. They differ in their definition of service even, particularly in terms of delivery deadlines, costs and pricing (with ratios varying from 1 to 10) and on data processing and organisational methods, etc. Furthermore, organisation of the entire door-to-door multimodal chain involves different stakeholders.

Express freight essentially includes packages, or even letters, for delivery within short deadlines (24 to 48 hours) and shipped using dedicated aircraft (all-cargo aircraft of various sizes). Goods are handled from one end to the other of the same organisational framework based on a dedicated powerful information system for tracking each individual item in real-time. For this purpose, specialised operators calling themselves ‘integrators’ have combined the separate key functions of conventional air freight – the ‘carrier’ function and the ‘forwarding agent’ function – because they market directly their door-to-door service to shippers.

General cargo involves larger batches (including 10-foot high pallets and even special shipments exceeding dimensional limits) subject to delivery deadlines generally ranging between 3 to 6 days. Quality of service and market prices are insufficient to justify and permit use of air transport for pre- and post-forwarding for intercontinental links (trucking services referred to later in this section). Finally, airlines receive most of their freight from freight forwarders and specialised forwarders (shipping agents).

The graph in Figure 1 represents the break-down of air freight according to the type of airline. A ‘passenger’-type airline does not market all-cargo flights but can carry goods during passenger flights.

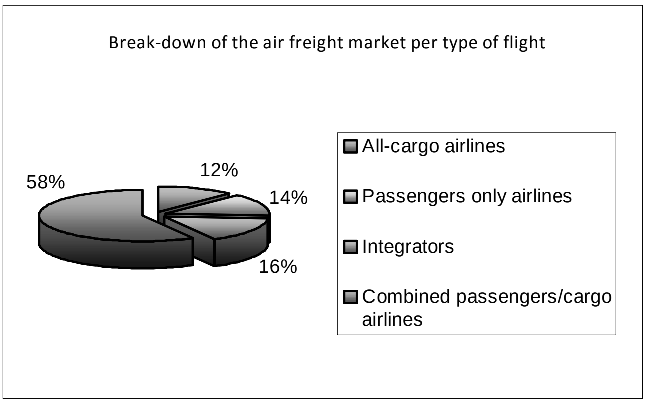

Figure 2. Break-down of the air freight market per type of flight (Source: Syndicat National des Agents et Groupeurs de Fret Aérien - SNAGFA, 2005)

A significant portion of continental links is and will be ensured by road within both market segments. It should be noted that **relevant potential flows involve a limited volume** i.e. several hundreds of tonnes per day. This volume is insignificant compared to the road traffic and congestion, safety and disturbance problems arising from such flows.

1.2 - A few air freight characteristics

Freight carried beneath passengers

This is a key component of air freight operation because approximately 50% of shipments are carried on board passenger aircraft. This proportion varies from one airline to another (e.g. this figure is 70% for British Airways and only 20% for Korean Air).

On average, each passenger ‘is sitting’ on approximately 20 kg of freight (other then passenger luggage). Marketing of hold space thereby contributes to the profitability of regular airline routes. This organisation allows operators to take advantage of flight networks and frequencies offered by airlines. However, this type of traffic only allows carriage of certain types of goods and involves very stringent securing.

Notion of truck service (trucking)

A truck service or trucking comprises a specialised road transport system organised such that it ensures flexible adaptation to the air transport format. This is an airport interlinking system, in which goods are shipped by truck with an Airway Bill ("*Lettre de Transport Aérien*"–*LTA*). Air trucking involves specific equipment: trucks are equipped with rollerways, container anchoring devices and air transport pallets identical to those used inside aircraft. Road transport is nearly as fast and ten times cheaper than air freight over short and medium distances, which are common on the European market (where 2/3 of air freight is transported by truck).

This system is undoubtedly a curb to the development of air freight from regional airports, it does nevertheless offer a number of advantages to air freight operators: reduced unit costs, greater flexibility, concentration of flows at a single platform, higher load factors for airlines and enhanced purchasing power for transport agents. A French decree (dated 13th July 2004) [78] grants special exemption to these trucks for travelling on French roads between 10.00 pm on Saturdays and 10.00 pm on Sundays.

1.3 - Air freight stakeholders

Shippers

Shippers are freight transport users and generally work with the shipping agent.

Air Freight Agents: Shipping agents, Freight Forwarders and Groupage Companies

Air freight agents act on behalf of shippers. They ensure safe arrival of the shipment, choose their sub-contractors and make sure that packages are secured. Subject to the instructions they receive, they are free or not in their selection of carriers and routes. The major air freight agents include DHL Danzas, Schenker, Kuehne+Nagel, Kintetsu, etc. It must be reminded that contrary to shipping agents, freight forwarders, by definition, can choose between several transport modes to achieve a transport from a point A to a point B, in order to find the better cost/service compromise.

Handling Companies and Ground Handling Service Companies

These companies are airlines, airport subsidiaries and specialised companies. This sector is opening to competition in Europe.

General Cargo Carriers

These are either passenger or combined airlines, in which air freight may represent a significant part of the activity (e.g. 18 - 20% of Air France's turnover), or companies handling only cargo (e.g. Cargolux or ATLAS Air). They work in collaboration with shipping agents and logisticians. Relations between these three stakeholders are critically important, as is control of the goods tracking system.

It should be noted that, in most cases, airlines are network-structured around 'hubs', which are the same as passenger airport hubs. This hub phenomenon has contributed to the scarcity of international lines leaving provincial airports. In France, the Roissy – Charles de Gaulle airport handles 87% of all air freight.

Management of unbalanced flows is a major issue for airlines due to the fact that load factors are high in the Asia to Europe direction, but low in the opposite direction. Companies have solved this problem by including intermediate stopovers and reducing prices.

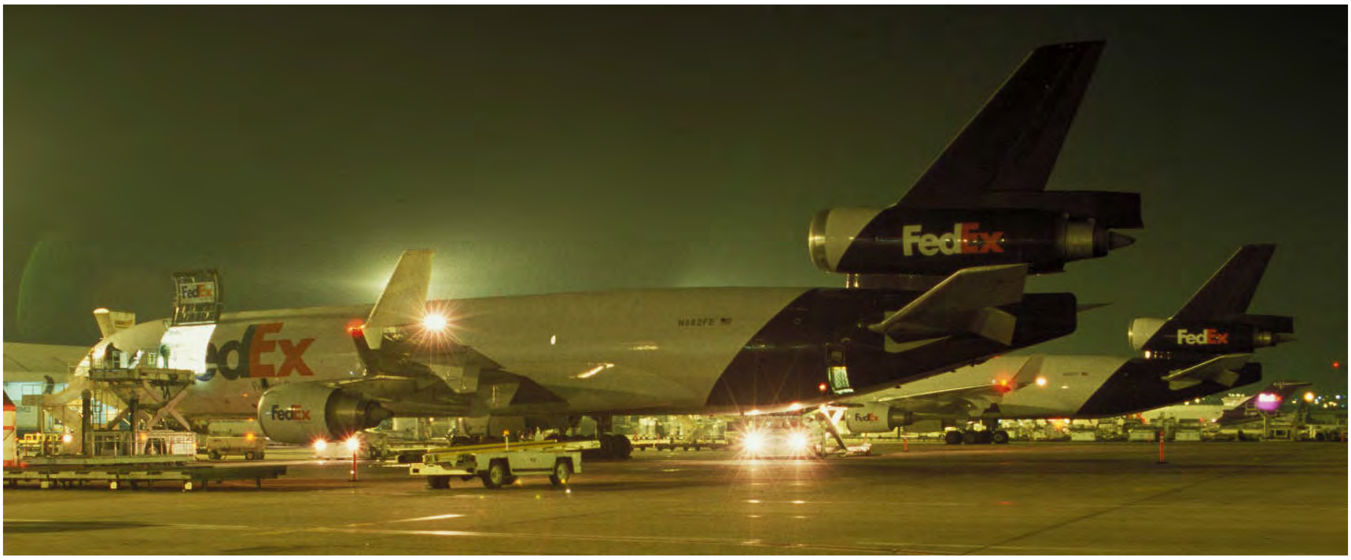

Figure 2. Fedex MD11 alignment (© photothèque STAC / Véronique PAUL – Graphix)

Integrators (or Express Delivery Services) : figures 2007

This activity was developed in the Unites States and mainly concerns express freight. Four main groups (75% of the international market) prevail on this market, including two American groups - Federal Express (Fedex) and UPS. DHL, which was American initially, is now operated by the German postal services and TNT is operated by the Dutch postal services. These companies also use airport hubs, where they work at night. They have set up hub chains all over the world. For instance, TNT has a hub at Liège, which is linked to 80 European airports (20% of all tonnage handled by air). Fedex's main hub is at Memphis and the company operates others both in the United States and on each continent. Its European hub is Paris Charles-de-Gaulle airport.

Integrators currently have the highest growth rates and should represent 50% of the air freight market in 2015. It should be noted that their operational boundary with general freight carriers is sometimes unclear because they tend to transport ever larger packages.

Airport Managers

Airport managers set up and operate airport platforms, manage airport infrastructures and offer various services to both airports (ground handling, security and safety, etc.) and passengers (shopping and services, parking).

Government Services

Government services include inspections inherent in goods transport (customs, phytosanitary and veterinary inspections) as well as safety inspections.

1.4 – Air logistical chain and capacity-related issues

The air logistical chain is complex because it is subject to multiple constraints (especially safety-related) and, as seen above, involves many stakeholders. Figure 3 details its sequencing:

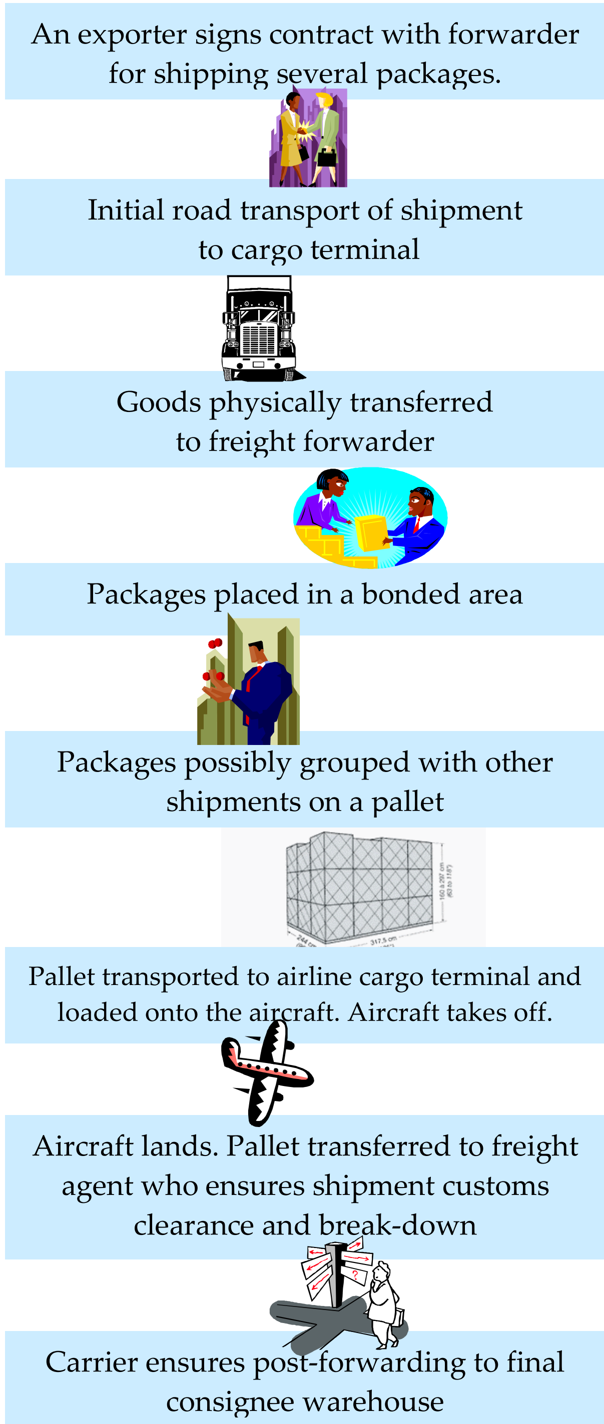

Figure 3. Air logistical chain sequencing

In this sequence, the main capacity-related issues referred to by air freight agents are as follows:

- Road congestion-related problem in urban areas, when pre- and post-forwarding by road (this issue will not be detailed here).
- Capacity of warehouses used by air freight agents and airlines; import/export ratio-related developments, in particular, require warehouse capacity adaptation.
- Transfer fluidity between picking up of goods by the agent till loading onto the

airplane is a major issue. Logistical chain fluidity can be hindered by ever stricter administrative requirements concerning safety and customs and sanitary inspections and this can specifically affect airport selection. Warehouse management must be optimised by transport agents and airlines.

- Unlike express freight, the issue of airport runway saturation is not a real problem for general cargo because time deadlines are not essential for this type of goods

1.5 - Goods transported

The type of goods transported by air is determined by competition with other transport modes (transport by air is 10 times more expensive than by road and 100 times more expensive than by sea, based on direct transport costs) and comprises:

- 70% of products with a high-added value: textiles, cosmetics, chemical and pharmaceutical products, automotive or air industry equipment, etc.

- 30% of products that are perishable due to either their nature (living animals, fruit and vegetables) or their function (press, exhibitions, postal freight).

Air freight represents ~1/3 of the overall trade between different regions of the world, but only 0.5% in volume. For France, it represents 0.1% in volume and 15% in value.

1.6 - Prospects

All before-crisis conducted studies (source: Boeing, Airbus, airlines, Merge-Global study) indicated that the freight sector will continue to develop at a rate of 5 - 7% per year until 2020. The air freight market was therefore forecasted to treble between 2001 and 2021. New studies (Boeing, Airbus, 2010) then foresee 1/3 less… this remains very uncertain.

Main factors for these forecasts (to use cautiously) :

- Economic factors - further globalisation of world economy and Asian economy boom
- Technical factors - increased capacity of combined and all-cargo aeroplane, air containerisation.
- Direct logistics flow production management methods, express freight boom

Example. Chinese-European market

Trade between Europe and China represents strong potential growth in air transport. For instance, express delivery service providers have long favoured the trans-Pacific route but are currently focusing more and more on opportunities arising from Chinese-European trade relations. European companies have reinforced their position by signing agreements with Chinese counterparts. On the other hand, it is difficult to know what strategy the major Chinese airlines will adopt for Europe.

However, unbalanced flows between China and Europe represent a curb to development this promising market.

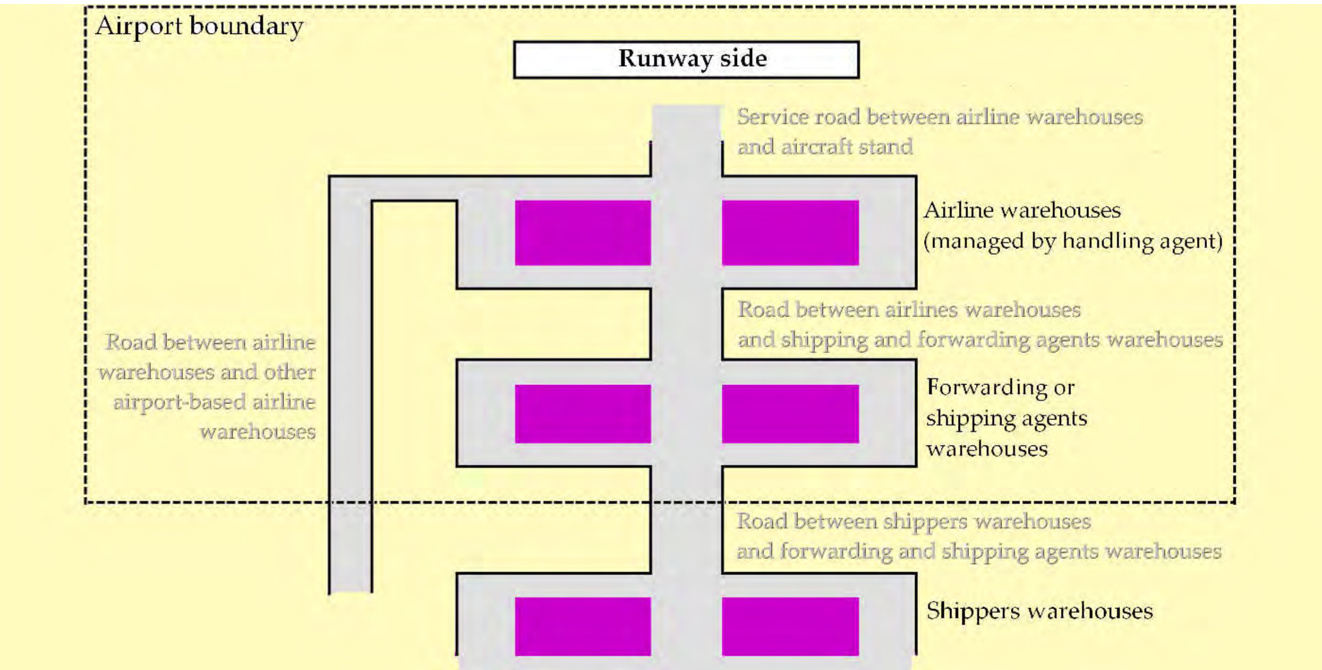

Figure 4. General Cargo flow

All-cargo airports

Noise pollution issues and night flight cancellation threats have created a new political and economic conditions that are highly advantageous to freight-dedicated airports (Châteauroux, Vatry in France). However, night flight cancellation threats are generally not brought to conclusion, under economical arguments. The night flight cancellation threat has been prevented so far at CDG, although operator *Aéroports de Paris* (Paris Airports) being even more under pressure, with some measures taken as night tariff extension – in 2009, consequence of "Grenelle" environment law, night period for landing fee at Roissy-Charles de Gaulle airport changed from 23:30-6:00 to 22:00-6 – or changes in trajectory – increasing altitudes for some trajectories by decree of the 15th November 2011. There were in 2011 an average of 160 movements per night at Roissy hub.

These airports are banking on both development of all-cargo operations and the possibility of becoming hubs for integrators. Furthermore, an airport such as Vatry has further advantages involving operating costs (royalties, cost of handling services), which mean relatively low aircraft turn-around costs, which can be twice as high at an airport like Charles de Gaule (CDG). Other advantages are that Vatry offers high property availability, non-congested motorway links and no noise emission restrictions.

Conversely, for an airline such as Air France, freight activity relocation to all-cargo airports is difficult to envisage because it already has an efficient hub (CDG), whilst 50% of its freight traffic is directly linked to passenger traffic. Other issues involve loss of competitiveness for the Ile-de-France region due to a 2- to 3-hour journey to Vatry and the loss of employment. Certain all-cargo operators based at Roissy airport reason differently that uncoupling infrastructures and personnel is inconceivable in operation and cost terms. These carriers are clearly against the relocation option, but when forced, they will decide to transfer their activity to other combined airports, such as Brussels or Luxemburg, or to freight-dedicated airports and they will know how to implement substitute land transport solutions.

The main role of all-cargo airports is therefore essentially to accommodate integrators or new irregular traffic, for which there is no longer room at CDG. In this light, their development should not only to be considered competitive, but also complimentary.

