INTERMODEL EU

Simulation using Building Information Modelling Methodology of Multimodal, Multipurpose and Multiproduct Freight Railway Terminal Infrastructures

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D8.1 – Definition and description of functional , economic and environmental analysis

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Executive Summary

This document overviews the existing socioeconomic, operational and financial requirements and constraints applicable to intermodal terminals from a high level point of view. The present document summarizes the contents of task 8.1 from WP8, and includes the work done within that work package (Functional, economic and environmental analysis) mainly within the months 10-21 of the project although officially spawning within the months 4 and 28.

According to the description of work, this document includes (sic) the Definition and description of functional, economic and environmental analysis of the project from a high level point of view, with the goal to work as a framework for the remaining of the WP8 activities. That is, to set the foundation on which the relevance of the KPIs defined in WP3, and the effect of future trends in transportation from the demand and technological requirements point of view, are to be assessed.

This deliverable can be divided in three main parts. The first one starts with an overview of the role that terminals have on the supply chain to then assess the main Functional, Economic and Environmental aspects to be valued during the design phase of an intermodal terminal. In a second part, a glimpse is provided on how the functional, economic and environmental performance is assessed both by the industry and the literature. In turn, the third part of the document does a qualitative check on what are the potential relationships within the indicators described in the D3.1 and how changes in the terminal derived from coping with requirements that terminals might face in the future (considering the trends identified in D8.2) are likely to affect the value of a selection of the KPIs used for the project.

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1. Introduction

1.1. Scope

The objective of the work package 8 is to identify and describe main functional, economic and environmental effects of terminals including their underlying driver models. This focuses on macro and micro economic and operational Key Performance Indicators (KPI) that are de facto industry standards. In case of planning new or optimizing intermodal terminals, these KPIs set the frame for investment decisions.
Within that context, Task 8.1 includes an overview of the major indicators, with a high level approach, that are relevant when assessing the feasibility of an intermodal terminal, including maritime and dry (rail) multimodal terminals.

1.2. Audience

This document provides context on the high level approach on the role of terminals in freight transportation network and is useful to provide context to readers not acquainted with the topic, as well as paving the way to the more specific deliverables 8.2 (trends in logistics affecting intermodal terminals) and 8.3 (assessment of relative weight of indicators when planning future terminal investments).

1.3. Definitions / Glossary

Amortization: Amortization is the paying off of debt with a fixed repayment schedule in regular instalments over a period of time. It also refers to the spreading out of capital expenses for intangible assets over a specific duration (usually over the asset's useful life) for accounting and tax purposes. (Investopedia, 2018).

Benchmarking: Benchmarking is comparing one's business processes and performance metrics to industry bests and best practices from other companies. (Drucker, 1995)

Breakbulk point: Location at which loads are broken down to smaller loads or consolidated. This can be e.g. at a harbour and rail terminal where bulk loads are loaded from vessels to waggons for rail transport.

Carbon footprint: Amount of greenhouse gases generated to do an activity measured in equivalent CO_2 mass units.

Datatype: A property of distinct values, indicating common features of those values and operations on those values.

Depreciation: Depreciation is an accounting method of allocating the cost of a tangible asset over its useful life. Businesses depreciate long-term assets for both tax and accounting purposes (Investopedia, 2018).

Dry port: Dry ports are inland intermodal terminals directly connected by rail with seaports, where container and freight can be handled in the same way as at the seaport, usually even performing customs and excise processes that otherwise would be carried at the sea terminal. Dry ports act as gateways to connect to other hinterland destinations of the port.

Environment: Surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans and their interrelations.

Environmental impact: Change to the environment, whether adverse or beneficial, wholly or partially resulting from environmental aspects.

Equipment: Equipment in this context represents all means of transportation to move, handle or manage freight.

Evaluation: The systematic collection of information about the activities, characteristics and outcomes of programs for use by specific people to reduce uncertainties, improve effectiveness and make decisions with regard to what these programs are doing.

Evaluation stakeholders: The term “stakeholder” within an evaluation context, refers to those who have a vested interest in that which is being evaluated, and thus, would be in a position to use the evaluation results in some way. Depending on their role relative to the program or initiative being evaluated, stakeholders are positioned to use evaluation findings in different ways (Preskill and Jones, 2009)

Freight: Freight comprises all kinds of goods, materials or liquids which can be either containerized or bulk and transported by road, rail or waterways.

Full container load (FCL): A full container load (FCL) is an ISO standard container that is loaded and unloaded under the risk and account of one shipper and only one consignee.

Functional performance: Performance related to the functionality of the construction works or an assembled system (part of works), which is required by the client and/or by users and/or by regulations.

Gate: A point at an intermodal terminal where a clerk checks in and out all containers and trailer. All reservations and paperwork are checked at the gatehouse.

Greenhouse (gas) effect: Environmental issue related to pollution. The greenhouse effect is defined as the amount of CO_2 (in kg) that reinforces the greenhouse effect to the same degree as the substance emitted. CO_2 emissions as a result of fuel combustion and CH_4 emissions are mainly responsible for the greenhouse effect.

Hinterland: In shipping, a port's hinterland is the area served inland from the port premises, both for imports and for exports. The size and form of a hinterland varies depending on political borders, physical land constraints and the ease, speed, and cost of transportation between the port and its surrounding area.

Less than full container load (LCL): Less-than-container load (LCL) is a shipment that is not large enough to fill a standard cargo container.

Full truck load (FTL): A Full Truck Load means enough freight to fill a Full Truck Load. Full truck loads are dedicated to one customer and are usually faster but more expensive.

Key Performance Indicator: Indicator that tells you what to do to increase performance dramatically. They represent a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization. The calculation of KPIs is one of the will be calculated at the end of the project.

Less than full truck load (LTL): Less than full truck load means that multiple orders are combined in a Truck Load.

Logistics grid: General infrastructure as roads, railways, inland waterways, airports, harbours, passenger and freight terminals together with the transportation equipment (trucks, trains, ships, planes, etc.) form the logistics grid.

Life cycle: The life cycle of equipment describes the time span from acquiring and installation of equipment to the moment the equipment is replaced or scrapped.

Port: This is usually understood as a synonym of seaport. Seaport is a coastal location with a harbour where ships dock and transfer goods to/from land. Port locations are selected to optimize access to land and navigable water, meet commercial demand, and shelter from wind and waves. There are also inland ports, e.g. airports or dry ports (see Dry port).

Terminal: In transport and logistics, terminal means a place where passengers or cargo is gathered before moving to transport. In seafaring context, terminal has a particular function in a port area, such as container handling, coal, oil, or passenger terminal. In a case of a small and specialized port, terminal could refer to an entire port.

Usability: The ability of a product to be used with effectiveness, efficiency, and satisfaction by specified users to achieve specified goals in particular environments (Shi, 2007)

Validation: Confirmation, through provision of objective evidence that the requirements for a specific intended use or application have been fulfilled.

Waterway: Any navigable body of water. It can refer to either general, open waters, sea shipping routes or river based navigated with barges, being referred as sea (maritime) and inland waterways. They are considered different transport modes, with different kinds of vessels circulating in either of them.

1.4. Abbreviations

ASAP: As Soon As Possible
BIM: Building Information Methodology
CH_4: Methane
CO: Carbon Oxide
CO_2: Carbon Dioxide
DSS: Decision Support System
EBIT: Earnings Before Interest and Taxes
ECA: Emissions Control Area
FCL: Full container load
FTL: Full truck load
GHG: Greenhouse Gas
GW: Global Warming
ITU: Intermodal Transport Unit
KPI: Key Performance Indicator
LCL: Less than full container load
LNG: Liquefied Natural Gas
LTL: Less than full truck load
NECA: Nitrogen Emissions Control Area
N_2O: Nitrogen dioxide
NOx: Nitrogen oxides
ORP: Occupational Risks Prevention
Pdf: Probability Distribution Function
PM: Particulate matter (air suspended)
ROI: Return On Investment
SECA: Sulphur Emissions Control Area
SOx: Sulphur oxides
SQM: square meters
TEN-T: Trans European Network of Transport

TEU: Twenty foot equivalent unit (standard container)
UCD: User Centered Design
VOC: Volatile Organic Compounds

1.5. Structure

- **Section 1:** contains an overview of this document, providing its Scope, Audience, and Structure
- **Section 2**: overviews the role of terminals in the supply chain
- **Section 3**: provides a view on the most relevant functional aspects to evaluate in a intermodal container terminal
- **Section 4**: analyses the economic performance of terminals and the most common aspects that need to be evaluated during such assessment
- **Section 5**: finalizes the preliminary assessment with a view on the impact of terminals on the environment from multiple perspectives
- **Section 6**: checks how both, the industry and the literature assess the performance of terminals in the multiple dimensions considered, identifying the most common used indicators to do so
- **Section 7**: considers the indicators defined in D3.1 and their potential relationships from a qualitative perspective and how potential changes in the terminal might affect them
- **Section 8**: provides a list of the references used

2. Definition and description of roles of terminals according to their position on the grid

The overall logistics network or so-called logistics grid comprises the general infrastructure as well as the required equipment to make it work. Infrastructure in this context includes roads and motorways, rail tracks, inland and sea waterways and flight routes as well as the facilities that allow access to the network or where the intermodal change happens such as harbours, airports, stations and their passenger and freight terminals, specialized to a kind of cargo and/or means of transport or having a multipurpose component.

The corridors (links) in the network and their corresponding nodes can belong to different hierarchical levels, from more global (pan European or even International one) to more local systems. For instance, in the European case there are two network levels defined at an European Level, being the so-called core and comprehensive Trans European Transport Networks or TEN-T (Figure 1).

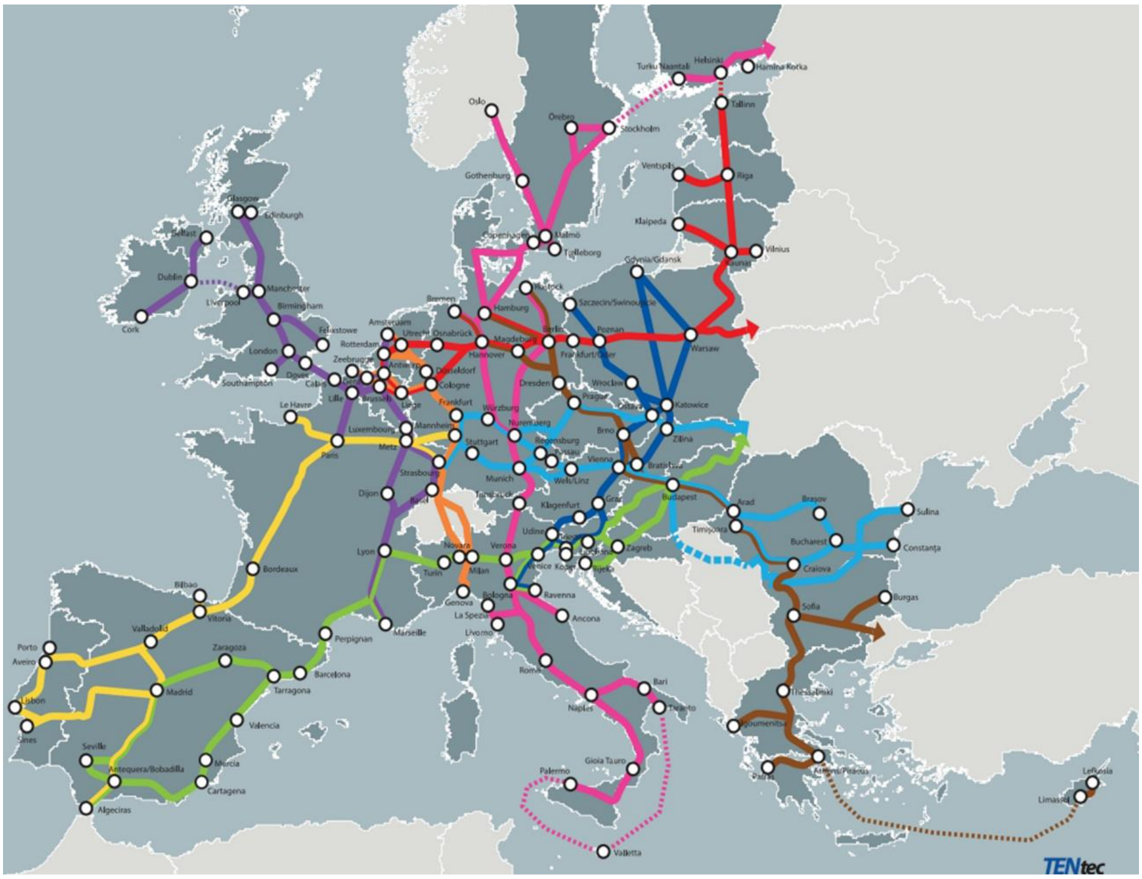


Figure 1: The Core Network Corridors and Nodes
(https://ec.europa.eu/transport/themes/infrastructure_en)

