Clusters 2.0

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D3.8

Scenarios and tools for shipment planning and asset optimization for logistics clusters networks

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Abstract
This document presents the D3.8 Clusters 2.0 Scenarios and tools for shipment planning and asset optimization for logistics clusters networks. Herein, the approach, the use cases, the tools, the data preparation and finally the test results are documented.

Legal Disclaimer

Abbreviations and Acronyms

Acronym	Definition
API	Application Programming Interface
CO2	Carbon dioxide
CSV	Comma-separated values
DoA	Description of Action
Dx.x	Deliverablex.x
EAB	External Advisory Board
EC	European Commission
EU	European Union
FEU	Forty Foot Equivalent Unit
FP7	7th Framework Programme
FTL	Full truck load
HBEFA	Handbook emission factors
ID	Identifier
IM	Intermodal
INEA	Innovation and Networks Executive Agency
KPI	Key Performance Indicator
LL	Living Lab
LTL	Less than truck load
NDA	Non-Disclosure Agreement
P&E	Planning and execution
TEU	Twenty Foot Equivalent Unit
UC	Use Case
WP	Work Package

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Executive Summary

The Clusters 2.0 deliverable "Scenarios and tools for shipment planning and asset optimization for logistics clusters networks" addresses a methodological approach to develop and assess intermodal potentials within supply chains under real market conditions. For that intermodal planning tools are developed and tested using real data. The approach is based on the real intermodal services that are established within the CLUSTERS2.0 clusters and shipment orders as provided by shippers. A matching algorithm was developed in order to identify possible matches to use existing intermodal services. "For the potential analysis "virtual" intermodal services where introduced on lanes with major volumes. The intermodal planning tool is part of the WP3 massification concept and supports shippers collaboration to exploit intermodal potentials with their supply chain through collaboration and co-ordination.

Within WP 3.6 we developed and applied an intermodal planning environment that is capable for assessing the potentials of collaborative demand planning of shippers as addressed in the massification concept. Making use of large-scale realistic demand data covering the area of the CLUSTERS2.0 clusters a significant potential of existing and newly "massification" services could be identified. Our study provided a potential of up to 60% over all transport orders with distances higher than 250 km that can be operated by intermodal transport.

The approach developed is supporting the activities as addressed in the massification workshops together with collaborating shippers. The concept proved to be feasible and transferable. Key achievement of this task is that precise analysis on the intermodal potential on trade lane basis can be carried out making use of operational intermodal service data and actual shippers demand data under various constraints and limitations. Moreover, the impact of newly "massification" intermodal services can be assessed making it a very useful assessment tool for the massification concept. In our analysis concrete services on 4 lanes could be identified for which demand is existing however no adequate intermodal service.

1. Introduction

1.1 The Clusters 2.0 Project

Clusters 2.0 vision is to leverage the full potential of European Logistics Clusters for an efficient and fully integrated transport system in Europe and demonstrate the scaling effects for the companies collaborating within logistics clusters.

One of the biggest challenges of European transport system is establishing collaboration among logistics stakeholders to optimize transport operations at lowest environmental impact and to leverage additional scale effects to reduce costs. Clusters 2.0 will provide solutions from four development streams:

- Establish freight logistics community approaches to scale supply chain efficiency through bundling their regular transportation demand with other shippers and to favour intermodal alternatives.
- Develop New Modular Loading Units and innovative handling and transhipment technology to accelerate handling processes within clusters for road and intermodal modes.
- Implement a first of a kind prototype on a Cluster Community System for standard message and information exchange and asset management within logistics clusters.

Clusters 2.0 will provide a toolbox for future logistics including large scale IT applications establishing and facilitating collaboration within and across logistics clusters. Compared to previous approaches Clusters 2.0 will advance by adding elements of horizontal collaboration, modularization and standardization of loading units to the concept of logistics clusters. Clusters 2.0 will increase the engagement, performance and coordination of terminals and hubs at cluster and network level targeting an increase by 50% of the freight managed within clusters intermodally.

1.2 Purpose of Document

This deliverable shall document conducted work and results for Scenarios and tools for shipment planning and asset optimization for logistics clusters networks.

The results are complementary to other Clusters toolbox elements as well as to WP3 activities such as "Massification".

1.3 Structure of the Document

The present deliverable consists of 7 chapters:

- Chapter one provides an introduction into the document as well as into the Clusters 2.0 project.
- Chapter two introduces the process approach of defining scenarios, using tools for shipment planning and asset optimization for logistics clusters networks and ultimately testing these.
- Chapter three structures and presents the identified use cases.
- Chapter four introduces the tools used for data management, calculation and optimization and finally for presenting the results.
- Chapter five presents the intermodal data collection within Clusters 2.0.
- Chapter six conducts the defined uses cases of chapter three and chapter seven concludes the document.

2 Scoping and Approach

This document is geared to the perspective of shippers. Scope of the present document is to prepare and to present a Scenarios and tools for shipment planning and asset optimization for logistics clusters networks. This implies to bundle freight flows between the Clusters by synchromodal connections.

To reach a modal shift, shippers need to:

- be aware of the non-road alternative,

- be willing the change their processes and their network structure

- be motivated by cost savings enabled

- be flexible to collaborate with other shippers in order to generate the critical mass to proceed with the modal shift.

The two main issues that are hindering the progression of the modal shift is:

- lack of visibility of non-road alternatives, due to a fragmentation of the transport offering.

- unknown potential of freight and order streams between Clusters (beyond the own company).

To address these aspects Clusters 2.0 prepared a tool for shipment planning and asset optimisation for freight flows between clusters. The tool aims to enable shippers to identify bundling volumes as well as modal shift potentials that enable:

- Reduction of inefficiencies in road transportation, by e.g., increasing load factor, reducing empty km.

- Shifting freight from road to rail and other modes.

- Lower freight transportation environmental and social impact.

We proceed in four steps towards the target:

- Step one identifies and defines relevant Test Cases that are meaning full to the shipper industry and reflect their main use cases. The Test Cases are to be tested based on shipper data for Clusters 2.0 area.

- Step two introduction of the shipment planning elements to model, optimize and present intermodal transport chains.

- Step three addresses the collection of intermodal schedules from the defined Clusters in the project. Each Cluster shall expose data on connections, terminals and schedules the project.

- Step four conducts the defined Test Cases of step one based on various shipper data. The result will be interpreted in means of modal shift potential as such and also under the perspective of bundling and optimization potential.

3 Definition of use cases

For the definition of use cases we build upon input from massification workshops and industry contributions we collected as part of the Clusters 2.0 project. Further to that, input has been collected as part of external communication during Clusters events and industry fairs.

We distinguish between two use case schemes:

- Planning and execution use cases (operational & tactical level perspective)
- Strategic use cases

3.1 Planning and execution scheme

The planning and execution scheme addresses the operational usage aspect of the shipment planning and asset optimization.

Use Case ID	UC_P&E_1
Use Case Name	Intermodal Chain Composition
Use Case description	Calculation of intermodal transport route(s) between 2 or more given locations for a certain departure time. Provision if possible, of one or more transport route alternatives.
Prerequisites	Intermodal network, intermodal timetables are available
Relevant KPIs	Number of intermodal transport chain transport alternatives, transport time, CO_2, transport production cost of the alternatives

Table 1: UC_P&E_1 - Intermodal Chain Composition

Process flow UC_P&E_1 - Intermodal Chain Composition:

define cargo type

- TEU
- FEU
- Dangerous Goods
- Quantity

define transport type

- door-to-door
- *door-to-terminal*
- *terminal-to-door*
- *terminal-to-terminal*

define transport service type

- sea (liner, tramp, ferry)
- rail (unaccompanied, accompanied)
- road (FTL, LTL)
- time (timeframe)
- preferred services

transport chain request

- according to routing algorithm specification: *search entry, reflect existing terminal services (time, routing, provider, capacity and costs)*
- define terminals and operators to be used

transport chain presentation

- alternativers are being presented

Table 2: Process flow UC_P&E_1 - Intermodal Chain Composition

Use Case ID	UC_P&E_2
Use Case Name	Intermodal Planning System
Use Case description	Calculation of intermodal transport route(s) between 2 or more given locations for a certain departure time for given transport orders and restrictions. Provision if possible, of one or more transport route alternatives. Allocation of transport orders to use transport service capacity in an optimized way.
Prerequisites	Intermodal network, intermodal timetables are available, transport orders available
Relevant KPIs	Number of intermodal transport chain transport alternatives per transport order, transport time, CO_2, transport production cost of the alternatives

Table 3: UC_P&E_2 - Intermodal Planning System

Process flow UC_P&E_2 - Intermodal Planning System:

data preparation
- Include transport order data set
- Include available capacities

Calculate transport chains for orders
- Calculate transport chains
  - validate origin, destination, type of good
  - routing restrictions, quantities and time frame for new transport
- Presentation of aleternative route results per transport order

Optimization step
- Perform allocation of transport service capacity per leg and transport order for all transport ordes
- Respect given transport capacity availability and service costs

Presentation
- Presentaition of the used service capacity to fulfill all transport demand
- Presentation of utilization rate per per service

Table 4: Process flow UC_P&E_2 - Intermodal Planning System

Use Case ID	UC_P&E_3
Use Case Name	Exception Handling
Use Case description	In case of delay or any other unexpected event, alternative routes can be requested. Alternative routes can contain other route/combination/service providers as well as postponement options.
Prerequisites	Intermodal network, intermodal timetables are available, a deviation can be simulated for a planned intermodal route.
KPIs	Number of intermodal transport chain alternatives, transport time, CO_2, transport production cost of the alternatives

Table 5: UC_P&E_3 - Exception Handling

Process Flow UC_P&E_3 - Exception

Situation: Transport order is given by customer. Transport chain is ongoing. Critical delay in the chain occurred (e.g. port strike, fire in terminal) – chain is broken.

get information

- Simulation of exception message
- Open in-execution transport chain data set on timetable level
- Planner evaluates the situation-> critical delay, planned chain is broken
- Check priority and contract obligations

check feasible solutions

- User, e.g. dispatcher, checks whether the load unit can be taken off the existing chain
  - no-> inform customer , load unit is stuck due to problem. Provide new arrival time and cost.
  - yes-> reroute: compose new intermodal chain routing, provide new arrival time and cost

reroute

- Compose new intermodal chain routing starting from new entry point
- Criteria:
  - Keep time - find route that time restrictions could be met.
  - Keep cost - find route that cost restrictions could be met.

Table 6: Process Flow UC_P&E_3 - Exception

3.2 Strategic and tactic scheme

Strategic level is relating to the identification of long-term or overall aims and interests and the means of achieving them. The strategy relates to the tactic that determines the plan how to implement the strategy.

At the strategic level, scenario variations regarding the composition and implementation, e.g. different modes of transport, can be considered within the logistic chain. A strategic route planning enables the user to analyze different scenarios beforehand – without the real-world contractual or capacitive restrictions. Based on this, modal shift potentials can be identified and negotiations for the use or setup of real transport and other logistic services can be conducted.
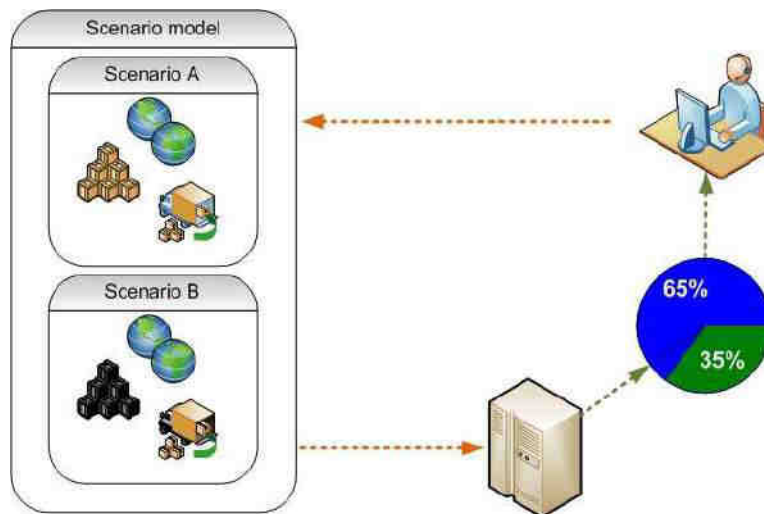
Figure 1: Principle of scenario modelling for route planning

There is a certain range of information needed, to facilitate a strategic scenario planning. The input given by user comprises:

- Locations (origin, destination) plus possible variations
- Load characteristics / container characteristics (type, size)
- Restrictions (e.g. time, transport modes, service providers, etc.) within given ranges
- Optimization method (e.g. time, costs, emissions) with allowed ranges