Example. Vatry airport

Vatry airport is well-equipped and provides a round-the-clock service. It has developed a multimodal area and has succeeded in attracting a large number of logistical operators. Traffic has increased from 8,730 tonnes in 2003 to 40,500 tonnes in 2008. A 8,100-m² second freight terminal increased airport capacity to 120,000 tonnes in 2007. However, 2010 traffic at Vatry airport was only 8,000 tons – Roissy CDG: 2.4 million tons (import+export+transhipment)

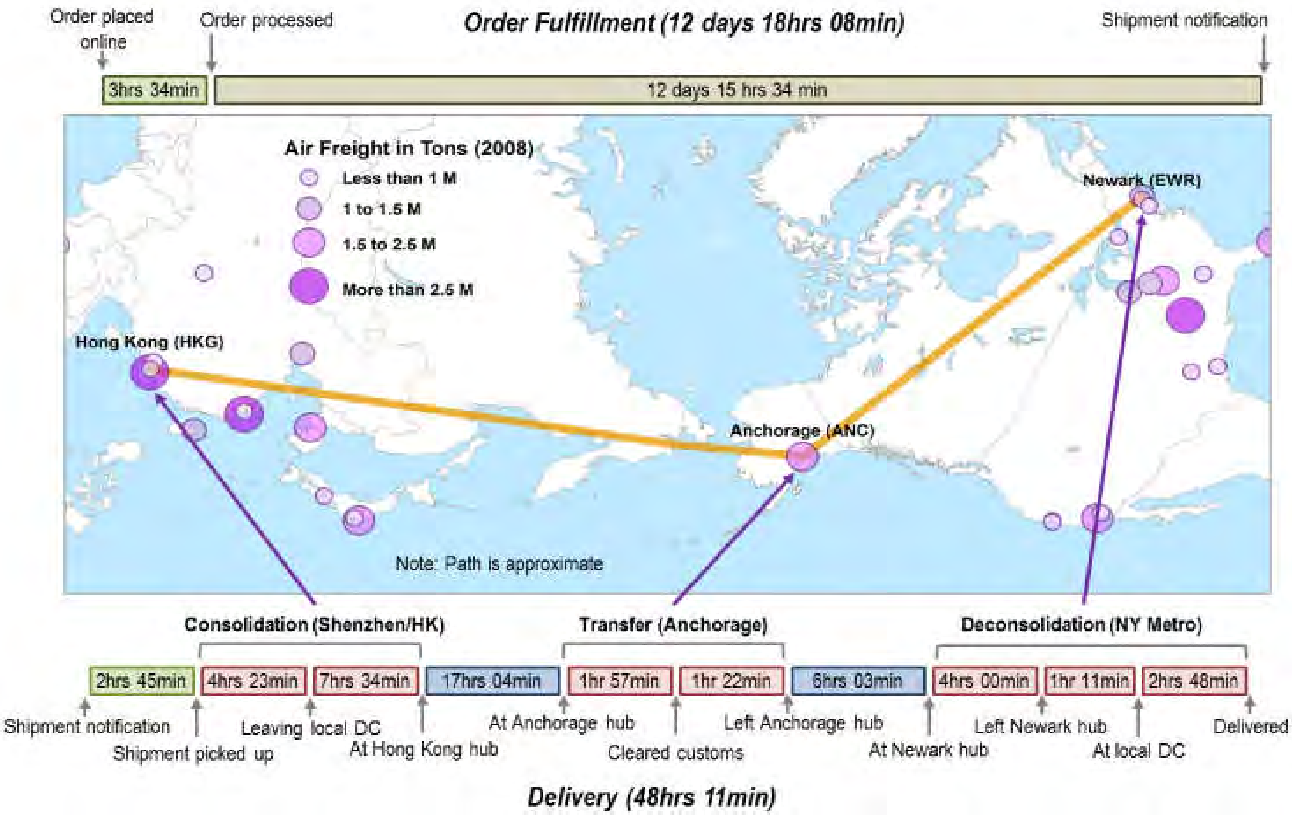

Figure 5: Order-delivery sequence of an Apple i-pad – *source Dr Jean-Paul Rodrigue, Hofstra University : Sequence from one observation.*

2 - Equipment Used for Air Freight

2.1 - Unit Load Devices (ULD)

2.1.1 – Pallets

Pallets are mainly used by air freight agents and airlines to group goods, which have been previously made secure. There are several types of pallets: the largest, known as P7A, are only loaded onto B747 Cargo aircraft. They can provide a volume of 39 m^3 and contain 29 tonnes of goods. Passenger planes (B777/A340/A330) can carry 10-foot high pallets with a net capacity of 19 m^3 containing goods weighing up to 6 tonnes in their holds. Pallets loaded onto A320/B737 aircraft only have a net capacity of 2.7 m^3.

2.1.2 - Containers

Unlike pallets, containers are closed containers of several types. The largest have a volume of 13 m^3 and are only used on cargo aircraft. Containers transported in the holds of passenger aircraft have a volume of 4 m^3. Some containers have a specific function such as isothermal or refrigerating containers, horse stalls, secured containers, etc.

Pallets are generally protected with a plastic film and are covered with a net.

Figure 9. Loading an express freight container into a truck (© photothèque STAC / Véronique PAUL – Graphix)

96 x 125 SCD type pallet

Dimensions (cm)	*Volume*	*Tare weight*	*Certified max. gross weight (kg)*	*Aircraft compatibility*
L : 317.5 w : 244 h : 299.7	17.3 m^3	125	6,800	B747F / B747 / A340 / A330 / B777

4-mm wide pallet entirely made of aluminium, with an edging comprising a groove for fastening the net and tie-down straps. The net is fitted permanently on one side (317.5 cm).

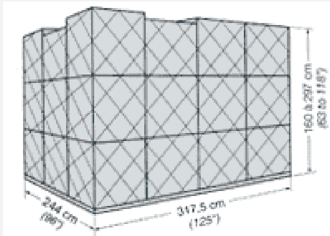

Figure 6 : example of an air pallet

Aircraft hold container

Dimensions (cm)	*Volume*	*Tare weight*	*Certified max. gross weight (kg)*	*Aircraft compatibility*
L : 317.5 w : 244 h : 162.5	10.8 m^3	285	6,800 on the deck 4,625 in the cargo hold	B747F / B747 / A340 / A330 / B777

Container made entirely of aluminium, open on the 317.5-cm side. Closed with a tarpaulin and net with straps. Adjustable ceiling, adapted for transporting clothes on hangers. Certain containers are fitted with securable solid doors.

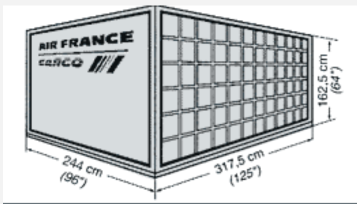

Figure 7 : Aircraft hold container

AKN air container

Dimensions (cm)	*Volume*	*Tare weight*	*Certified max. gross weight (kg)*	*Aircraft compatibility*
L : 156 w : 153.4 h : 160	3.9 m^3	120	1,587	A340 / A330

Container made entirelyof aluminium, open on one side (156 cm). Closed by a dual metal door. Handled with an elevator. Adjustable ceiling, adapted for transporting clothes on hangers. Securable door.

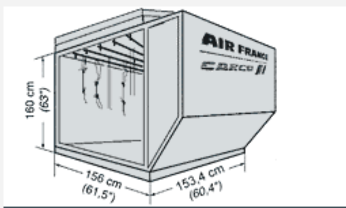

Figure 8. AKN air container

2.2 - Aircraft

2.2.1 – Cargo hold capacity of combined aircraft (mixed passenger and freight)

Example : Boeing 777	
Cargo hold volume (m^3)	Capacity (tons)
80 6 pallets + bulk products	23 to 32

Example : Airbus A310-300	
Cargo hold volume (m^3)	Capacity (tons)
	13 tons on 3,500 NM (220 passengers) or 7 tons on 4,000 NM

NM = Nautical miles

Example : Airbus A330-300	
Cargo hold volume (m^3)	Capacity (tons)
132	32 tons on 4,500 NM (295 passengers) or 20 tons on 5,000 NM

For further details, consult passenger aircraft characteristics

The "quick change" system should be noted. This involves quick conversion of a passenger aircraft (removing seats, even floor) into a freight aircraft. Reversibility increases the price of an aircraft by 15%.

Last, it is believed that a 70% increase in the number of freight aircraft can be achieved by converting second-hand passenger aircraft on the market.

2.2.2 - Description of a cargo aircraft

Physical characteristics

Ideally, a cargo aircraft has a cargo hold height of 3 m and a ground clearance of 1.2 m to be independent (very rare). It has large lateral or axial doors (a B747 has both). Quality of floor and wall anchorage points is essential.

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Figure 10. Internal view of a Boeing 747 cargo hold – © photothèque STAC / Véronique PAUL – Graphix)

Economic aspects

An annual flight time of 5,000 hours is an ambitious objective for a long-range cargo aircraft. The weight/volume ratio varies between 140 and 200 kg/m^3. Compared to combined aircraft, the long-range cargo aircraft has two advantages:

- Transport of products not authorised on combined aircraft.
- Guaranteed capacity, regardless of the passenger load factor.

There are operational differences between a combined aircraft and an all-cargo aircraft – with a combined aircraft, freight pricing is determined as a marginal cost because flight profitability is ensured by passenger traffic.

2.2.3 – Different types of cargo aircraft

There are approximately 2,800 cargo aircraft worldwide (at 1st January 2011). Examples of five types of cargo aircraft are provided below:

Feeders

Feeders can carry between 10 and 30 tonnes of freight over medium-range distances. The main purpose of these aircraft is to "feed" hubs.

Mc Donnell Douglas DC-9 Freighter			
Freight tonnage (kg -- m^3)	*Passenger version (seats)*	*Range (km)*	*Speed (km/h)*
15,343 -- 102	139	1,295	907

Figure 11. A "feeder" aircraft – the Mc Donnell Douglas DC-9 Freighter

"Regional Freighters"

Regional freighters are medium-range aircraft that can carry between 25 and 55 tonnes of freight. They are often single aisle passengers aircraft converted into a cargo carrier.

Boeing 707 Freighter			
Freight tonnage (kg -- m^3)	*Passenger version (seats)*	*Range (km)*	*Speed (km/h)*
30,000 -- 213	189	9,270	973

Figure 12. A "Regional Freighter" aircraft - the Boeing 707 Freighter

"Long-range Freighters"

Long-range freighters are medium- to long-range aircraft that can carry between 40 and 70 tonnes of freight. They are larger than “regional freighters”. The equivalent passenger version has twin aisles.

Airbus A300			
Freight tonnage (kg -- m^3)	*Passenger version (seats)*	*Range (km)*	*Speed (km/h)*
45,000 -- 305	266 / 361	7,500	897

Figure 13. A "Long-range Freighter aircraft - the Airbus A300

"Large Freighters"

Large freighters are long-range aircraft that can carry between 70 and 115 tonnes of freight.

Boeing 747-400 Freighter			
Freight tonnage (kg -- m^3)	*Passenger version (seats)*	*Range (km)*	*Speed (km/h)*
112,000 -- 700	421 / 520	15,540	938

Figure 14. A "Large Freighter" aircraft - the Boeing 747-400 Freighter

Specific aircraft

This category is dominated by Russian aircraft and satisfies a demand for cargo aircraft that can cover irregular routes and carry non-standard goods. The An-124 is ideal for transporting helicopters, aircraft engines and oversize freight.

Antonov An-124			
Freight tonnage (kg -- m^3)	*Passenger version (seats)*	*Range (km)*	*Speed (km/h)*
120,000 – 1,000	88-seat module	16,500	865

Figure 15 : The Antonov AN-124

The Airbus A380-800 F project

A cargo version of the Airbus A380 was proposed and orders were placed by Fedex and UPS in 2002 and 2005 (10 aircrafts each). However, due to delays in the A380 program, Fedex and UPS had decided in 2007 to order the B777-F instead and Airbus had therefore abandoned the all-cargo version, up to significant better economical conditions.

The A380 was to carry 150 tonnes of freight and up to 33 containers on the main deck, 25 on the upper deck and 13 on the lower deck. In comparison, the A300-600 can carry 21 containers on its main decks and 15 in its cargo hold. The Boeing 747-400 Freighter can carry 39 pallets + bulk products.

Other cargo aircraft...

There are also turboprop all-cargo aircraft or “Quick Change" aircraft such as the ATR 42, ATR 72 or Bae ATP. In most cases, these are converted passenger aircraft. Their payload varies between 5.7 and 7 tonnes. They are used as feeders by express delivery service providers over long-range routes, particularly for night flights. A four-engined jet aircraft, the Bae 146, with a 10-tonne capacity, is also used by such providers. Its particularity is that due to its high wings and four motors, it can take off over short distances and does not generate much noise.

The detailed characteristics of cargo aircraft can be found on the SNAGFA website (www.snagfa.com), in the “Discover airfreight” section.

3 - Airport runway capacity

As stated above, saturation of airport runways is not a critical issue for general cargo. Nevertheless, this section provides the main facts for understanding the notion of airport runway capacity, regardless of freight and passenger problems. This information is taken from the "Manuel de détermination de la capacité d'un aéroport" (*Airport Capacity Determination Manual)* edited by the Service Technique de l’Aviation Civile [French civil aviation technical department] in November 2005 [80]. This manual can be referred to for further details.

3.1 - Definitions

Several definitions are used to characterise airport runway capacity. It should be noted that the runway system includes the runway, taxiways and standing areas.

Technical hourly capacity of a runway system

Technical hourly capacity is the maximum flow of aircraft that can transit through a runway system in one hour during a peak traffic period. This capacity is determined based on the system’s operating practices, applicable air traffic rules and a delay time acceptable to operators.

Declared hourly capacity

Declared capacity is determined by the airport authority and represents the maximum flow of aircraft or passengers that the airport can accommodate throughout the year based on all airport chain components, external constraints (environment, etc.) and a certain level of service quality. It is expressed as aircraft or passenger movements over a period of time, which can be one hour.

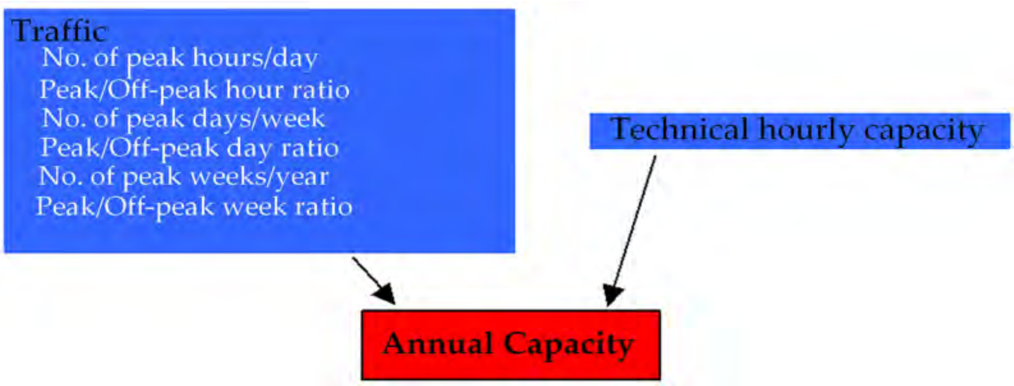

Figure 16. Parameters affecting annual capacity of an airport runway system

Airports can decide to set their declared capacity relatively close to the optimum capacity by specifying the delay time to the airlines. Thus, airports can sustain a higher technical capacity at certain moments in the day, when parameters are favourable. Declared capacity is mostly used to determine the volume of time slots that can be offered to airlines.

Annual capacity

Annual capacity is the maximum flow of aircraft which can transit through the runway system in a year based on its operating practices, safety regulations and a flight delay acceptable to operators (see Figure 15).

3.2 - Parameters affecting capacity

The number of aircraft handled by an airport runway system during one hour depends on the time resulting from aircraft separation in compliance with regulatory procedures and runway occupancy time.

The following main factors have a direct impact on technical capacity level (see Figure 17):

- **Infrastructure**: number, configuration and state of components [runway(s), exit(s), taxiways, standing area(s)].
- **Traffic**: type, combination of aircraft categories, combination of arrivals and departures.
- **Procedures**: applied to factors causing time- or space-based aircraft separation, which are statutory and necessary for safety reasons. Others depend on local characteristics and operational constraints. They specifically depend on the structuring of arrival and departure flows within the terminal air space and on the level of airport facilities (radar, ground radar, ILS, etc.).

In terms of infrastructure, the runway system has a direct impact on the technical capacity. Different runway systems include:

- Single runway system.
- Parallel runway system, also characterised by planned usage (specialised runways, unmarked parallel runways, other runway categories, etc.): runways pairs (close parallel runways, <760 m) or distant parallel runways (>760 m).
- Converging runway system.
- Cross-cutting runway system.

Exit taxiway positioning also has a significant impact on capacity:

- Minimising Runway Occupancy Time (ROT) is very important. An exit taxiway must be positioned to prevent U-turns on the runway and to minimise the taxiing time required to access directly the exit taxiway.
- Exit taxiway alignment and use of quick exits, in particular, reduce both landing distance and exit taxiing time because of higher exit speed.

Appendix 1 can be referred to for further details.

Runway length is a factor to be taken into account. Whilst this may not be a problem for large airport, it may be a limiting factor for small provincial airports. For instance, although a 2,100 m runway can be used by a Boeing 737, a Boeing 747 or Airbus 380 requires a runway longer than 3,000 m.

More than length, another issue was raised by Airbus A380 : resistance of the taxiway pavement. Such an aircraft is indeed too heavy for numerous airports. Thus, many pavements had to be rebuilt in the USA and in other countries, due to the arrival of A380.

Finally, it should be noted that meteorology has a significant impact on runway capacity. This is due not only to increasingly strict procedures affecting aircraft traffic, but also modification of infrastructure state, which increases aircraft ROT.

Runway systems can be optimised by taking action on other factors: pilots (improved arrival and departure flows), control (reduced separation rules) and airport management (upgrading infrastructures, quick exits, etc.).

Technical hourly capacity also depends on terminal air space organisation, which must properly separate arrival and departure flows. The following section may be referred to in relation to this issue.

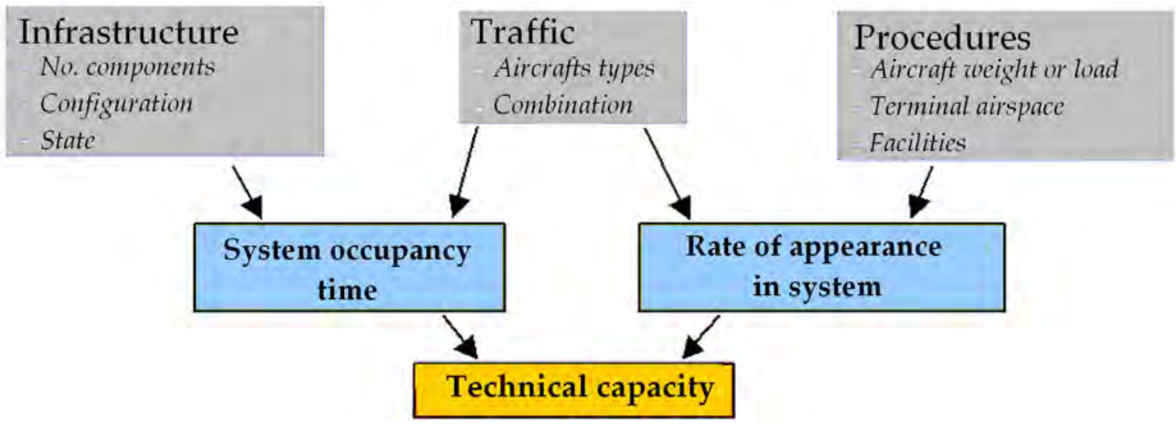

Figure 17. Parameters impacting technical capacity of an airport runway system

3.3 - Capacity assessment

Capacity assessment involves implementing tools (software or methods) that simulate real conditions by taking into account all identifiable factors. Approximate values only are provided here.

The capacities shown in Figure 17 have been determined based on observations made at existing airports; they mainly concern declared hourly capacities. At certain times of the day and subject to certain weather and traffic conditions, the technical hourly capacity may be higher.

Configuration	Movements /hour
Single runway without full parallel taxiway	10 – 20
Single runway with full parallel taxiway	35 – 50
Two close parallel runways	80 – 90
Two independent parallel runways	100

Figure 18. Observed capacities based on runway system

Capacity variations for the same runway system are due to the impact of parameters that vary from one airport to another.

It should be noted that unmarked parallel runway systems provide the highest capacity and an optimum safety level. Specialised parallel systems have a smaller capacity. Dual runway systems provide even smaller capacities. Converging or cross-cutting runway systems provide the smallest capacity and the lowest safety level.

Based on the above figures, we can assume that the optimum capacity per specialised runway varies between 40 and 50 arrivals per hour and 45 to 50 departures per hour.

It would appear that the capacities retained vary from one airport to another. They depend on airport infrastructure configuration and on the adopted airport strategy. Declaring a capacity much smaller than the optimum in good weather conditions allows possible delays to be curtailed, when weather conditions are poor. However, fewer time slots can be marketed in this case. This strategic decision is made by the airport manager.

Appendix 2 includes tables comparing hourly capacities at various American and European airports.

Annual capacity assessment

Annual capacity is calculated based on daily capacity; i.e. the sum of all movements that can be handled a runway system over a day. However, the number of movements usually varies hour by hour because it depends on the demand structure (combination of arrivals and departures, of aircraft categories). Traffic structure is determined by the number of peak and off-peak hours, as well as their ratio between them (see Figure 18).

Some methods (e.g. 40th hour formulae) allow annual capacity assessment in terms of movements, based on the hourly traffic of representative movements. The STAC "Manuel de détermination de la capacité d'un aéroport" (a*irport capacity determination manual*) [80] should be referred to for further details.