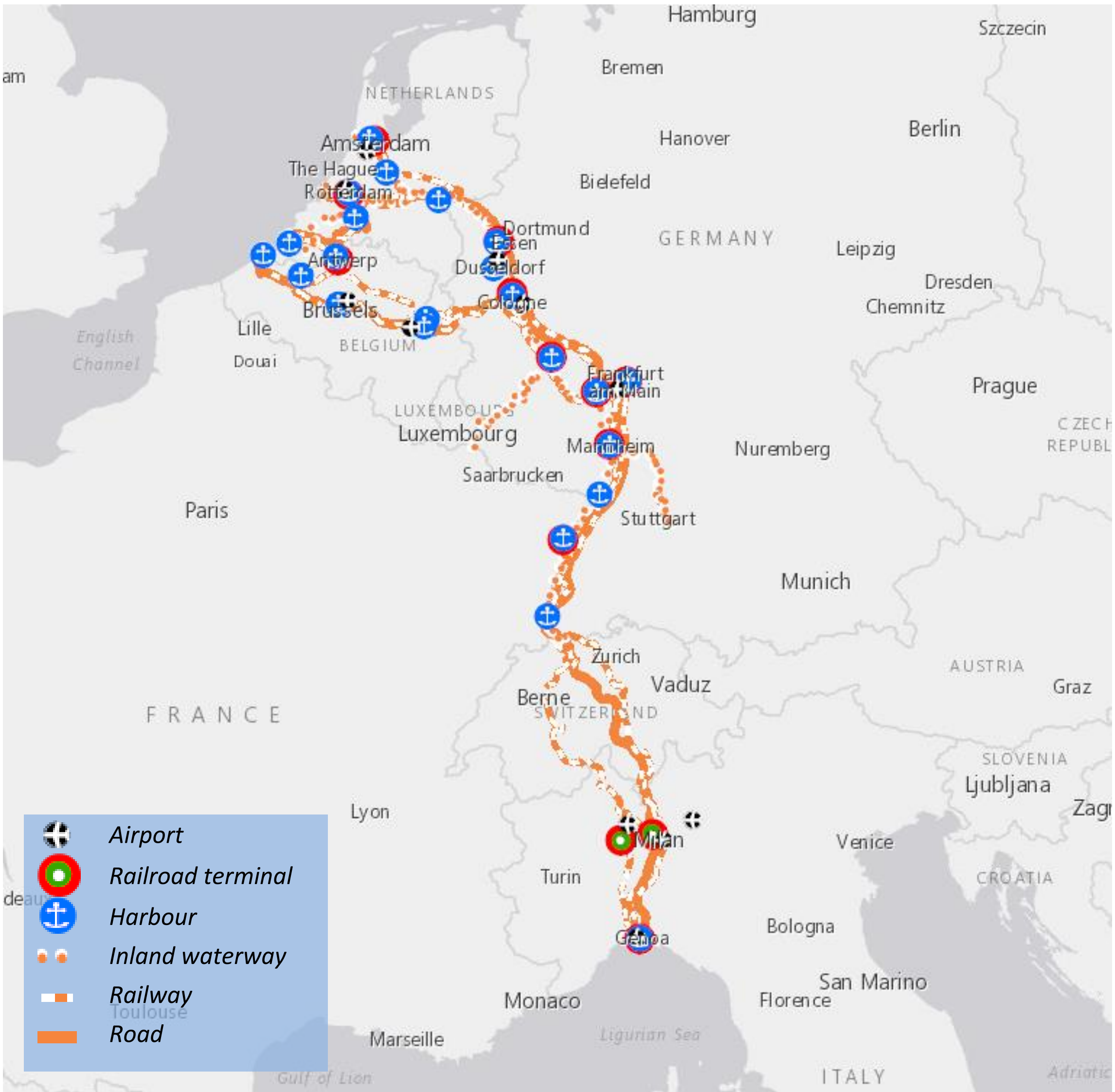


Figure 2: Core infrastructure, example of Rhine – Alpine Corridor
(http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html)

Corridors and terminals are complemented with any means of transport necessary to move, handle or manage freight. These include trucks and trailers for road transportation, tractor units and waggons for rail transportation, planes for air transports and vessels transports on inland and sea waterways but also cranes and other kinds of stowing units. Passenger transportation is not in scope of the project. A full ontology on the terminology of the means of transport used in intermodal freight terminals can be found in the ontology developed within the project (deliverable 5.2).

The project focuses on intermodal terminals (layout, and different functional areas and buildings) and the means of transport. Taking the ontology defined at the beginning of the project, the means of transport can be further concretized depending on the mode of transport (vessel, rail and the broad term vehicle) (Figure 3). Among those, further subcategories are possible (Figure 4). For instance, vehicles could refer to external trucks and any kind of equipment used to operate each of a terminal's processes or subsystems (quay, yard and interconnection).

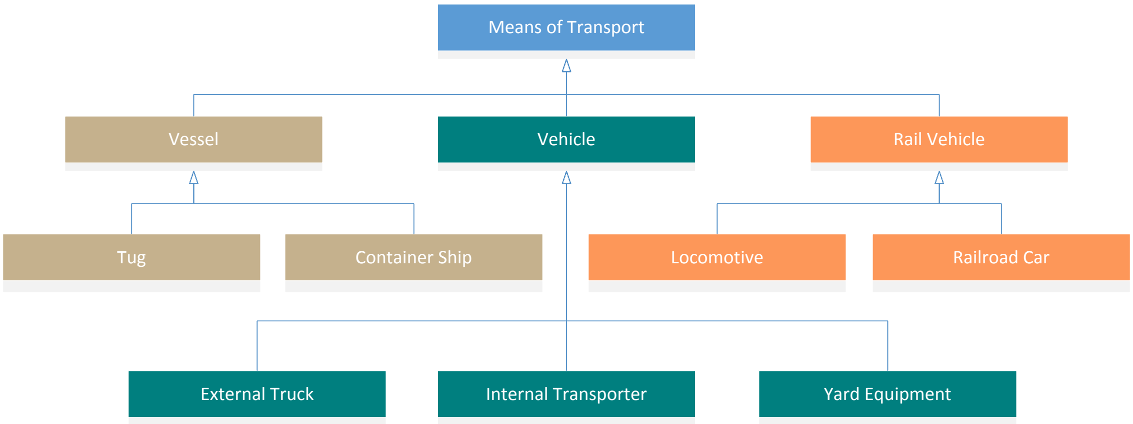


Figure 3. Classification of intermodal means of transport
Source: D5.2 Ontology and Conceptual Modelling (Intermodel project, 2017)

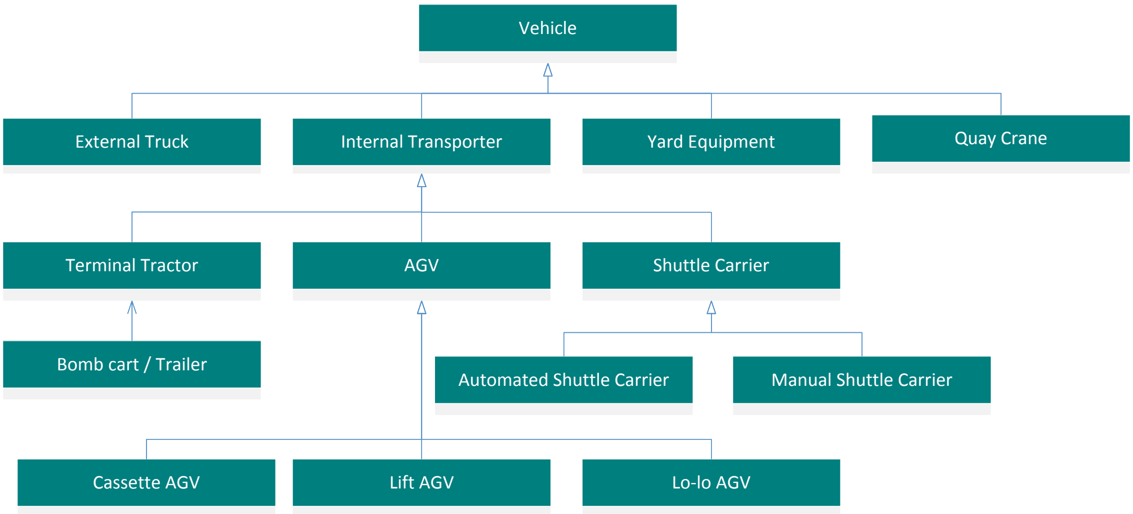


Figure 4. Classification of vehicles
Source: D5.2 Ontology and Conceptual Modelling (Intermodel project, 2017)

2.1. The role of terminals

Terminals and intermodal terminals are access points to the general logistics grid. Intermodal terminals in addition connect different transportation modes (air, road, rail, water) and thus allow transportation across different ways of transportation. Typical examples are containerized goods from China which arrive at a port in Italy (e.g. La Spezia), then transported from an intermodal terminal in Italy (e.g. in Melzo) by rail to an intermodal terminal in Germany and finally transported by truck to their final destination ("last mile").

Figure 5: Example for typical multimodal transport (containerized goods produced in Asia and sold in Europe)

The example shows the pivotal role of intermodal terminals. Functional problems (e.g. lack of capacity) in any node along the transportation process can delay the whole logistics chain. Competitiveness of intermodal transportation (rail and road for instance) when compared to monomodal transportation chains (pure road transport usually), depends heavily on efficient offloading and loading processes at the terminals.

Integration and systematic exchange of information along and across the whole logistics chain is an integral part of current technological development and trends (Figure 6). In fact, it exists a mutual reinforcing between technical development and business evolution. Internet of things, for instance, will allow that a shipment (e.g. a container) can provide its owner information about the whereabouts and condition of the goods. Consequently, issues or delays will be identified immediately, anticipated and mitigated. This requires to intermodal terminals to have in place processes and technologies to comply with customers' increasing demands for tracking, tracing and, ultimately, flexibility. Deliverable 8.2 will mainly focus on the identification of any technological and business trends in logistics, comprehensively, to assess their influence on future requirements placed on intermodal terminals and produce feasible future scenarios to test.