The user should get a result set by the tool specifying all relevant parameters for the decision making – assuming that the request can be fulfilled:
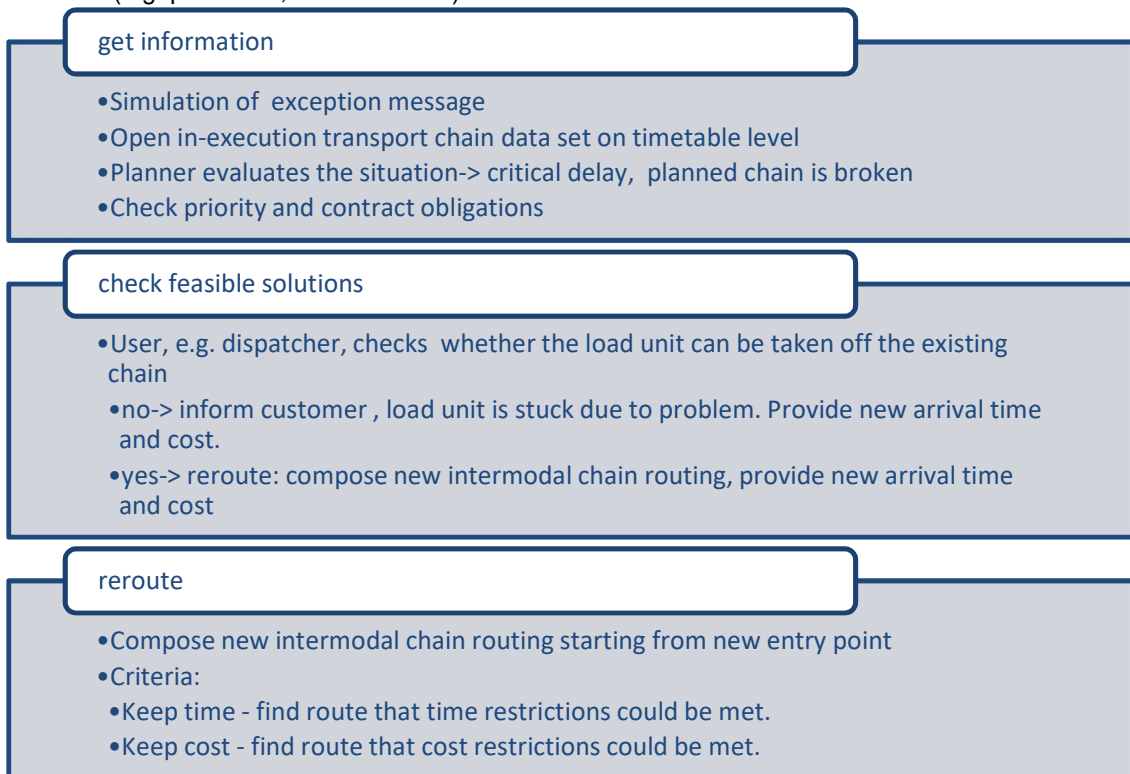
Routing (inter or single modal routing) with respect to restrictions

- Modes of transport
- Terminals used
- Travel time
- Distance
- Costs

The strategic scenario service will provide all this information needed for a strategic decision making on the one hand in a graphical way, and on the other hand with fact sheets, naming the routing, cost figures, time, capacities, etc. The underlying algorithm has to combine appropriate services and operators and consolidates transports according to the input parameters for a certain period of time (e.g. month, year).

After a scenario is created, it has to be filled with transport data. These data can be historic data which will be evaluated for their potential of being transported over new transport services. However, the common use case is to generate future transports from advised orders

and to find new transport services that can be operated in cooperation with other companies more cost efficient than the already offered transport services.

After the scenario is filled with transport data, the application and its incorporated algorithms calculate new transport relations from the scenario. The result contains all information allowing the user to analyse and comprehend the solution of the scenario.

With the solution and its containing information, the user then can evaluate the result by different aspects. For instance, what modes of transports are used in the shipment, the total costs for a transport or its duration.

After this, the user can adapt or create a new scenario to evaluate the changes to the calculated transport services resulting from modifying the transport data.

As Figure 2 shows, these steps can be executed iteratively to allow a flexible search for new transport services.
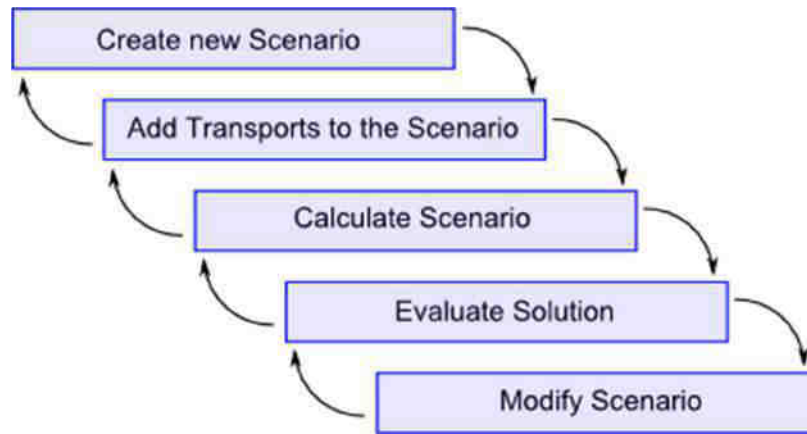
Figure 2: Strategic routing scenario method

Use Case ID	UC_STR_1
Use Case Name	Strategic Planning
Use Case description	Calculate different alternative routes for certain A-B relations for different departure times. Compare relevant times and costs (monetary and environmental) for different alternatives. Allow and disallow certain Terminals and certain operators.
Prerequisites	Intermodal network and intermodal timetables are available
KPIs	Number of intermodal transport chain alternatives, transport time, CO_2, transport production cost of the alternatives

Table 7: UC_STR_1 - Strategic Planning

Use Case ID	UC_STR_2
Use Case Name	Network Simulation and Assessment
Use Case description	Calculate for a set of transport orders per transport order different intermodal routing alternatives. Select the cost optimal solution for the overall system, taking into account all transport orders and order constraints. Check different scenarios, where operators and networks can be enabled and disabled.
Prerequisites	Intermodal network, intermodal timetables are available, a deviation can be simulated for a planned intermodal route.
KPIs	Number of intermodal transport chain alternatives, transport time, CO_2, transport production cost of the alternatives

Table 8: UC_STR_2 - Strategic Planning

4 Introduction of used tools for shipment planning and asset optimization

This section explains the 3 building blocks that are used in Clusters 2.0 for shipment planning and asset optimization.

Intermodal Routing & Planning Service	Intermodal Data Management	Simulation Platform

4.1 Intermodal Routing Service and Planning Tool

The intermodal routing and planning service is an software application designed to solve problems concerning intermodal routing and planning. Based on regular services of multiple modes of transport such as rail, barge, air, road, sea, the routing service can provide possible intermodal door-to-door routes, in general with a road leg at the beginning and at the end. While aiming for "optimized" door-to-door chains in order to support efficiency and decarbonisation of transports, the challenge is to provide meaningful and optimized solutions already at the stage of the initial chain composition. To achieve this task, constraints and performance indicators have to be respected and assessed.

The planning and optimization function perform an allocation of given transport orders towards given transport service capacities. The result of the optimization is an allocation of transport orders towards specific transport services. The optimization takes constraints of the order itself, but also transport service limitations into account. Inputs to the optimization are transport order and transport service data. Depending on the given input parameters, the service

calculates alternatives. The optimization step assesses alternatives and allocates orders to available service capacities.

4.1.1 Functional overview of Routing & Planning Use Cases of the intermodal routing service

In the following diagram, the functional module structure and the main use cases are illustrated. For Clusters 2.0 we make use of the described Use Cases 1, 2, and 3.
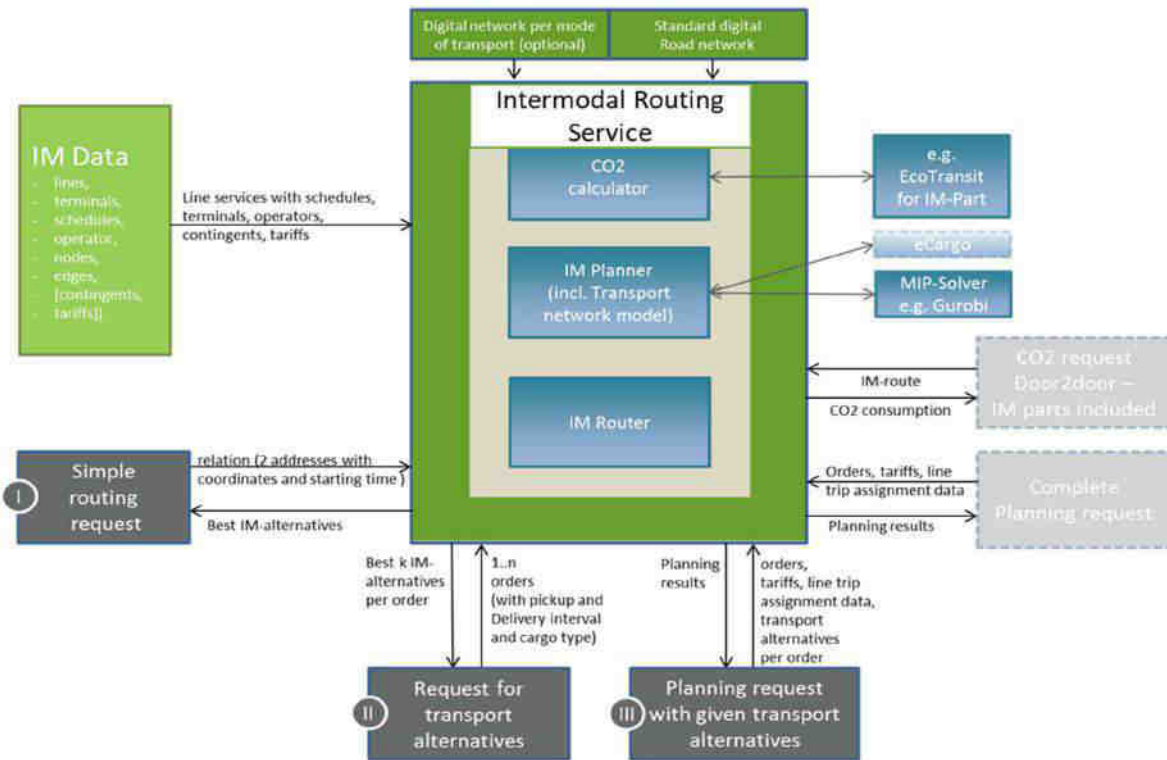
Figure 3: Functional overview of intermodal routing service in Clusters 2.0

The main modules of the comprehensive intermodal routing service are the Intermodal (IM) Router and the Intermodal Planner. The IM router handles routing requests and returns transport chain proposals. These transport chain proposals include transport service information (transport mode, transport service times, transport operator, distances, and transport costs).

Transport costs do include monetary costs (based on given transport service costs) but also environmental costs (CO_2 emissions). Carbon emissions are being calculated within the CO_2 module of the intermodal routing service based on given vehicle profiles and transport chain attributes (distance, mode). The emission calculation can be applied, using agreed default values per mode, or, by applying (real measured) historic averages – to reflect EN16258:2012 standard on emission calculation.

The module IM Planner performs an allocation of given transport orders towards given transport service capacities based on provided transport chain alternatives. The IM planner

module incorporates a solver engine (in Clusters 2.0 GUROBI). The result of the optimization is an allocation of transport orders towards specific transport services.

4.1.2   Use cases of the intermodal routing service

Use case requirements for all Use Cases

- Valid IM Data (terminals, operators, regular services incl. costs, terminal transfer modalities) must be in place

- Digital Road Map must be in place

- Digital networks per mode of transport (optional)

Use Case I: Simple routing request

The functionality of the simple routing request is to search for intermodal transport chains between locations for a certain start or end time, respecting given chain composition restrictions (e.g. mode, operator). Results are based on Intermodal data.

The simple routing request returns a set of composed transport chains between these two locations (addresses or geo-locations), which match the applied routing restrictions for a certain starting time.

A transport chain can consist of a single or multiple transport leg elements. The transport chain can include only a single or multiple transport modes.

Transport modes supported are:

- Road
- Rail
- Inland water ways (Barge)
- Air
- Deep sea
- Short sea

Routing restrictions supported are:

- Excluded transport modes
- Excluded transport service operators
- Excluded terminals
- Accompanied transport
- Unaccompanied transport
- Maximum costs allowed
- Maximum distance for alternative terminals

A simple routing result can either be based on a road routing or a timetable-based transport service or a combination of both. Depending on the transport service availability announced in the IM data, the intermodal routing result set consists of a single or multiple transport chain results.

Transport chain results of a simple routing request consider the given start time of the request and deliver different chain alternatives accordingly. Each alternative presented in the results consists of a unique service composition (with respect to chain composition and operator).

Each transport chain proposal results in itinerary and Key Performance Indicator (KPI) (km, travel-time and costs - € and CO_2; both based on given data sets or data models.

Input

- Origin address (with coordinates)
- Destination address (with coordinates)
- Starting time
- Restrictions (optional)

Output

- List of routes (= transport alternative), each of them consisting of a sequence of leg descriptions containing
  - Station (Origin address, Terminal or destination address)
  - Results concerning the inbound leg to the actual station such as
    - Mode
    - Regular service
    - Times (Arrival time, handling time, departure time, …)
    - costs
    - KPIs (distance, duration, emission, …)

Use case II: Request for transport alternatives

The request for transport alternatives provides optimised intermodal transport chain alternatives per specific order respecting given restrictions, especially time window constraints.

The request for transport alternatives uses functionality and restrictions as described in use case I "simple routing request" and enriches it with additional order specific restrictions (time windows).

Input data consist of a specific transport order including the set of restrictions. The transport order consists at minimum of:

- Minimum two locations (origin and destination),
- Time window describing earliest pick-up time at the origin and the latest delivery time at the destination.