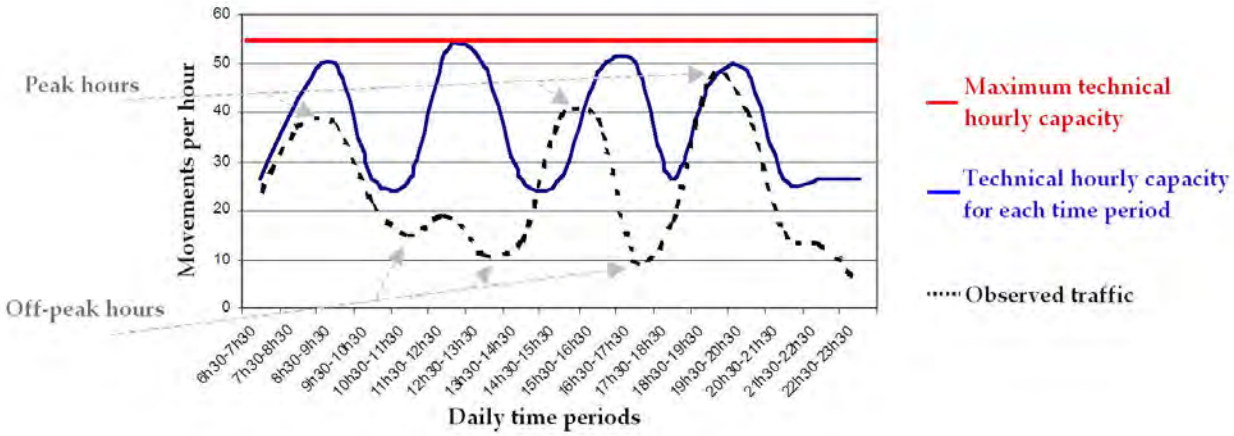

Figure 19. Daily traffic structure and capacity (source: STAC)

Example of Roissy airport

Roissy airport has implemented two pairs of runways since the end of 2000. The two existing runways, north and south of the airport, have both been doubled by a second runway.

Both new runways are 2,700 m long (compared with 3,600 m for the original runways) and are mainly dedicated to landing.

The layout of the two pairs of runways can be used for simultaneous take-off and landing. Air traffic in the Paris area was reorganised at the start of 2002 to ensure that the Roissy runway pairs operate at optimum capacity.

All these considerations and assessments concern both passenger and freight operations. However, airport runway capacity for air freight is not currently a major issue in France.

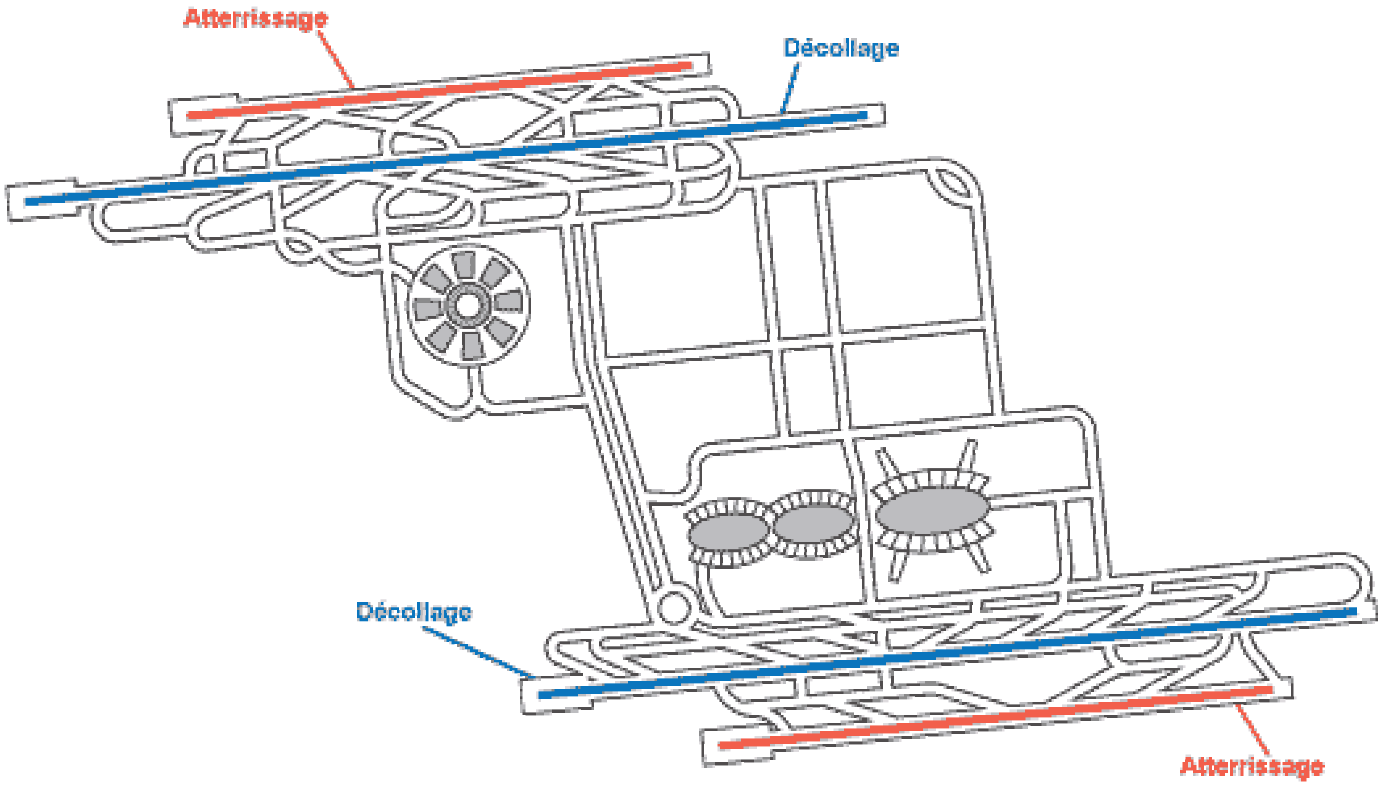

Figure 20. Runway configuration at Roissy airport (Atterrissage = Landing, Décollage = take-off)

4 - Air Corridor Capacity

Flight punctuality depends on proper operation and coordination of a complex system involving multiple stakholders and sensitive to the slightest malfunction of just one of its components. There are more than 70 causes for flight delays, which are sometimes cumulative and thus lead to further delays. Studies conducted in 2000 have revealed that causes of delays either originate in airlines (including delays caused by passengers themselves), air control, airports, safety inspections and meteorological conditions.

Insufficient air control system capacityt can be one of the causes of delay in the European airspace at certain locations and during specific peak periods (related to traveller traffic). During such periods, traffic clogs airport facilities and saturates regional control capacity at some moments. Furthermore, air transport is subjected to network effects. If a disturbance affects traffic flow in France, this can impact north - south and north-east – south-west traffic routes crossing French territory.

In common with airport runway capacity, air corridors do not represent an essential issue for air freight capacity. The following section provides only information contributing to an understanding of the major issues involved .

4.1 - Air corridors

Safety requires that all aircraft follow a predetermined marked route, the so-called “air corridor”, and comply with both horizontal and vertical separation distances, whose purpose is to prevent any risk of collision or aerodynamic disturbance.

Greatest possible airspace must be provided for air navigation as often as possible, so that a maximum number of aircraft can pass through it under optimum safety conditions.

Each pairing of air traffic controllers monitors hourly 22 to 28 aircraft, which are spaced at approximately 9 to 15 km. In the vicinity of large airports, 8 to 15 aircraft with very different speeds and courses can be simultaneously monitored by a single control position. A “safety net” is used to warn a controller of collision risks between aircraft. An aircraft will land approximately every 2 minutes in good conditions.

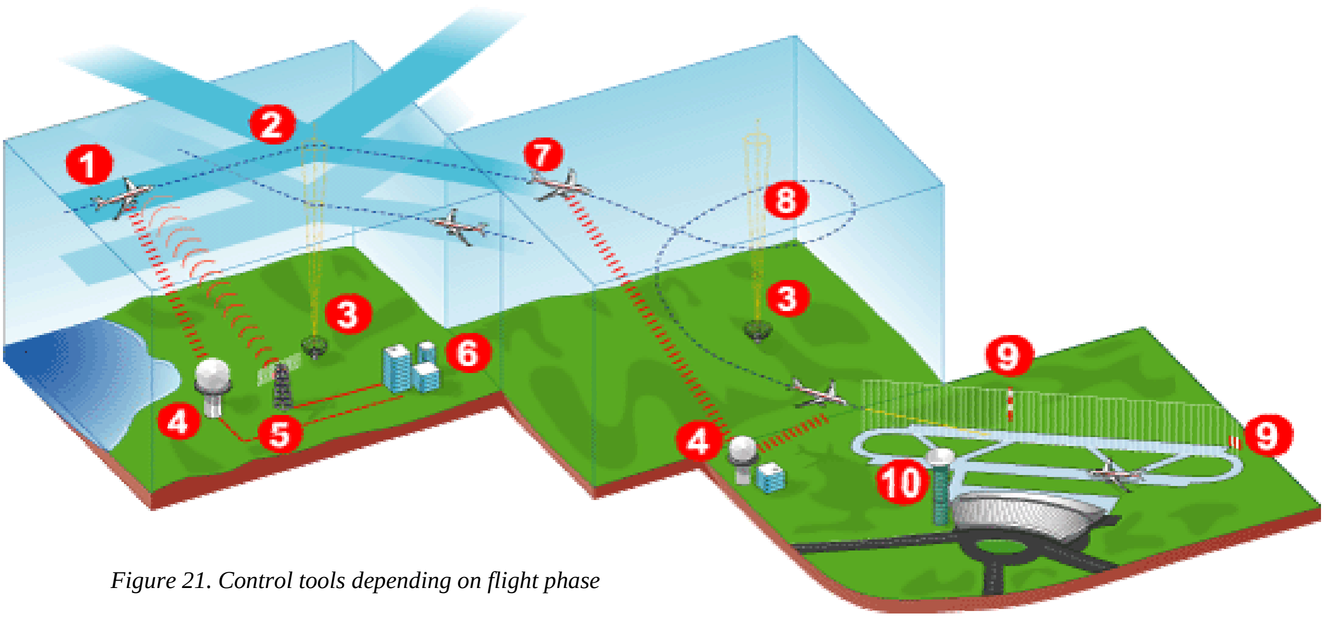

Figure 21. Control tools depending on flight phase

1 Aircraft entering a control sector
2 Air corridor
3 Radio beacon
4 Monopulse radar
5 Radio transceiver

6 Regional air navigation centre
7 Aircraft entering an approach sector
8 Holding pattern
9 ILS-assisted landing beacon
10 Control tower and ground control radar

In capacity terms, the performance of an airport is partly dependent on controlling arriving aircraft within the terminal airspace. The diagram in Figure 20 can be used to analyse various control methods according to flight phases (source www.aviation-civile.gouv.fr):

- Regional control. Management of aircraft travelling outside areas close to airports within corridors with a width of 10 Nautical Miles (10 NM = 18 km) and separated vertically by 300 m.
- Approach control. Management of descent phase down to 6 - 10 NM (11 - 18 km) from the runway. The distance between aircraft is then reduced to 3 NM (for "heavy" aircraft, distance ahead of “light”, “medium” and “heavy” aircraft are 6, 5 and 4 NM respectively).
- Aerodrome control. Control tower visual monitoring of aircraft final descent phase. The tower controller ILS / Instrument Landing System technology to follow accurately the aircraft course. At large airports, the aerodrome controller transfers aircraft control responsibility to the ground controller as soon as the runway has been cleared and the latter controller guides the aircraft to its standing area, as it does from the standing area to the runway for take-off.

4.2 - Tools and developments

In certain cases, traffic exceeds the possibilities of the airways open. For efficiency and safety reasons, aircraft must then be made to wait on the ground and take-offs are regulated by allocating time slots.

In Europe, the Central Flow Management Unit (CFMU) has been responsible for regulating such movements since 1995. The CFMU may impose delays on the ground for certain flights, if necessary, to ensure safe air traffic flow. When airborne delays are required, aircraft are directed to racetrack-shaped circuits, where they have to wait for landing authorisation. The "Arrivals” controller keeps aircraft on “standby” and organises their exit from the holding stack to regulate the flow of arrivals.

Factors contributing to greater capacity can be grouped into four categories: spatial organisation (airway network, etc.), sizing (number of control positions, etc.), productivity of control units (assistance tools, etc.) and use of resources (sharing airspace with military forces, etc.).

Maestro software was developed by the DGAC and is used for limiting airborne delays by improving the sequencing of arrivals in large airports and by contributing to an optimum use of runways.

In January 2002, vertical upper airspace separation was reduced to 300 m above the European continent. This change has meant that airspace is now more accurately divided. As result, 16 new control sectors will ultimately be opened in French upper airspace. Finally, pending deployment of the latest version of the European air route network, ARN-V3 (Version 3 of the European air route network) has already generated greater control system capacities and enhanced traffic fluidity.

5 - The Air Freight Terminal

5.1 - Definitions and operating modes

Freight terminals are used for cargo break-down between land transport and air transport. They represent a key link in the freight transport chain. A freight terminal is only used for handling freight traffic corresponding to a certain annual tonnage. Below 1,000 t/year, a passenger terminal is considered sufficient.

A freight terminal can involve a single or multiple operator(s). In a “single operator” terminal, handling operations are performed by a single organisation, which may be private if the owner is a carrier (e.g. Air France cargo terminal at Paris – CDG). Operating modes have an impact on freight terminal efficiency. If there are several operators or import-export circuits, it is then necessary to multiply building areas ensuring identical functions. This leads to a decrease in tonnage handled per building m². A 20% building area loss has been evaluated in comparison with a “single operator” terminal.

5.2 - Freight terminal operation

A freight terminal is divided into four sectors: an office and administration sector particularly dedicated to customs authorities, a platform section for loading/unloading trucks, a bonded warehouse section in a reserved area and a section leading to the runways, which is dedicated to aircraft loading/unloading. Terminal design and organisation vary, depending on growth in freight volumes and integration of increasingly modern methods based on computerisation and implementation of complex global logistics.

The diagram in Figure 22 illustrates the operating principle of a freight terminal.

The optimum depth for a freight terminal is between 45 and 70 m and this ensures the most direct freight circuit structure possible. A ceiling height of 7 m is currently adopted because it provides enough space for installation of 4 storage racks.

In general, the freight terminal is not very far from the passenger terminal (combined aircraft). However, this is not always the case. At Roissy – Charles de Gaulle airport, combined freight must be transported over distances of 4 to 5 km to reach the aircraft at present.

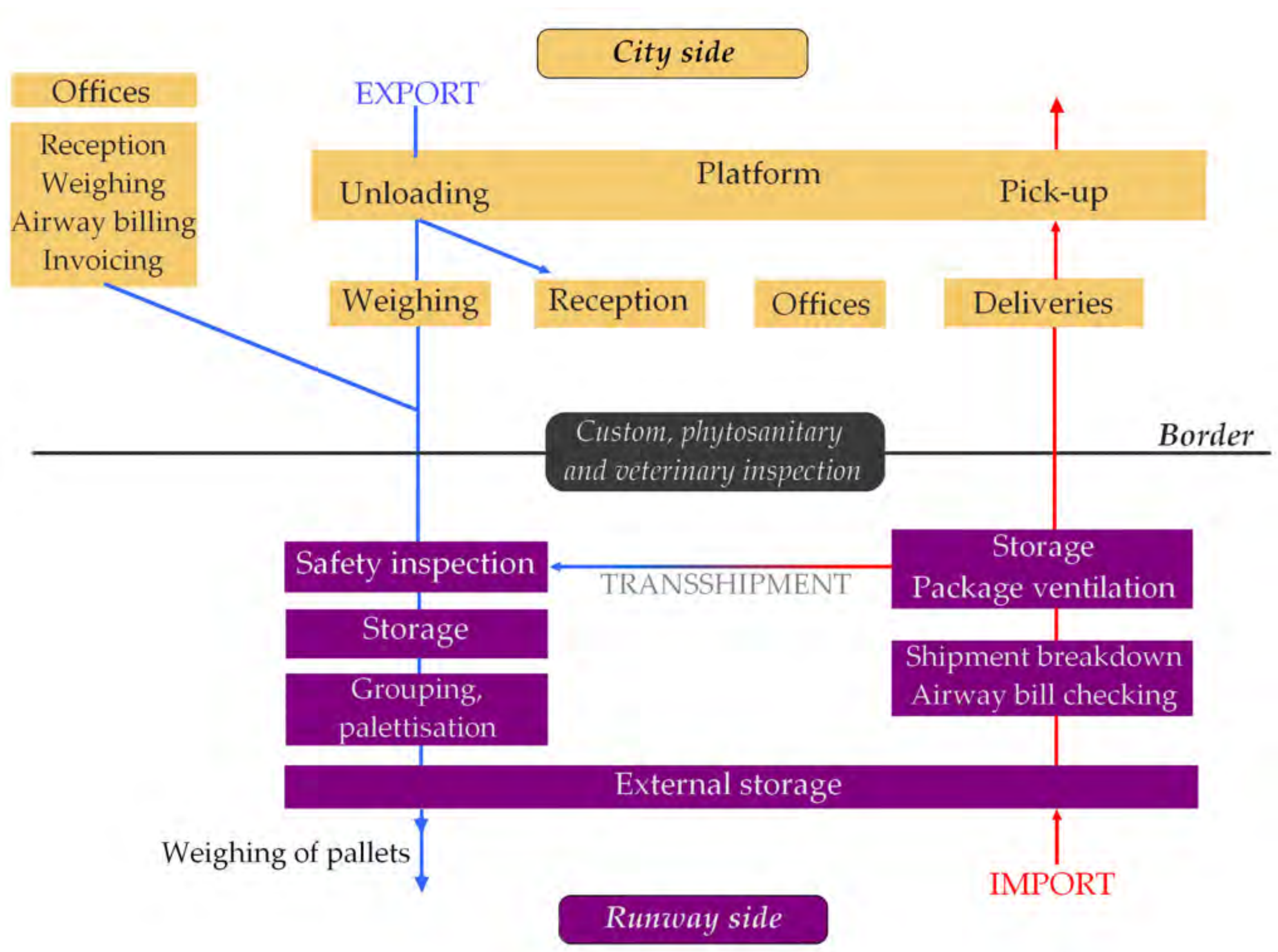

Figure 22. Freight flow in the air freight terminal – for further detail, see STAC (Service Technique de l'Aviation Civile).

5.3 - Freight terminal design

The tonnage handled each year is not usually representative of the freight terminal because traffic is not uniformly distributed in time. Peak traffic is generally used as a reference in developing a detailed design for the premises. In most cases, daily peak traffic is the most relevant indicator (e.g. representing large cargo carrier handling).

However, it is very difficult to associate a building area with the tonnage being handled because air freight characteristics are highly variable: different weights and dimensions, different storage times, different freight categories (specific handling, etc.). The traffic structure therefore has to be accurately known along with the operating mode implemented inside the terminal.

Global ratios for an air freight terminal are therefore very approximate: they vary between 3 t/year/m² (irregular diversified traffic or traffic to be stored for long periods) and more than 20 t/year/m².

Example
With its General Cargo freight terminal extending over 8,000 m², Toulouse - Blagnac airport claims a freight handling capacity of 50,000 tonnes per year.

It is then necessary to define accurately the requirements and areas required for the different modules. For instance, storage areas are determined based on package volumes and average densities handled during peak periods as well as estimated storage times. The average area required for handling a 3-tonne pallet is considered to be 20 m² (including handling-related traffic).

5.4 - Express freight

Specific facilities have been provided for express freight at major platforms. In most cases, these are combined with sorting hubs. The data given below were provided during a meeting with Fedex, whose European hub is located at Paris – Charles de Gaulle airport.

For the express delivery service provider, the main advantages at CDG are its opening hours and enviable capacity in terms of runways and available land. The possibility of developing other land transport options (TGV / high-speed train freight) in addition to road transport is also a great asset (*Carex* project, see rail transport section). However, it should be noted that if the airport ever became saturated in a few years time, the express delivery service provider would consider extending its business to another European site. Development of an all-cargo airport, such as Vatry, would nevertheless be an unfeasible project. The geographical distance between customers and Vatry represents a competitive disadvantage and would put an end to massive use of Air France flights. A second runway would also need to be built.

In terms of platform handling capacity, no facility area ratio is used and only certain values are provided: a 80,000-m² platform can be used for handling 1,000 tonnes per day. The hourly handling capacity can reach 30,000 parcels and as many envelopes during peak hours.