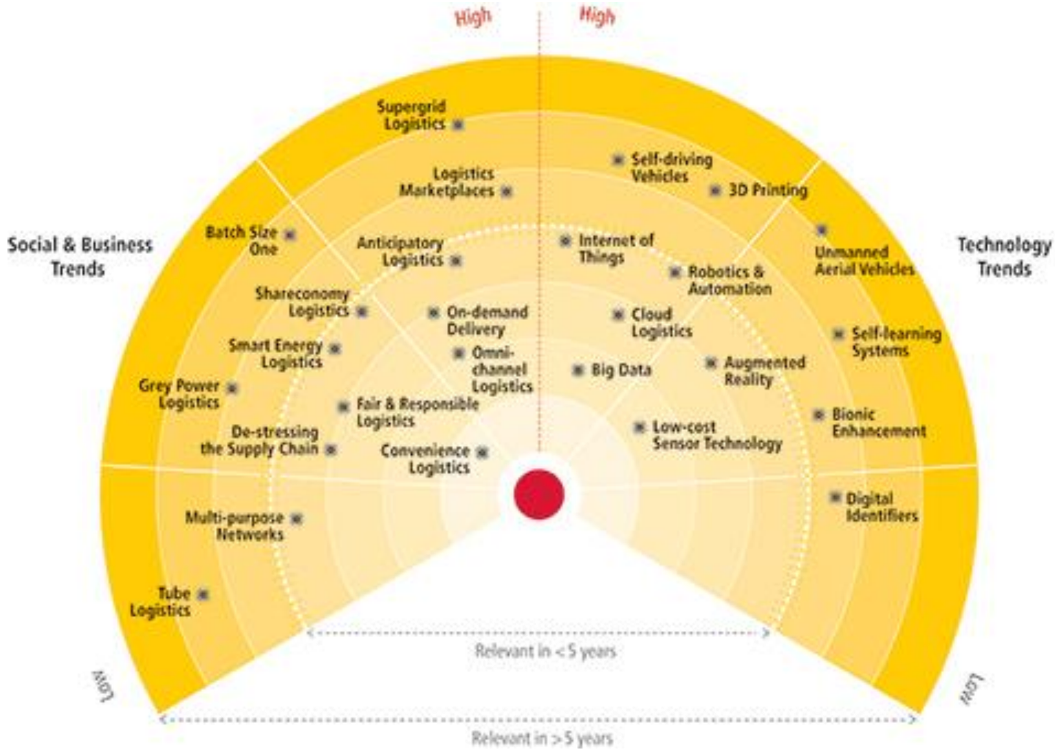


Figure 6: Logistics Trend Radar – developments with potential impact on freight terminals
(http://www.dhl.com/en/about_us/logistics_insights/dhl_trend_research/trendradar.html)

3. Functional analysis

Functional analyses assess current operational performance and support identifying improvement potential. Operational performance can be measured on various levels. This includes the logistics network as a whole or, more typically, the terminal as such and all of its sub-processes (including preparation and maintenance processes).

Operational performance of processes is typically measured on terminal level as total throughput (= handled containers or bulk volume). Total throughput can be broken down further to the specific functions or sub-processes within the terminal (i.e. cross dock or consolidation activities, shunting area, storage, etc.) or considering dividing the processes happening in a terminal from a functional or physical point of view. Functionality could even be addressed focusing to any of the elements at work at a terminal, by registering the productivity achieved by one specific resource, either a type of resource (crane) or a resource unit (crane #2”).

The definition on the different functional areas in a terminal were already addressed in a previous deliverable (D2.1, section 4). To summarize, they are typically divided, according to physical structure into waterside (or loading/unloading), stacking (yard), delivery/receipt (truck and/or rail area), internal transport, and other uses (warehousing, office space, inspection, repair and maintenance), etc.

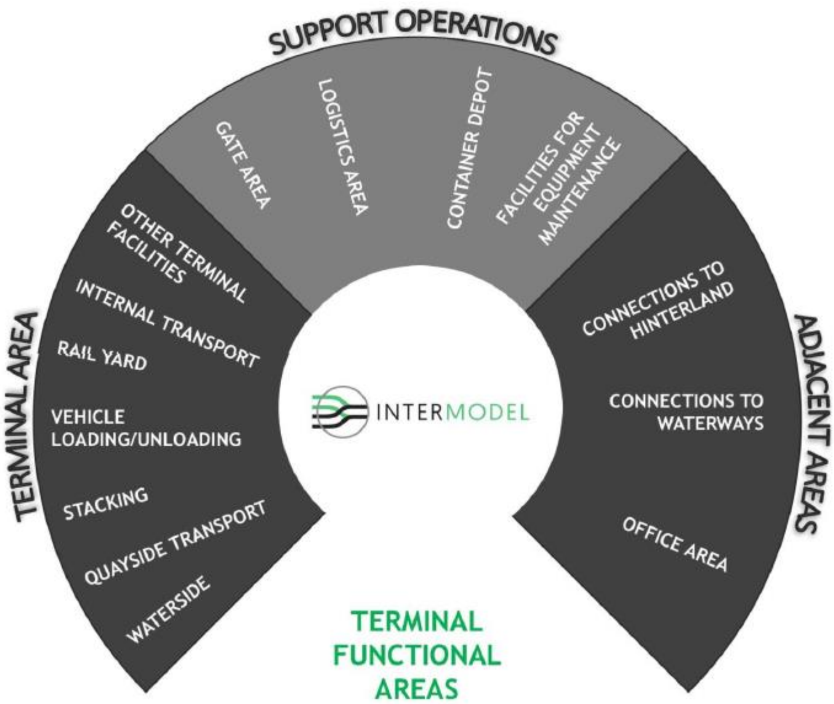


Figure 7. Terminal functional areas

Source: D2.2 Integrated planning Environment (Intermodel project, 2017)

Assessment, for any subsystem or the whole terminal cannot be done only on absolute terms (total throughput, available capacity, number of yards, lanes, etc) but needs of relative values to properly assess performance and add context. Performance (relative) values to any resource being used (area, equipment, berth length, staff) are far more relevant to assess the operation of a terminal and detect where it should be improved, if there is room for it. This is especially true when benchmark values from other terminals / alternative designs can be used.

The following exemplary selection of indicators (Table 1) shows the measurement of input factors that have an effect on the throughput of a terminal.

Table 1: Exemplary key performance indicators to measure process efficiency, utilization and productivity of critical processes within an intermodal terminal

Type of KPI	KPI name	Purpose
Operational	Waiting hours of trucks at terminal door	Measurement of process efficiency
Operational	Average time spent by truck at terminal	Measurement of process efficiency
Operational	Average time spent by train at terminal	Measurement of process efficiency
Operational	Number of trains/trucks that spent over 50% more than the average time for trains/for trucks	Measurement of process efficiency
Operational	Hours of machinery inactive per year	Utilization, productivity
Operational	Hours of machinery working per year	Utilization, productivity
Operational	Volume related to space (TEUs per sqm, tons per sqm)	Utilization, productivity

3.1.1. Capacity vs Quality considerations

The objective of the functional analyses is to identify the best setup for the expected or targeted volumes that is, not only to obtain the design that can handle the needed throughput but also, that makes a better use of the resources used.

Consequently the simulations show along defined scenarios (see previous work package D3.2 mainly, but also D2.3 and the final deliverables of WP4 and WP5) the functional effects of adding capacity to specific processes (e.g. three cranes instead of two), adding or prolonging rail tracks or changing the setup (e.g. reducing maintenance through utilization of alternative materials or equipment).

Dimensioning the terminal is tightly linked with the knowledge of the flows interacting with it. That is, truck, rail and barge/vessel arrival patterns and average dwell times. It then, becomes important to know the expected arrivals and departures thorough the year/week/day and set some quality standards (that could be a specific set of KPIs constructed with that purpose) to assess not only the throughput but, the quality offered, understanding quality in terms of time related and safety parameters.

From an analytical point of view, quality related to level of usage (that is, congestion) in intermodal terminals has been assessed in the form of waiting time over service time (W/S), berth occupancy rate and total turnaround time -and its two components, service (berthing) time and waiting time-, among others. In all cases considering both, average values and their probability distribution function (pdf) (Dragović et al., 2005; Henesey et al., 2003; Huynh and Walton, 2005).

Waiting time over service time ratio (W/S) is in fact a performance indicator found in a broad range of papers, from Fourgeaud (2000) to the UNCTAD (2006) indicators. It expresses the idea that transport units with less cargo to discharge cannot afford waiting as long as transport units which may have several times more cargo. W/S as indicator, however, can be misleading since its value increases as the turnaround time decreases, due to, for instance, a better performance of the terminal operative, paradoxically resulting in 'worse' congestion performance in terminals with faster operation.

Berth/gate/slot occupancy rate, in turn, is commonly used as a means to express the degree of congestion a specific terminal is facing. Usually, a maximum waiting probability is given, from which the maximum occupancy rate can be obtained by means of simplified queuing problems (Bassan, 2007). However, to calculate those, it is necessary to know the arrivals traffic pattern, the number of berthing points and the service time as well as the maximum waiting time allowed (Fourgeaud, 2000).

Average dwelling (or turnaround) time spent at the terminal is an indicator easier for the terminal customers to understand, especially if it is considered that internalizes possible unexpected unplanned delays. At the same time it can be decomposed in service plus waiting time, being the first term related to the terminal's performance while waiting depends on service time (in both, average value and pdf) as well as the occupancy the terminal faces.

Most models for ports in fact, use Queueing theory models to assess the maximum desirable occupancy rate in a berth terminal. In that case, ship arrivals are taken with the shape of a pdf's in the Erlang family (Aspereren et al. 2005; Fourgeaud, 2000), although other distributions would apply depending on the kind of vessel and regularity of service (Aguilar and Obrer, 2009). As a result, diagrams like the ones in Figure 8, can provide the theoretical relationship between usage of the infrastructure (in this case the berth) and the time the average user (vessel) has to wait because no server (berth in this case) is available at its arrival. Adding additional servers (berths, cranes, gates), being totally interchangeable, reduces the average waiting time.

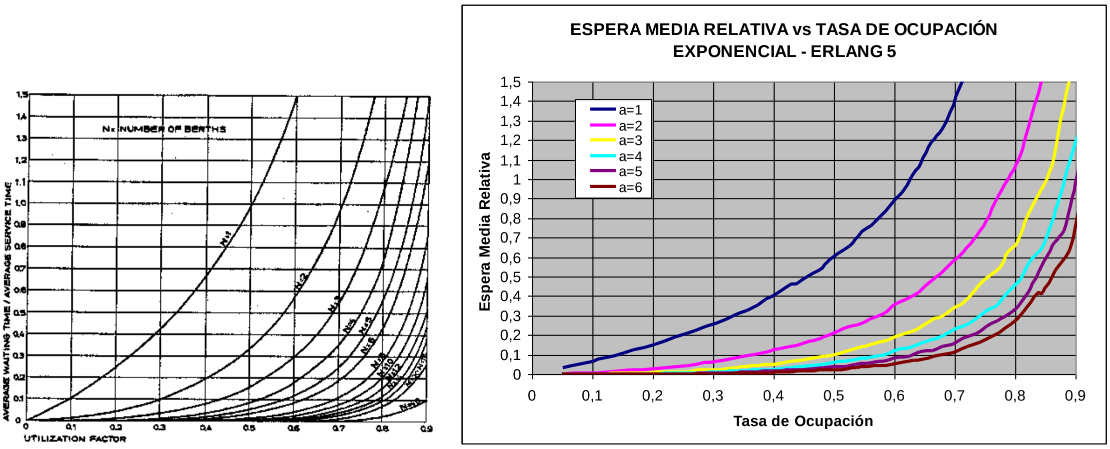


Figure 8: Waiting time / service time according to occupancy rate and number of berths in a random arrivals (left) and Erlang 5 (right) situation.
(Agerschou 2004, Aguilar and Obrer, 2009)

However, nowadays terminals are far more complex than a server / user queueing system. Being complex combinations of the both the ones that are in place. For instance, the turnaround time of a specific ship is berthed cannot be extrapolated from a statistical function since it will need to consider not only if there are mooring points available but also, the length of berth available, how many quay cranes will be operative and if it will be feasible to use them on that ship, where the containers to be loaded and unloaded will be coming from inside the terminal, that is, the dispatching and absorbing capacity of the terminal's stacking blocks at a given time, etcetera.