Optionally, the restrictions introduced in Use Case I can be applied:

- Transport mode
- Transport Service Operator
- Accompanied Transport
- Unaccompanied Transport
- Maximum Costs allowed

The request results in a server response, describing a set of different valid transport chains. Valid means: The returned set of transport chain alternatives respects given restrictions and meets the order time window of earliest pick-up and latest delivery as well as the restrictions given. Duplications of transport services proposed within the alternatives are possible in case time constraints are fulfilled.

The number of loading units e.g. container handed over with an order does not affect the resulting transport alternatives.

Input

- General restrictions
- List of transport orders, each consisting of
    - Pickup-Location with coordinate
    - Delivery Location with coordinate
    - Earliest and latest pickup date and time
    - Earliest and latest delivery date and time
    - No of transport units (used for emission calculation)
    - Order specific restrictions (optional)

Output

For each transport order, the intermodal routing service returns a

- List of routes (=transport alternative), each of them consisting of a sequence of leg descriptions containing
    - Station (Origin address, Terminal or destination address)
    - Results concerning the inbound leg to the actual station such as
        - Mode
        - Regular service
        - Times (Arrival time, handling time, departure time, …)
        - costs

KPIs (distance, duration, emission, …).

Use case III: Planning request with given alternatives

The planning request allocates given transport orders to transport services in an optimized way respecting given capacity limitations.

Required input are transport orders including calculated transport chain alternatives. Transport chain alternatives can originate from Use Case II or some other source of the same content format. For the proposed transport services within the calculated transport chains alternatives, costs and maximum available capacity per voyage have to be given.

The server request triggers a solver process consisting of model creation and model solving. The model creation step spans a network of transport services and costs described by the transport chain alternatives and the given available capacities. In the second process step, the model is being solved.

The solver solution provides an optimized allocation of orders to transport services by minimizing costs under the constraints of not exceeding the given capacity limitations of the transport services.

Input

- List of transport orders, each consisting of
    - Order ID
    - No of transport units (to be checked against capacity of voyage)
    - Pickup-Location with coordinate
    - Delivery Location with coordinate
    - Earliest and latest pickup date and time
    - Earliest and latest delivery date and time
    - Order specific restrictions (optional)

Output

For each transport order, a

- List of valid transport alternatives, each of them consisting of a sequence of leg descriptions containing
  - ID of regular transport service (empty, if mode of transport = road leg)
  - Terminal from
  - Terminal to
  - Mode of transport
  - Departure date and time at Terminal from
  - Road leg costs (if mode of transport = "road leg", not used if timetable-based road transports are modelled)

list of voyages, used in transport alternatives above, each of them containing

- ID of regular transport service (empty, if mode of transport = road leg)
- Terminal from
- Terminal to
- Mode of transport
- Departure date and time at Terminal from
- Available capacity
- Costs

4.1.3 Algorithm basis of the Intermodal Routing Service for transport logistics

This sub-chapter describes the main components of the algorithm used by the Intermodal Routing Service

Overview and logistic assumptions

Before the algorithm is presented in more detailed, this chapter gives an overview over the main components of the intermodal routing algorithm. Each component of the algorithm is responsible for optimizing one part of the routing problem. This chapter also comprises the heuristics applied to each optimizing component of the algorithm used to simplify the complex problem.

The first assumption from a logistic point of view is the observation that usually mainland transports have higher costs than intercontinental deep-sea ones. The algorithm tries to find economical mainland transport services first – due to the potential savings are higher in the hinterland. Thus, the first step of the algorithm is to find service point locations nearby for the transhipment from truck to barge or rail. In practice, the typical drayage distance is about 150 km. To reduce the complexity, only those service point locations being max. 150 km away from the transport location are regarded.

After valid service point locations are found, a new transport service is calculated to each terminal of the corridor. Service point locations with multiple transports are preferred. The schedule for this transport service is calculated based on transport distances, durations and time windows.

![Clusters 2.0 logo]

The costs for each calculated schedule are compared to the typical transport by truck. This way only these scheduled ones will be used that are cheaper than a truck drayage to the terminal. This way, the terminals with the lowest drayage costs are selected.

Now, the main haulage transport service will be calculated between all terminals selected. In general, this is known as a pickup and delivery problem with time windows (PDPTW).

Consolidation

The advantage of barges and trains compared to trucks are their mass capacity. To achieve the amounts needed for a profitable operation of these means of transport, it is usual to consolidate transports of several companies. Usually a freight forwarder organizes the consolidation of these transports.

The consolidation of these transports is carried out at service point locations. Trucks transport containers to a service point location where they are transshipped for the haul. The typical drayage distance is about 150 km.

For this reason, the algorithm first determines the coordinates of a transport origin, respectively its destination, and searches for service point locations within a distance of 150 km. Figure 4 shows this step by an exemplary transport starting at Regensburg and the service point locations Bamberg, Nuremberg, Augsburg and Munich.
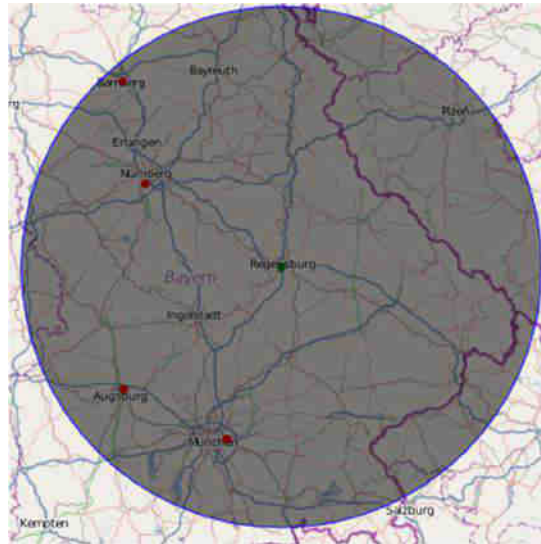
Figure 4: Exemplary area of a 150km radius around Regensburg

This step is repeated for every transport origin and destination.

Costs for the truck drayage are calculated by searching for the shortest path from the origin to the destination. The search for the shortest path is realized with Dijkstra's algorithm. This algorithm determines the shortest path on the road network. Alternatively, the distance can also be calculated as air-line distance between both points.

The shortest path is then used to calculate the costs for the transport:

$$c_d = \frac{2d}{v} c_t$$

With

c_d: costs for the drayage [€]
d: calculated distance: [km]
v: average velocity per hour: [km/h]
c_t: costs per driving hour [€/h]

The factor two in the above formula results from calculating a round trip (direct to and from). For calculating the complete drayage costs, the algorithm also considers that two TEU loading units can be transported with a single truck.

Experience data for the average velocity is 50 km/h and 60 €/h for the costs per driving hour. Thus, a distance of 300 km would result into costs of 360 € for two TEU.

The costs of the drayage could be reduced if a vehicle routing was used to consolidate two TEU or LTL.

Calculation of main haul schedule

All service point locations selected in the previous step are now processed according to the amount of TEU that could be consolidated at that location. A high amount of TEU is preferred to early achieve low costs in this step. This results from a fixed degressive cost function.

As various real schedules show, transport services are mostly operated on a weekly interval. This heuristic is also used in the calculation of intermodal transports by this algorithm. However, this does not impede that multiple transport services are operated within the week.

For each pair of service point location and port an initial schedule is calculated, as shown in Figure 5.
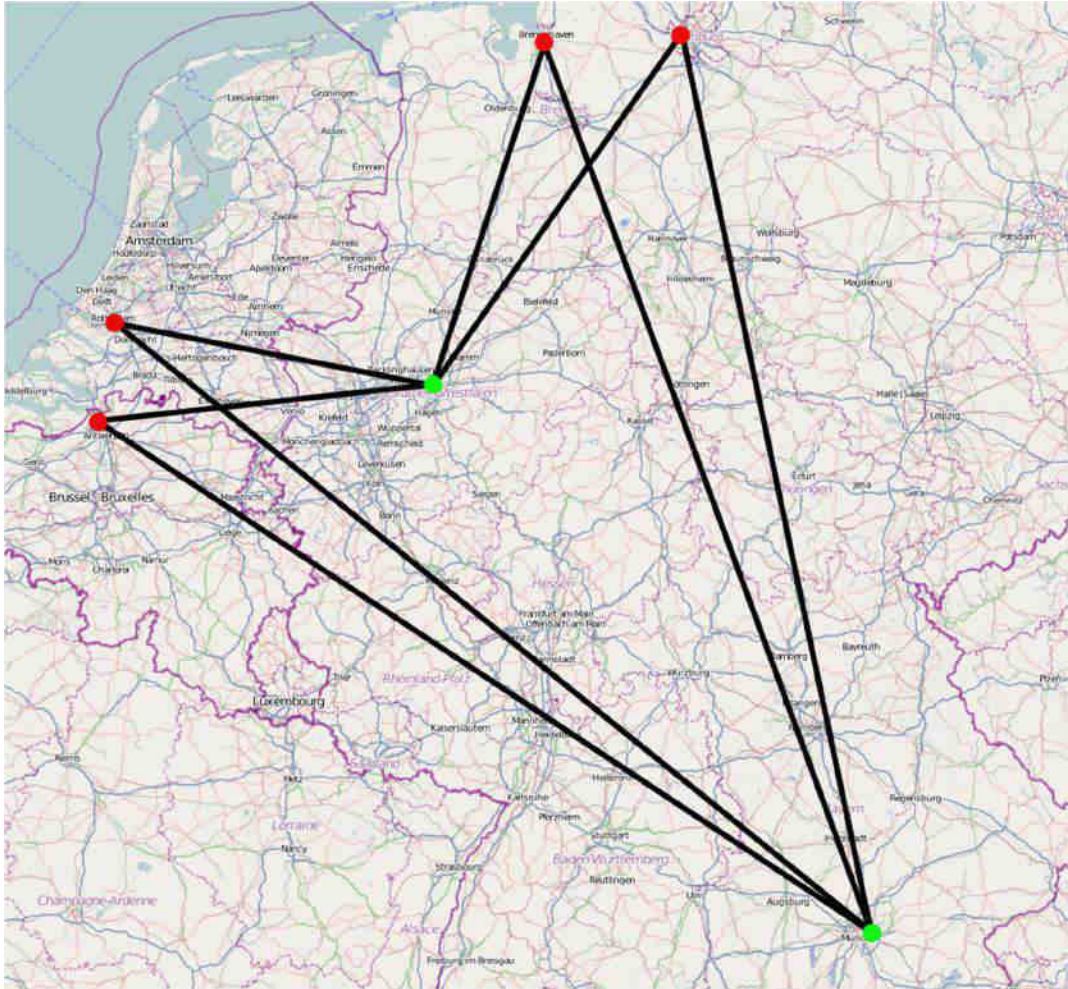
Figure 5: Example of calculating intermodal schedules

Due to the fact that shipments should be preferably delivered earlier than too late, the algorithm tries to find a cheap matching arrival day for the schedule within a week going backwards. The concrete approach is demonstrated with the following example.

Example

Figure 6 describes the initial situation for one week. The delivered TEU are listed for each day.

Figure 6: Initial situation

Now, the algorithm searches for the cheapest day of transport within this week by testing the benefits of transporting the shipment one day earlier. This can be seen in Figure 7.

Figure 7: First step

In this case, transporting the shipment at Friday does not result in a higher transport amount and is therefore not cheaper. Again, the algorithm is trying to transport the shipment one day earlier, as can be seen in Figure 8.

Figure 8: Second step

This also results in no improvement. However, as Figure 9 shows, indeed, the next step does result in an increase of amounts and – due to the fixed cost degression – a potential cost reduction.

Figure 9: Third Step increases transport quantities

This step is repeated up to the beginning of the week, as shown in Figure 10.

Figure 10: Final steps

In this process, two exceptions have to be respected. The first is related to time windows. Typically, time windows are open only for a limited time in which the shipment has to be picked up or is delivered. In case of a pickup or delivery occurring outside a time window, costs for storing the shipment or penalty costs have to be included in the cost calculation. To simplify the process of calculation, time windows are assumed to be open for the entire week.
The second exception results from the dimension of the means of transport. In case of higher amounts resulting in the above aggregation than the means of transport can transport a new (second) schedule has to be regarded in the further process.

After the transportation costs for each day found for every week, the total costs are aggregated over all relevant weeks. The day with the lowest costs is selected for the arrival of the transport service.

Now, the starting day and time of the departure is calculated from the distance and the average speed of the means of transport. Again, the distance can be either calculated with help of Dijkstra's algorithm or via airline.

Despite the costs for transshipment, cost calculations may allow trimodal transport chains. In practice, however, the effort for organizing such transport chains is too high, this making trimodal transport chains rare. Due to this reason, the algorithm does not try to combine multiple modes of transport for the haul.

After the schedule is calculated, the costs for the transport service including the drayage will be calculated for the amount of TEU transported on the service. These costs are then compared to the costs of each direct transport from the transport location to the port by truck.

To calculate the costs for a transport service, the following cost function is used.