Figure 23. Identification and sorting of express freight parcels at Fedex (© photothèque STAC / Véronique PAUL – Graphix)

5.5 - Development: the G1XL example

Extra Large Terminal No. 1 at Paris – Charles-de-Gaulle was inaugurated in 1998 and cost 150 million euros overall. It should be noted that 70% of freight handled at G1XL comprises international/international transit (truck and aircraft). The terminal is fully automated: electronic labelling of pallets, 28 automated pallet transport trucks, pallets controlled inside the terminal by RFID (*Radio Frequency Identification*), etc.

With an area of 120,000 m² (palettisation warehouse 5 hectares, storage warehouse 5 hectares and aircraft loading area 2 hectares), the terminal can be used for handling 1.4 million tonnes of express freight per year (approx.12 t/m²/year).

Key characteristics are as follows:

- Area: horizontal ground-based terminal extension favoured as opposed to vertical rack-based extension.

- Number of aircraft stands: 6.
- Sufficient truck bays (on city side) and upstream parking areas for truck holding and prioritisation.

The storage area has 10 bays for trucks connecting to passenger flights.

Figure 24. Wire-guided pallet truck inside G1XL terminal (© photothèque STAC / Véronique PAUL – Graphix)

Example of Hong Kong Air Cargo Terminals Limited (HACTL)

The HACTL company handles 80% of freight at Hong Kong airport. A new, fully automated terminal, "Super Terminal 1", was developed at the end of the 1990s. The ultimate annual capacity of freight facilities is estimated at 5.5 million tonnes (with several additional improvements in handling conditions) for a terminal area of 325,000 m². 2.7 million tons (import 0.7 + export 1.4 + transhipment 0.6) were handled between October 2010 and October 2011. Due to insufficient space, the objective is to turn freight around as quickly as possible. Large carrier freight can be delivered to customers within three hours and only one hour is required to transfer freight from passenger area to freight area. Freight for delivery China is then forwarded by truck or ship. Freight handling is automated at facilities arranged on 5 levels, which can be used for automatically storing or releasing goods. At HACTL, freight traceability is ensured via a connection to the electronic data of companies and freight operators. The investment cost for this cargo centre was 1.1 billion USDs.

Cost of warehouses

Warehouse rental in an airport area obviously varies from one airport to another. At airports like Washington DC, Gatwick, Dublin, Frankfurt or Paris, rents amount to 200 euros/m²/year and this figure is even 375 euros at Heathrow.

6 - How Is Airport Freight Capacity Evaluated?

6.1 - All-cargo airports

Determining the annual capacity of an all-cargo airport must be envisaged by considering a global system. In this case, airport capacity is lower or equal to the capacity of each airport system component.

For an all-cargo airport such as Vatry, France, there is no capacity constraint due to the runway because it cannot be saturated by traffic at present, but it could become a limiting factor, if the airport became a European hub for an integrator. In this case, the airport would need to be capable of accepting a rate of 40 to 50 freight aircraft arrivals/departures per hour during peak hours in addition to existing traffic. Based on this assumption, a new runway would have to be built and this would involve significant investment and heavy administrative procedures. This would be possible in areas with sufficient property resources, such as in the Marne region for example.

Number of airplane stands can be a restricting factor. For instance, the four stands available at Vatry in 2005 caused a number of problems. Four new stands overcame this constraint in 2006. This criterion is therefore not determining and can be easily solved.

It appears that the real bottleneck is the terminal capacity. We have already seen that it is difficult to retain a reliable ratio for determining the freight terminal capacity. Figures vary between 3 t/m²/year and 20 t/m²/ year depending on type of freight, type of service (express, general cargo, oversize packages, etc.), storage times, etc. Handling time is also a major factor: depending on the handling areas, capacity is also impacted by the time during which these areas are in use. If the handling process is efficient, more aircraft and freight can be handled using the same areas.

With a 4,200 m² freight terminal in 2005, Vatry could handle exceptionally a maximum of 700 tonnes during a peak day. This is a peak figure, but its annual capacity is estimated at 60,000 tonnes and therefore falls within the ratios quoted above. The Vatry airport manager had nevertheless decided to build the second freight terminal – opened in 2007 – to increase the capacity. Designing and building a new terminal is a much easier and quicker solution than building a new runway, even in a favourable case such as Vatry. A new runway requires revising the noise exposure plan and this invariably demands a very lengthy consultation procedure.

6.2 - Combined airports

Evaluating the freight capacity of combined airports would seem to be less obvious. At first sight, one may assume that passenger traffic (both in terms of aircraft runway movements and airport spatial occupancy) would restrict airport freight capacity. Furthermore, building a runway at a combined airport is subject to more constraints (property/land restrictions and heavy environmental impacts). On the other hand, there is no real competition because freight and passenger peak hours are often separated. We may even assume that freight takes advantage of capacities set aside for the passenger. It should also be recalled that passenger flight capacities are widely used for freight.

As we saw above, therefore, freight capacity of a combined airport is restricted by "conventional" factors, specifically related to the aircraft stand design and number, on the one hand, and to freight terminal design and facilities, on the other hand.

Other factors that may ultimately restrict airport capacity are difficult to evaluate. These include land availability for extending or building terminals as well as road and motorway network congestion. So-called "environmental capacity" should also be mentioned: quotas or taxation on night flights, for example, can limit freight development at combined airports in urban areas.

Figure 25 : Plane at its stand in Roissy – Charles de Gaulle airport (near G1XL terminal). The blue engine is supplying electrical power to avoid emptying of plane's batteries. Number of stands is not a major issue for capacity - © Florence Lambert (DRIEA)

Figure 26 : This plane, called "Beluga", is used by Airbus to transport airplanes sections. Despite its enormous volume, this giant is not the largest plane in the world, if we consider each dimension separately : the longest and heaviest one is the Russian Antonov An-225 Mriya, the tallest Airbus A380-800, and the widest was the Hughes H.4 Hercules "Spruce Goose" (largest wingspan, 97.5m !), of which only one was ever built, in 1947. New concepts under development (manufacturers projects, European project NACRE / New Aircrafts Concepts Research, NASA, etc.) such as giant flying wing, could overpass these dimensions, but it should not lead to commercial applications before many years.

– Credit Bernard Tocheport, photoamateur.net

Appendix 1. Runway Occupancy Time and Exit Taxiway Location *Source: "Manuel de détermination de la capacité d'un aéroport", STAC, novembre 2005 [80]*

Runway Occupancy Time (ROT) during landing is the time between the moment when the aircraft passes over the runway threshold and when it leaves the runway and passes a point located 90 m[1] from the runway centreline (easements cleared).

Case 1. Braking distance less than distance between runway threshold and exit taxiway (Figure 24).

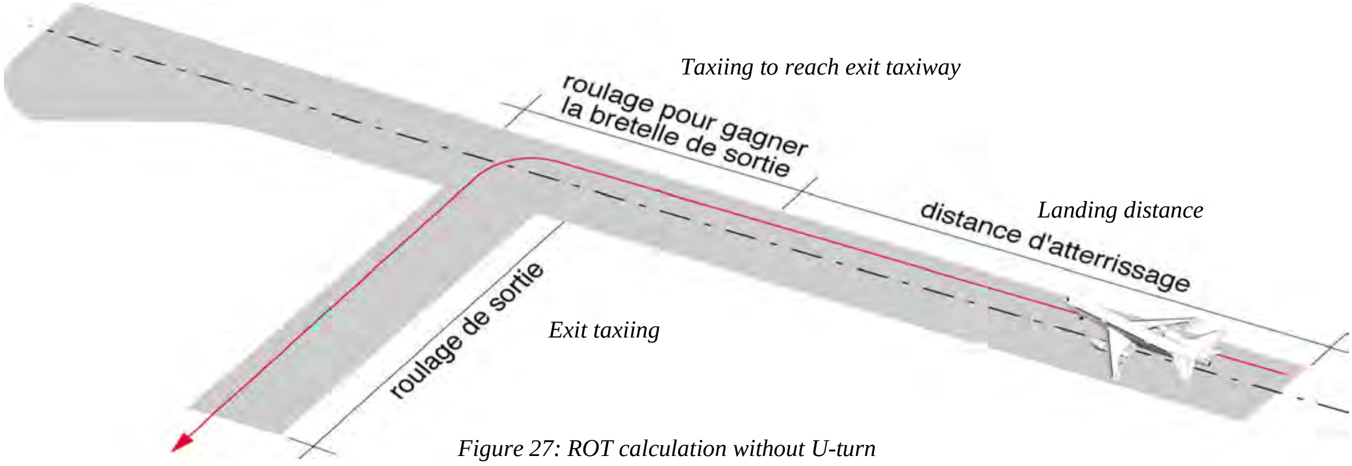

Figure 27: ROT calculation without U-turn

Case 2. Braking distance greater than distance between runway threshold and exit taxiway (Figure 25).

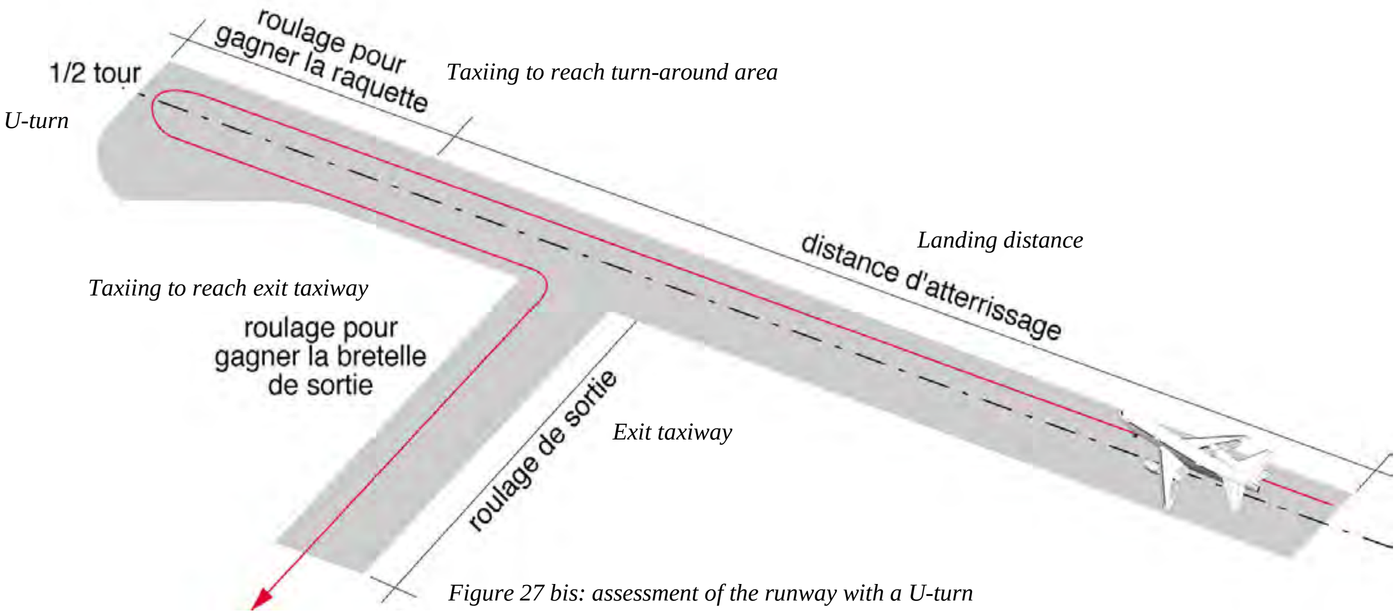

Figure 27 bis: assessment of the runway with a U-turn

The ROT may be very long in this case because a U-turn takes between 50 and 60 seconds.

The main parameters referred to in this section are:

- Aircraft braking distance, which depends on the aircraft weight, approach speed, braking performance characteristics and exit speed.
- Exit taxiway location.
- Exit configuration: straight or quick exit.

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[1] ***The 90 m distance applied involves clearing easements governing Category I and II runways controlled with instruments. This distance is reduced to 75 m for runways controlled by visual procedures and is increased to 150 m for Category III runways controlled with instruments.***

Appendix 2. Hourly Capacities of American and European Airports

Tables in Figures 28 and 29 provide various aircraft movement capacities:

- Optimum capacities correspond to aircraft movements that can be handled in one hour under so-called 'optimum conditions' i.e. good weather allowing visual aircraft approaches.
- Reduced capacities are those corresponding to poor weather conditions, under which instrument-assisted approaches are required.
- Declared capacities (*see* European airport table) correspond to the number of aircraft that can be handled in one hour at a platform. This notion is represented by a fixed value quoted by airport managers, on the basis of which airline flights are scheduled.

These figures were taken from two official documents ([81] for American airports and [82] for European airports); this partly explains why the notion of capacity is not expressed in the same way.

In the United States, airports rarely provide a "declared capacity". American airports prefer to specify a range of optimum capacities for good weather conditions and a range of reduced capacities evaluated under poor weather conditions. This is a marketing strategy and it allows them to accept all flight requests made by airlines.

USA airports	Optimum capacities (movt/hour)	Reduced capacities (movt/hour)	Number of runways used simultaneously	Configuration
Atlanta Hartsfield International	185-200	167-174	4	2 parallel runway pairs
Boston Logan International	118-126	78-88	3	1 pair and 1 cross-cutting
Baltimore-Washington International	111-120	72-75	3	2 cross-cutting runways
Charlotte/Douglas International	130-140	108-116	3	2 parallel runways and 1 cross-cutting
Cincinnati-Northern Kentucky	123-125	121-125	3	2 parallel runways and 1 cross-cutting
Denver International	204-218	160-196	6	4 parallel runways and 2 perpendicular
Dallas-Fort Worth International	261-270	183-185	7	2 pairs, 1 parallel runway, 2 converging
Detroit Metro Wayne County	143–146	136–138	5	3 parallel runways and 2 cross-cutting
Newark International	92-108	74-78	3	1 pair and 1 cross-cutting runway
Honolulu International	120-126	60-60	3	2 parallel runways and 1 cross-cutting
Houston Bush Intercontinental	120-123	112-113	3	2 parallel runways and 1 converging
New York Kennedy International	88-98	71-71	2	2 parallel runways
Las Vegas McCarran International	84-85	52-57	2	2 parallel runways
Los Angeles International	148-150	127-128	4	2 parallel runways pairs
New York LaGuardia	80-81	62-64	2	2 cross-cutting runways
Orlando International	144-145	104-112	3	1 pair and 1 parallel runway
Memphis International	150-152	112-120	4	1 pair, 1 parallel runway , 1 converging
Miami International	124-13	95-108	3	1 pair and 1 parallel runway
Minneapolis-St. Paul International	115-120	112-112	3	2 parallel runways and 1 cross-cutting
Chicago O'Hare International	200-202	157-160	5	2 parallel, 2 cross-cutting, 1 converging
Philadelphia International	100-110	91-96	3	1 pair and 1 cross-cutting
San Diego Lindbergh Field	43-57	38-49	1	Single runway
San Francisco International	95-99	67-72	3	1 pair and 1 cross-cutting

Figure 28. Optimum and reduced capacities of major American airports
– Source: Airport Capacity Benchmark Report 2001, *US Department of Transportation, Federal Aviation Administration, United States, 2001 [81]*

The approach is different in Europe. Airports specify a declared capacity, which is often lower than the optimum capacities that they are capable of handling under good weather conditions. The notion of “good weather” represents various favourable flight conditions and does not simply mean a sunny day! In France, these conditions occur during at least 90% of airport daily opening hours.

European airports	Programmation capacity (movt/hour)	Number of runways used simultaneously	Configuration
Amsterdam Schiphol	108	3	3 parallel runways or 2 parallel +1 converging
Barcelona	Nc	2	2 parallel runways
Berlin Tegel	40	2	Pair
Brussels Natinal	68	2	Cross-cutting runways or 2 parallel runways
Copenhague	81	3	Cross-cutting runways or 2 parallel runways
Corfu	10	1	Single runway
Faro	18	1	Single runway
Florence	12	1	Single runway
Francfort	76	3	1 pair and 1 cross-cutting
Geneva International	38	1	Single runway
Kos	6	1	Single runway
Lille	30	1	Single runway
London Luton	30	1	Single runway
London Stansted	36	1	Single runway
London Gatwick	48	1	Single runway
London Heathrow	78	2	2 specialized parallel runways
Luxemburg	35	1	Single runway
Lyons St Exupéry	50	2	Pair
Madrid Barajas	55	2	Cros-cutting runways
Manchester	47	1	Single runway
Marseille Provence	30	2	Pair
Milan Malpensa	58	2	Pair
Milan Linate	32	1	Single runway
Munich Franz Josef Strob	82	2	2 unmarked parallel runways
Nantes	16	1	Single runway
Nice Côte d'Azur	49	2	Pair
Paris Charles de Gaulle	105	3	Pair and 1 parallel runway
Rotterdam	30	1	Single runway
Strasburg	20	1	Single runway
Stuttgart	35	1	Single runway
Toulouse	42	2	Pair
Venice	20	2	Pair

Figure 29. Declared capacities of major European airports

- *Source: European Database of Major Airports in the ECAC States 1998, Annual Report, Eurocontrol [82]*

Appendix 3. Some Air Freight Statistics

Freight traffic at international airports

Airport	Cargo Metric Tonnes	% change	Rank 2010	Rank 2009	Change
Hong Kong (HKG)	4,168,394	23.2	1	2	+1
Memphis (MEM)	3,916,937	5.9	2	1	-1
Shanghai Pudong (PVG)	3,227,914	27.1	3	3	-
Incheon (ICN)	2,684,500	16.1	4	4	-
Anchorage (ANC)	2,578,396	33.1	5	5	-
Paris (CDG)	2,399,067	16.8	6	10	+4
Frankfurt (FRA)	2,275,106	20.5	7	8	+1
Dubai (DXB)	2,270,498	17.8	8	7	-1
Tokyo Narita (NRT)	2,167,843	17.1	9	9	-
Louisville (SDF)	2,166,226	11.1	10	6	-4
Singapore (SIN)	1,841,004	10.9	11	11	-
Miami (MIA)	1,835,793	17.9	12	12	-
Los Angeles (LAX)	1,810,345	15.5	13	13	-
Taipei (TPE)	1,767,075	30.1	14	15	+1
London Heathrow (LHR)	1,551,405	15	15	16	+1
Beijing (PEK)	1,549,126	5	16	14	-2
Amsterdam (AMS)	1,538,135	16.8	17	17	-
Chicago (ORD)	1,424,077	30	18	18	-
New York JFK (JFK)	1,343,114	17.4	19	19	-
Bangkok (BKK)	1,310,146	25.3	20	20	-
Guangzhou (CAN)	1,144,458	19.8	21	21	-
Indianapolis (IND)	947,279	5.2	22	22	-
Newark (EWR)	854,750	9.6	23	24	+1
Shenzhen (SZX)	809,363	33.6	24	27	+3
Tokyo Haneda (HND)	804,995	1.9	25	23	-2
Osaka (KIX)	759,278	24.7	26	26	-
Luxembourg (LUX)	705,370	12.2	27	25	-2
Kuala Lumpur (KUL)	697,015	15.6	28	29	+1
Mumbai (BOM)	671,238	18.5	29	30	+1
Atlanta (ATL)	659,129	17	30	31	+1

Figure 30. Ranking of world freight airports, 2010 / 2009 – source ACI & CAPA / Centre for Asia Pacific Aviation

Note : as for sea ports, ***there is more than twice as much traffic in airports as actual international traffic****. Each airport counts import + export + transhipment tonnages, so one ton of cargo carried from Hong-Kong to Newark with transit at Anchorage Airport for example – see figure 5 – will be counted three times.*

Freight traffic at French airports

Airport	Freight transported by aircraft	Trucking service	Airmail traffic
Paris (CDG+Orly)	1,860,580	NA	257,110
Toulouse-Blagnac	51,093	NA	5,325
Marseille-Provence	43,171	13,938	8,028
Vatry	37,632	NA	NA
Lyon Saint-Exupéry	35,525	104,450	3,207
Bâle - Mulhouse	32,148	51,412	20
Saint Nazaire	12,353	NA	NA
Nice Côte d'Azur	11,356	8,744	3,370
Bordeaux Mérignac	9,574	14,063	6,133
Nantes	8,655	21,027	0
Rennes	8,298	737	3,220
Châteauroux	6,761	NA	NA

Figure 31. Freight traffic (tonnes) at major French airports in 2005

Comment 1. *Strasbourg-Entzheim and Lille-Lesquin airports have declared trucking traffic of 17,020 tonnes and 44,554 tonnes for 2003 respectively.*

Comment 2. Freight at Paris

- *88% freight (1/3 handled by integrators) and 12% airmail.*
- *Air France Cargo, La Poste and FedEx represented 64% of total tonnage in 2001 and 90% of all-cargo flight tonnage.*
- *Traffic percentages: North America (33%), Asia - Pacific (24%), Europe (16%).*

Air freight carriers

It should be stated that Air France-KLM was the largest general air freight carrier in 2010 and the second one including integrators. It carried 11.4 billion t.km between April 2010 and March 2011, or 7% of world total. It does not appear in the IATA ranking below, because each cargo company of the group is counted separately (Mainly Air France Cargo, KLM cargo and Martinair, owned by KLM). The main Air france-KLM international hub is at Paris CDG airport. This is also the case for the FedEx European hub, Federal Express (integrator) being the largest air freight carrier in the world.