As a result, the discrete simulation of representative scenarios that the terminal might face or should be prepared to cope with, is the best option to assess the overall performance, although simplistic queueing analytical values can be used beforehand to provide an order of magnitude of the necessary infrastructure and superstructure to be put in place to deal with the expected throughput values.

Figure 9: Melzo Intermodel Terminal with Gantry cranes for loading/offloading containers between train and truck

3.1.2. Scenarios definition, addressing current and future needs

When planning an intermodal terminal the main risk would be on being able to know in advance its expected usage. That is, the terminal should perform well not only in the scenario of processing a number of ITUs or TEUs corresponding to its designed capacity, but also to be able to face varying trade flows both in absolute numbers (total yearly throughput) but considering seasonality or variations during a given day. How well a terminal can cope with such variations, its resiliency, and how well the designers identified the future requirements a terminal would face are critical for the operational and, subsequently economic, success of a specific terminals.

The risks regarding the evolution of trade and to which the design should be able to adapt to without incurring in major costs can be summarized into:

➔ Trade volume evolution expected during the lifespan of the terminal.

➔ Trade composition:
  - Percentage of import versus export, amount of transhipment
  - Variations on the type of cargo being transported (container traffic evolution, bulk or other formats not yet widespread (3D printers cartridges for instance).

➔ Potential changes of trade flows which might affect functional performance:
  - Change of routes (e.g. import/export to/from other ports lead to over- or under capacity)
  - Change of export to import ratio (e.g. additional area needed for container storage)
  - Change of ratio bulk to container (e.g. terminal set up not designed for bulk)
  - Change of standards (e.g. longer trains require different layout and additional equipment)
  - Change of regulations (e.g. emission reduction schemes, additional security measures)

Overall, terminals need to be able to be flexible and prepared to adapt to the most feasible changes in trade that could happen in the future while ensuring that the resources are used efficiently and the quality provided to the final user is sufficient to keep attracting customers.

4. Economic analysis

The economic analysis looks at the feasibility of building and operating a terminal. The terminal can be analysed standalone regarding its profitability (microeconomic analysis) or in combination with the local or regional logistics infrastructure (macroeconomic analysis).

4.1. Microeconomic analysis

The microeconomic analysis of terminals focuses on financial aspects of building and operating freight terminals. The underlying assumption is that the owner, which can be a private or public body, intends generating profits with the terminal operations itself or at least needs to cover the operating costs. Therefore, the economic analysis has two perspectives which are brought into relation to each other. One is the income side representing the revenues generated from provided terminal services. The other perspective is the cost side which looks at the terminal costs of operations as e.g. labour, energy and equipment costs including depreciation. The profitability results by comparing the two perspectives.

This can be done by calculating the financial key performance indicator EBIT (Earnings before Interest and Taxes). These KPIs are suitable in this context as it focuses on the elements which can be influenced by the terminal operations itself. Financing aspects as interest rates and taxes are exogenous factors which are not part of the scope of the project.

The main influence factors of the financial results are driven by the nature of a terminal. An intermodal terminal requires significant investments in land and equipment at the beginning which have to be maintained. Therefore layout and size are driven by existing standards and the expectation regarding market requirements and freight volumes to be handled.

Revenue streams depend on the capability to provide the services which are demanded by the respective market (e.g. ability to handle containers and bulk and in the requested volume) in time.

Operating costs are driven primarily by the costs of the facilities, equipment, energy and labour costs. Energy and labour costs can be steered along the demand so that peak and low seasons can be serviced. But facilities and equipment usually can only be enhanced or reduced mid-term. That leads to the difficult question how to size the whole terminal operations so that it can handle peak seasons without causing unnecessary costs during low seasons through underutilization. A review of actual handling costs showed that small and extra-large intermodal rail terminals achieve the lowest handling costs. The reason behind are either very limited investment and focus in the case of small terminals or the effect of economies of scale and high utilization in the case of extra-large terminals (Wiegmans and Behdani, 2018).

4.1.1. Operational Performance and EBIT

Operational performance analyses and describes the feasibility of operations under the given setup. It describes the economic performance before depreciation and amortization. Only direct operational expenses as in the example above energy, repair and maintenance, labour costs, rent and lease costs, administration etc. are considered.

EBIT is a financial key performance indicator which in addition to Operational Performance includes investment costs as depreciation tangible assets and costs of especially intangible assets as acquired brands as amortization. This is done by allocating a share of the total costs to the respective month. The share is usually calculated by distributing the total cost over the life time of the assets. An example could be a crane which costs 1.2 Mio EUR and is used over 20 years (=240 months). The monthly depreciation for this crane will 5.000 EUR (1.2 Mio EUR / 240 months = 5.000 EUR / month).

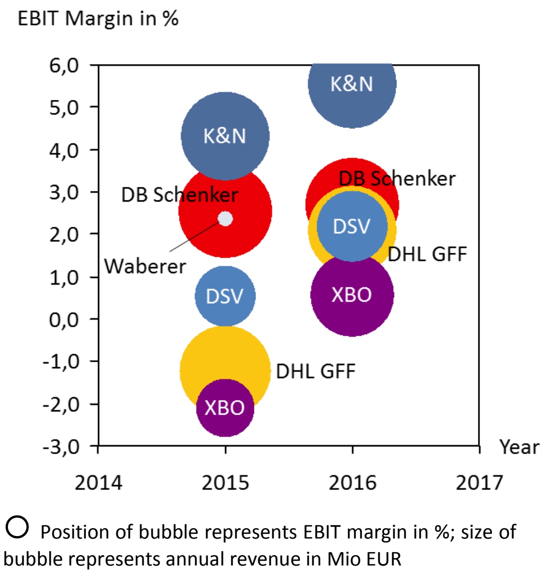
Profit & Loss Statement (schematic and exemplary)	**Full Year (in EUR)**
Net Revenue	5,580,000
Cost of Sales	1,245,000
Gross Profit	4,335,000
Direct operating expenses	3,536,000
Energy (incl. Fuel)	857,000
Repair and maintenance	187,000
Travel and entertainment expenses	17,000
Telecommunication expenses	34,000
Personnel expenses	1,872,000
Rent & Lease	484,000
Administration, insurance and other	42,000
Other	43,000
Operational Performance	799,000
Depreciation	587,000
Amortization	32,000
EBIT	180,000
EBIT Margin	3.2%

Figure 10: Regular economic analyses with exemplary terminal profit and loss statement

In the following schematic example the profit and loss statement of a terminal is shown. It explains the basic logic of the usually monthly financial analysis and result of a terminal. As described above exogenous aspects which cannot be influenced by the terminal operations as alternative financing options and taxes are not included.

The EBIT margin puts the achieved result in relation to the generated revenue. The Logistics industry is an industry with rather small EBIT margins as the competition is intense, the market highly fragmented and the value added of the Logistics service to the individual good comparatively small. According to a study of Price Waterhouse Coopers (PWC) the EBIT margins of Logistics companies over the last 5 years ranged between -1% and 8% (Tipping and Kauschke, 2016).

The following overview (Figure 11) shows the EBIT margins of selected industry leaders. Even the biggest players in the European Logistics market do not reach a market share of more than 5% which shows the fragmentation of the market.



Company	Revenue in Mio EUR		Profit for the period (EBIT in Mio EUR)	
	2015	2016	2015	2016
DB Schenker	15,451	15,128	395	410
DHL GFF	14,890	13,737	(181)	287
DSV	6,613	8,807	268	194
K&N	14,221	14,046	723	780
Waberer	522	N/A	12	N/A
XBO	6,327	12,134	(159)	70

Figure 11: EBIT Margins of leading logistics companies 2015 and 2016
Sources: Published Company Annual Reports 2016

4.1.2. Effective and efficient productions

An effective and efficient production (functional model) leads in most cases to sound financial results. Total quality management (see Deming 1986) defined all types of inefficiencies as waste, which causes unnecessary costs.

The right setup of facilities and equipment to handle the actual freight volumes allows operating efficiently. Over or under-capacities lead to described waste which typically will increase operating costs.

A vivid example is the number of gantry cranes. Two cranes can increase loading and offloading capacities of containers e.g. from ships to trains or trains to trucks. However, two cranes instead of one crane need also more space and increase maintenance costs. If the two cranes cannot be fully utilized overall costs and costs per handled unit increase significantly. This again will have negative effects on the profitability of the terminal in total (see above “Melzo Intermodel Terminal with Gantry cranes”).

In all cases, the additional dimension time has to be considered. In case of investing or disinvesting into production processes, the overall costs have to be taken into account. In peak season, two cranes might be efficient. However, if the second crane is not needed on average days the benefits of the peak season might not compensate for the additional costs. Before such an investment is taken, a business case is usually prepared which analyses the costs and benefits over the full life cycle of a crane or any other investment.

4.2. Macroeconomic/influence on hinterland

The macroeconomic analysis of a terminal goes beyond the terminal and the logistics network itself. Especially intermodal terminals have to be seen as part of the infrastructure, which supports and enables the economic development of a region or country. This infrastructure consists at the core of roads, railways and inland waterways as well as harbours, airports and terminals as access points and places of lading. Easy access to intermodal logistics networks attracts industries and services.

4.2.1. Node / breakbulk point

Terminals are a part of the local key infrastructure. Especially the complementing combination of port and rail terminal connects the worldwide ocean freight logistics with overland transports on the continent. These locations are typical breakbulk points as loads are split or consolidated for further transport on land or water. Without these intermodal terminals, the efficient further distribution of imports into Europe or the consolidation of exports to markets outside of Europe would not be possible.

A prominent example is the region of Milano in Northern Italy. Milano as the industry hub in Northern Italy is connected to the harbour in La Spezia via train and road connections and thus companies can import and export from and to all markets worldwide. At the same time, the Alpine road and rail corridor provides easy and fast access for these Northern Italian companies to all markets north of the Alps (Rail Freight Corridor RHINE-ALPINE, 2017).

The macroeconomic perspective of this example shows clearly that a terminal should be seen as part of the local infrastructure. Terminals are economic enablers which can bring added value to their region even if the terminal operations itself cannot cover their costs. A pure micro economic view on terminals might be not enough to identify the value added. A similar conclusion was drawn based on an analysis of the potential impact of the enlargement of the Aberdeen harbour. The Aberdeen Harbour based on published data plays a key role in the local and Scottish economies.

In 2013 it generated around £1.5 billion Gross value Added (GVA) and overall 12,000 jobs. Out of this £1.5 billion, alone £1.4 billion and 9500 jobs are associated with Aberdeen and the region (BiGGAR Economics, 2015).