Rail

$$c_h = c_l d + c_w n_w + 2 c_t n_b$$

With
c_h: costs for the haulage [€]
c_l: costs per locomotive [€/km]
d: calculated distance [km]
c_w: costs per wagon [€/(day * wagon)]
n_w: number of wagons [wagon]
c_t: costs per transshipment per box [€/box]
n_b: number of transshipments [box]

The number of wagons required depends on the loading scheme of the wagon. Transshipment costs are usually calculated by box and not per TEU.
It is assumed that costs per locomotive is around 12.50 € per km, the costs of a wagon is about 22 € per day and the transshipment costs around 20 €.

Barge

$$c_h = c_f + \frac{d}{v} c_v + 2 c_t n_b$$

With
c_h: costs for the haulage [€]
c_f: fixed costs of the barge for the period [€]
d: calculated distance [km]
v: average speed [km/h]
c_v: costs per hour [€/hour]
c_t: costs per transshipment [€/box]
n_b: number of transshipments [box]

The number of wagons required depends on the loading scheme of the wagon. Transshipment costs are usually calculated by box and not per TEU.

Truck

$$c_d = \frac{d}{v} c_t$$

With
c_h: costs for the haul [€]

d: calculated distance: [km]
v: average velocity per hour: [km/h]
c_t: costs per driving hour [€/h]

Figure 11 shows the break-even point for rail, barge and truck haulages according to the cost functions explained above.
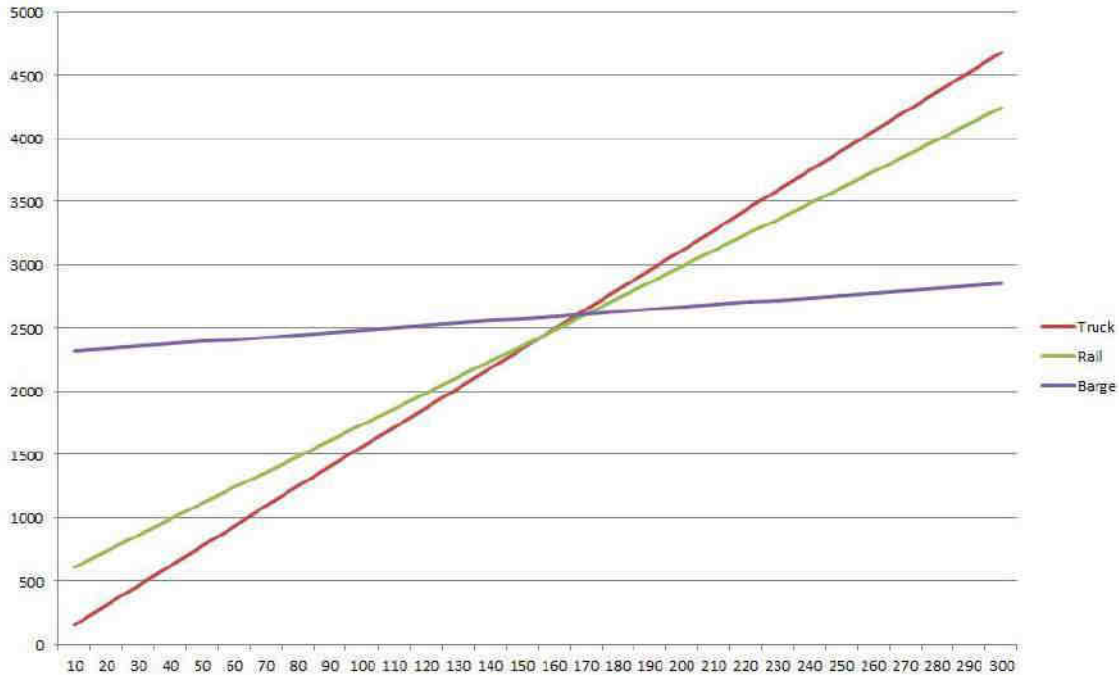

Figure 11: Break-even point of different means of transport

This corresponds to literature where the break-even point of alternative modes for transport is beyond distances of about 150km.

4.2   Data management with the "Intermodal data manager"

The intermodal routing service requires digitalized intermodal data on networks, terminals and timetables. For the Clusters 2.0 project we use the web-based application "Data Manager" by PTV to create, manage and expose the data to the intermodal routing service. The web-based application provides a graphical user interface that allows the user of the application to manage the data sets in a comfortable way.

This chapter introduces the main data content blocks: network, terminals and timetables. Finally, this deliverable reports about the data collection in Clusters 2.0.

4.2.1   Data Management - Networks

For the Clusters 2.0 project we use a web-based application to manage the different intermodal networks. The main idea is, to create a mode specific network, which is designed

by a set of nodes and edges. Each node has a certain geographical location. The connecting edge between two nodes has a certain distance (direct air-distance).

EXTID	NAME	COUNTRY	POSTCODE	CITY	STREET	HOUSENR	LATITUDE	LONGITUDE
20990581	GEMBLOUX	BE		GEMBLOUX			50,57159	4,69054
20990582	OTTIGNIES	BE		OTTIGNIES			50,67398	4,56919
20990584	MACHELEN JCT	BE		MACHELEN JCT			50,91359	4,42269
20990585	ANTWERPEN CENTRAAL	BE		ANTWERPEN CENTRAAL			51,22791	4,43513
20990586	BERCHEM JCT	BE		BERCHEM JCT			51,20012	4,43196
20990587	ANTWERPEN OOST	BE		ANTWERPEN OOST			51,28113	4,44191
20990588	MECHELEN	BE		MECHELEN			51,03037	4,48992
20990591	NAZARETH JCT	BE		NAZARETH JCT			51,14367	4,59805
20990593	LANDEN	BE		LANDEN			50,74848	5,07885
20990594	AARSCHOT	BE		AARSCHOT			50,98475	4,82416

Figure 12: Network nodes and locations – Example

FROM EXTID	FROM NAME	FROM COUNTRY	FROM CITY	TO EXTID	TO NAME	TO COUNTRY	TO CITY	DISTANCE
GVSE_2_9233	Alhama de Aragón	ES	Alhama de Aragón	GVSE_2_9232	Ariza	ES	Ariza	11
GVSE_2_9233	Alhama de Aragón	ES	Alhama de Aragón	GVSE_2_9234	Ateca	ES	Ateca	8
GVSE_2_9234	Ateca	ES	Ateca	GVSE_2_9233	Alhama de Aragón	ES	Alhama de Aragón	8

Figure 13: Network nodes and connecting edges – Example

To create an edge between two nodes, the datamanager offers a set of graphical map interaction features, such as create connection or delete connection.
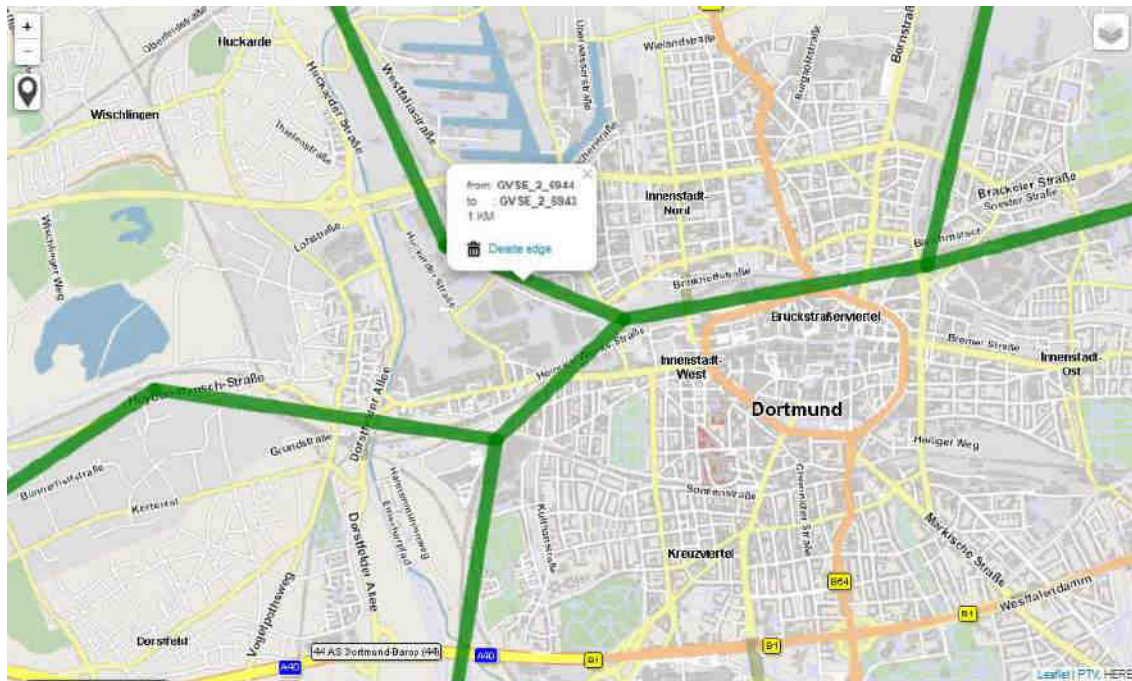

Figure 14: Network nodes and connecting edges

In Clusters 2.0 we use existing network data collected in previous projects for rail- and sea networks, which is enriched by Cluster 2.0 specific extensions.

The following two figures present the underlying network data sets for the rail and sea networks which are used for Clusters 2.0.

Figure 15: Digital railway network

Figure 16: Digital sea network

4.2.2 Data Management - Terminals

Terminals are an essential element in intermodal transport. They determine a physical location, where loading units can be moved between vehicles and modal networks, e.g. from truck to train.

The Data Manager provides different data fields to describe a terminal, e.g. unique identifier, terminal name, connected networks, opening hours. Further to that it links each terminal location to digital map coordinates (Latitude, Longitude).

Figure 17: Data management Terminal example

4.2.3   Data Management - Schedules

Schedules build the basis for the intermodal routing service. A schedule regarding the intermodal routing service in Clusters 2.0 describes a recurring transport service with a specific description of the line and stop sequence.

Each line contains:

- Unique identifier
- Description of the line route, consisting of at least two stops (start and stop) including a link to the modal network used:
- One or multiple service days
- Closing time & departure time
- Arrival day and time, earliest pick-up time
- Calculated distance

- Transport cost indication

To add schedules to the Data Manager three options exist:

- Use the web-application graphical user interface
- Use the digital import option CSV of the Data Manager
- Use the Data Manager web API to expose intermodal data, including schedule data

In Clusters 2.0 we use the GUI and the CSV option of the Data Manager to import data.

The figure below presents a screenshot of the visualization of the graphical user interface.

Figure 18: Data Management - schedule example

The digital import option via a CSV import sheet requires intermodal data to be prepared in the following structure:
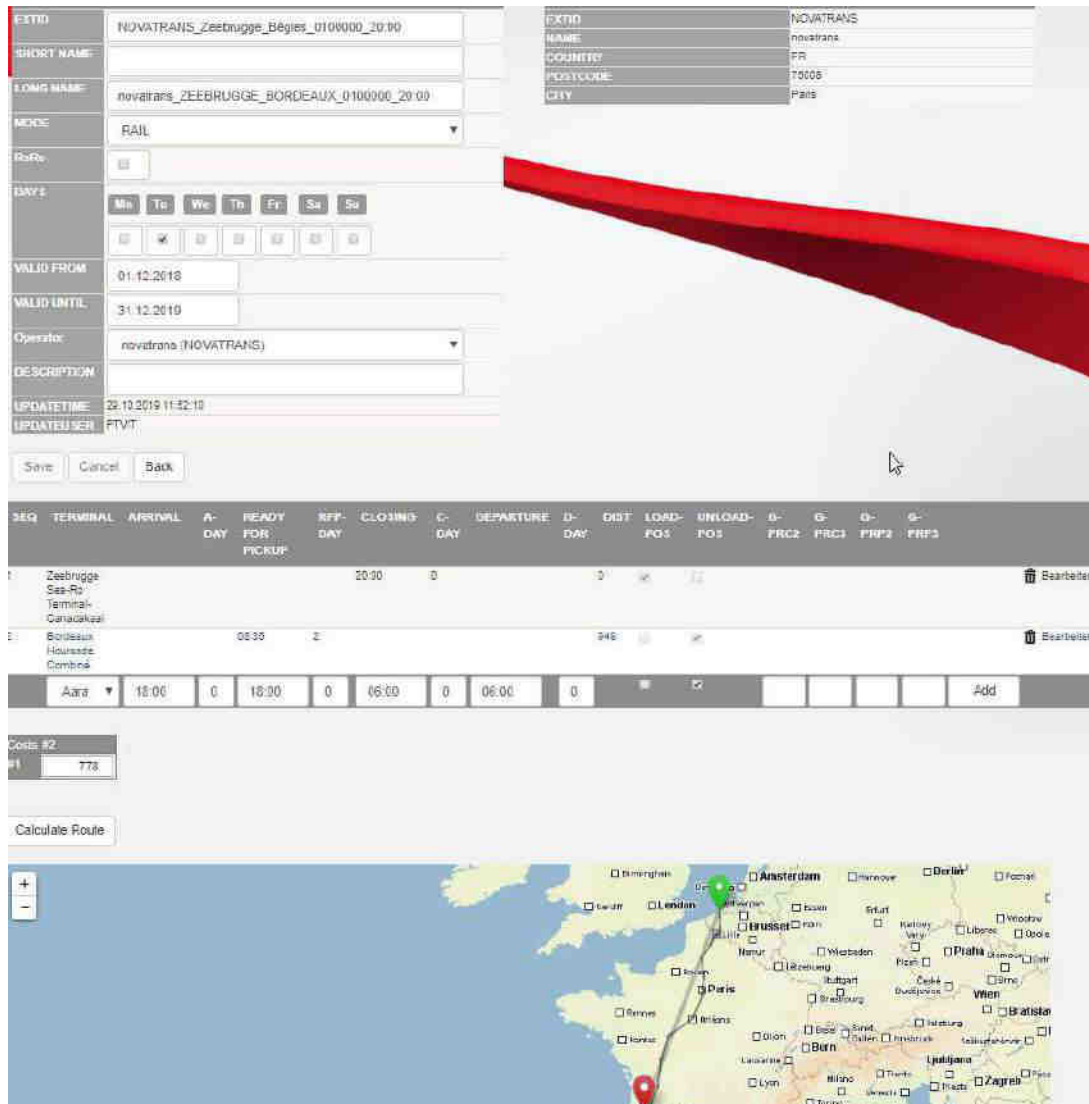
Operator; Mode; Valid from; Valid to; Departure terminal; Arrival terminal; Train nr.; Mo; Tu; We; Th; Fr; Sa; Su; Code Closing; Closing time; Departure time; Arrival day; Arrival time; Ready for pick time; Code Pickup

The figure below presents an example of the CSV structure being used within GUI of a Table Calculation tool.