Rank	International (million ton.km/ FTK)		Domestic (million ton.km)		Total traffic (million ton.km)	
1	Cathay Pacific Airways	9,587	Federal Express	8,322	Federal Express	15,743
2	Korean Air	9,487	UPS Airlines	4,979	UPS Airlines	10,194
3	Emirates	7,913	China Southern Airlines	1,295	Cathay Pacific Airways	9,587
4	Lufthansa	7,422	Air China	904	Korean Airlines	9,542
5	FedEx	7,421	China Eastern Airlines	713	Emirates	7,913
6	Singapore Airlines	7,001	Hainan Airlines	421	Lufthansa	7,428
7	China Airlines	6,410	All Nippon Airways	417	Singapore Airlines	7,001
8	UPS Airlines	5,215	United Airlines	413	China Airlines	6,410
9	EVA Air	5,166	Japan Airlines	405	EVA Air	5,166
10	Cargolux	4,901	Delta Airlines	363	Cargolux	4,901

Figure 32. Major carrier freight traffic expressed in FTK (freight tons.km), 2010. According to IATA's Business Intelligence Service, the figures above are based on airline reports and then ***they do not include trucking services****. – source IATA (WATS)*

Note : IATA's definition for FTK : Freight Tonne kilometer – The sum of the products obtained by multiplying the number of metric tonnes of revenue freight, including express, covered by airway bills, carried on each sector of a flight by flight stage distance.

Appendix 4. Air Transport Security

Air freight security has become a major issue nowadays. As noted previously, security can affect airport capacity because it can cause a slowing down in the logistical chain fluidity.

Since 1999, carriers can only load secured freight in aircraft cargo holds and airlines are legally responsible for the security of the goods they load onto their aircraft. They entrust their freight security to professional organisations, certified as “approved agents”. Nevertheless, part of the freight cannot be inspected with X-ray equipment after packaging. The French law of 3rd January 2002 has complemented the system by entrusting the security of this freight to the shipper, who must inspect it visually prior to packaging. In this case, the shipper must obtain “recognised shipper” certification.

Based on regulations 2320/2002 of 16th December 2002 [83], the European Union has adopted common rules regarding civil aviation safety. Each Member State of the EU is required to adopt a national safety programme and set up a competent authority for coordinating and controlling programme implementation. France's European neighbours are therefore obliged to align themselves with the EEC text, which nevertheless imposes standards that are less strict than current French standards. In addition to the major issue of passenger safety, another problem concerns distortion of the resulting competition (cost of measures, administrative procedures, etc.). According to carriers, freight security policy in France is starting to have a significant financial impact on the logistical chain. Implementation of new regulations may involve an extra cost amounting to 10% of the price of a flight.

A recent study estimated the direct cost of security in France at around 400 million euros in 2003 in relation to measures taken by airport managers and at 120 million euros in relation to measures taken by airlines or their subcontractors. These figures have doubled since 2001. The average cost of security in France is 8 eurocents per kg of freight, which represents a 5% increase in freight cost.

The security process

On arrival at the unloading bays, truck drivers must check in and show their personal identification. Packages are then unloaded and placed in an area upstream from the security area. Packages are then inspected physically and a safety certificate is edited, tracing all the security operations performed. The goods are then placed in storage. An approved agent must then guarantee the integrity of the security chain as far as transfer to an airline and loading onto an aircraft.

As regards all-cargo flights, a French Interministerial Decree lays down that inspections must be conducted on one shipment sample. Shipments from regular customers must be subjected to 5% random inspection.

Appendix 5. Cost Notions

Air transport prices vary considerably depending on direction of travel, destination, relevant market and negotiations on volume to be carried. Reliable value assessments cannot therefore be provided. For instance, it should be noted that on certain flights, aircraft may depart with a 70% empty cargo hold. Overall, freight represents 20% of income generated by a combined passenger/freight aircraft.

Main components of air freight pricing

Notion of weight/volume ratio

The weight/volume ratio has been established at 1/6 for air freight since 1981. Under ideal conditions, one tonne must occupy a volume of 6 cubic metres. This ratio is derived simply from aircraft carrying capacities. Any shipment requiring less than 6 m^3/ton – or 6L/kg, i.e 1/6kg/L = 0,17kg/L – is taxed on a gross weight basis. When the density of goods is less than 1/6 kg/L, the shipment is taxed on a volumetric correction basis.

Examples

- - A 2 kg shipment occupying 12 L (= 12 dm^3) will be taxed on a 2 kg basis.
- - A 1 kg shipment occupying 12 L will be taxed on a 2 kg basis.

This ratio is highly advantageous compared to other transport modes. For instance, the minimum taxable weight for a 1 m^3 air freight shipment is 67 kg, but for a similar volume road and sea transport shipment this is 350 kg and 1,000 kg respective. Aircraft are therefore relatively attractive in relation to bulky product packaging.

However, very long packages (longer than 3.10 m or 6 m in the case of a Boeing 747) are generally subject to an additional tax or to a tax on occupied space because they exceed the normal dimensions of a 10 – 20 foot pallet. These surcharges are optional and the airlines reserve a right of decision on them.

Finally, the tax applied to air shipments does not account for the number of packages. Assembling several small packages to form a single package is not compulsory, except in cases of very small individual packages.

Other components

The airport-related percentage of air freight cost represents less than 10% of the overall transport cost (4% fees, 5% rental) and a maximum of 15%, if the airport assists. Fees relate to overflying, terminal services, aircraft approach, landing, standing and airport terminal usage. There is also in France an additional civil aviation tax (1.25 euro/tonne).

The cost of fuel represents between 25% and 30% of operating costs for all-cargo commercial equipment.

Example quotation

We do not provide ratios in this section because air transport pricing is extremely variable (type of consignment, speed – trucking or air freight, etc.). This example quotation remains strictly informative (see Figure 33).

However, some average figures can be obtained by a very simple way, dividing turnover by traffic for a given company. For example, the 150 world biggest airlines had a total cargo revenue of 38.44 billion \$ in 2010 (source *FlightGlobal*). Assuming that these 150 companies ensure almost 100% of total world traffic and dividing this sum by total world traffic 2010, the average price to transport one ton of goods on one km is approximately 0.25\$.

The same method with Air-France KLM cargo leads to 0.26 € /t.km (turnover Q2+Q3 2011 (April-September): 1.49 billion € ; traffic Q2+Q3 2011 : 5,68 billion t.km – source Air France KLM), or ~ 0.35\$/t.km

For reference, road transport is invoiced a little bit more than 0.06 €/t.km in France (2011), rail transport an average of 0.045 €/t.km, pipelines 0.04 €/t.km and inland waterway 0.03 €/t.km (maritime transport : highly fluctuant, but less than 0.01 €/t.km ; down to less than 0.001€/t.km in some cases, depending on type of consignment, ship size and freight rates)

Note that at a world scale, **only 45% of available tons.km (ATK), or capacity, are used**. This figure vary according to the economic climate (39% at the beginning of 2009, 47% average 2010, 45% in September 2011), to company (large companies can more easily adapt supply and demand : Air France KLM Cargo ensured in Q2+Q3 2011 a 65% use of its capacities) and to region (Asia/Pacific : 57% in September 2011 ; Africa : 24% - IATA figures). This is a factor of prices variability. Goods can be accepted at lower price to ensure optimisation of available capacity (low marginal cost, a plane empty and another fully loaded have close production costs)

From	Toulouse – Blagnac
To	Ouagadougou Aéroport
Goods	IT equipment
Invoice value	
Volume	3.33 m^3
Gross Weight	353 kg
Taxable weight	556 kg

Export air quote	
Pick-up	
Air security	26.85 €
TGA	10.00 €
Cross-docking	77.77 €
Export customs	54.88 €
Airway bill tax	23.40 €
Air freight	1,722.25 €
War risk	53.00 €
Fuel surcharge	35.33 €
Insurance	
Total	**2,063.48 €**
Distance	4,100 km
Total (€/t.km)	**1.44 €/t.km**

Figure 33: a quotation example (figures 2008). When compared to Air France KLM 2011 average revenue per t.km (0.26€ in 2011 - see upon), it shows the high variability of air freight prices.

Cost of aircraft

'Catalogue' prices of new all-cargo aircraft (airlines then negotiate hard these prices with manufacturers)

Boeing (source manufacturer website, average 2011)

- B767-300 Freighter : 175 million USD
- B 777 Freighter: 280 million USD
- B747-800 Freighter: 333 million USD (135 t capacity)

Airbus (catalogue price 2011)

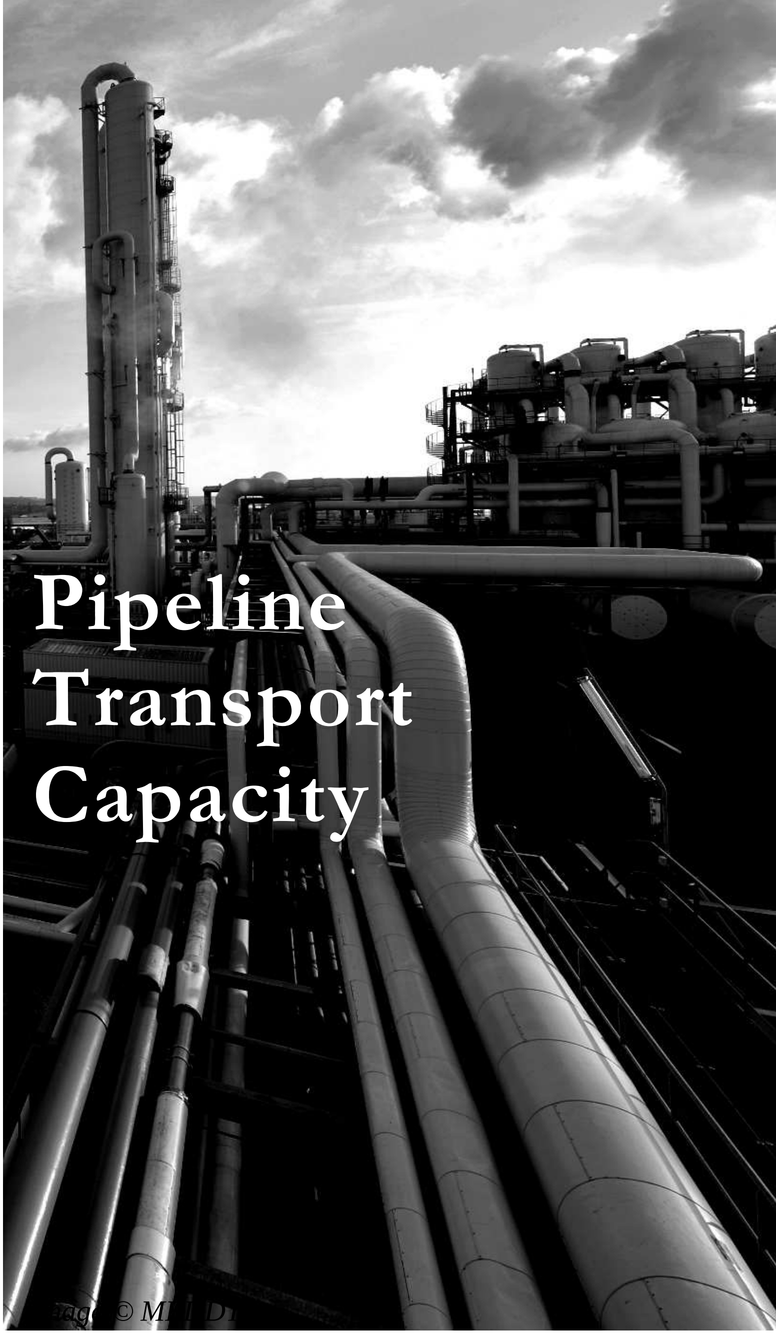
- A330-200 Freighter : 203 million USD (69t capacity)
- A380: project suspended up to 2015 (150 t capacity)

Converted aircraft

Converted aircraft are less than 15 years old, they have been amortised as passenger transport aircraft and their residual value represents around 15% of the price of a new aircraft. Conversion costs vary between 4 to 10 million USD depending on the type of aircraft; conversion work takes 2 months.

Example : an Airbus group plant at Dresden, EFW, converts A300-600 and A310 into their cargo versions. Aircraft are purchased second-hand for less than 15 million USD and conversion costs 7 - 9 million USD. Fedex, which is the largest plant customer, can therefore acquire an aircraft for approximately 22 million USD, for example

Section 9 - Pipeline Transport Capacity



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Introduction

The purpose of this section is to present the principal information necessary to understanding pipeline transport capacity.

Petrochemical products are transported by oil pipelines (oleoducts) in large volumes. In certain cases, notably where petroleum pipelines do not exist, road and rail transport offer competitive alternatives. To analyse the overall transport network capacities, it is useful to estimate the capacity of the pipeline networks. It is made within this section in France as an example.

The problem is different for gas, which is transported mainly through gas pipes in a gas distribution network. Nonetheless, this guide includes certain data representative of networks, stakeholders and traffic flows, allowing us to grasp the main issues in capacity terms.

It may be remembered that pipelines are basically a one-way system. For example, oil pipeline transport amounts 248 million tons or 16.3 % of European Union imports (source Eurostat 2011, figure 2009. Value : 81 billion € or 6.8%) but only 0.7% of exports. Pipes are particularly suited to these inherently unbalanced flows between producers and users.

Note that in most cases, only oil pipelines are taken into account for statistics. Other types of pipelines, and particularly gas pipelines, are excluded.

Chemical industry products, such as hydrogen, oxygen and nitrogen are also transported by gas pipes. In the case of hydrogen, Western Europe has a pipeline network of approximately 1,500 km (900 km in the United States). France, Germany and the Benelux countries are the main countries operating the hydrogen pipeline network. Other smaller pipelines exist in Great Britain, Sweden and Italy. This distribution method proves to be most economical when transporting large volumes of gases over short, medium and long distances. With regard to its distribution as a fuel for road vehicles, hydrogen – where not produced at the distribution station itself – could be transported by road, rail or by waterway or by a gas network. These issues are not discussed here.

Pipelines are also widely used for internal transport in some plants (refineries, chemical industry, etc.). This will also not be discussed here

1 - Oleoducts

In this section, both the exact term "oleoduct" and the general term "pipeline" are interchangeable.

1.1 - Definitions and general points

A pipeline consists of a network of pipes (almost always below ground) known often as the "line", pump stations (to propel the liquid) and terminals at the ends of the line. At the outlet terminal, the product must be delivered to the client in a quality and quantity equal to that at the point of entry. Pipelines are used to exchange products between refineries, petroleum depots and port installations. Lengths can vary between several km to several hundred or even several thousand km.

1.1.1 – Pipeline characteristics

A pipeline is characterised mainly by the line, which is formed from steel tubes. Its usual diameter is between 6 and 42 inches (i.e. 15 cm to 1 m), but can be much larger. The wall thickness is between 4 and 13 mm. Pipelines are elevated or buried in the ground at depths from 60 cm to over 1 m, depending on when it was built and the terrain through which it passes. The pipe characteristics (diameter, thickness, steel grade) are defined by calculations involving many parameters, including the required flow rate, the profile and type of terrain, environmentally sensitive areas to be crossed, current legalisation, etc..

Pump stations propel the liquid(s) through the line. Achievable flow rates can be between several hundred m^3/h and 2,500 m^3/h. These volumes are considerable higher than is possible with other means of transport. The displacement speed, however, remains low: 1 to 3 m/s (i.e. 3.6 to 10 km/h).

All the pipeline installations are remotely controlled by a central control room, able to detect any anomalies which may arise and to take appropriate action.

1.1.2 – Pipeline operation

Transport of products requires that the line should always be full (one product propelling another) and that the outlet terminal has sufficient capacity to receive the products.

A pipeline is said to be 'multi-product' when it transports several different products. Products are propelled according to a pre-defined sequence. The sequence is arranged according to the compatibility and the specifications of the products to be conveyed.

1.1.3 – Benefits of pipeline transport

A pipeline has several advantages, some of which are decisive over other means of transport. Pipelines provide:

- a means of bulk transport;
- transport with a high degree of safety, with less than two incidents per 10,000 km of pipeline per year;
- guaranteed supply, unaffected by bad weather or atmospheric conditions, with high operating availability;
- a means of bulk transport which is more economical over medium and long distances and which requires very few handling operations;
- the most appropriate supply method between large centres which are at a great distance from sources of production or importation of hydrocarbons.

The disadvantage, however, is that if the electricity supply to the pump stations fails, this can cause the flow in the pipeline to stop. On DMM and ODC military installations (see network description) autonomous operation is provided by internal combustion engines, however these installations are currently being electrified.

1.2- Networks, stakeholders and product flow

The first oleoducts were built in France in the 1950s and the major part of the network was developed in the 1960s and 1970s. Currently, there are almost no oleoduct construction projects in France. At a world scale however, great sections are under project or achievement, often generating geopolitical and environmental issues.

There are two types of oleoducts, depending on the product to be transported: crude oil or multi-products (refined products: petrol, diesel, heating oil, jet fuel, etc.) Appendix 1 shows the oleoduct networks in France.

1.2.1. Transport of crude oil

Crude oil is unloaded at four sites in France: Le Havre-Antifer, Fos-Lavéra, Donges and Dunkerque, from where it is conveyed to the refineries. The two main oleoducts used for crude oil are the Ile-de-France Le Havre–Grand-puits pipeline and the South European pipeline (operated by la Société du Pipeline Sud Européen - SPSE), which serves the Lyon, Cressier (Switzerland), Alsace regions and the refinery at Karlsruhe in Germany. Also to be noted are the networks at Parentis and Lacq in the southwest, the oleoduct from Le Havre to Petit Couronne (near Rouen) and the small auxiliary networks primarily around the ports of Le Havre and Marseille.

1.2.2 - Transport of refined products

There are four main pipelines used to transport refined products:

- from Le Havre to Paris (LHP) operated by the company Trapil: this was the first line constructed in France, in 1953. It consists today of four pipes serving the Parisian region. It extends to Orléans, Tours and to Caen;
- from the Mediterranean to the Rhone (Société du Pipeline Méditerranée - Rhone - SMPR), operated by Trapil, serving Nice, Feyzin (the Lyon region), Grenoble and Geneva from Lavera;
- from Donges to Melun and to Metz (DMM), owned by the state and operated by Société Française Donges Metz (SFDM);
- the Common Defense Oleoducts (ODC), constructed by NATO initially for military supplies and which currently also supplies civilian industrial activities. These are operated by Trapil.

The Trapil company currently operates a network of approximately 4,700 km of pipelines, 850,000 m^3 of storage and 160 pump stations and delivery stations.

It should be noted that there are few interconnections between these different networks and that those that do exist are little used.

In Europe?

There is little product exchanged between the networks of different European countries and France (consisting mainly of the supply by the SPSE network to the Reichstett refinery on the German border). This is because France developed its own network of pipelines and refineries according to its own needs. Some balancing of demand and exchanges take place with our European neighbours, though these are made primarily by ship.

The transport of petrochemical products is organised according to the areas concerned. Some countries have no oleoducts and product is transported by road (Greece, for example). Other countries (Spain, for example) operate independently, like France. There are many more exchanges between Germany, Switzerland and the Benelux countries, due largely to the role played by the Rhine in the transport of petrochemical products (what is more, the Rhine duplicates a pipeline). Finally, the essential role played by the port of Rotterdam in supplying refined products to the great industrial centres of Germany should be noted.

1.2.3 – Product flow

Mainland transport of crude oil in pipelines in 2005 was 38.3 million tonnes through networks longer than 50 km and 60.9 million tonnes through networks less than 50 km long. This corresponds to a total product flow of 15 billion tonne-km.

Mainland transport of refined products in pipelines in 2005 was 41.3 million tonnes through networks longer than 50 km and 18.7 million tonnes through networks less than 50 km long. This corresponds to a total product flow of 7.8 billion tonne-km.