4.2.2. Direct employment provider

Terminals provide operational (“blue collar”) and administrative (“white collar”) jobs. Due to the non-production nature of the business, the total number of jobs is limited. The German terminal Cologne Eifeltor which is with around 1400 containers handled daily one of the biggest intermodal terminals in Europe employs between 50-60 persons full time (Cityinfo-Koeln.de, 2018). Most of the jobs at a terminal are blue-collar jobs to operate and supervise the terminal. Administrative jobs at a terminal typically focus on handling shipment related documents, planning and accounting.

4.2.3. Indirect employment provider

In addition to direct employments terminal generate jobs indirectly through the fact that the terminal is a customer of the local business. These are especially services, which are required by the terminal as construction work and maintenance of facilities and equipment.

4.2.4. Prerequisite to further logistics

Terminals attract typically further logistics business as warehousing, forwarding and trucking companies. Depending on the kind of goods handled by the terminal further industries as e.g. chemical or petroleum industries set up their operations or storage facilities as well.

Figure 12: Duisburg harbour with surrounding industry settlements (source: Google maps)

4.2.5. Refund to public bodies

Terminal operations are taxpayers as all other local businesses. Countries and localities benefit from the terminal operations in form of taxes and fees, which they receive from the terminal operator and related businesses. Even if the terminal itself is not producing profits, the surrounding businesses -which are attracted by the terminal operations- pay taxes and generate further jobs. This generates direct income from taxes and indirect income from consumption for the cities and regions.

5. Environmental analysis

Preliminary results from the study on external costs of transport infrastructure "Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities" (Essen, 2018) show that the EU-28 member states incur to an estimated € 1000 billion of annual costs (or its 7% GDP) of externalities caused by transport (including infrastructure).

This comes to confirm that transportation is one of the main producers of carbon emissions (Umwelt Bundesamt, 2019, European Commission 2011). Intermodal terminals, as part of logistics networks can contribute to either increase or reduce the overall carbon footprint and air pollution of transportation. The integration of state of the art solutions at operational, technological and fuel consumption level has an effect on the affectation of the environment.

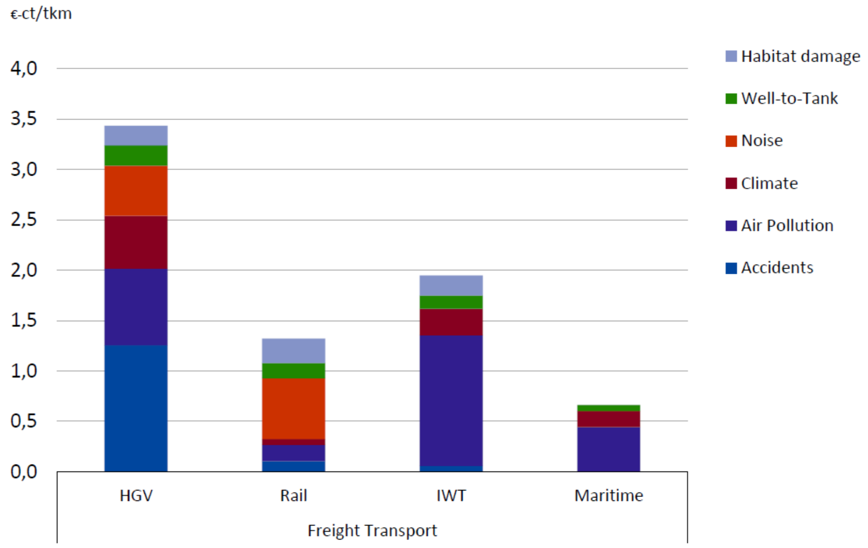


Figure 13: Freight average external costs per mode at EU28 level.
Source: Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities (Essen, 2018)

On top of that, the use of intermodal terminals optimizes the flow of cargoes, thus, reducing the number of transport units circulating with a better use of available capacity (groupage). Moreover, in the case of intermodal inland terminals working as an extension of maritime terminals (dry ports), their use allows replacing road transportation for rail traffic for a significant length of the supply chain, leading to a sensible reduction on emissions and carbon footprint per tonne transported.

Impact of intermodal terminals on the environment might be produced during construction, maintenance, operation (exploitation) or as cause of the induced traffic and impact can be on either the air (pollution, and GHG), water and groundwater, landscape occupation and barrier effect, accidentally, noise and vibration, and congestion derived.

5.1. Impact on air

5.1.1. Pollution versus Global warming effects

Impact on air comes from two different sides, either impact on the immediate surroundings (pollution) or the contribution to the Global Warming (Greenhouse gases effects) and the increase of solar radiation over the population.

The impacts of pollution are down to domestic impact (in the closest area of influence to the terminal). It arises as a relevant indicator due to its impact on human health. The epidemiological body of research, deem that, among the different air pollutants resulting from human activity, PM and NOx have the most direct effect on the health of the exposed nearby population.
On the other hand, Global Warming is often referred to as the meteorological and climate disruption, sea level increase, change in energy requirements, agricultural losses, water cycle distress, extreme phenomena (e.g. draughts, floods, heat/cold waves), ecosystem transformation, human and animal migrations, change in disease propagation, etc. Therefore, it provides a rather global scope and its effects are felt on the whole globe and not just in the surroundings where the activity takes place.

5.1.2. Carbon footprint as a measure of air pollution

Carbon footprint is a term coined in the 1990s (Wright et al., 2011) which is used as a measure of the GHG emissions produced by an individual, activity or product. All gases contribution to the Greenhouse effect are accounted for, and their emissions translated into an equivalent amount of CO_2 emitted. That is, emissions of a certain gas like O_3, CH_4 or NOx (the most common GHG after CO_2) are translated in the equivalent amount of CO_2 gas that would have the same effect in increasing the GW (that is, contribute at an equivalent level to absorb infrared radiation).

In order to assess the Carbon footprint of a terminal, or any other activity, not only direct emissions made during its construction and operation are to be considered but also any indirect emissions coming from processes upstream and downstream necessary for the construction and operation of such infrastructure like:

- Transportation of materials used for construction, assembled parts, pieces of equipment and fuel/energy consumed or combusted to transport them.
- Wastes produced because of the activity of the terminal and their transport and treatment.
- Construction of the components being used, emissions produced during their construction and the transportation, waste, energy production and transportation for the materials being used and the products or pieces of equipment needed and all the secondary derivatives stemming from there.

- Fuel production, that is emissions generated to produce the fuel being consumed during either construction or operation of the facility, including not only equipment consumption but also energy used for lighting, office spaces and a long etcetera.

As a result, the calculation of total carbon footprint of any activity becomes a gigantic mission and it is materially impossible to calculate a complete accurate number for any product being manufactured, not to say a whole transport terminal. However, guidelines on how to estimate an order of magnitude exist as well as some calculators to estimate the value like the ones provided by the International Organization for Standardization (ISO) to assess the Life-cycle assessment (LCA) of industrial activity.

5.1.3. Impacts during construction, maintenance and operation

Air impact during construction of a terminal may arise mainly from the construction processes being used (CO_2 emissions due to cement setting), construction transportation needs (pollution and GHG related with transportation) and the use of heavy machinery and equipment during construction.

During the operational life of a terminal, pollution (domestic effect) may have its source in operating equipment and vehicles in the terminal (cranes, trucks and reach stackers, facilities energy requirements, etc.), traffic increase in the hinterland due to road carriers' growth, and vessels in hoteling and manoeuvring operations. On top of those, additional energy and emissions from maintenance work during the life span of the infrastructure are to be considered.

Either used in construction phases or induced (by the terminal) in the operational phase, an increase in traffic volume aggravates the quality of air. ICE powered vehicles exhaust several GHG (greenhouse gases), each with a certain potential to global warming measured in emitted mass equivalent of CO_2. In this regard, CO_2 has a global warming potential of 1, CH_4 a global warming potential of 25 and N_2O a global warming potential of 298 (IPCC 4th Assessment Report, p.212). Moreover, they also pollute with CO_2, NO_X, CO and PM.

Vessels powered by marine diesels are estimated to account for 99% of the world's fleet of ships (European Environment Agency, 2009). Their associated pollutants are mainly CO, VOC (volatile organic compounds), NO_x (nitrogen oxides), PM (particulate matter), CO_2, SO_x and heavy metals. Being SO_2 the largest contributor, with up to 80% of total emissions (European Environment Agency, 2009). The quantification of those impacts as attributable from the construction or expansion of an intermodal (in this case maritime) terminal could only be argued when the expected activity would contribute to an overall increase on traffic or at least on the vessels-km generated (more than tone-km) with a global perspective.

Additional and necessary considerations include: i) the dead weight of the ship; ii) installed horsepower; iii) kind of fuel expected to be used at port, anchoring, coastal shipping and open sea shipping by the vessels (bunker with either high or low sulphur components, LNG, methanol, electric and the combination of them depending on where the vessel is operating); iv) and installed improvements to reduce emissions or improve fuel efficiency (mainly scrubbers or any other kind of filtering). Of relevant consideration will be where the port is located, especially if within a SECA, NECA or ECA zone or in any area with additional stringent air pollution regulative requirements.

Finally, it should be considered if the new facilities and/or equipment provide the capacity to reduce emissions by, for instance, providing access to the power grid to allow vessel electrification during, at least, port operations and thus reducing most of the harmful pollution (not GHG emissions) arising from their activity.

Similar considerations are needed for rail traffic regarding the kind of power used by trains, especially in cases where electrification exists but only up to the technical area (gate) of the terminal but where operations from the shunting yard to the loading / unloading tracks are operated with diesel engines (the most common case).

The energy expenditure of a terminal (facility energy requirements or other energy supplies) during its operational life also contributes to pollution and climate change and has to be accounted for, albeit it may be delocalized depending on the energy sources. At an operational level, efficient operational processes that result in a reduction of waiting times, e.g. trucks at loading and unloading or berthing time, would reduce, in turn, the overall carbon emission and thus air pollution. Therefore, consideration on times are relevant when assessing the overall impact (but mainly air related) of the operation of an intermodal terminal.

5.2. Noise and vibration pollution

According to the World Health Organization, the nuisance of noise derives in cardiovascular diseases, cognitive impairment in developing children, sleep disturbance, high levels of stress, etc. which can be summarised in a loss of healthy years (World Health Organization and JRC, 2011).

In the case of a new intermodal terminal, noise pollution can be traced back to the induced hinterland volume of traffic and terminal operations, machinery and vessels. In addition to those derived from machinery during initial construction phases

Real exposure levels are complex to study: mainly depending on road quality, source of noise and sound propagation mechanisms. In this regard, distance to the closest human settlements may alleviate the impact of noise and vibrations.

In terms of land vehicles, sound pollution due to tyre-pavement contact is currently the most important source; hence investing in porous asphalt (both in the nearby road network and terminal pavements) may play a major role in ameliorating this nuisance.

As for the terminal role, the terminal operations and equipment that produe sound and vibration pollution are: ship engines, trucks, shunting locomotives, trains, cranes, reach stackers and any other kind of engine vehicle. Moreover, the OECD (2015) state that the most important noise sources in terminals come from engines, hence a switch to electric powered machinery would help in this regard. Which in turn would have a direct positive effect on air pollution.

5.3. Accidents and congestion

Although accident costs are not a true environmental effect derived from the terminal operation but namely an externality (an unaccounted cost to the final marginal user), it has deemed necessary to provide a summary on how it can be accounted for and the impact in the global assessment (regarding external costs) spawning from the terminal operational activity.