Figure 19: Data Management – Spreadsheet

After data preparation in the specified format, the CSV file can be imported at once.

4.3 Simulation Platform

4.3.1 Planning system framework as Simulation Platform for Clusters

General overview

A trip planning system in transport logistics in general is a software solution, which automatically plans orders to trips. It aims to optimize trips and includes all restrictions which are relevant for the planner and the customers. Main purpose of the planning application is to support business processes related to a wide range of logistic tasks.

The planning system framework in Clusters 2.0 is a state-of-the-art trip planning software solution by PTV. The application framework is used for various transport and logistic use cases. It has a large number of functionalities and features, uses high performance planning methods and algorithms to provide valid planning solutions with the possibility to enhance the results step by step considering all kinds of parameters and additional information which arise during planning and execution.

Selected functions of relevance for the Simulation Platform

In order to give an overview regarding complexity and maturity of the trip planning solution, the following list presents selected functions of the system:

- Planning combined multi-drop transports
- Daily trip planning for varying quantities and delivery points
- Multi-day trip planning
- Pre-combined trip planning and multi-depot planning
- Planning with sub depot trips
- Calculation of transport costs, toll charges and CO_2 emissions based on emission calculation standards (HBEFA, EN16258:2012)
- Integrated data supply
- Different vehicle profiles
- Assignment of orders to one or more task fields
- Order grouping
- Single user solution or multi-user system
- Suggestion functions
- One database.

Insight into application GUI of the host application framework

The generic structure of the application's graphical user interface is presented in the following pictures. The graphical user interface (GUI) - layout can be individually modified in order to fit user preferences; though it can only consist of 4 elements (figure 10):
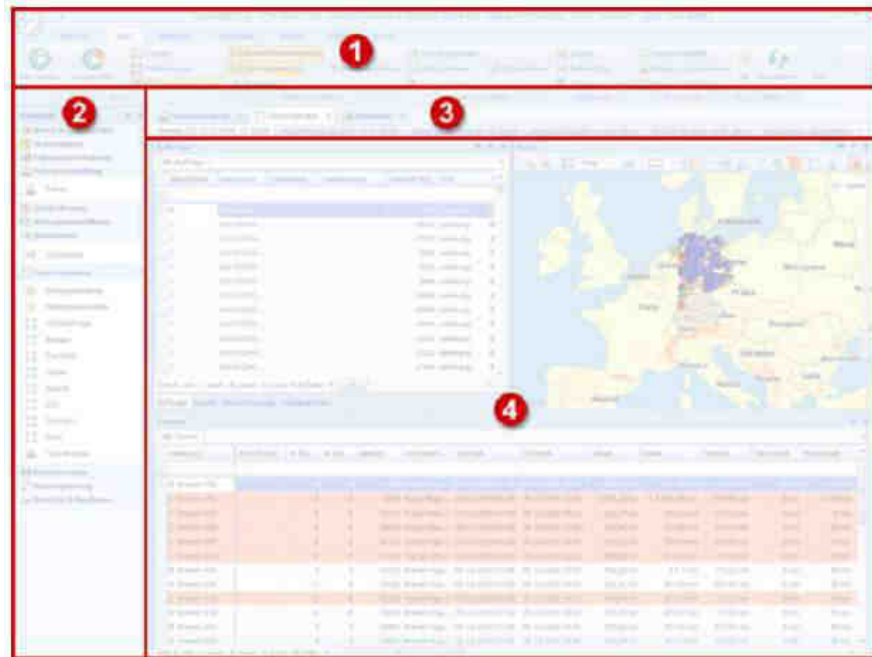
Figure 20: General GUI structure

(1) Ribbon: Each program item has a ribbon in which the functions are listed by topic. In regard to the planning, use case functions are for example "performing automatic planning" and "planning function selection".

(2) Navigation tree: Different application use cases can be selected in the navigation, e.g. users and rights, master data, routing, trip planning. The user can use the navigation tree to navigate between different program areas.
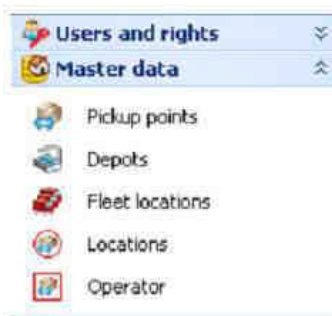
Figure 21: Planning system GUI - Navigation tree

(3) Tab: presents the active program areas.

Figure 22: Planning system GUI – Tab

(4) Content area: the content area shows the data the user is currently using. Data to be displayed depends on the program item selected.

4.3.2 Planning and optimization application – Transport order management

In Clusters 2.0 we use the Planning and optimization application mainly to have a professional visualization of the different function and results. In regard to data management, the application provides a comprehensive transport order data management functionality.
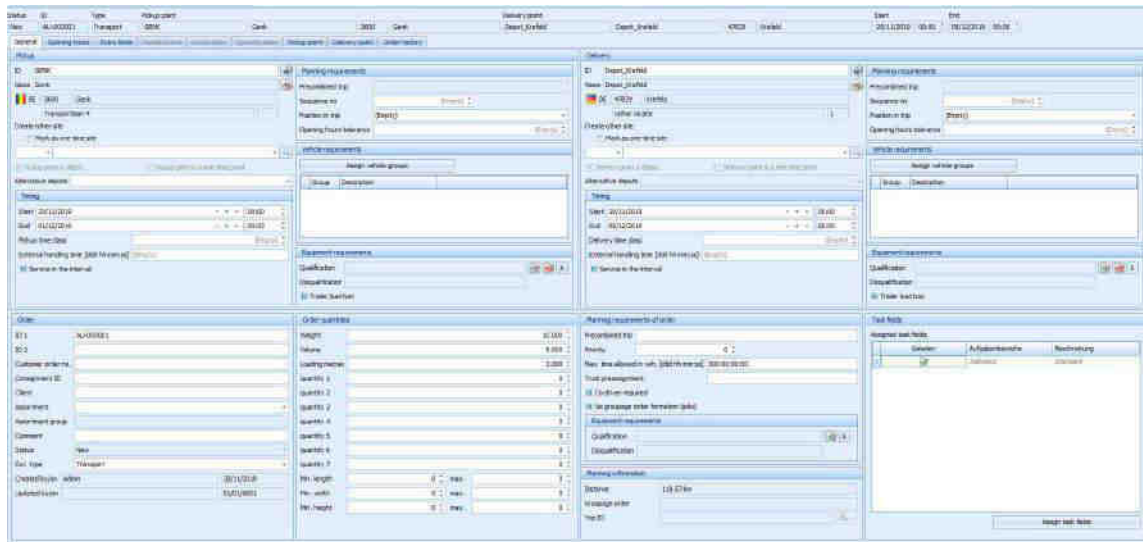
Figure 23: General GUI – Transport order management

5 Preparation of Clusters tests

For the Intermodal Routing Service intermodal schedule data is required. Unfortunately, there is no harmonized or comprehensive set of intermodal schedule data available for Europe. We therefore need to collect and to model the data accordingly to be used for the Routing Service. Within Clusters 2.0 we identified several logistic clusters that participate in the project. From each of these clusters we collected intermodal schedule data.

5.1 Data collection in Clusters

In order to collect schedule data each cluster, several online – meetings have been performed with the clusters. In the meetings, the process-flow of preparing and using the Intermodal Routing Service has been explained in detail.

After a detailed introduction to the process flow, the used tools and the potential use cases of the Intermodal Routing Service, the data collection was kicked off with a set of questions:

- *To which modal networks exist links?*
- *Which connections to other terminals/clusters exist (from and to the cluster)*

- *What are the linked terminal names and locations?*
- *Which schedule based services exist (from and to the cluster)?*

The following Clusters participated and contributed to that collection:

- Bologna, IT
- Dourges, FR
- Duisburg, DE
- Piraeus, GR
- Trelleborg, SE
- Trieste, IT
- Zaragoza, ES

Besides large intermodal operators that expose their intermodal service offering at large on the internet, several other intermodal operators expose their offering only to a limited audience, e.g. only to a specific cluster or to just one county. To reach a comprehensive and meaningful schedule catalogue to integrate into the Intermodal Routing Service, we aim at collecting that data at local cluster level.

Main target of the collection activity is to achieve:

- comprehensive understanding which connection to other clusters exist
- fill template on intermodal data per cluster
    - which terminals (including locations) are connected, and
    - receive schedule descriptions of intermodal services between clusters.

The Figure 24 below visualizes the for two examples of the different intermodal network of of different operators for the same area:
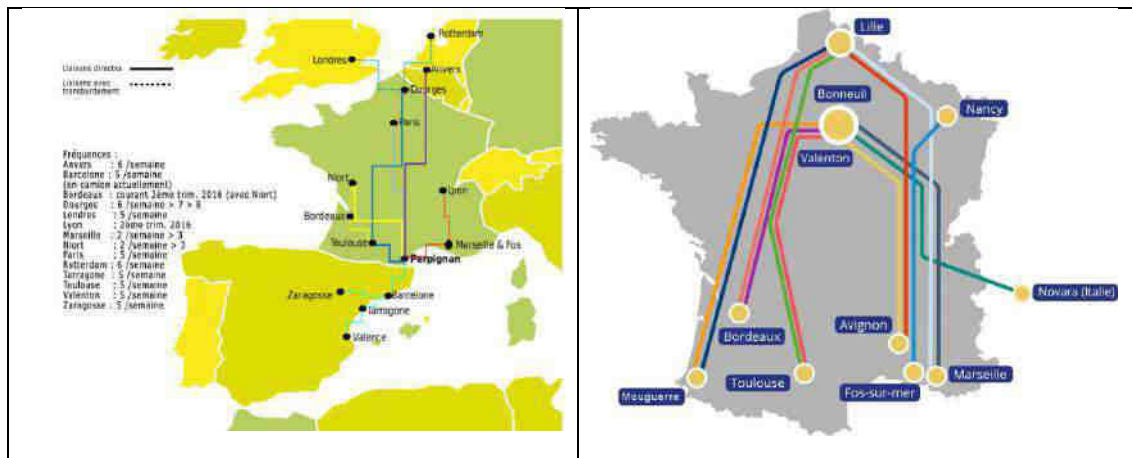
Figure 24: Network extract examples of an intermodal operators

Figure 25 presents for the example of France different national clusters and their outreach. For each identified cluster, network connections and terminals locations were collected and modelled using the Data Manager tool introduced in Chapter 4.