Therefore, transport of petrochemical products by pipeline totals 22.8 billion tonne-km. This product flow has been stable for the last dozen years.

Appendix 2 provides the product flows and technical characteristics for the different networks.

For information, Appendix 3 provides the national petrochemical product flows as transported by other means.

1.3 - Capacity

Oil pipelines have an unknown significance for goods transport. Huge amounts of oil flow permanently all over the world. For example, this is the first goods transport mode in Russia. Russian oleoducts alone ensured carriage of 2,250 billion t.km in 2009, or the same amount that road, rail and inland waterway together for the same year in the European Union (source – Eurostat 2011). It remains however relatively low in consumer countries (European Union : 120 billion t.km).

The capacity of an oleoduct depends on the capacities of its constituent parts (the line, the pump stations and the terminal stations) and also on a 'network' effect.

Note. The concept of authorised capacity, shown in the tables in Appendix 2, does not necessarily represent the maximum pipeline capacity. It is the maximum capacity authorised by the French state at the time of pipeline construction and declared to be of public interest. This authorised capacity is, however, almost always much higher than that actually achieved.

1.3.1 - Pipes

Pipe capacity depends on:

- the operating period of the installation (a pipeline may reasonably be expected to operate 300 days per year, 20h/24);
- the maximum flow rate, which in turn depends on the pipe diameter and the number of available pump stations.

The density of the products is between 0.75 and 1 tonne per m³

On the SPSE network (crude oil) flow rates are between 1,800 and 4,500 m³/h in 40" (100 cm) pipes and between 600 and 1,200 m³/h in 24" (60 cm) pipes.

On the LHP network (Trapil, multi-product) the flow rate in a 20" pipe can reach approximately 1,800 m³/h. As an example, the flow rate in the Roissy supply (LHP network) can, in peak periods, reach 15,500 m³/day (equivalent to 500 tankers per day) in a 22" pipe.

1.3.2 - Pump stations

Flow through a pipeline is obtained by the use of centrifugal pumps to pressurise the liquid filling the pipe.

Pipe capacity may be increased without constructing new pipelines by raising the pump station pressures or by creating extra pump stations.

1.3.3 - Terminals

The terminal installations connect each line to the refineries or storage facilities. Marketing petrochemical products requires companies to hold considerable stocks. Appendix 4 has a table showing the civil depots and their capacities. The product volumes processed in the refineries (4 million tonnes for a small refinery, 15 million tonnes for a large refinery) are, in general, insufficient to saturate the lines.

1.3.4 – Network effect

Evaluating the different parameters described above can seem relatively straightforward. However, all these parameters and their interactions (the network effect) must be taken into account, making it difficult to evaluate network capacity.

A typical example might be the limitation on pipe flow rate caused by the flow rates in downstream network pipes or by the connection to another network. Other examples limiting network capacity include: local networks around refineries, any refinery breakdowns or clients not ready to receive their product.

1.3.5 – Setting quotas

In the event of an isolated incident or sudden increase in demand, the pipeline operator might find himself unable to satisfy the demand. In this case, the operator sets quotas: he negotiates with the client a deferment on part of the delivery. Quota setting, affecting approximately 7% of product transport on the LHP network, does not impact the client demand and further investment in the pipeline is not justified.

If, however, this quota-setting recurs, perhaps due to sustained increases in demand, then the pipeline operator might envisage small-scale investments to improve pipeline capacity.

The oleoduct networks are not saturated. For the networks conveying refined products, this is primarily because the products are standardised, i.e. the batch received by the client is not necessarily the batch despatched but is a product with identical characteristics. However, a client requesting delivery of his own product (invoking "segregation") reduces the pipeline transport capacity. When the product transported is non-standardised (when conveying a product with particular characteristics, for example), the additional constraints would result in a reduction in capacity (without increasing the total tonnage transported).

Example. Mediterranean - Rhône pipeline (multi-product)

The maximum flow rate of the main branch of the SPMR network is 1,300 m^3/h, the equivalent of more than 1,000 tanker trucks (semi-trailers) per day.

The SPMR network connects five refineries, an inlet station and 28 outlet stations. A storage depot with a capacity of 92,000 m^3, at the centre of the network, allows transport flow to be regulated through the different pipes forming the network.

Product is propelled by 17 pump stations and a dozen outlet stations ensure distribution to the connected depots. Of these depots, the final delivery to the service stations, factories, shops and houses is made by tanker trucks over short distances.

Example. Southern European Pipeline *(crude oil)*

Though the current SPSE transport flow is 20 million tonnes per year (the authorised capacity is 75 million tonnes), the company could increase transport flow to 40 million tonnes per year without constructing new lines.

For the temporary storage of crude oil in transit, the SPSE port terminal at Fos-sur-Mer has 40 storage tanks with a total capacity of 2.26 million m^3. The capacity could be extended.

1.4 - Transport tariffs

Oleoduct transport tariffs are relatively low, between 2 and 5 € per tonne per 100 km, depending mainly on the product type.

Example. Trapil average tariff: 0.04 €/t/km.

The construction of an oleoduct represents a considerable investment: nearly 300,000 €/km (source: TRAPIL). The Fos-Manosque pipeline construction, achieved in December 2007, was particularly expensive: 120 M€ for 140 km. It remains however far cheaper than rail or road construction, with almost no impact if buried.

2 - Gas networks

Unlike the transport of petrochemical products, gas transport is effected almost entirely by pipes. The transport of LNG (Liquid Natural Gas) or LPG (Liquid Petroleum Gas) is not discussed in this section and is not considered within the scope of this multimode-based guide.

2.1 - Definitions and general points

2.1.1 – Institutional context

With regard to energy markets, the first European directive [84] required that from 10th August 2000 the energy market be completely open and equal. The essential issue in this directive is to allow the market to be opened to competition for the benefit of all clients, whilst always maintaining a framework which encourages investment in the large national and international infrastructures intended for natural gas distribution.

The French law dated 3rd January 2003 transposed the requirements of the first directive into French legislation. Public service obligations were imposed on the pipeline operators to guarantee supplies.

2.1.2 – Gas transport

In this organisation, the gas pipeline operator is a key figure: he conveys natural gas from the suppliers to their clients, in optimum cost and safety conditions and without preference amongst clients.

He manages supplier access to the network notably at the network inlet stations, announcing to the gas stakeholders the capacity available on the network.

Over 95% of gas consumed in France is imported, 82% of which is supplied from Norway, Russia and Algeria. In 2003, natural gas represented over 14% of the energy consumed in France.

2.2 - Networks, stakeholders and transport flow

2.2.1 – Transport networks

The gas transport network includes all the high pressure (up to 85 bar) pipelines which transport gas to industrial consumers who are directly connected and also the low pressure distribution network (up to 16 bar). The transport network is also employed for international transport.

It consists of:

- a main network: large diameter (normally over 600 mm), linking the points of interconnection on neighbouring transport networks, storage facilities and LNG carrier terminals;
- regional networks: networks conveying gas from the main network to consumers or to distribution networks not directly connected to the main network.

A shipper wanting to transport gas to a consumer's premises must reserve capacity at the inlet and outlet stations of the main network as well as at the local delivery station.

2.2.2 – Stakeholders and transport flow

Two operators manage the gas transport network in France:

- **GRTgaz**, owned by Gaz de France, manages independently the operation and marketing of the gas distribution service on 31,500 km of network. GRTgaz manages the longest gas transport network in Europe.GRTgaz manages the five inlet points in France (in 2004, an input of 605 TWh, 65 TWh of which transits to Spain, Switzerland and Italy): Taisnières (30%), Dunkerque (29%), Obergailbach (18%), Montoir de Bretagne (13%, from the LNG carrier terminal) and Fos-sur-Mer (7%, from the LNG carrier terminal).
- **TIGF** (Total Infrastructures Gaz France), 100% owned by the Total group, created in 2005, manages a network of 4,900 km (i.e. 13% of the network) in the southwest.

88 TWh was exported from France in 2004, at Oltingue (70%) for GRTgaz and at Larrau (30%) for TIGF.

The GRTgaz and TIGF networks are connected.

The Appendix 5 describes the French gas network.

	1973	1979	1985	1990	1995	2000	2002	2003	2004
Transport	17 974	22 678	26 619	30 162	31 759	34 232	35 133	35 762	35 740
Distribution	71 392	84 030	104 226	119 150	136 860	159 020	171 339	176 541	179 820

Figure 1 : Growth in natural gas pipe lengths in France

Fig 2. Construction of a large section pipeline. Section and speed of flow are not the only parameters determining capacity.

2.3 - Capacity issues

In winter, the high demand for gas in France cannot be satisfied solely from the resources at the country borders. Some of the demand is met from underground reservoirs (aquifers or saline cavities) located across the country. Seasonal activity sometimes results in network saturation, not just in winter due to the high demand for gas, but also in summer since advantage is taken of this period to replenish the underground stocks.

The conveyance of gas also presupposes that gas delivery pressure be guaranteed. The three fundamental variables used in calculation of capacity are flow rate, calorific value and pressure. GRTgaz uses a calculation model allowing these magnitudes to be determined for the entire pipe network, according to different assumptions made with regard to supply and demand in particular.

Capacity depends on the level of consumption. Taking the simple case of a pipe connecting point A to point B with regional branches intended to supply local consumers. Each branch represents a pressure drop which varies with consumption. If, for example, the capacity of the link from A to B is defined by the maximum flow rate at point B, then this is limited by the pressure losses at each local branch.

Capacity depends on underground stock movements. If underground storage is linked to the pipe network, off-takes or replenishments will modify the pressure and flow rate in the link and the flow rate at point B will be affected.

The network configuration is also a determining factor in the calculation of capacity. Flow rates into the distribution networks have a major influence.

GRTgaz calculates capacities at inlet stations, outlet stations and at the links between balancing zones. Marketable capacities are published on the GRTgaz website, thereby offering to their suppliers an overview of the gas network transport possibilities.

Capacity is measured in MWh, per hour and per day.

1 m^3 LNG = 600 m^3 of gas = 6.2 MWh

Standard figures : conversion from liquid (LNG) to gas depends on elevation and temperature, whereas conversion from gas to energy (MWh) varies in relation to gas composition (percentage of methane - CH4).

1 MWh = 1,000 kWh = 1 million Wh = 3.6 GJ

1 Wh = 1 Watt during 1 hour

1W = 1 Joule per second (1J/s), so 1Wh = 3,600 J and 1MWh = 3.6GJ (3.6 GigaJoule or billion Joule)

2.3.1 - Developments

The pipe networks used in gas transport have had problems due to significant saturation, notably in the Rhone valley, where duplication of the artery is very difficult technically and would therefore be costly. Transport flow is redirected to the southwest network, resulting in similar saturation problems. The project to reinforce the Algeria – Spain – France links, either by MEDGAZ or by LNG carrier ports, would represent additional transport flow.

For this reason and in view of the increase in natural gas consumption, the Guyenne artery in Gironde (for the connected networks of GRTgaz and TIGF) installed almost 50 years ago and forming the backbone of the French national gas transport network, must today be reinforced. After a first phase of pipeline doubling in 2002 and 2003, the extension to this doubling will soon happen.

Projects to reinforce the network in north-eastern France can also be cited.

2.3.2 – LNG carrier terminals

An LNG carrier terminal is an installation to receive, store and regassify liquid natural gas (LNG) and to deliver the gas to the main transport network. The two LNG carrier installations in France are at Montoir de Bretagne and Fos-sur-Mer.

The LNG carrier terminal at Fos-sur-Mer

At Fos-sur-Mer, *Gaz de France operates a quay dedicated to LNG importation, able to receive 65,000 m³ LNG carriers. The maximum processing capacity (storage and regasification before distribution) of these installations is* ***4 Mt/yr****. This LNG carrier terminal has a* ***storage capacity of 135,000*** *m³. In 2005, LNG imports totalled 3.9 million tonnes.*

A second LNG carrier terminal was commissioned in 2007. It receives ***160,000 m³ LNG carriers*** *and could achieve a processing capacity of 13.2 Mt/yr.*

Five projects are currently in course in France : Antifer, Dunkerque, Verdon, "FosFaster" (Fos-sur-Mer), "Cap Tonkin"(Fos-sur-Mer). In 2008, 53 LNG terminals were in operation throughout the world.

The LNG carrier terminal at Montoir *is the largest in Europe, with a storage capacity of 360,000 m³.*

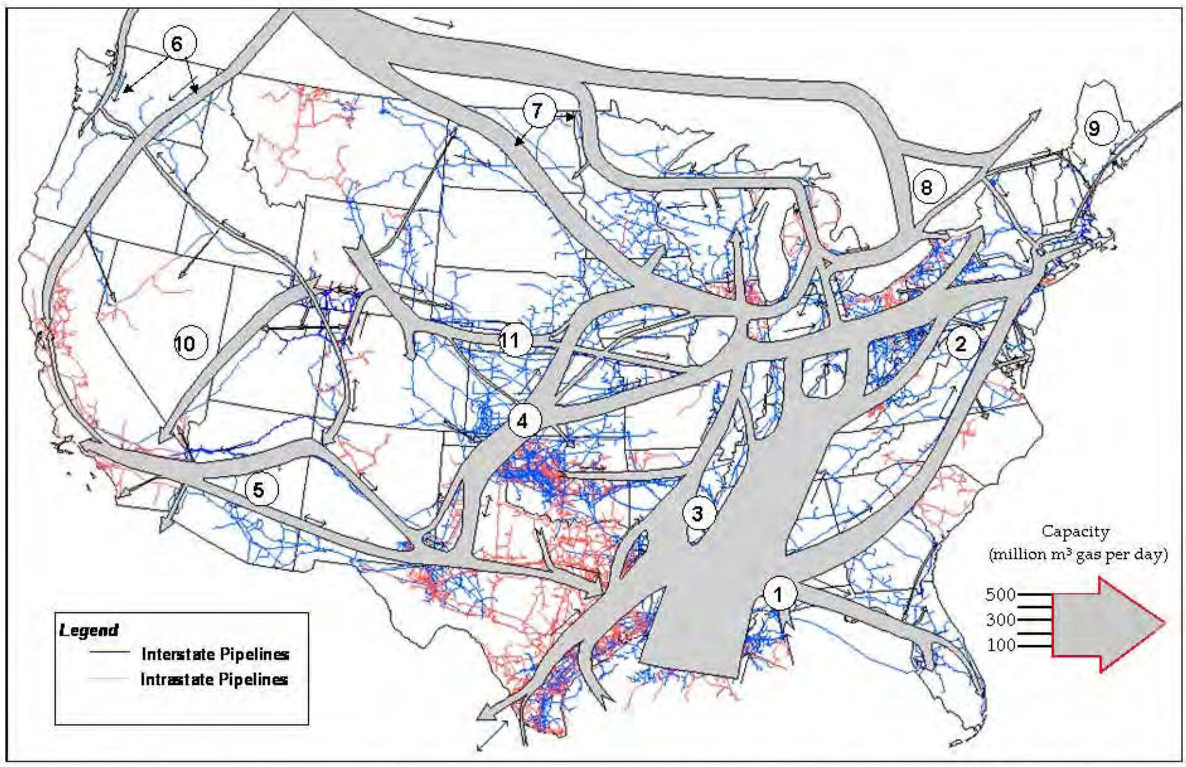
2.4 - Tariff setting

Users of the gas transport network are subjected to an 'inlet-outlet' tariff, dependent on 'balancing zones'. In France, the tariff setting methods are defined in decree No. 2005-607 of 27 May 2005 in relation to the tarification rules applicable to the use of the natural gas networks [85], and by the law of 27 May 2005 which defines the balancing zones of the natural gas networks [86].

Balancing zones

The zone, including the inlet and outlet stations and a gas exchange point, in which each shipper is obliged to balance the gas they take off and deliver. In 2006 there were five balancing zones: the north, the west, the east, the south and the southwest zones.

Figure 3 : Trans-Alaska Pipeline System, running on 1,300km from Arctic Ocean to Valdez (Gulf of Alaska). Elevated pipelines offer cheaper investment and easier maintenance, but cause environmental insertion problems.
source Wikimedia commons - photo Luca Galuzzi – www.galuzzi.it



Source: Energy Information Administration, Office of Oil and Gas, Natural Gas Division, GasTran Gas Transportation Information System.

Figure 4 : gas pipelines network in the USA (48 lower states) : the trunk noted "1" represents more than 1 million m³ GNL per day (for reference : 1 m³ liquid gas LNG = nearly 600 m³ gas) – year 2009.

Appendix 1. Oleoduct Networks in France

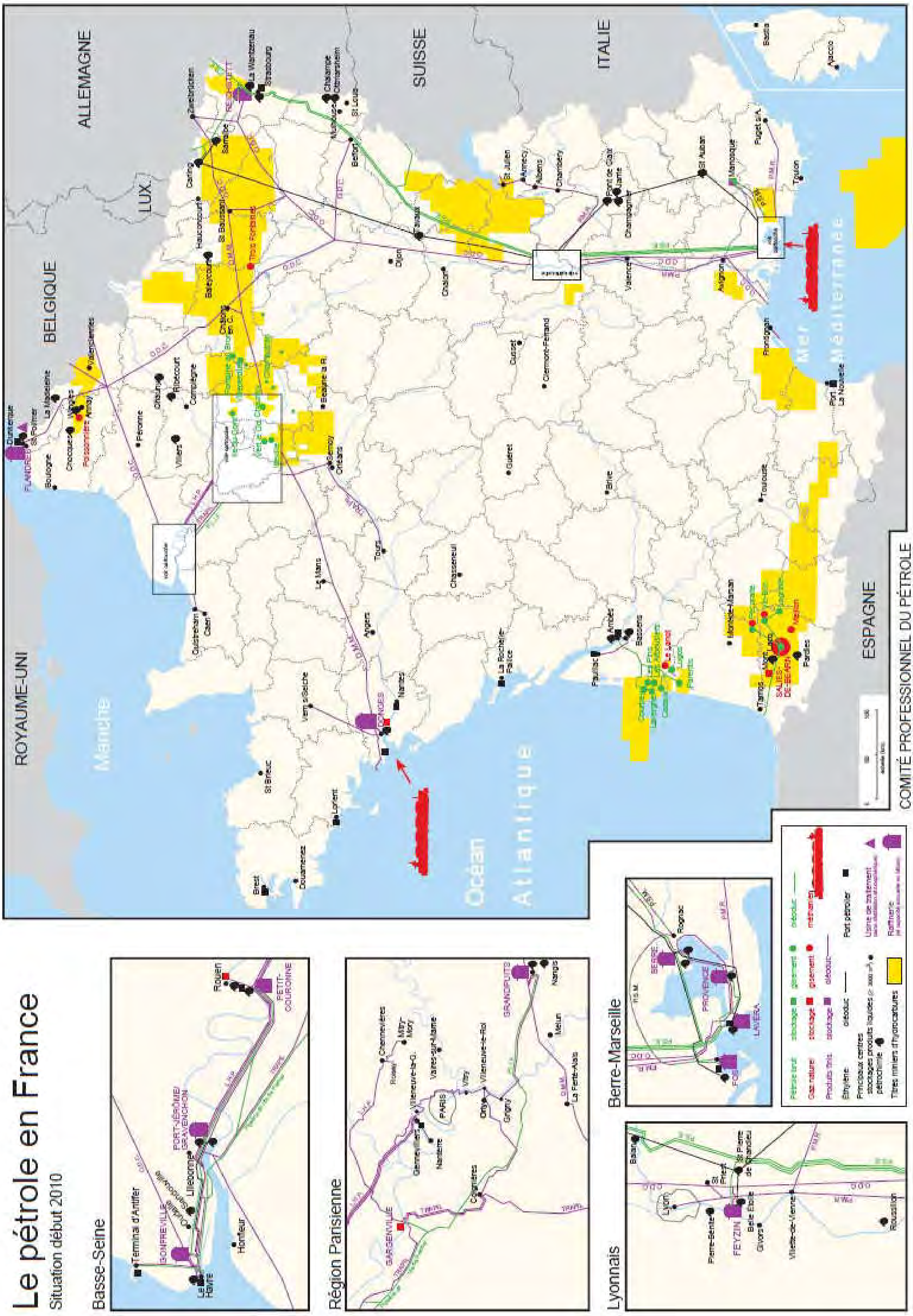


Figure 3. Oleoduct networks in France in 2010

Appendix 2. Petrochemical Products Transported by Oleoducts

Figures for 2005.