Part of accidents costs are already internalized through insurance policies. On the other hand, however, direct, indirect and intangible costs add up to accident costs. The most important components being medical and administrative costs, production losses, material damages and the perceived value of pain, grief and suffering (Maiback et al., , 2008). The average social accidents costs (market prices in €2010) in EU are 1,870,000 € for fatalities, 243,100 € for severe injuries and 18,700 € for slight injuries (Ricardo-AEA, 2014).

Accidents (the ones coming from traffic) and congestion, likewise impact on air, depend mainly on the volume of traffic (density of vehicles per kilometre). Therefore, the induced number of freight vehicles in the neighbouring areas to the terminal might increase both externalities.

A different approach is in order when accounting for accidents coming from the terminal activity. In that regard, the System for the Occupational Risks Prevention (ORP) implemented at terminal operation level and any preventive measures implemented either during planning (visibility, safety areas, turning lane, dead angles) operation (first assistance capabilities, etc.) and personnel training will have an effect on reducing the probability of fatalities happening and the overall resulting impact.

As for congestion, it is argued not to be a true externality (Ricardo-AEA, 2014), since its negative impact is already included in the user travel time (internalized). Derived from congestion, however, additional fuel consumption arise from stop-and-go conditions, in which case this externality would already be accounted under pollution and climate change externalities.

5.4. Barrier effect and visual pollution

The construction of a new infrastructure inevitably modifies the landscape, resulting in a loss of landscape quality and enjoyment of leisure time in the country.

Extensive use of land is required to deploy berthing areas, storage areas, shunting areas, warehouses and offices, etc. Intermodality requirements, in terms of railway tracks or new road connections, both in ports and dry terminals, pose further barrier effects in the vicinity of the port. With this, land utilization and barrier effect become a substantial aspect to consider.

Moreover, there is a direct environmental impact in the coastline, insofar it arises changes in coastal sediment transport and microscale currents.

Overall, visual and barrier impacts are difficult to quantify. Few methodologies have been developed; subjectivity underlies visual pollution, whereas complex patterns and uncertainties in the natural ecosystem difficult the assessment of the barrier effect.

5.5. Ecosystem and water pollution

Construction or renovation phases may entail intensive geotechnical operations: excavations; land's levelling out; soil consolidation and strengthening, etc. This may directly affect the water table and aquifers. Moreover, the port may pose a barrier effect in the natural underground flow regime, redirecting it around the whole infrastructure, resulting in a large environmental impact. Saltwater intrusion may be a consequence, incurring in additional public expenditure to alleviate or return to an original situation.

Machinery is doomed to contribute to the ecosystem pollution in the form of oil leakages, during either construction or operational phases. Vessels may pollute with oil and sewage spillage, antifouling applied in ships' hull, garbage disposal from crew, etc.

Dredging operations also pose a threat to the ecosystem, by changing the aquatic habitat and seabed, but also by spreading contaminated sediments (which may occasionally carry poisonous substances) (OECD, 2011).

Another impact is related to ballast water used in vessels tanks for stability purposes, releasing ballast water may introduce invasive species from other habitats, hence a posing a threat to the local marine ecosystem (OECD, 2011).

Along the same lines, ships may spill dangerous substances to the local marine ecosystem such as sewage, sludge and oil during its berthing time, most probably owing to unavoidable leakage.

6. Measuring Functional, Economic and Environmental aspects of terminals. Sources for assessment.

6.1. Existing Key Performance Indicators (KPI) for functional, economic and environmental analyses

6.1.1. Business standard parameters

The KPIs are exemplary and were selected based on the following criteria.

a) Each KPI is a proven industry standard (e.g. benchmarking of published annual reports of leading logistics companies or KPIs are used in publications of neutral bodies)
b) Each KPI is a proven standard to measure relevant operational, financial or socio-economic aspects of a terminal
c) Each KPI is success critical in optimization or investment scenarios in at least one dimension (operational, financial, socio-economic)

Typical KPIs published (selection)		Contship Italia	Dachser	DB Schenker	DHL	DSV	Geodis	Kühne & Nagel	LKW Walter	Waberer	Xpo-logistics
Financial	Revenue	X	X	X	X	X	X	X	X	X	X
	Gross Profit	X	X	X	X	X	X	X	X	X	X
	EBIT	X	X	X	X	X	X	X	X	X	X
	Cash Flow	X	X	X	X	X	X	X	X	X	X
Operational	Number of shipments			X	X	X					
	Handled units/volumes (Air, Sea, Road, Rail)	X	X	X	X	X	X	X	X	X	X
Socio-economic	Number of employees (FTEs)	X	X	X	X	X	X	X	X	X	X
	Emissions (e.g. sustainability reports)				X	X		X			
	Energy consumption	X		X	X	X					X
Ratios	Gross Profit Margin	X	X	X	X	X	X	X	X	X	X
	EBIT Margin	X	X	X	X	X	X	X	X	X	X
	Profitability ratios (e.g. ROCE)	X	X	X	X	X	X	X	X	X	X
	Revenue per FTE	X	X	X	X	X	X	X	X	X	X
	Revenue per handled unit	X	X	X	X	X	X	X	X	X	X

Figure 14: Selected KPIs typically used and published by leading logistics providers

Source: Annual Reports 2016: Contship Italia (EUROKAI), Dachser, DB Schenker, Deutsche Post DHL, DSV, Geodis (SNCF), Kühne & Nagel, LKW Walter, Waberer, Xpo-logistics

Revenue

Revenue represents the income from the sale of goods and services in the course of the 'ordinary activities'. This mainly includes in the logistics industry income from rendering core transportation services. The revenue of Intermodal terminals is generated by providing their specific transportation services (e.g. loading, unloading, handling of goods) to external and internal customers.

Gross Profit

Gross Profit is the difference between revenue and the cost of making a product or providing a service, before deducting overheads, payroll, taxation, and interest payments. It is typically used in the Logistics sector as an indicator for operational performance. This includes also e.g. gross profit per product, gross profit per customer and ratios as gross profit margin = gross profit / revenue.

Earnings before interest and taxes (EBIT)

EBIT is a measure of a firm's or function's profit that includes all expenses except interest and income tax expenses. In the context of terminals it measures the overall profitability of the terminal operation before financing and tax aspects. EBIT by products and customers as well as EBIT margins are widely used as profitability measures.

Volume

Volumes represent handled units of the reported period. Depending on the business segment the volumes are measured differently.

- Airfreight transport volume is measured in tons
- Road-freight is measured in truck loads (FTL = full truck load; LTL = less than full truck load)
- Rail freight is measured in ton-kilometres or containers (TEU = twenty-foot equivalent unit; FEU = forty-foot equivalent unit)
- Sea or ocean freight is measured in containers (TEU = twenty-foot equivalent units; FEU = forty-foot equivalent unit)

Employees

Employees represent the equivalent of full time employees of a firm or function. In the context of terminals the number of full time equivalents is required e.g. for productivity calculations and estimations of personnel costs.

Carbon emissions and energy efficiency

All gases that are harmful to the environment are disclosed in the form of CO2-equivalents (CO2e). Some companies use a carbon efficiency index (CEX) to quantify the greenhouse gas emissions in accordance with the Greenhouse Gas Protocol standards and DIN EN 16258[1].

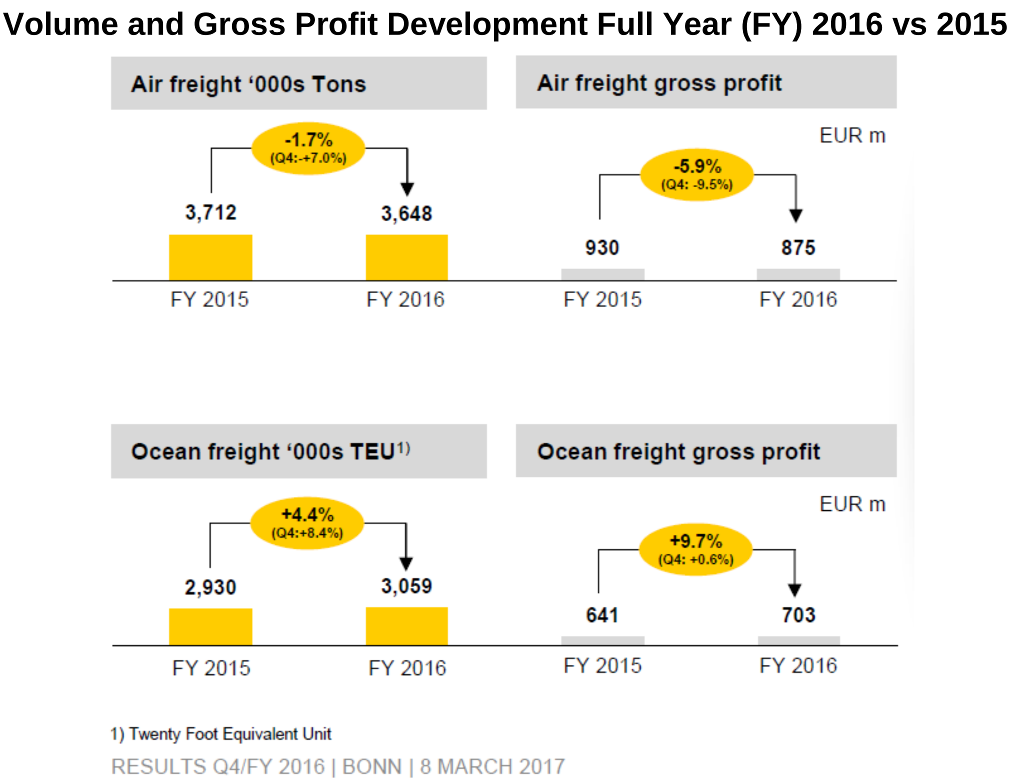


Figure 15: Example for published KPIs in Logistics industry
(DP DHL Group FY/Q4 2016 Analyst Call, March 8th, 2017)

6.1.2. Literature and observatories standards at planning level

Likewise, in the literature and current observatories, the indicators found to assess any of the previous dimensions are waste and differ depending on the sources. As already assessed in D3.1 (Study of the state of the art and description of KPI and KRI of terminals, hinterland mobility and rail network) a clear differentiation exists between indicators related to operational and financial aspects of the activity (intermodal terminal in this case) and other indicators related with quality, environmental effects and sustainable measures. The first set being the one usually found in business reports and the second coming from public agencies and research, mainly.

This aspect was fully explored during the development of D3.1 and therefore in here just the major findings will be provided to refresh the concept. We emplace the reader to

[1] Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passenger s); EN 16258:2012

read through D3.1 if further details on the different indicators and the sources used are to be consulted.

Operational and financial performance indicators

The conducted research performed showed how, usual indicators address productivity at the more stringent equipment/infrastructure part of the terminal, that is berths and quay productivity for maritime terminals and rail trucks and cranes for loading or unloading (either reach stackers or gantry cranes) for dry port terminals. From there, relevant indicators stem to all major determinants in the productivity: lifting equipment and labor productivity, pick-up/delivery cycle times, track and physical layout, train reliability, management information systems and work practices (Ferreira and Sigut, 1993).

Regarding financial performance, most of the literature distinguishes on indicators performing operational and those, which address the long-term financial viability of terminal operations. In particular, the terminal operating cost and the overall terminal cost (including capital provision) per container handled are the indicators required to manage a terminal together with the return on investment (ROI) and EBIT related ratios. Table 2 provides an overview of the most common indicators found in the literature for seaport terminals and intermodal freight terminals.