Figure 25: National Clusters example

Further to the network and terminal aspect, the collection of intermodal schedule data is of vital importance. The figure below presents an example extract of a filled schedule collection template from a Cluster:

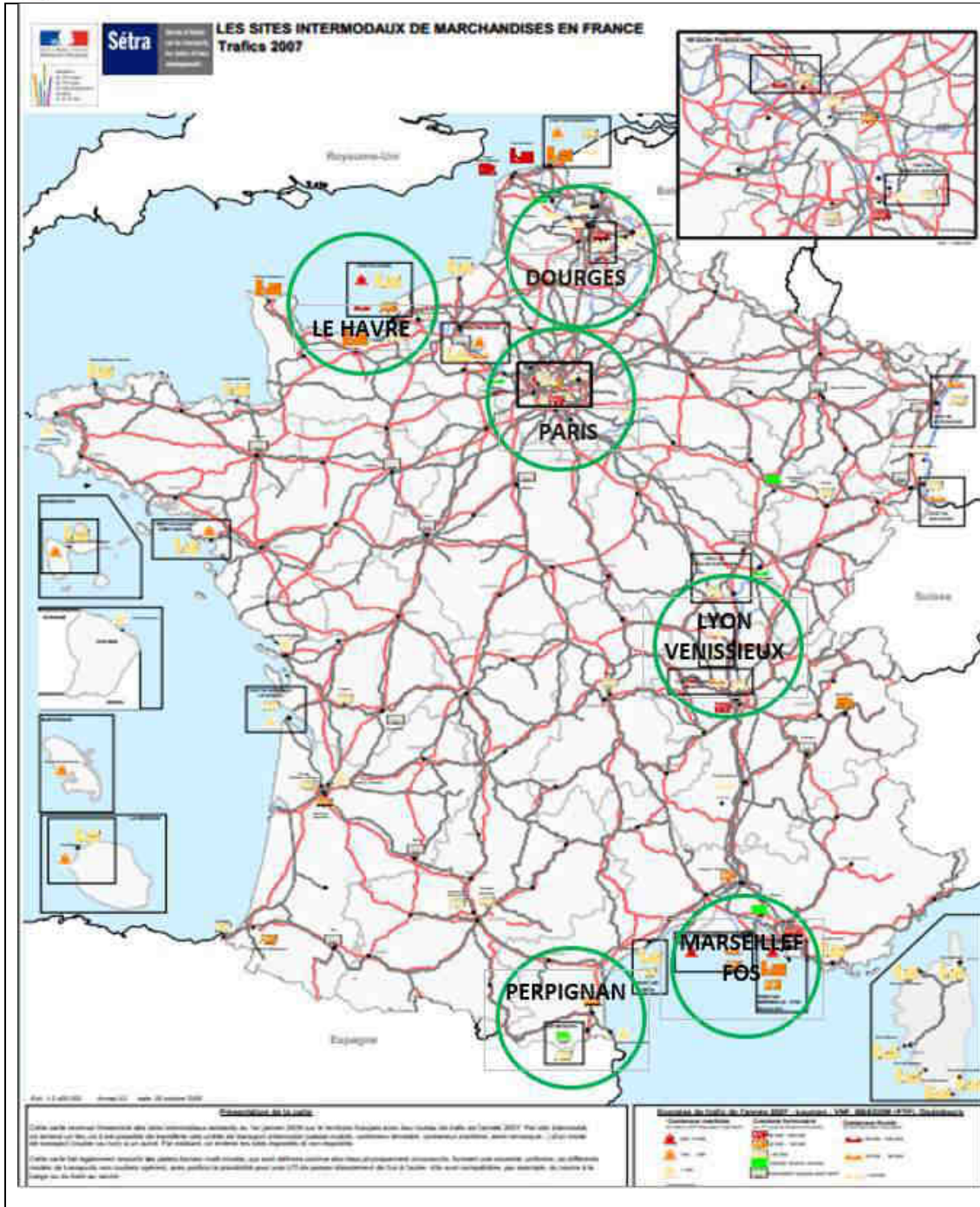| Operator	Mode	Valid fro	Valid t	Departure termina	Arrival terminal	Train nr.	Mo	Tu	We	Th	Fr	Sa	Su	Code Closing	Closing time	Ready for pi	Code Pickup
MERCITALIA	RAIL			BOLOGNA	LIVORNO TDT	75677	X							A	10:00	18:00	A
MERCITALIA	RAIL			BOLOGNA	PADOVA	54237	X		X		X			A	18:30	12:30	B
MERCITALIA	RAIL			LA SPEZIA	MILANO SMIST.MIST	54198	X	X	X	X	X	X		A	09:30	22:00	B
MERCITALIA	RAIL			LA SPEZIA	MILANO SMIST.MIST	54198	X	X	X	X	X	X		A	18:05	06:00	B
MERCITALIA	RAIL			LA SPEZIA	MILANO SMIST.MIST	54198					X			A	19:00	09:00	B
MERCITALIA	RAIL			MILANO SMIST.MIS	LA SPEZIA	51131						X		A	18:00	05:30	B
MERCITALIA	RAIL			MILANO SMIST.MIS	LA SPEZIA	51131	X	X	X	X	X	X		A	18:20	03:50	B
MERCITALIA	RAIL			TRIESTE SAMER	LUDWIGSHAFEN KTL-I	41852	X			X				A	07:00	06:30	B
MERCITALIA	RAIL			LUDWIGSHAFEN KT	TRIESTE SAMER	41853		X			X			A	22:45	23:00	B
MERCITALIA	RAIL			TRIESTE SAMER	MUENCHEN RIEM UBF	41854	X	X	X	X	X			A	05:00	21:10	A
MERCITALIA	RAIL			MUENCHEN RIEM U	TRIESTE SAMER	41855	X	X	X					A	08:20	01:00	B
MERCITALIA	RAIL			MUENCHEN RIEM U	TRIESTE SAMER	41855						X		A	08:20	01:00	C
MERCITALIA	RAIL			BARI SCALO FERRU	BUSTO ARSIZIO 2	58000	X	X	X	X	X			A	16:30	10:00	B
MERCITALIA	RAIL			BARI SCALO FERRU	BUSTO ARSIZIO 2	58014						X		A	11:30	06:00	C
MERCITALIA	RAIL			BUSTO ARSIZIO 2	BARI SCALO FERRUCC	51065		X		X	X			A	12:30	07:40	B
MERCITALIA	RAIL			BUSTO ARSIZIO 2	BARI SCALO FERRUCC	51067	X		X					A	12:30	07:50	B
MERCITALIA	RAIL			BUSTO ARSIZIO 2	BARI SCALO FERRUCC	51069							X	A	06:00	09:00	B
MERCITALIA	RAIL			BICOCCA	MILANO SMIST.MIST	5900A		X	X	X	X			A	13:30	06:00	C
MERCITALIA	RAIL			BICOCCA	MILANO SMIST.MIST	59002	X	X		X				A	18:00	06:00	C

Table 9: Example of a filled schedule collection template

The collected intermodal schedule data has been imported using the Intermodal Data Manger tool. Examples from the data included for the French Cluster are presented in the Table 10: Intermodal Data collection example - Dourges Cluster.

ID	Cluster	Operator	No. timetable services	Service map
FR-01	Dourges	Novatrans	172	

FR-02	Dourges	Naviland Cargo	198	
FR-03	Dourges	VIIA	9	

FR-04	Dourges	Froidcombi	4	

Table 10: Intermodal Data collection example - Dourges Cluster

Other Clusters 2.0 schedule data overview:

ID	Cluster	Operator	No. timetable services
FR-01	Dourges	Novatrans	172
FR-02	Dourges	Naviland Cargo	198
FR-03	Dourges	VIIA	9
FR-04	Dourges	Froidcombi	4
SE-01	Trelleborg	TX Logistik	24
ES-01	Zaragoza	Renfe	22
ES-02	Zaragoza	Continental	4
ES-03	Zaragoza	Medway	4
ES-04	Zaragoza	Acciona	2
IT-01	Bologna	MERCITALIA	111
IT-02	Bologna	GTS	94
DE-01	Duisburg	Duisburg	4
GR-01	Piraeus	Piraeus	4
AC-01	All Clusters	Hupac	483
AC-02	All Clusters	TX Logistik	96

Table 11: Intermodal data - other Clusters

![Clusters 2.0]

5.2 Cost calculation model for Clusters intermodal schedules

For the calculation of costs as part of the intermodal routing we utilize as default the following two cost schemes prepared by European Intermodal Association (table 12 and table 13).

Based on this data average kilometric price per mode and for terminal activities can be derived.

Road vs Rail Transportation Costs

DIST	ROAD VAR Euro/Km	ROAD TOT Euro	RAIL FIX Euro	RAIL VAR Euro/Km	RAIL TOT Euro	RAIL TOT Euro/Km	Δ TOT Euro	Δ TOT %
100	1.57	157	498	0.23	521	5.21	3.64	232%
200	1.57	314	498	0.23	544	2.72	1.15	73%
300	1.57	471	498	0.23	567	1.89	0.32	20%
400	1.57	628	498	0.23	590	1.47	-0.10	-6%
500	1.52	760	498	0.23	613	1.23	-0.29	-19%
600	1.52	912	498	0.23	636	1.06	-0.46	-30%
700	1.52	1064	498	0.23	659	0.94	-0.58	-38%
800	1.52	1216	498	0.23	682	0.85	-0.67	-44%
900	1.52	1368	498	0.23	705	0.78	-0.74	-48%
1000	1.52	1520	498	0.23	728	0.73	-0.79	-52%
1100	1.52	1672	498	0.23	751	0.68	-0.84	-55%
1200	1.52	1824	498	0.23	774	0.64	-0.88	-58%
1300	1.52	1976	498	0.23	797	0.61	-0.91	-60%
1400	1.52	2128	498	0.23	820	0.59	-0.93	-61%
1500	1.52	2280	498	0.23	843	0.56	-0.96	-63%
1600	1.52	2432	498	0.23	866	0.54	-0.98	-64%
1700	1.52	2584	498	0.23	889	0.52	-1.00	-66%
1800	1.52	2736	498	0.23	912	0.51	-1.01	-67%
1900	1.52	2888	498	0.23	935	0.49	-1.03	-68%
2000	1.52	3040	498	0.23	958	0.48	-1.04	-68%

Source : European Intermodal Association, 2012, Page 84.

Source : AECOM, 2014, Page 79.

Table 12: Road versus rail transportation cost comparison

Road vs Intermodal Transportation Costs

Distance	Road	Intermodal						Difference	
	Total Euro	Short Haul Euro	Terminal Euro	Rail Euro	Terminal Euro	Short Haul Euro	Total Euro	Total Euro	Total (%)
100	157	-	-	-	-	-	-	-	-
200	314	-	-	-	-	-	-	-	-
300	471	157	40	521	40	157	915	444	94%
400	608	157	40	544	40	157	938	330	54%
500	760	157	40	567	40	157	961	201	26%
600	912	157	40	590	40	157	984	72	8%
700	1064	157	40	613	40	157	1007	-57	-5%
800	1216	157	40	636	40	157	1030	-186	-15%
900	1368	157	40	659	40	157	1053	-315	-23%
1000	1520	157	40	682	40	157	1076	-444	-29%
1100	1672	157	40	705	40	157	1099	-573	-34%
1200	1824	157	40	728	40	157	1122	-702	-38%
1300	1976	157	40	751	40	157	1145	-831	-42%
1400	2128	157	40	774	40	157	1168	-960	-45%
1500	2280	157	40	797	40	157	1191	-1089	-48%
1600	2432	157	40	820	40	157	1214	-1218	-50%
1700	2584	157	40	843	40	157	1237	-1347	-52%
1800	2736	157	40	866	40	157	1260	-1476	-54%
1900	2888	157	40	889	40	157	1283	-1605	-56%
2000	3040	157	40	912	40	157	1306	-1734	-57%

* The assumption is that intermodal has 100 km pre- and post-carriage.

* The assumption is made that the terminal is 40 Euro per container move based on input of Steve Declercq (Duisport Business Development Director).

Source : European Intermodal Association, 2012, Page 84.

Source : AECOM, 2014, Page 79.

Table 13: Road versus intermodal transportation cost comparison

6 Use Case Testing

6.1 Testing Use Case P&E 1 - Intermodal Chain Composition

Within this use case, we calculate an intermodal door-to-door transport chain. The result provides a set of transport chain alternatives which match the given restrictions. Restrictions can be e.g.: Avoid Transport mode network, avoid Operator, avoid Terminal.

The intermodal routing result includes:

- Combined transport networks
- Routing restrictions
- Network restrictions
- Calculation of transport costs

In the following example case, we calculate a route and intermodal alternatives for a trip from Rotterdam, NL to Aalen, DE. The result is presented in a table view, as well as a visualization in map.
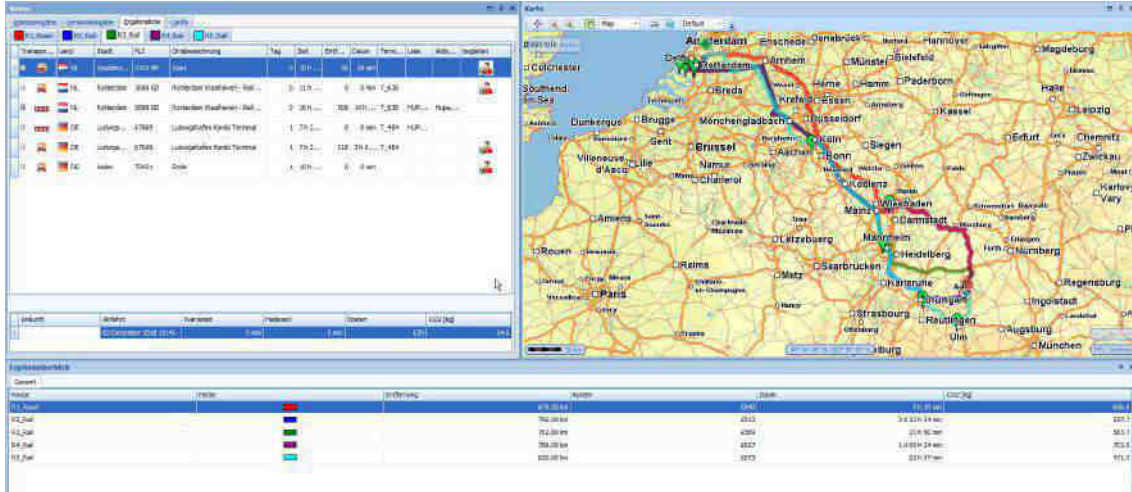
Figure 26: Testing Use Case P&E 1 - Intermodal Chain Composition