Crude oil transport, pipelines over 50 km

Name	Owner	Pump stations	Length km	Dia. in inches	Theoretical authorised capacity (Mt/an)	Tonnage	Tonne – kilometres (billions)
S. European Pipeline	SPSE	19	1,773	24, 34, 40	75	19.94	11.86
Gennes - Cressier	PL du Jura	2	56	16	4.5	2.57	0.14
Oberhoffe - Carling	Total	1	107	16	7	1.63	0.16
Le Havre - Grandpuits	Total	5	252	20	11.5	6.62	1.22
Le Havre - Petit Couronne	Shell	1	76	28	23	6.57	0.49
Others			456			1.00	0.06
Total			**2.720**			**38.32**	**13.93**

Figure 4. Crude oil transport, pipelines over 50 km

Crude oil transport, pipelines under 50 km

Dénomination	Propriétaire	Stations de pompage	Longueur (km)	Diamètre (pouce)	Capacité théorique ou autorisée (Mt/an)	**Tonnage (Mt)**	**Tonnes kilométriques (milliard t.km)**
Antifer - Le Havre	CIM	1	27	42	22,5	13,52	0,36
Le Havre - Gonfreville	Total	1	17	34	45	12,59	0,10
Le Havre - Port Jerome	Exxon / Mobil	1	37	22 et 26	13	7,76	0,28
Lavera - La Mede	Total	1	9	34	26	6,74	0,06
Fos - Berre	Shell	1	26	20	6,2	5,26	0,14
Autres			238			15,04	0,31
Total			**353**			**60,91**	**1,25**

Figure 5. Crude oil transport, pipelines under 50 km

Source: Ministère de l'Economie, des Finances et de l'Industrie / Direction des Ressources Energétiques et Minérales

Transport of refined products, pipelines over 50 km

Dénomination	Propriétaire	Stations de pompage	Longueur (km)	Diamètre (pouce)	Capacité théorique ou autorisée (Mt/an)	**Tonnage (Mt)**	**Tonnes kilométriques (milliard t.km)**
La Mède - Lyon - Genève	SPMR	13	765	10, 12 et 16	9,2	10,65	2,23
DMM	SFDM	8	627	10 et 12	2,5	2,76	0,60
LHP	Trapil	28	1 368	de 10 à 32	25	19,74	3,81
Lavera - Manosque	Geosel	4	173	20	15	4,72	0,18
Donges - Vern s/Seiche	Total	1	93	12	3	1,23	0,11
Total			**3 026**			**39,10**	**6,94**
Oléoducs de Défense Commune			**2 260**			**2,24**	**0,64**

Figure 6. Transport of refined products, pipelines over 50 km

Transport of refined products, pipelines under 50 km

Dénomination	Propriétaire	Stations de pompage	Longueur (km)	Diamètre (pouce)	Capacité théorique ou autorisée (Mt/an)	**Tonnage (Mt)**	**Tonnes kilométriques (milliard t.km)**
Gonfreville - Le Havre	Total	2	11	16	3,5	1,41	0,02
Feyzin - Oytier St Oblas	Total	1	22	12	3	0,98	0,02
Berre - Fos	Shell	1	27	20	6,2	1,66	0,04
La Mede - Lavera	Total	3	23	16 et 18		4,05	0,03
Reichstett - Strasbourg	CRR	1	21	10 et 12		2,17	0,02
Autres			260			8,45	0,12
Total			**364**			**18,72**	**0,25**

Figure 7. Transport of refined products, pipelines under 50 km

Source: Ministère de l'Economie, des Finances et de l'Industrie / Direction des Ressources Energétiques et Minérales

Note: in the case of the (little used) interconnections between networks, the tonnes transported are counted twice.

Appendix 3. French national flow of petrochemicals by all modes

Source: MTETM / SESP, SITRA-M 2002

In 2002, petrochemicals transported by road represented:

- 79 million tonnes;
- 7 billion tonne-km.

It should be noted that this transport flow consisted almost entirely of refined products. The large part played by road transport is due to the inadequacy of the oleoduct network in serving the southwest region and by the need for road transport to supply the outlet stations (service stations).

Volumes transported by road are four times higher than by oleoduct.

In 2002, petrochemical transport by rail represented:

- 6.4 million tonnes;
- 2.5 billion tonnes-km.

In 2002, petrochemical transport by waterway represented:

- 3.4 million tonnes;
- 0.4 billion tonnes-km.

For rail and waterway transport, once again it was refined products that were carried.

The vast majority of crude oil is transported only by oleoducts.

Appendix 4. Civilian storage depots for fuel distribution

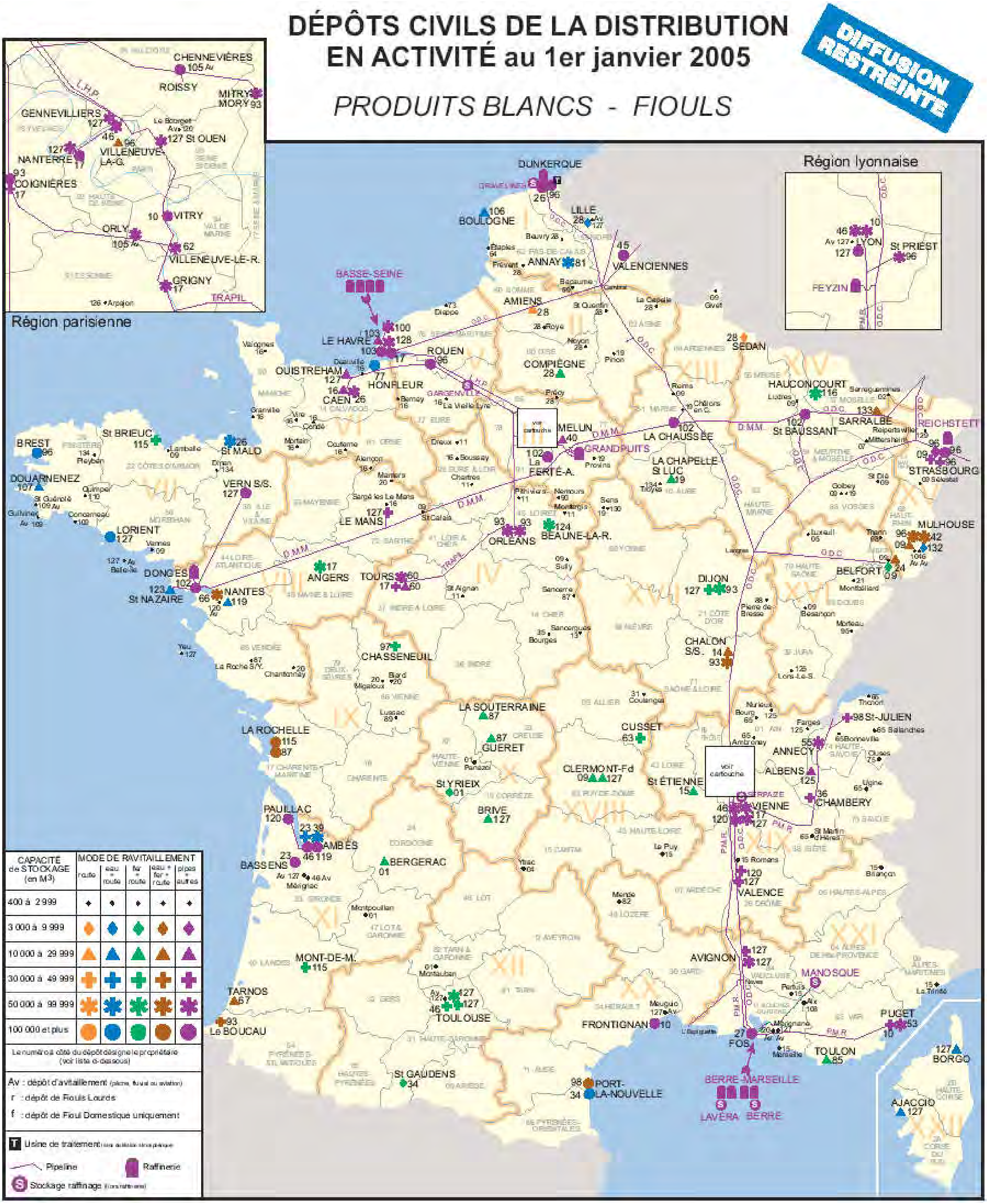


Figure 8. Civilian storage depots used for fuel distribution, in 2005 – Source: Comité Professionnel du Pétrole

Appendix 5. Gas transport networks in France

Figure 9. Gas transport networks in France. The map in 2011 is similar.

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www.tigf.fr - *TIGF*

Lexicon and glossary of abbreviations

For the most part, the general terms are taken from the "Combined transport terminology" proposed by the European Economic Council (Economic and Social Council, United Nations). Terms concerning waterway transport are drawn mainly from the Vnf internet site (www.vnf.fr). [TERM] : French terms, for reference

Accompanied combined transport (ACT) [Transport combiné accompagné] : the conveyance of a complete road vehicle assembly, with driver, by another means of transport

ACTIF : *Aide à la Conception de systèmes de Transports Inter-opérables en France.* [ACTIF: Assistance in the design of inter-operable transport systems in France]

ADT / AADT [TMJ/ TMJA (Trafic Moyen Journalier, Trafic Moyen Journalier Annuel)] : Average daily trafic / Average annual daily traffic

Air freight terminal [Aérogare fret] : sector dedicated to handling air cargo

AWB / Airway Bill [LTA / *Lettre de Transport Aérien*] : in air freight, the transport contract linking the consignor, the forwarding agent and the shipper]

AFITF : *Agence de Financement des Infrastructures de Transport de France* [Agency for Financing of Transport Infrastructure in France]

Approved carrier [Agent habilité] : approval granted by the Ministry of Transport to freight carriers which are legally and technically qualified to implement air cargo safety procedures

Articulated lorry [Ensemble articulé] : motorised vehicle with a semi-trailer attached

ASFA : *Associations des Sociétés Françaises des Autoroutes* [Association of French motorway companies]

AUTF : *Association des Utilisateurs de Transport de Fret* [Association of freight transport users]

BAL : *Block Automatique Lumineux* [automatic block with colour-light signals; signals to maintain separation between trains are laid out along the trackside at regular intervals and determine block lengths. While advancing, the train sets the signal immediately behind to red, sets its preceding signal to amber (yellow) and possibly activates the Acli (flashing warning light). If certain conditions are satisfied, a train stopped at a light can recommence. The BAL requires track circuits (detection of the train by the electrical shunting of track) to be in place. The distance between two signals is less than or equal to 3 kilometres (often 1,500 m on main lines). The minimum distance between two trains at normal speed is always equal to two blocks plus the train length

Ballast [Ballast]

- **rail transport**: ballast is the bed of gravel on which the railtrack is supported; consisting of compacted hard stones, its purpose is to distribute loads, absorb vibrations, anchor the sleepers and to quickly drain away flood waters]
- **maritime transport**: the double hull of a ship which can be filled with fuel or water to weigh down or modify the trim (equilibrium) of the ship. Also, the liquid contained within ballast]

BAPR : *Block Automatique à Permissivité Restreinte* ; [automatic block with restricted permissivity; a system to control the separation between moving trains. BAPR operates like BAL but with longer blocks (approximately 10 kilometres) on lines with low-density traffic]

Barge [Barge] : a non-motorised vessel for waterway transport. Open-topped for bulk transport. Convoys are formed by coupling several barges end-to-end

Barge [Chaland] : open top boat, flat bottomed, for river goods transport

Boat [Bateau] : name for a waterway transport vessel, whatever its dimensions

Boatage [Lamanage] : mooring a ship

BM : *Block Manuel* [manual block] ; the signalman sets the signal to danger after the train has departed, the receiving station authorises the sending station signal to be set to clear once the train has arrived. The minimum separation between two trains is equal to the distance between the stations. This distance can be very long if some intermediate stations are unmanned

Bogie [Bogie] : trolley mounted beneath a railway vehicle to which the axles are attached

Barrowing [Brouettage] : in a port facility, to transfer goods (containers, trucks, etc.) from one terminal to another

Break bulk or breaking bulk [Rupture de charge] : to transfer goods from one transport mode to another

Cabotage [Cabotage routier] : national road transport carried out by a road vehicle registered in another country

CAF : *Comité des Armateurs Fluviaux* : waterway ship owners committee. Protects the interests of ship owners. Represented on the Vnf (soon ANVN, *Agence Nationale des Voies Navigables*) board of directors

Cargo ship [Cargo] : in marine transport, a freighter allocated to transport of general goods

Catenary [Caténaire] : components supplying electrical power to an electric train. The catenary consists of two contact wires suspended from droppers supported on one or two carrying cables. The catenary is supported by stanchions. Cables are essentially made of copper (contact and feeder cable) and alu-steel and bronze (carrying cable, feeder)

CCNR : Central commission for Rhine navigation

CDG : Charles de Gaulle airport

CETMEF : *Centre d'Études Techniques Maritimes Et Fluviales* [Centre for maritime and waterway technical studies]

CFMU : Central Flow Management Unit. European centre regulating air traffic movements

Charterer [Affréteur] : see Chartering

Chartering [Affrètement] : a transport convention whereby an individual or company makes available to a third party (the shipper) a ship, an aeroplane or a motorised land transport vehicle for the conveyance of goods

In martime transport, charters can be:

- **by journey**: the ship owner puts all or part of his vessel at the disposal of the charterer for one or more journeys. The freight charge is calculated by per tonne, per m^3, per unit or as a package price in order to cover financial charges, operating and variable costs
- **by time**: the ship owner commits himself to putting a manned ship at the disposal of the charterer for a defined period. The ship is rented according to a daily rate. The price covers the financial charges and operating costs; bare boat: the ship owner, for a rental fee and for a defined period, puts at the disposal of a charterer a ship not manned nor equipped, or with a skeleton crew and equipment

Channel [Chenal] : 1) The natural channel is the minor bed of a watercourse, over which water preferentially flows. 2) The navigation channel is the passage for which the navigation characteristics are known and which is reserved for the navigation of boats

Combined transport [Transport combiné] : intermodal transport where the majority of the journey is undertaken by rail, waterway or by sea and where the initial and final road journeys are as short as possible

Complete batch [Lot complet] : a complete batch involves a single delivery from a single consignor to a single delivery address and occupying a complete load unit

CNBA : *Chambre Nationale de la Batellerie Artisanale* [National chamber of inland waterways transport sector: administrative public organisation representing inland waterways transport sector]

CNO : *Centre National des Opérations* : [National operations centre (railway operations); coordonates all basic activities of the COGC, regional operations centres]

CNR : *Comité National Routier* [National roads committee]

CNR : *Compagnie Nationale du Rhône* [National company of the Rhone]

COGC : *Centre Opérationnel de Gestion de Circulation* [COGC: Traffic management operational centre (regional centres)]

COLT : *Coopération Opérationnelle Lignes Tgv*. [TGV lines operational cooperation]

Corner fitting [Pièce de coin] : piece normally fitted to the upper corners of a container, into which twistlocks or other devices can be inserted, allowing the container to be hoisted, stacked or fastened

Courier service / Parcel service [Messagerie] : the service depends on consolidating parcels and sorting them after being routed to particular distribution zones. The operation depends on coordination of the regional consolidation / break-bulk platforms star-connected on lines linking one to the other. This complex "hub and spokes" network organisation today forms the fundamental nature of its activity

Container [Conteneur] : generic term for a box designed for goods transport, sufficiently robust for repeated use, normally stackable on 4 levels or more (10 or more for empty containers : main difference with swap bodies, which can only be stacked empty on 3 or 4 levels) and equipped for transfer between transport modes

Crude oil [Pétrole brut] : oil extracted from oil wells, treated only to remove sand and water. Measured in barrels (1 barrel = 159L), often in barrels per day (bpd).

Consignee [Destinataire] : entity certified to take delivery of goods

Cross-docking [Cross-docking] : to move goods from the arrivals wharf to the departure wharf without passing through stock

Crossings [Voie de croisement] : rail transport, a track allowing trains to pass on a single-track line

DA : *droit d'accès* [rail transport, right of access. Used in France, toll for network use]

DC : *droit de circulation* [rail transport, right to proceed]

Deadweight tonnage [Port en lourd] : cargo capacity of a ship: the difference in weight of a ship when fully laden and when empty, or the maximum cargo load permitted according to international safety regulations, including cargo, ballast and provisions

Demurrage [Surestaries] : dépassement du délai de planche, ou starie, donnant lieu à une indemnité de retard, payée par le chargeur au transporteur. [Demurrage, period in excess of laydays, resulting in delay charges paid by the shipper to the transport operator]

DMM : Donges - Melun – Metz pipeline

Dolphin [Duc d'Albe] : mooring structure not connected to the shore

Double road train [Train double] : consisting of an articulated vehicle and a semi-trailer the front of which is supported either on a removable front-axle or on the fifth wheel of the first semi-trailer, in place of the front axle

Draught [Tirant d'eau] : the submerged depth of a boat. Varies with the payload. Sometimes wrongly used in place of mooring, which involves the depth of a canal

Dredging [Dragage] : A certains endroits, cette opération doit être renouvelée régulièrement pour garantir un mouillage suffisant. [Dredging: a navigable canal is dredged with a dredger, machinery designed to clear the bed of sand, gravel or silt. At certain places, it must be regularly done to ensure sufficient draught

Dry port [Port sec / port avancé] : a logistics platform mainly receiving sea containers for storage and repair, not necessarily presenting easily identifiable maritime commercial and legal logistics; each able to carry out transport and logistics operations. A dry port can additionally be categorised as having a commercial and legal dynamic (ship owners, chamber of commerce) of a well-identified port which is the source of its financing. See appendix 7 of the maritime part for more detail on this subject

EBU [UENF / Union Européenne de Navigation Fluviale] : European barge union

ECMT : see ITF

EDI [EDI] : Electronic Data Interchange. Used by forwarding agents to reserve hold space with airline companies and for tracking

EF : *entreprise ferroviaire* [railfreight operators; a private or public company having rail transport as its main activity and which must provide the means of traction]

EILU [UECI / Unité Européenne de Chargement Intermodale : European Intermodal Loading Unit (45' palletwide container, to ensure optimal use by each mode of transport)

EPOC : *Entité de Production d'Optimisation du Combiné* [Rail-road production optimisation unit]

Equipment [Armement] : all equipment and crew needed to operate a ship. Also, a shipping company

ERTMS [ERTMS] : European Rail Transport Management System

ETCS [ETCS] : European Train Control System

Express freight [Express] : goods delivered within strict time constraints. These are often small packets

Feedering [Feedering] : short sea transport linking at least two ports in order to consolidate or redistribute goods (normally in containers) either coming from or bound for transport on the high seas from either port

FIATA : *Fédération Internationale des Associations de Transitaires et assimilés* [International Federation of Freights Forwarders Associations, represents the interests of forwarding agents by the International Air Transport Association (IATA), the UIC (International Union of Railways), the International Road Union IRU, World Customs Organisation WCO, World Trade Organisation WTO, International Chamber of Commerce ICC, etc.]

FNTR : *Fédération Nationale des Transports Routiers* [National federation for road transporters]

Foot [Pied] : 1 foot = 12 inches = 0.3048 m. 1meter = 3.28 feet.