Table 2. Most common operational and financial indicators found in the literature review

Category of performance indicator	Subcategory of performance indicator	Performance indicator	Main sources
Operational	Productivity/ utilization	Quay productivity/utilization Terminal area productivity/utilization Storage area utilization Equipment productivity / utilization Gate utilization Berth occupancy Labor productivity/utilization	UNCTAD (1976) Ferreira and Sigut (1993) Le-Griffin and Murphy (2006) Marlow and Paixao (2003) Hakam (2015) Thomas and Monie (2000) Talley (1996)
	Time-related	Turnaround time Waiting time Service time Maneuvering time Berthing time Idle time Cut-off time Dwell time Total time delays Time for administrative procedures	Le-Griffin and Murphy (2006) Cariou (2012) Chung (1993) De Langen, Nijdam and Horst (2007) Ducruet et al. (2004) Marlow and Paixao (2003) Nam et al. (2002) Suarez-Aleman et al. (2013) UNCTAD (1976) Pachakis and Kiremidjian (2004) Tahar and Hussain (2000)

Category of performance indicator	Subcategory of performance indicator	Performance indicator	Main sources
Financial	Investment and funding	Infrastructure construction Equipment purchase Profitability Turnover Revenues/Expenditures	Ferreira and Sigut (1993) UNCTAD (1976) Chung (1993) Talley (2007)
	Costs and pricing	Labour costs Equipment costs Infrastructure costs Maintenance costs	Ferreira and Sigut (1993) Marlow and Paixao (2003) Talley (1996) UNCTAD (1976)

Source: D3.1 (Study of the state of the art and description of KPI and KRI of terminals, hinterland mobility and rail network) (Intermodel Project, 2017)

Quality service and environmental performance indicators

Regarding dimensions not directly related with the original purpose of the terminal (manage containers between different means of transportation in an effective manner), the categorization to be used becomes more blurry. D3.1 proposed to distinguish between quality, environmental and socio-economic related.

Quality includes any indicators referring to how the service provided is perceived by its final users, being time related indicators the ones that seemed to have a major relevance in the literature (service time, waiting time and the relationship between the two). Other quality indicators included: i) Reliability (no delays, no wrong delivery); ii) flexibility (if a system can easily respond to changes in requirements); iii) qualification (terminal's capability); iv) terminal accessibility during the day (opening times and/or easiness of physical access); v) safety; and, finally, vi) security (% of lost or damaged cargo).

Environmental indicators found range from air emissions to noise hindrance, erosion of river banks, habitat loss and disturbance of animal habitats. The energy consumption and the use of renewable fuels together with transport accidents were also recommended.

Finally, socio-economic indicators include those that measure the return, either positive or negative, that the construction and operation of a terminal is likely to have on the society. Indicators in that dimension would include gross value added, employment, fiscal revenues or contribution to the flow-back to the treasury of the administration, and resulting trade values. Of more interest even, is the use of these metrics relative to throughput or resources used in any of their possible options: employment generated per tone processed, kWh consumed, square meter, and so on).

Table 3. Most common quality service, environmental and economic impact indicators found in the literature review

Category of performance indicator	Subcategory of performance indicator	Performance indicator	Main sources
Quality service	Safety and security Flexibility Reliability and service care Accessibility and connectivity	Time-related indicators % of lost or damaged cargo No delays, no wrong delivery Employees qualification Incidence of train/vessel delay in departure (%) Schedule reliability	Ballis (2004) Huynh et al. (2015) Walton (2005) Dragović et al. (2005) Henesey et al. (2003) Notteboom (2006) Marsden et al. (2005) Agerschou (2004) Fourgeaud (2000)
Environmental /sustainable	Accidents Noise Air pollution Climate change Water pollution Habitat loss Hydrologic impacts Energy consumption Sprawl Congestion Resource efficiency	Number of transport accidents, fatalities, injured, polluting accidents, etc. Crash casualties and costs Air pollution emissions Embodied emissions Noise pollution exposure People exposed to traffic noise above 55 LAeq Impervious surface coverage Habitat preservation Community livability ratings Water pollution emissions Use of renewal fuels Energy efficiency Vibrations Mode split	Litman (2007) Litman (2016) GPI (2008) Marsden, et al (2005) Hanaoka and Regmi (2011)
Socio-economic impact	Economic impact Return on investment	Value added per ton Employment per unit of land Value added per invested euro by the public sector Port-related employment Port value added	ESPO (2010) De Langen et al. (2007)

Source: D3.1 (Study of the state of the art and description of KPI and KRI of terminals, hinterland mobility and rail network) (Intermodel Project, 2017)

7. Cause-effect relationship between indicators and future terminal requirements

7.1. Relationship between indicators being used in the INTERMODEL project

As a result of D3.1 a list of potential indicators to be used for assessment of the design of terminal was provided (Table 4) resulting in 5 different categories or dimensions (listed in the previous section) and 40 indicators. This section provides a critical review on the potential relationship between the indicators from a high-level (strategic) perspective.

Table 4. Indicators and their dimensions that could be potentially used / obtained at the end of the Intermodel project

Key Performance Indicators (KPIs)	Performance Indicators (PIs)
Operational	
1-Intermodal terminal throughput (volume) 2-Equipment utilization 3-Gate utilization 4-Labour utilization rate 5-Storage area utilization 6-Rail track utilization 7-Berth utilization 8-Turnaround time 9-Waiting time	28-Maneuvering time 29-Service time 30-Berthing time 31-Idle time (equipment)
Financial	
10-Return On Investment (ROI) 11-Terminal's profitability 12-Operating efficiency (operating margin) 13-Operating revenues per unit 14-Operating benefits per unit 15-Direct jobs sustained by terminal activities 16-Indirect jobs sustained by terminal activities 17-Road and rail track maintenance cost	32-Capital Expenditure (CAPEX) 33-Operational Expenditure (OPEX) 34-Corrective maintenance cost - equipment 35-Preventive maintenance cost - equipment 36-Corrective concrete structures maintenance cost 37-Preventive concrete structures maintenance cost
Quality, environmental and safety	
18-Easiness of entry and exit from highways 19-Easiness of entry and exit from rail network 20-Energy consumption per handled unit 21-Carbon footprint per unit 22-Delays produced (reliability) – road 23-Delays produced (reliability) – railway 24-CO, NOX, SOC, PM emissions 25-Population exposed to high levels of traffic noise 26-Number of road accidents 27-Number of railway accidents	38-Waiting time / turnaround time 39-Use of alternative fuels from total consumption 40-Accidents related to hazard cargo

Source: D3.1 (Study of the state of the art and description of KPI and KRI of terminals, hinterland mobility and rail network) (Intermodel Project, 2017)

Before we can start the assessment, and at a first glance, throughput strikes as not really a performance indicator since the project aims at modelling a terminal where throughput is necessarily introduced as an external variable or input to create the scenario against which the proposed modelled design has to be tested. Therefore is more of a value that is necessary to bring context on how the remaining indicators perform, this is why it was kept and was given the first position in the list of indicators from D3.1.

Considering that, it becomes clearly necessary to assess the potential influence that varying the throughput would have on the remaining KPI and PIs as a first step to, in a second step, understand the logic between all of them. The assessment here is produced qualitatively, a second assessment, gathering the information provided in all the remaining pieces of work of the project, is to be produced at the end of this project's life and presented through report D8.5 (Summary of results of work packages 2-7 and implications. Recommendations for new and to be renewed intermodal terminals from the functional, economic, and environmental perspectives)

The structure of this section follows the aforementioned logic: First of all an assessment on the influence of the throughput to the remaining indicators -grouped by thematic approach to ease the follow-up-; then an assessment of the relationship of each group on the remaining ones is provided and; finally, considerations on the specific relationships between each individual indicator within a group are provided.

7.1.1. Throughput variations effect on the remaining dimensions

Considering that the terminal configuration (infrastructure) is maintained, it can be foreseen how any increase in container flow would likely lead (or approach to) to congestion situations and increased processing times for containers, thus leading to slow down processing and as a result, having a negative effect on the smoothness of the supply chain.

As stated, an increment on terminal volumes suggests an increase on the use of the available handling equipment (gantry cranes, yard cranes, reach stackers…) and operational areas of the terminal (storage area, quayside area…) which could be translated into a positive effect on productivity, depending on the number of movements necessary to process a given container. However, this fact can lead to increased operational costs and waiting times, therefore reducing the beneficial effects on productivity and the perceived quality of the terminal to its final customers.

The more throughput capacity, the more environmental –negative- effects will be produced from the terminal operation. Environmental performance is likely to decrease not only in absolute numbers but also in relative ones, at least once certain threshold is met when adding a container would reduce in more energy consumption due to increased movements necessary per container and/or congestion can start to be felt either inside the terminal, its gates and/or its surrounding network.

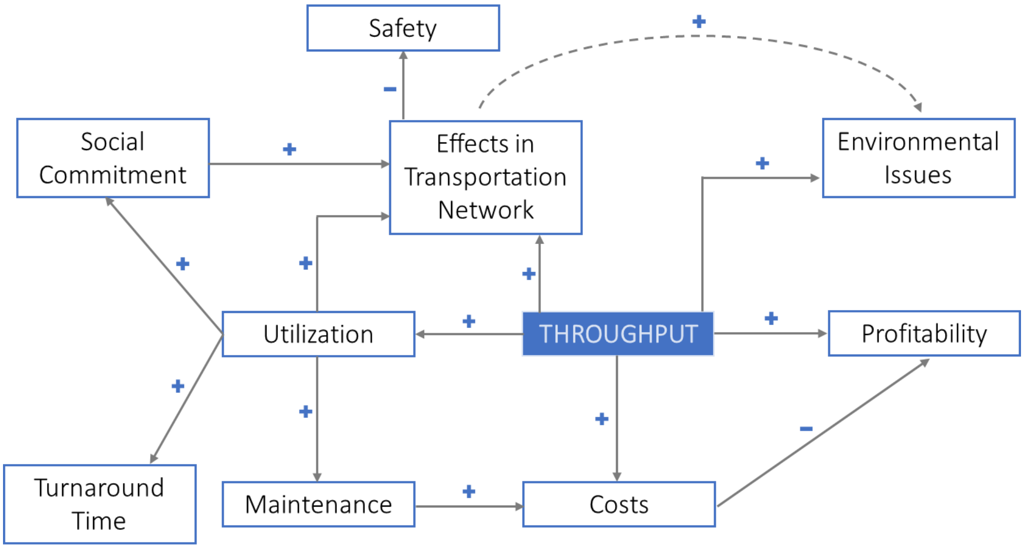


Figure 16: Estimated cause-effect relationship between main dimensions

Figure 16 provides an overview on the potential relationship between the main groups of indicators being used (Table 4). Note that a positive sign indicates that an increase in the indicators in that dimension produce increases in the value of the indicators at the end of the arrow and not if they could be deemed as positive (good) or negative (bad). To assess the nature of such increase please refer to the indicators definition in D3.1 or the (upcoming) grading system for each indicator as provided in D8.3.

7.1.2. Variations on utilization (use of infrastructure and superstructure assets)

This section assesses the effects on the remaining sets of indicators from variations in the use of either equipment and infrastructure (that is, increases on the usage of equipment, labour and facilities of the terminal such as cranes, gates, stocking areas, rail tracks and berths).

As a result of a more intensive use of the terminal assets, more maintenance effort (absolute numbers) is to be expected, with maintenance tasks having to be carried out more regularly due to the new operating conditions to ensure the effectiveness and to keep safety during working times.

Both corrective and preventive measures applied to infrastructure, e.g. rail track, or to superstructure involves an investment for implementing them. The increased maintenance work on the terminal means a rise on the general costs, particularly in

OPEX which is mainly related with running operation costs (at least in absolute numbers).