6.2 Testing Use Case P&E 2 - Intermodal Planning System

For this use case we created a test of test transport orders and imported these to the simulation application. We used the intermodal routing service to determine for each transport order transport alternatives that respect all constraint of the transport orders.
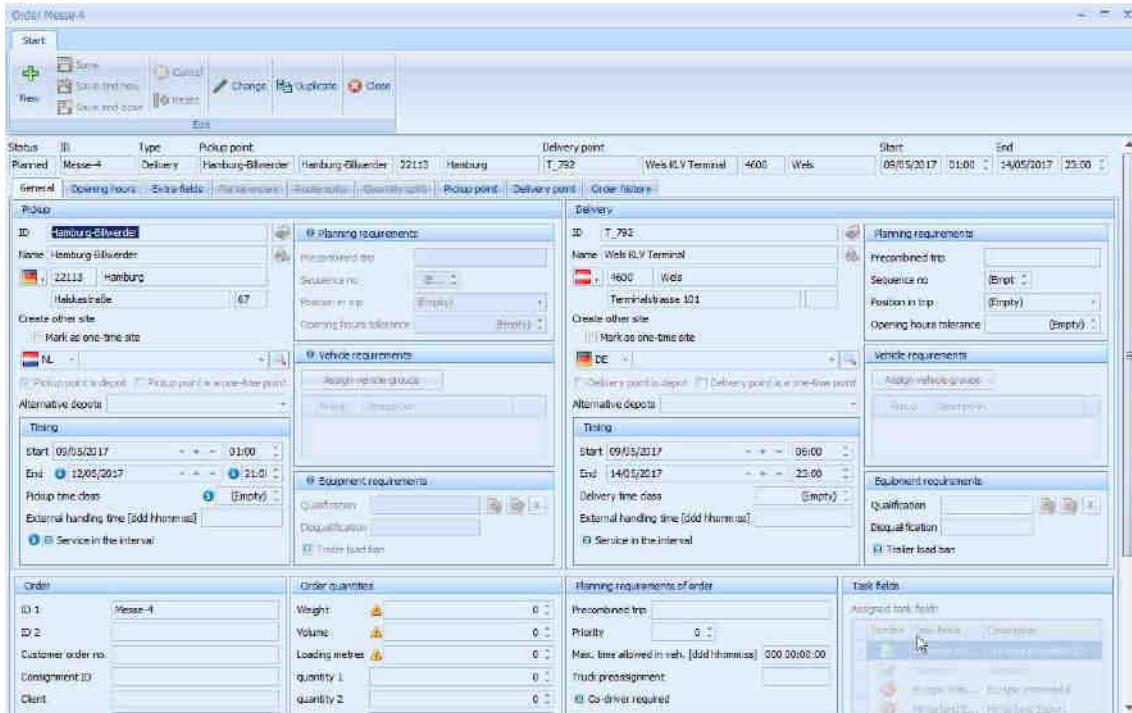

Figure 27: Testing Use Case P&E 2 - Intermodal Planning System – Example order

Ultimately, we performed an allocation planning which does a selection of which alternative shall be select with respect to a cost optimal overall system solution.

Figure 28: Testing Use Case Intermodal Planning System – conducted planning

6.3 Testing Use Case P&E 3 - Exception Handling

This Use Case is like Use Case P&E 1. The main difference is a modification of arrival times of the underlying schedules.

6.4 Strategic Scenarios

6.4.1 Testing Use Case STR 1 - Strategic Planning

- Exclude a transport network
- Exclude a terminal

Exclude a terminal

Pos.	excluded	code	name	coun...	postalCode	city
0	☐	AARA	Aarau	CH	5033	Buchs
1	☑	AARHUS	Aarhus Container Terminal North	DK	8000	Aarhus
2	☐	T_3	Aarhus Container Terminal East APM	DK	8100	Aarhus
3	☐	T_4	Aberdeen	GB	AB11 5SS	Aberdeen
4	☐	ABZ	Aberdeen International Airport	GB	AB21 7DU	Aberdeen
5	☐	T_5	Aberdeen Searoute	GB	AB11 6LX	Aberdeen
6	☐	PSR	Abruzzo Airport	IT	65128	Pescara

Figure 29: Testing Use Case P&E 3 - Exception Handling – Exclude Terminals

Example: Exclude a Terminal (test with and without Terminal Herne)

Intermodal chain with terminal Herne enabled:
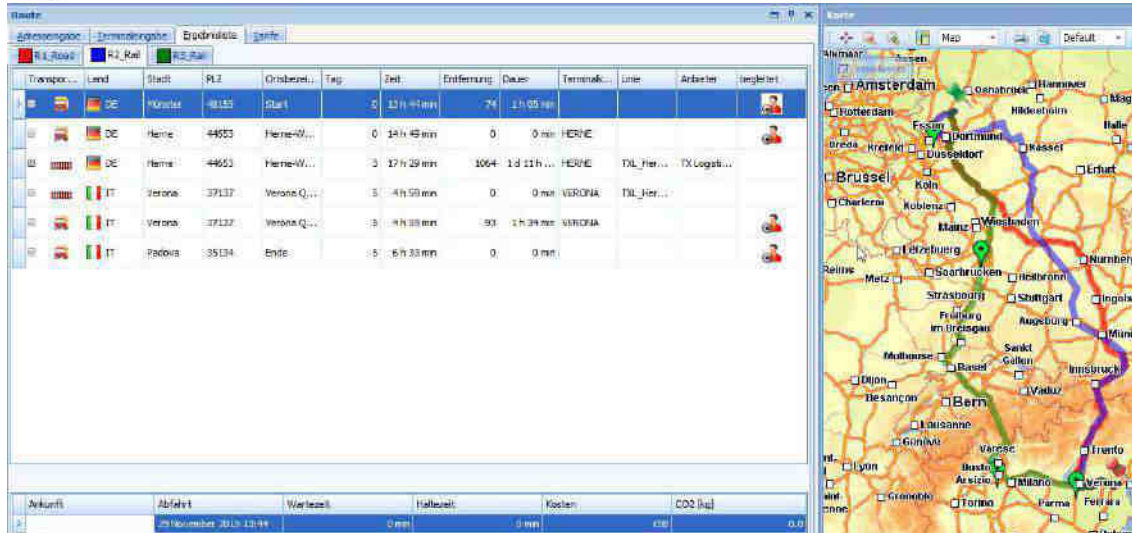
Figure 30: Testing Use Case P&E 3 - Exception Handling – Route with terminal Herne
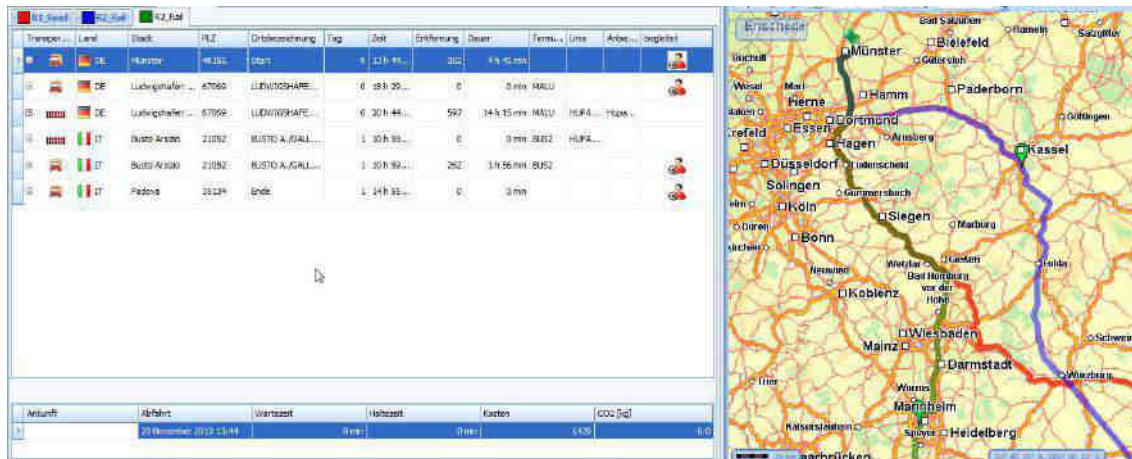
Intermodal chain with terminal Herne excluded:

Figure 31: Testing Use Case P&E 3 - Exception Handling – Route without terminal Herne

6.4.2   Testing Use Case STR 2 - Network Simulation and Assessment

Variation of capacity: For all 3 used services, a capacity of 20 loading spaces is available.

Figure 32: Testing Use Case Intermodal Planning System – conducted planning

For the second service (Cologne – Busto) we reduce the capacity from 20 to 2. Now, 2 of the 4 planned slots are above capacity (lilac colour).

Figure 33: Testing Use Case Intermodal Planning System – reduced capacity

In a next step we remove the planned allocation of all service, while all planned alternatives of the transport orders remain valid (since no schedule is completely removed, but just the available capacity has been reduced). Finally, we perform the allocation planning again:

Figure 34: Testing Use Case Intermodal Planning System – re-planning result

As a result, all orders and the related transport services could be planned to existing alternatives.

7   Results from testing with Clusters data, road ahead & Conclusion

7.1   Results from testing with Clusters data

We tested with anonymized shipper data of various shippers of different industries. To perform the analysis the shipment order data have been reviewed and modified transferring volumes into transport orders. The result was a set of derived transport orders for FTL equivalents. Finally, the transport data has been modified in the way that pick-up and delivery locations, pick-up and delivery times and order constraints have been anonymized but still allow the calculation of meaningful testing.

During all tests, we review the results from a shippers' perspective addressing a lane assessment in terms of lead time and costs. This explicitly includes the identification of a modal shift potential in a comparison to a road-only haulage.

The modal shift scenario addressed the usage of existing intermodal services that can be "filled" up with cargo as well as the consideration of new intermodal services as resulting from the massification approach. The massification approach ask for critical mass of intermodal volumes to set up collaborative trains operated and shared by several shippers. We assume for our tests, that transport orders can be combined without constraints.

Overall, we defined a test instance of about 220.000 transport orders with origins and destinations all over Europe. Each transport order contains a description of an origin and a destination as well as pick-up and delivery time windows. The transport orders can be clustered by lane distance (distance origin – destination). Based upon the assumption that for intermodal transport a distance between origin and destination is recommended to be +250km, we filtered the transport order accordingly. Around 100.000 transport orders are in the lane distance interval 250km – 3000km with this subset we ultimately conducted the testing.
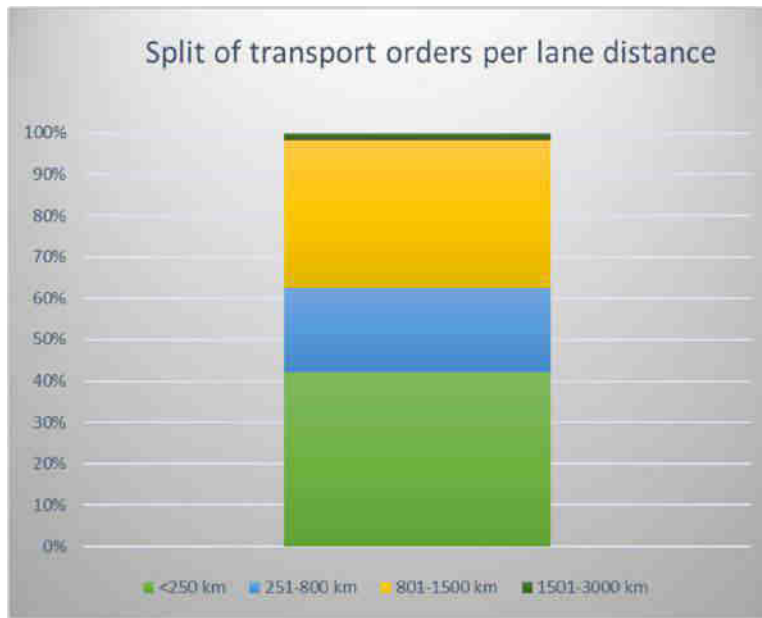
Figure 35: Split of transport order per lane distance

The mean average lane distance of a transport order of the data set is about 620 km. We aggregated transport orders of a certain lane. In total 3980 lanes could be identified. After the aggregation, we calculated for each lane intermodal alternatives plus one road only alternative as baseline. (Figure 36 and Figure 37).

In order to assess how existing services can be used by the shippers' transport demand a collection of already implement intermodal services in the CLUSTERS2.0 clusters Dourges, Duisburg, Antwerp, Bologna, Zaragosa and Trelleborg have been made. In addition, intermodal "massification" services have been implemented on lanes that show significant volumes, namely on the corridors: Cologne to Prague, Warsaw to Cologne, London to Manchester and Nurnberg to Dourges.
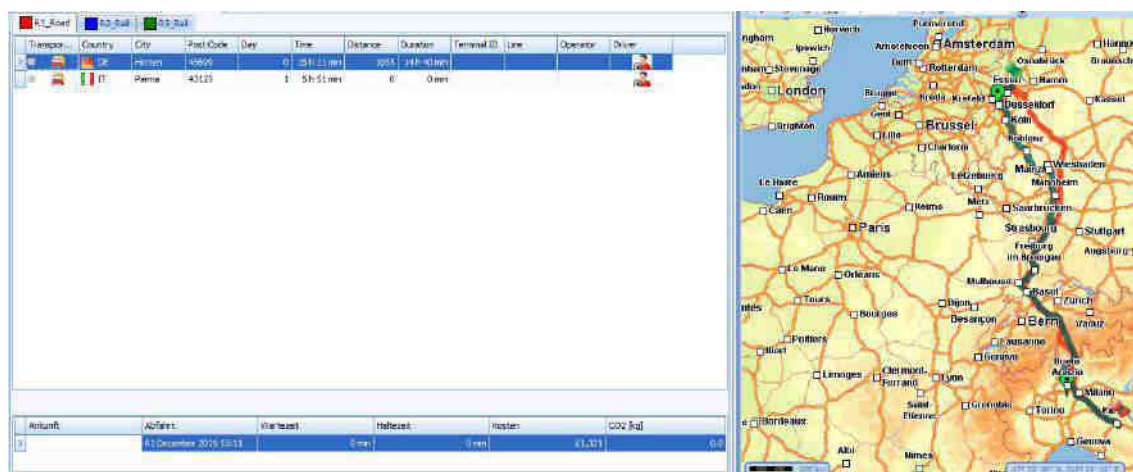
Alternative 1: Road only.