Forwarding agent or Freight forwarder [Commissionnaire de transport] : intermediary who, on behalf of the shipper, takes the necessary measures and/or provides associated services to transport goods, choosing among all available modes. There is an obligation to perform. The entity that deals with the import, export and transit of goods on behalf of the consignor is often called the forwarding agent or customs broker

Fore hire or Reward [Compte d'autrui] : transport, paid for and carried out for a third party]

Free port [Zone franche] : zone where goods can be manufactured and/or stored without taxes or charges being levied]

Freycinet [Freycinet] : Charles Louis de Saulces de Freycinet, Minister of Public Works from 1877 to 1879, who standardised many transport regulations. His name is used in connection with loading gauges when applied to boats and canals. A Freycinet barge is 38.50 m long and 5.05 m wide. A Freycinet lock measures 39 m long and 5.20 m wide

Gantry crane [Portique roulant] : mobile crane able to manipulate loads in three directions (XYZ) and able to move itself in one direction, either on rails or on rubber tyres, and usually within a limited handling zone

Gas pipeline [Gazoduc] : pipeline dedicated to the transport of pressurised gaseous materials

General Cargo [General Cargo] : air cargo sent as standard freight, which is neither express, hazardous nor over-sized

General cargo [Marchandises générales] : (all modes) normally refers to finished or semi-finished products, new cars, perishable fruits, sugar, cement, fertiliser, etc., transported in containers or conventionally, most often on regular routes. Not bulk cargo

GID : *Gestionnaire d'Infrastructure Délégué* [rail transport, delegated infrastructure management]

GPF : *Gare Principale de Fret* [rail transport, main freight terminal]

Groupage [Groupage] : the action taken to group together goods from several sources or destined for several destinations, and the organisation and conveyance of the lot thereby consituted by a shipper. The consolidator is a freight forwarder who groups freight from several consignors, into batches forming loading units and then consigns them to transport companies

Gross tonnage [Jauge brute] : freight *volume* capacity of a sea-going ship. Calculated in 'gross registered tonnage' (grt) : 1 grt = 100 cubic feet = 2.83 m^3. Used for calculation of taxes, but not reflecting actual capacity (see maritime section)

GVWR [PTAC / *poids total autorisé en charge*] : Gross Vehicle Weight Rating: weight limit in the state of registration which a loaded vehicle or trailer may attain (passengers, driver and baggages included). This weight features in the registration document and on the manufacturer's plate

Handling [Handling] : (air transport) all handling operations: unloading, storage, palletisation, loading onto aircraft

Headroom [Hauteur libre] : on waterways, this is the clearance between the water surface and the underside of a bridge or a tunnel roof

HGV [PL / *Poids lourd*] : Heavy Goods Vehicle

Height above waterline [Tirant d'air] : the vertical distance between the water surface level and the highest part of a boat, i.e. the height of the boat above water. Sometimes wrongly used to describe the headroom under a bridge or in a tunnel. The error is so frequently used that it is acceptable in spoken form

Hinterland [Hinterland] : geographical and economic land area from which the sea or river port accepts goods for transport

IATA : International Air Transport Association, created in 1945 to encourage commercial development of air traffic, both passenger and freight

ICAO [OACI / *Organisation de l'Aviation Civile Internationale*] : International Civil Aviation Organisation, created in 1947 to define the principles of aerial navigation and to promote development of international air transport

ICT (NICT) : (New) information and communications technologies

ICTAAL : *Instructions sur les Conditions Techniques d'Aménagement des Autoroutes de Liaison* [Instructions on the technical conditions for construction of inter-urban motorways]

ICTAVRU : *Instructions sur les Conditions Techniques d'Aménagement des Voies Rapides Urbaines* [Instructions on the technical conditions for construction of urban express roads]

Identification [Signalement] : marine transport, procedure to declare a port of call, made to the harbour master's office

INCOTERM [INCOTERM] : International Commercial Terms. All terms defining the contractual responsibilities of buyers and sellers (for transport, insurance, etc.)

INRETS : *Institut National de Recherche sur les Transports et leur Sécurité* [National research institute for transport and safety. Now Ifsttar – *Institut Français des Sciences et Technologies de Transports, de l'Aménagement et des Réseaux*]

Integrator [Intégrateur] : a company combining the functions of airfeight company, air freight agent and often road-based courrier. These companies are well established in the market for parcels weighing under 30 kg but currently compete with freight companies for general cargo

Intermodal (transport) [Intermodal (transport)] : carriage of goods using two or more means of transport, but using the same loading unit or the same road vehicle, and without unpacking or repacking

ITF (EX-ECMT) [ITF (EX-CEMT)] : International Transport Forum (ex-ECMT: European Council for Ministers of Transport)

ITU [UTI / Unité de Transport Intermodal] : Intermodal Transport Unit. Containers, swap bodies and semi-trailers appropriate for intermodal transport. Pallets could also be considered as ITUs as they are not the cargo itself.

ISO : International Standards Organisation

ITS [ITS] : intelligent transport technologies and services

Just-in-time [Juste à temps] : a production organisation method, avoiding unnecessary stocks by receiving components just when they are required for assembly

KVB : *Contrôle de Vitesse par Balises* [rail transport, speed control by distress beacon: ad hoc data acquisition. Compares permissible speed with actual speed. If braking is too late or ineffective, the KVB at first alerts the driver and then, applies the emergency brakes. KVB reduces traffic fluidity (data is made available only to the following beacon) but ensures almost absolute safety]

Land container [Conteneur terrestre] : a container responding the standards of the International Union of Railways (UIC) – see also swap body]

Laydays [Staries - délai de planche] : time period, defined by agreement, granted to the ship owner to load and unload a ship or convoy]

Laying up period [Chômage] : Laying up period: during these stoppages in waterway navigation, which can last several weeks (some reaches are dry, others have sufficient water to moor the boats) maintenance actions and repairs are carried out, impossible when boats are moving and when the waterway is full of water. In France, the laying up periods are published each year in March by the Minister of Transport.

LCV [VUL / véhicule utilitaire léger] : Light commercial vehicle

LGV : *Ligne à Grande Vitesse* [high speed railway line]

LHP : [Le Havre – Paris Trapil pipeline network]

Lift on – Lift off (Lo-Lo) [Lift on - Lift off (Lo-Lo)] : loading and unloading of Intermodal Transport Units requiring hoisting equipment (vertical handling)

Light-running [Haut-le-pied] : used in railway and road transport to denote any non-commercial movement of a vehicle on the network for operational reasons. For railway rolling stock, this refers to locomotives moving but not drawing wagons

LNG [GNL – gaz naturel liquéfié] : Liquified Natural Gas. Natural gas cooled to approximately -160º C, at which temperature it becomes liquid and occupies considerable less volume than when gaseous (i.e. 1/600th of its volume, depending on temperature and altitude (pressure)). It becomes much more economical to transport and store

LNG carrier [Méthanier] : ship transporting liquified natural gas

LNG Terminal [Terminal méthanier] : port installation for reception, storage and regasification of LNG transported by ship and its injection into the main gas network

Loading gauge [Gabarit] : maximum dimensions, both height and width, that a railway vehicle and its load must respect with regard to tunnels and trackside obstacles

Lock-full [Éclusée, Bassinée ou Sassée] : all the operations necessary to bring boats through locks. False lock-full refers to locking through with no boat in the lock

Logistics [Logistique] : design and management of the supply chain in the widest sense. Alternatively, all activities intended to deliver a quantity of products in good condition, at least cost and within a programmed period, where and when the product is required. All actions involving transport, storage, handling, stock management, transmission and processing of data form the supply chain

Low water mark [Etiage] : low water level

LV [VL / véhicule léger] : Light vehicle

MA 80/100/120 : *Marchandises 80/100/120* [indicates conventional freight trains permitted to run at 80, 100 or 100 km/h (almost always at 100 km/h)]

Maritime container [Conteneur maritime] : a container sufficiently robust to be stacked in a container ship and hoisted from the top. In general, it responds to the standards of the International Standards Organisation (ISO)]

Maximum permissible weight [Poids maximum autorisé] : total weight of (road) vehicle (or combination of vehicles) stationary and ready to operate, including the load, declared permissible by the competent authority in the country of the vehicle's registration. The maximum permissible weight for international transport set by European commission is 40t (with 5 axles or more – see road transport section)

Multimodal (transport) [Multimodal (Transport)] : routing of goods via two or more methods of transport. Differs from "intermodal" (see definition)

Multiproducts pipeline [Pipeline multiproduits] : pipeline transporting different products, in predefined sequences

NAF : *Nomenclature des Activités Françaises - Insee* [List of French commercial activities – used for statistics]

NATO [OTAN : *Organisation du Traité de l'Atlantique Nord*] : Northern Atlantic Treaty Organisation

Nautical mile [Mile marin] : international measure of distance, corresponding to 1852 metres

Navigation rectangle [Rectangle de navigation] : in waterway transport, it is the area through which a boat passes. Its base is formed by the navigation canal, which has sufficient water depth beneath the hull. In the same way, beneath a bridge or in a tunnel, the height of the rectangle is given by the headroom which ensures sufficient clearance for the boat to pass

Net tonnage [Jauge nette] : gross tonnage less the volume occupied by the cargo hold, machinery and crew accommodation

ODC : *Oléoducs de Défense Commune* [Common defence organisation oleoducts]

OECD [OCDE : *Organisation de Coopération et de Développement Économiques*] : Organisation for Economic Co-operation and Development

Oil-ore carriers [Pétro-minéraliers] : ships able to transport raw crude and bulk goods simultaneously

Oleoduct [Oléoduc] : pipeline destined for petrochemical transport

Overpanamx (or postpanamax) [Overpanamax (ou Postpanamax)] : a ship for which one of its dimensions exceeds that of Panamax

Own account [Compte proper] : transport of own goods on owned or rented vehicles. In France, own account transport require neither subscription nor authorisation, except when made using vehicles on long-term rental

Owner [Armateur] : he who equips and operates ships for commercial navigation. Also, ship owner

Pallet [Palette] : support, usually of wood (but also made of chipboard, plastic or even metal), used to facilitate good handling. The standardised dimensions most used in Europe are: 1000 mm x 1200 mm (ISO) and 800 mm x 1200 mm (CEN)

Panamax [Panamax] : ship having dimensions which allow passage through the Panama canal: maximum length 295 m, maximum overall width 32.25 m and draught of 12 m

Pantograph [Pantographe] : articulated mechanism located on top of locomotive for collecting electrical current

PAR : *Poste d'Aiguillage et Régulation* [rail transport, train-regulating signal centre]

Passing track [Voie d'évitement] : main track (i.e. open to all trains) enabling certain trains to be overtaken by others

Payload [Charge Utile] : maximum permissible cargo weight as declared by the competant authority in the country of the vehicle's registration. The maximum weight of goods that a vehicle may carry

PCU [UVP / Unité de Voiture Particulière] : Passenger Car Unit

Pipeline [Pipeline] : English word meaning 'line of pipework', all pipes used in fluid transport

Port authority [Port Autonome] : in France, national state body supervised by the Ministry of Transport, with legal status and financial independence, which jointly carries out public service missions of an industrial and commercial nature

Private siding [ITE: *Installation Terminale Embranchée*] rail transport, a private siding is an installation permitting loading and unloading of goods to and from railcars by the client.

Proceeding downstream [Avalant] : a boat moving with the current (or moving towards the arbitrary downstream of a summit reach) is said to be moving downstream or is a downstream mover

Push boat [Pousseur] : boat used to push barges. Craft power can vary from 300 to 9,000 hp (i.e. 200 to 6,000 kW), even more on the lakes of the USA

Pushed convey, towed convey [Convoi poussé, convoi remorqué] : rigid assembly of boats, at least one of which is motorised. Most of the boats are pushed (by a pusher)

Quota setting [Contingentement] : in the event of an isolated incident or sudden increase in demand, a deferment of part of the delivery by oil pipeline is negotiated

Rail bridge [Pont Rail (Pra)] : a structure enabling a railway line to cross over an obstacle (road, river)

Rail gauge [Écartement des voies] : separation between two rails on a railtrack, measured between the inner faces of the rail heads. The gauge is 1.435 m in France and several other European countries. See world map in rail section.

Reach [Bief] : stretch of water in canal or river between two installations (barriers or locks)

Rigid truck [Porteur] : motorised utility vehicle of one piece, equipped for loading

Road bridge [Pont Route (Pro)] : a structure enabling a road to cross over a railway line

Road train [Train routier / Ensemble routier] : consisting of a motorised road vehicle to which a trailer is attached : either an articulated vehicle, a road trailer or a double trailer

Refinery [Raffinerie] : plant including several petrochemical processing units, designed to extract the maximum amount of useful refined products from crude oil

Reach Stacker [Reach Stacker] : automatic crane equipped with frontal lifting device for moving or stacking ITUs / Intermodal Transport Units

RFF : *Réseau Ferré de France* [French rail network, manager of the railway infrastructure in France]

Rail-road transport [Ferroutage / Transport combiné rail-route] : transport combining road and rail transport

Roll on – Roll off (Ro-Ro) [Roll on - Roll off (Ro-Ro)] : facility whereby a road vehicle, a wagon or an intermodal transport unit (ITU) on its own tyres or on tyres fitted for this purpose, can be loaded onto or unloaded from a ship. It can also be used for rolling roads.

RVB : *Renouvellement de Voie et de Ballast* [rail transport, track and ballast renewal (ballast, sleepers, new rail)]

Savoyarde : semi-remorque bâchée destinée au transport de marchandises générales, dites diverses ou conventionnelles. [semi-trailer with lashed cover destined for general cargo transport, known as general or conventional cargo]

Scrapping [Déchirage] : destruction of a boat

SDEVN : *Schéma Directeur d'Exploitation des Voies Navigables* [Navigable waterway operations master plan]

Sea-river barge [Navire fluvio-maritime] : Sea-river barge: marine craft designed to access waterways, having adjustable headroom

Section [Canton] : in railway transport, a length of railtrack which forms the basis of the system allowing trains to be separated; it is the distance between two signals

Self-propelled barge [Automoteur] : motorised barge. Prefered to 'barge'

Semi-trailer [Semi-remorque] : an unpowered goods transport vehicle without front axle, destined to be drawn by a motorised vehicle so that a substantial portion of its weight is supported by the tractor vehicle

SFDM : *Société Française Donges Metz*

Ship owner [Fréteur] : entity that provides a ship and receives freight (price of transport – see freight rate) in counterparts

Shipper (or Forwarder) [Chargeur (ou expéditeur)] : he who entrusts to others (forwarding agent, transport broker, transport operator / carrier) the responsibility for conveying his goods to a recipient

Shipping conference [Conférences maritimes] : agreement concluded between ship owners to ensure correct operation of maritime shipping over customary routes at steady tariffs (no more existing, since 2009)

Short maintenance periods [Blanc travaux, term limited to French Network] : periods during which no train movements are planned on a given railway line in order to allow everyday maintenance of the railway infrastructure; in general, this daily period lasts at least 1h50 per track, per day. Swiss maintenance periods is planned with massified (not everyday) 4h periods.

Short-sea shipping [Transport maritime à courte distance] : transport of goods by sea between ports situated in Europe or between European ports and ports in other countries having shorelines bordering one of the enclosed seas acting as European borders.

Siding [Voie de garage] : service line allowing trains to be halted without impeding other trains

Signal box (or signal tower) [Poste d'aiguillage] : building containing all the controls for the points and signals for a given zone. Also, the area under control of a signal box

SNAGFA : *Syndicat National des Agents et Groupeurs de Fret Aérien* [National union of air freight agents and consolidators]

SNCF : *Société Nationale des Chemins de Fer* [The French railway company]

SPMR : *Société du Pipeline Méditerranée - Rhône* [The Mediterranean pipeline company]

SPSE : *Société du Pipeline Sud Européen* [The South European pipeline company]

Stacking [Gerbage] : storage or transport of Intermodal Transport Units (ITU) on top of each other

Stationary wrong-track running signalling / Permanent contraflow installation [IPCS : *Installation Permanente de Contre Sens*] : rail transport, signalling system allowing contraflow running.

Stores [Avitaillement] : supply of fuel, foodstuffs, etc. needed on board ship during a voyage]

Stowage [Arrimage] : action to rigidly attach goods aboard a ship

Supply Chain [Supply chain / chaîne logistique] : flux physiques et d'informations visant à optimiser la chaîne logistique globale des fournisseurs aux clients. [Physical flow of goods and data, aiming to optimise the overall logistics chain from suppliers to their clients]

Summit reach [Bief de partage] : the summit reach is situated at the high point of the land traversed by the canal

Swap body [Caisse mobile] : unit designed for goods transport, optimised for dimensions of road vehicle and fitted with anchoring mechanisms allowing trans-shipment between transport modes, normally rail – road

Tachograph [Chronotachygraphe] : an instrument mounted on the dashboard of a road vehicle which records the driving and rest times of the driver and road speed onto a disc. It is compulsory for all vehicles (transporting goods and passengers, for own use or on other's account) having a maximum authorised payload > 3.5 tonnes, or with capacity over 9 passenger places (including the driver). Ref EEC No.3820/85 and No. 3821/85 dated 20 December 1985

Tare [Tare] : weight of one Intermodal Transport Unit (ITU) or of a vehicle, without loading.

Tautliner [Tautliner] : *semi-remorque à rideaux coulissants* [Curtain-side semi-trailer]

TEN [RTE / *Réseau Trans-Européen*] : Trans-European Networks, constituted *inter alia* the trans-European transport network (TEN-T)

Terminal [Terminal] : place equipped for transshipment and storage of Intermodal Transport Units (ITUs)

TEU [EVP] : Twenty-foot Equivalent Unit. Unit of measurement corresponding to a 20' ISO container (20 feet, or more exactly 19 feet and 10.5 inches – 6.05 m). Used to express transport capacity or flows. One 40' container is equivalent to two TEUs – 12.19m

TGV : *Train à Grande Vitesse* [High speed train]

THG [TMD : *Transport de Marchandises Dangereuses*] : transport of hazardous goods

Tidal range [Marnage] : difference between low and high-water marks

Time-distance Graph (or trafic Graph/Diagramm) [Graphique horaire (ou graphique de circulation)] : system used to organise all the train paths allocated to the national railway network and the time intervals reserved for maintenance and investment work on each section of the network

TKT : Tonne-kilometre transported. Unit equivalent to the tonne-kilometre

TLF : *Fédération des entreprises de Transport et Logistique de France* [Federation of transport and logistics companies in France

Tonne-kilometre or ton-kilometre [Tonne-kilomètre] : goods transport unit of measurement corresponding to one tomme of goods transported over one kilometre

Total permissible train weight [PTRA] : weight limit of a double or articulated road train. Different from the sum of the GVWRs

Tractive unit [Tracteur routier] : motorised road vehicle not equipped for unloading. Destined to draw other non-motorised road vehicles (normally semi-trailers) attached to fifth wheel

Trailer [Remorque] : an unpowered goods transport vehicle with at least two sets of rubber tyres (front and rear) intended to be drawn by a motorised vehicle, excluding semi-trailers.

Train running data [Marche d'un train] : current train movement characterised by its passage at a given position, at a known speed and time

Train path [Sillon] : infrastructural capacity required to run a given train between two points on the railway network during a given time period. There are catalogue, bespoke, regular and optional train paths. A catalogue train path is designed by the infrastructure manager to model the supply capacity in anticipation of requests from railway users. A bespoke train path is drawn up by the infrastructure manager in response to the requirements of railway users. A regular train path is a reserved train path, the use of which is practically reserved for the use of the user who has reserved it. An optional train path is a reserved train path the use of which must be confirmed by the railway user who has reserved it. A "last-minute path" can be drawn up up to few days and even hours before the train being proceeding.

Tramp shipping [Tramping] : ship operation without fixed itinerary. Also, the action of a ship owner in making his ship available on the cargo market

Transshipment [Transbordement] : transfer of an international transport unit (ITU) from one means of transport to another. Can be used to design transit (same mode).

Transitaire : no translation in English (often translated by freight forwarder, but with the difference that a *transitaire* only proposes *one* mode of transport)

TRM : *Transport Routier de Marchandises* [Road cargo transport]

TRO : *Tarification Routière Obligatoire* [Compulsory road charging, old French regulation, not existing yet]

UIC [UIC] : *Union Internationale des Chemins de fer*, International Union of Railways; international association of railway operators and infrastructure managers – www.uic.org

ULD : Unit Load Devices : unit load in air freight

Unaccompanied Combined Transport (UCT) [Transport combiné non accompagné] : the conveyance of a road vehicle assembly or an ITU / Intermodal Transport Unit, without driver, by another means of transport

Unladen weight [PV / *poids à vide*] : the weight of a vehicle in running order, i.e. full of fuel, tools and manufacturer's spare wheel, without driver or passengers

UNOSTRA : *Union Nationale des Organisations Syndicales des Transporteurs Routiers Automobiles* [National union of road transport vehicle organisations]

Unpacking / Packing [Dépotage / Empotage] : unloading goods from or loading goods into an intermodal transport unit / ITU]

URF : *Union Routière de France* [French road union]

Van [Fourgon] : road vehicle with rigid-walled body

Vehicle-kilometre [Véhicule-kilomètre] : unit of measurement corresponding to the movement of a road vehicle over one kilometre

VTS [VTS] : Vessel Traffic Service. Aid for port navigation

VNF : *Voies Navigables de France* [Navigable waterways in France] – soon ANVN : *Agence Nationale des Voies Navigables*

Wet dock [Darse] : water surrounded by wharves allowing ships to moor in port

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This guide on freight network capacity is a methodological presentation edited by the Scientific and Technical Network of the French Ministry of the Ecology, Sustainable Development, Transportation and Housing.

Its aim is to provide the reader with helpful information on each transport mode for the evaluation of relevant parameters enabling characterisation and measurement of the capacity of different freight networks with a view to multimodal analysis.

In particular, this document is intended for design engineers confronted with the cross-disciplinary problem of goods transport systems and corridors, who wish to perform estimates based on the comparative capacity of different freight transport modes. It is also intended for freight forwarders.

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Le Sétra appartient au Réseau Scientifique et Technique du MEDDTL