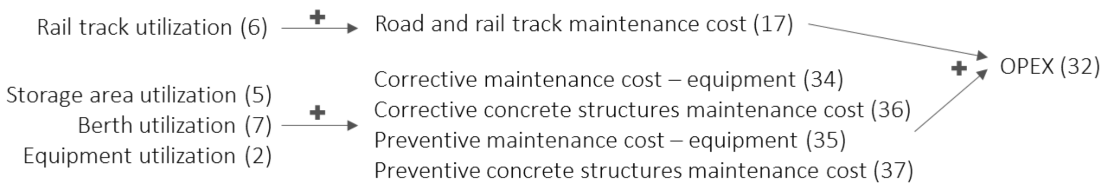


Figure 17: Expected relationship (at indicator level) from variations on the use of infrastructure and equipment on maintenance needs (coming from an increase of throughput)

As reflected in Mokhtar and Shah, 2013, throughput obtained on the terminal does not necessarily imply a notable boost in efficiency. Container terminal operators must be responsible of an adequate allocation of inputs to ensure the utilization of obtained resources. It must be underlined that handling a larger number of TEUs gives the need to assure that efficiency is not being worsened by an excess of unproductive movements or a poor performance planning, leading to an increment on operating times.

7.1.3. Variations on time related indicators

With reference to operational times, a major volume of freight handled increases turnaround times of vessels (in case of maritime ports) (Figure 8), either caused by an increase in transport units to be processed (more vessels with the same amount of cargo) or due to longer loading/unloading times if vessels and trains carry more containers on average. In any case, the number of trucks going through the terminal gates is to increase.

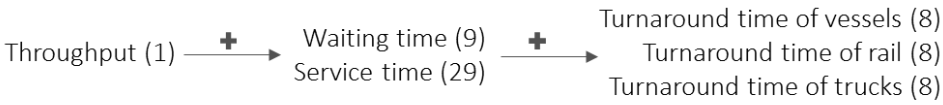


Figure 18: Expected relationship (at indicator level) of throughput with time related indicators

The relationship throughput-time is not straight forward, however, if scheduled efficiently the terminal should be able to cope with the increase in traffic with the current resources and not implying a reduction on quality provided. However, since the assessment does not consider changes in how the terminal is operated nor the traffic distribution, a decrease in quality (increase in turnaround time) is more than probable. As a result.

7.1.4. Variations socio-economic indicators – jobs generated

However, increases in throughput are more than likely to produce a beneficial return on the society by means of increased in the workforce necessary. Not only jobs directly related with terminal works will need to be filled to account for the additional work to be done, extended work shifts, etcetera, but also more throughput should be easily translated into more jobs generated by the incoming economic activity related with the increase of trade.

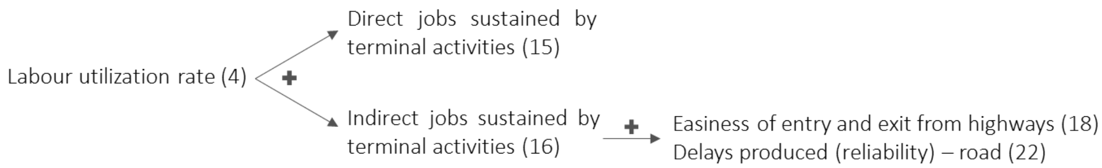


Figure 19: Expected relationship (at indicator level) of throughput with labour utilization

That is, in order to cover the labour resource demand, it is necessary to set a labour planning which indicates the staff needed. In case of additional terminal activities or unplanned demand, flexible employees and/or fixed staff working overtime may cover the labour schedule.

And on top of that, additional traffic means the attraction of more companies (or increase in production of the existing ones) to set their business in the area around the terminal which means that indirect employment will be generated.

However, this positive effect is likely to have a negative impact on the social aspect as well, since traffic volume in the surrounding network is likely to be affected with the increase of private vehicles circulation, increasing traffic intensity and reducing the quality of service of the rod network. From the combination of the increase of trucks used to transport the goods with the use of a larger number of private vehicles due to the newly developed business area, real affectation on the network is more than likely, while causing a greater damage on the environment through increases in air, noise and water pollution as well as the carbon footprint of the terminal.

7.1.5. Effects in Transportation Network

When referring to road transport, terminals can be exposed to problems of traffic congestion not only on the accesses to the infrastructure but also on the connecting roads with the network (entry and exit from highways). Traffic of trucks going in and out is a typical activity on intermodality. To guarantee a smooth flow of vehicles becomes necessary if the optimal distribution of containers (import or export) is to be ensured. In an additional note (adding the safety factor into the mix) , less network congestion also means an improvement (in fact reduction) in the number of accidents occurring derived from the terminal’s activity.

The basis for railway transportation of freight is to manage a proper scheduling for trains. The key concept is the provided time windows by the rail operators which lead to available time periods when the circulation of trains is possible. This is a special issue if freight and passengers transport are sharing the same infrastructure.

7.1.6. Environmental issues

Environmental impact is focused on activities handled on the terminal and these describe emission factors in qualitative terms, so indicators have been provided per unit of freight transported (TEUs). Directly related with throughput, affectation on the environment grows with trade (in absolute numbers).

Throughput (1) $\xrightarrow{+}$
Energy consumption per handled unit (20)
Carbon footprint per unit (21)
CO, NOX, SOC, PM emissions (24)
Population exposed to high levels of traffic noise (25)

Figure 20: Expected relationship (at indicator level) of throughput with environmental indicators

Container intermodal terminals should become not only productive and competitive, but also more eco-friendly. It is a great challenge to combine efficiency and productivity in order to get sustainability goals. In terms of energy consumption, profitability and operational efficiency are connected to obtain a reduction on consume per handled unit (Spengler et al. 2016). Unproductive movements of containers and an inadequate scheduling of activities can greatly affect the increase of wasted energy.

Noise from the terminal activity and additional noise generated in the network is not a major problem unless the terminal is located near or on the surroundings of a dense population area and the issue concerns when referring to operations handled within the limits. Therefore the relationship between

Besides the relationship between throughput and environmental indicators which has been arguably been assessed as having a negative effect in absolute numbers and, once certain threshold is met, in relative numbers of well, this section assesses the relationship between the environmental indicators provided in Table 4 that were not already addressed in the previous diagrams (Figures 17 to 20).

A straightforward relationship that can be observed is the positive implications from increasing the use of alternative fuel sources for the equipment used at the terminal, mainly LNG or electric powered cranes / reach stackers (Figure 21).

Use of alternative fuels from total consumption (39) $\xrightarrow{-}$
Carbon footprint per unit (21)
CO, NOX, SOC, PM emissions (24)

Figure 21: Expected relationship (at indicator level) between indicators 39, 21 and 24 (user of alternative fuels, emissions and carbon footprint)

7.1.7. Variation of Costs and Profitability

Every activity performed on the terminal is associated to costs. In consequence, operational costs will increase with the throughput. Therefore, expenditure is closely linked with terminal profitability.

On the other hand, increase throughput is likely to have a direct positive effect in terms of probability (more containers, more revenues) depending on the existing trade-off between revenues and operational (OPEX) costs.

The maximization of annual capacity haulage is one of the most representative strategic goals to reach for seeking the greatest profit on a terminal. Every container unit generates an income for the terminal. In order to compete with other terminals, especially between geographically close ones, customers should be attracted by the conditions and services offered. The terminal competitiveness is determined by operational efficiency, particularly on loading/unloading activities, and contractual rates offered to customers.

7.2. Effect of future requirements on the performance of terminals

Terminal design and investments are decided on a long term, public concessions usually exceed the 25 year mark as it does the expected life cycle of the investments made. Considering that designing, planning and construction, it means that terminals have to withstand at least 30 years of operations. Therefore, when planning, it is also necessary to assess how the design of the terminal will perform in a market with dynamic varying conditions.

To cope with that, the DSS behind a terminal design can be approached with the:

- Provision of multi-stage designs, that would allow to adapt to the changes through the expansions of the terminal.
- Provision of designs flexible enough to be adaptable to the potential changes in the market.
- A combination of the two.

In order to be certain that the chosen design will meet the future requirements it becomes critical to (1) identify what this requirements will via the definition of future scenarios. Work does not stop there, then it is also important to (2) assess the feasibility of each scenario and (3) test the different design against the most probable scenarios and those that, if happening, might have a bigger adverse effect.

The tool provided as a result of the INTERMODEL project would allow to perform point (3), that is, to test potential future scenarios with different development levels of the terminal or more or less designs. D8.2 deals with point number (1) and produces an incipient assessment on (2). Finally, this section (thus D8.1) explores what might be the potential effect of some future trends in logistics translated as requirements upon the terminal, from a qualitative perspective (Table 5).

Table 5. Effect of certain market trends on a selection of the KPIs

		Increase capacity of L/U area	Increase storage	Increase access capacity	Increase superstructure (yard)	Increase superstructure (L/U)	Reduce noise	Reduce emissions	Water pol. Prevention	Process optimization	Synchronize	Automation	More durable equipment
Functional	Infrastructure usage	-	-			-				-			
	Superstructure usage			-	-	-				-			
	Labour usage			-	(-)	(-)				-		+	
	Customer time at terminal	-	-	-	-	-				-	-	-	
	Equipment efficiency use		+		-	-				+	+	+	
Economic	Revenues (13)												
	Profitability (10, 11, 12, 14)	-	+/-	-	-	-	(-)	(-)	(-)	+	+	+/-	
	Direct Jobs			+	+	+				(-)		-	
	Indirect jobs				+	+				(-)		+	-
	Network maintenance												
	CAPEX	+	+	+	+	+	+	+	+	(+)	(+)	+	+
	OPEX		-	+	+	+				-	-	+	-
	Maintenance	+	+/-	+						-		+	-
Quality / Environmental / Social	*Connectivity*												
	Energy consumption per unit		-		-	-				-	-	-	
	Emissions (all) (not congestion)					-		-		-	(-)	-	
	Noise (not congestion)						-			-	(-)	-	
	(Water pollution)		(+)						-				
	Congestion	(-)	-	-	-	-				-	-	-	
	Safety (network)			+						+	+		
	Safety (terminal)	(+)	+	(-)	(-)	+				+	(+)	+	
	Environment (infrastructure)	-	-	(-)									

The approach was discussed internally between T8.2 involved partners and afterwards presented and discussed in a workshop developed with that purpose during a GA meeting held in Barcelona in 2018. Table 5 provides the output at the end of the discussion sessions.

Before assessing the effect of logistic trends on the indicators, it becomes necessary to introduce the following clarification terms for disambiguation purposes:

- The assessment of the KPIs is based on representative measures (e.g. increasing length of berth or adding additional equipment)
- All dimensions stay the same except for the selected measure (i.e. operated volume and revenues, cost levels, prices are stable).

Take into account that in reality changes of the infrastructure, superstructure or processes would only be done if justified by a business case. In fact, in real life scenarios indicators are expected to be linked thus, variations in one of them might produce variations on some others or even all of them.

To summarize: the expected variation of KPIs to changes on the market under certain changes in the terminal necessary to adapt to future market trends is done in isolation (i.e. if a piece of equipment is added and the volume stays the same, the productivity of that equipment decreases and the profit per unit decreases as there are additional cost of the additional equipment). However, in reality the motivation to add equipment is either to solve a problem (“congestion within the terminal”) or preparing for expected additional volume or adjusting to future standards (bigger vessels, longer trains etc.).

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