Figure 36: Alternative 1 - Road only
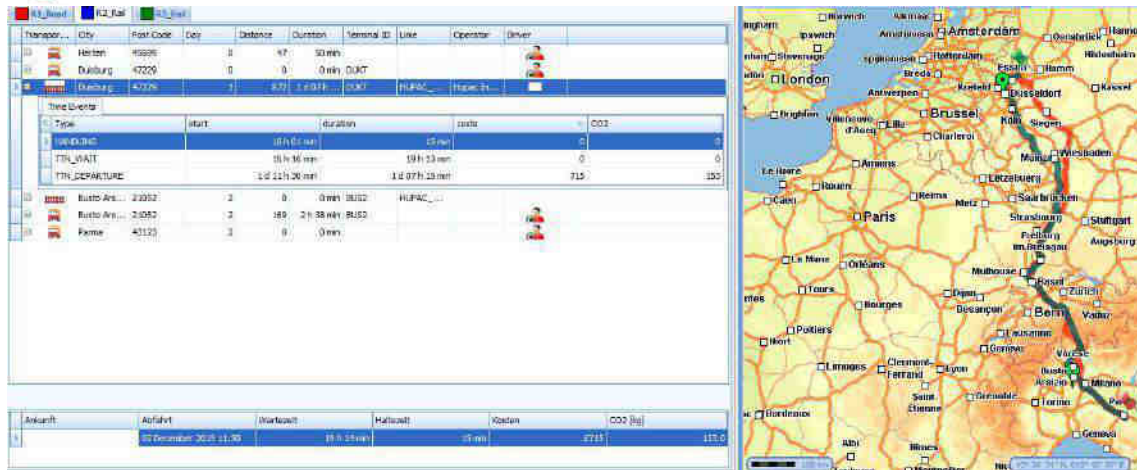
Alternative 2: Intermodal.

Figure 37: Alternative 2 – Intermodal alternative

For 2938 lanes (65% of all lines), only trucking options could be identified based on the available schedule data. For 1042 lanes (35% of all lanes), we could identify intermodal alternatives.

In general, we identified that there is a significant dependency of the modal shift potential based on the **access to terminals** and the available **service offering** by intermodal operators. In several reviewed cases, terminal access was given in general within 100km or less driving distance; but no adequate service offering for intermodal transport for the envisaged trajectory was in place (Figure 38 and Figure 39).

- The yellow box icons in the map present simulated transport order pick-up locations.
- The Blue triangular icon represents a Cluster (of Clusters 2.0)
- The black-dotted lines represent intermodal service routes

Figure 38: Reduced access to intermodal terminal and services

Figure 39: well established access to intermodal terminal and services

Based on the identified intermodal alternatives per transport order, we carried out an assignment optimization (see chapter 4.1.2 – Use Case III) taking into account capacity limitations on intermodal services. We assumed initially, that capacity per service is set to a maximum of 50 TEU per train. After some initial tests, it became obvious that some services are utilized rather strongly and whereas others would require additional volumes to be filled.

Even with a maximum capacity of 50 TEU, some lanes showed much more demand due to this we modified the capacity for 4 lines from 50 capacity to 100 on the lanes:

- Piacenza-Neapel,
- Segrate-Bari,
- Brescia_Venezia,
- Praha-Cologne.

After these modifications, all transport orders could be planned to the given fictive capacity. In total the allocation step identified 155 intermodal services on 37 physical lanes to which intermodal transport order segments should be booked to.

The resulting network structure is visualized in Figure 40.

Figure 40: Allocation planning result

Finally, the aggregated transport orders were disaggregated, and an intermodal potential was calculated. Overall, we identified that from the data sample we used a potential of about 60% could be identified that can either be brought to existing services or to the newly introduced "massification" services.

7.2 Outlook towards exploitation of the routing service

In order to exploit the Intermodal Routing Service to a large audience, a web application has been designed.

The web-application is available under this URL: https://research-ui.cloud.ptvgroup.com/main.

The application requires a login which will be shared interested Clusters. Contacting point for interested Clusters is the Clusters 2.0 website: http://www.clusters20.eu/contact/.

The web-application contains a full implementation of the use case Intermodal Chain Composition. This use case can be used, e.g. for future massification workshops acting as support tool or for shippers which have not yet full access to intermodal data.

- Exclude terminals, exclude operator / schedules (Figure 42)

- Definition of constraints of the routing which shall be considered (Figure 43)

Transport modes

Pos.	excl...	Code	Name
0	☐	TM_HANDLING	Handling
1	☐	TM_TSC	Trans-shipment
2	☐	TM_ROAD	Road
3	☐	TM_TTN_ROAD	Timetable Road
4	☐	TM_TTN_RAIL	Timetable Rail
5	☐	TM_TTN_AIR	Timetable Air
6	☐	TM_TTN_BARGE	Timetable Barge
7	☐	TM_TTN_SHORTSEA	Timetable SSV
8	☐	TM_TTN_DEEPSEA	Timetable Deep-Sea

Figure 41: web-application - intermodal chain composition - request definition 1 (exclude transport modes)

PTV GROUP Clusters 2.0   Intermodal Portal

Terminals

Pos.	Excluded	Code	Name	Cou...	Postal code	City	Street	Nr.
0	☐	ITRAN	Port of Ravenna	IT	48100	Ravenna	Via Trieste	
1	☐	IQUQR	Port of Umm Qasr	IQ		Umm Qasr		
2	☐	USHOU	Port of Houston	US-TX	77036	Houston	Port Road	
3	☐	MXVER	Port of Veracruz	MX	91700	Veracruz	Av. Marina Mercante	210
4	☐	MVD	Carrasco/General Cesáreo L. Berisso International ...	UY	140000	Montevideo	Viaducto a Interbalnearea y Ruta 1...	
5	☐	TBS	Tbilisi Airport	GE		Tiflis (Novoalexeyev...		
6	☐	GIG	Rio de Janeiro/GaleãoⓄAntonio Carlos Jobim Inter...	BR		Rio de Janeiro	Estr. Itacolemi - Galeão	
7	☐	MUC	Munich Airport	DE	85356	München	Nordallee 25	
8	☐	DBV	Dubrovnik Airport	HR		Dubrovnik		
9	☐	MTY	General Mariano Escobedo International Airport	MX		Monterrey	Nuevo León	

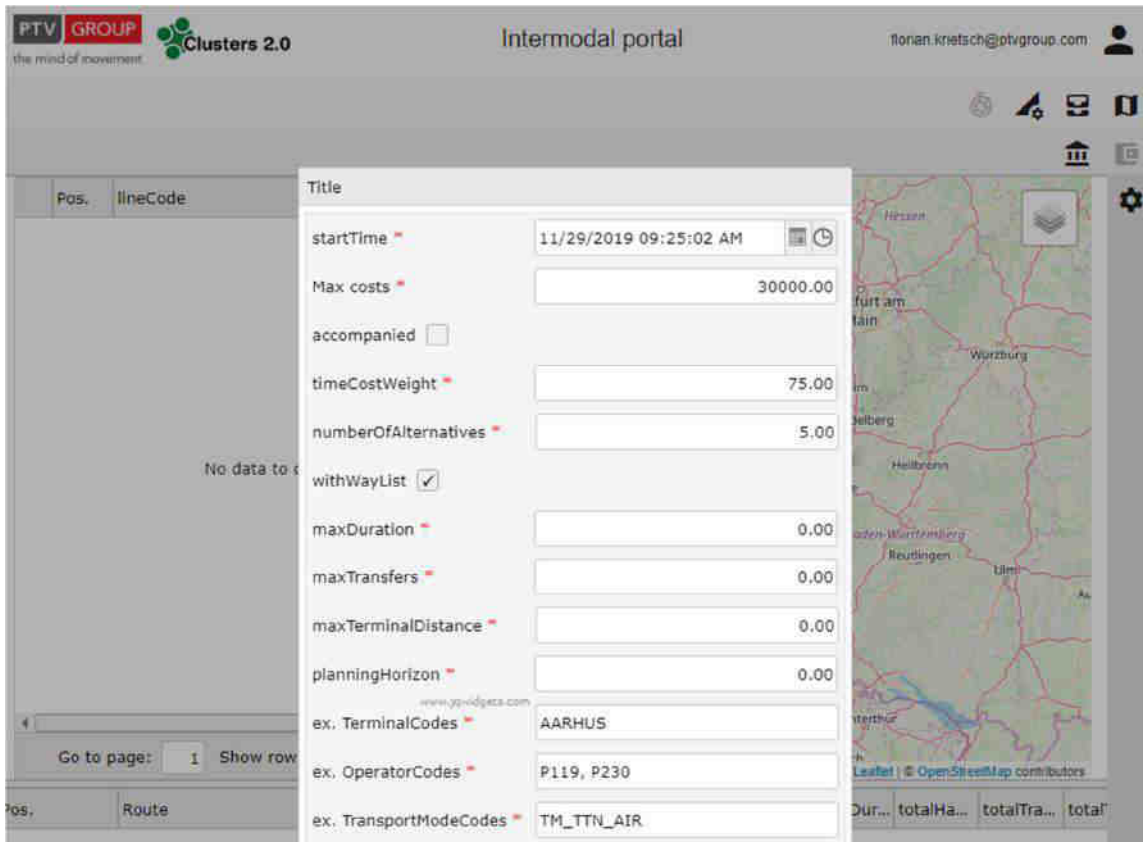**Figure 42: web-application - intermodal chain composition - request definition 1 (exclude terminals)**

Figure 43: web-application - intermodal chain composition – request definition 2 - constraints

With the given settings, the Intermodal Routing Service calculates if possible, the number of envisaged alternatives. Finally, the results for the different intermodal chain composition alternatives are presented each in a map polygon and within a detailed table view per mode, leg and related costs (Figure 44).
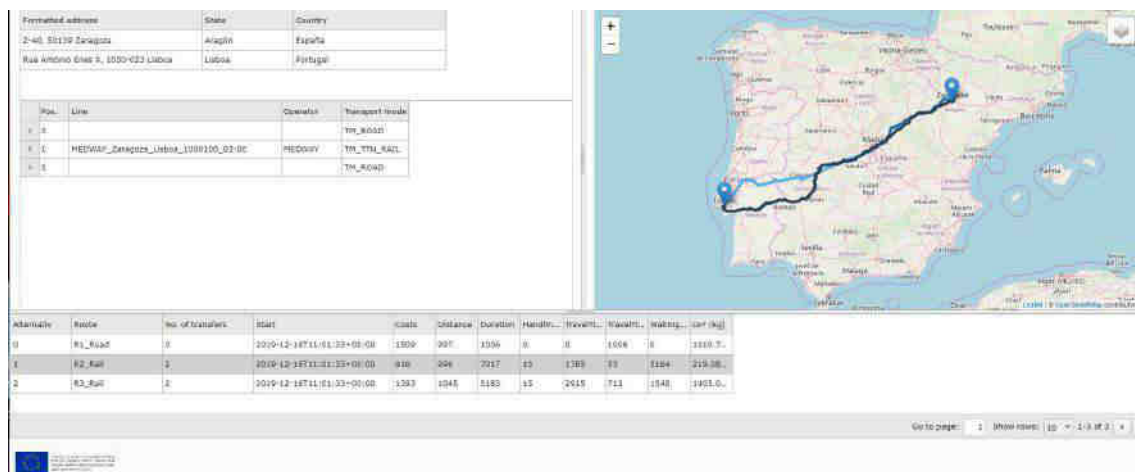

Figure 44: web-application - intermodal chain composition -result presentation

7.3   Conclusion

Within WP 3.6 we developed and applied an intermodal planning environment that is capable for assessing the potentials of collaborative demand planning of shippers as addressed in the massification concept. Making use of large-scale realistic demand data covering the area of the CLUSTERS2.0 clusters a significant potential of existing and newly "massification" services could be identified. Our study provided a potential of up to 60% over all transport orders with distances higher than 250 km that can be operated by intermodal transport.

The approach developed is supporting the activities as addressed in the massification workshops together with collaborating shippers. The concept proved to be feasible and transferable. Key achievement of this task is that precise analysis on the intermodal potential on trade lane basis can be carried out making use of operational intermodal service data and actual shippers demand data under various constraints and limitations. Moreover, the impact of newly "massification" intermodal services can be assessed making it a very useful assessment tool for the massification concept. In our analysis concrete services on 4 lanes could be identified for which demand is existing however no adequate intermodal service.