HARMONY
SPATIAL & TRANSPORT PLANNING FOR A NEW MOBILITY ERA

Holistic Approach for Providing Spatial & Transport Planning Tools and Evidence to Metropolitan and Regional Authorities to Lead a Sustainable Transition to a New Mobility Era

D8.1 The HARMONY MS support for TEN-T corridors

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SUMMARY SHEET

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Responsible Author(s):	**Davide Fiorello (TRT), Loredana Zani (TRT), Francesca Fermi (TRT), Sebastiaan Thoen (Significance), Michiel de Bok (Significance)**
Responsible Co-Author(s):	
Peer Review:	**Manos Chaniotakis (UCL), Lampros Yfantis (Aimsun)**
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LIST OF ABBREVIATIONS

Abbreviation	Explanation
FS	Firm Synthesizer
TFS	Tactical Freight Simulator
TRUST	TRansport eUropean Simulation Tool
TEN-T	Trans-European Transport Network
SUMP	Sustainable urban mobility plan
IWW	Inland Waterways

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EXECUTIVE SUMMARY

The main objective of the HARMONY project is to develop a new generation of harmonised spatial and multimodal transport planning tools which comprehensively model the dynamics of the changing transport sector and spatial organisation, enabling metropolitan area authorities to lead the transition to a low carbon new mobility era in a sustainable manner.

The HARMONY Model Suite (MS) aims at enabling end-users such as planners, decision makers, researchers and transport operators/providers to couple/link independent models and analyse a portfolio of regional and urban interventions for both passenger and freight mobility, including policies and capital investments, land-use configurations, economic and sociodemographic assumptions, travel demand management strategies and new mobility service concepts.

Against this background, the activities of task T8.2 of Work Package 8 directly contribute to the realisation of HARMONY objectives O7, namely exploring the potential linkage between the HARMONY MS (metropolitan-level) and aggregate EU-wide transport models. With this respect, the potential inputs that the MS might receive from large scale models and the outputs it might provide to those models have been defined. This might help extending the estimation of the impact of new mobility solutions to the TEN-T corridor level.

Furthermore, to address the challenges of using these interface variables, two use cases have been designed to test the linkage between a European scale transport network model (TRUST) and the models developed within the HARMONY MS for Rotterdam (freight demand) and Turin (passenger demand). In both cases, the large-scale model provides data on through traffic due to long distance movements that affect the metropolitan areas of interest. Nevertheless, in principle also the other direction is applicable and the HARMONY MS might offer useful information on the future development of local mobility within nodes in the context of the mobility transitions and innovation.

The main goal of Deliverable 8.1 is to address the topic of linkages between models of different scale and nature, describing the two use cases involving some components of the HARMONY MS for both passenger and freight transport demand.

1. Introduction

Reducing greenhouse gas emissions and energy consumption are primary goals for urban areas when designing and managing future and present transport infrastructures. Despite technological advancements and new mobility services constituting potential key tools to achieve those goals, the complexity of metropolitan areas and the difficulties in the integration of different developments in different sectors pose many challenges in the implementation of effective, holistic, all-encompassing transport and spatial plans. For this reason, local metropolitan authorities require decision support tools to plan, develop strategies and test scenarios for future infrastructure development or for present-day infrastructure optimal management.

HARMONY's goal is to provide metropolitan authorities with and aggregate multiscale spatial and transport planning framework to enable them to progress a sustainable transition towards a low-carbon new mobility era. HARMONY's main objective is, in fact, to assist metropolitan authorities with evidence-based decision making, by providing a state-of-the-art model suite that quantifies the multidimensional impact of various policies, investments and mobility concept applications.

The HARMONY Model Suite deals with local demand, but it cannot be neglected that part of traffic in metropolitan areas depend on the interaction with the surrounding area or long-distance trips from and to external zones. The relevance of this component is generally limited with respect to overall mobility at metropolitan scale, but they can be significant in specific situations, for instance in areas with a large maritime port or in attractive regions for tourism. Within this context, exploring the linkage between the HARMONY MS (metropolitan-level) and aggregate EU-wide transport models would allow to explore on one hand the impacts of long-distance demand on mobility of cities and metropolitan areas, and on the other hand to extend the estimation of the impact of new mobility solutions at local level to the TEN-T corridor level they belong to.

As an example, policies affecting long distance transport demand such as TEN-T corridors infrastructures or harmonised road charging can affect the mode choice and therefore modify the travel pattern of incoming / crossing demand affecting metropolitan areas.

The main objective of Deliverable 8.1 is to address the topic of linkages between models of different scale and nature (e.g., using output of one model as input for another), describing the two use cases involving some components of the HARMONY MS for both passenger and freight transport demand, respectively in the pilot cities of Turin and Rotterdam.

The Deliverable is structured in the following sections:

- Section 2 presents an overview of the potential interactions of metropolitan and large-scale models
- Section 3 reports the application developed for freight transport demand in Rotterdam, with the linkage of the HARMONY MS with the TRUST European network model.
- Section 4 presents the application developed for passenger transport demand in Turin, with the linkage of the HARMONY MS with the TRUST European network model.

2. Potential interactions of metropolitan and large-scale models

2.1 General concept

Metropolitan and Regional transport models, such as those integrated in the HARMONY Model Suite, deal with local demand, which is the largest part of personal mobility and is generated locally.

In fact, looking at EUROSTAT statistics[1], *urban trips (trips of less than 100 km within the same urban area) represent a substantial proportion of daily short-distance mobility (less than 300 km): from 41 % in Slovenia to around two thirds in Germany, 85 % in Portugal (influenced by the fact that only the two metropolitan areas, Lisbon and Porto, were surveyed) and almost all the total short-distance trips in Romania (99 %)*.

Nevertheless, part of traffic in metropolitan areas depend on the interaction with the surrounding area or long-distance external zones. There is traffic incoming to or departing from the metropolitan area and crossing traffic, with travel patterns that differ from internal demand. These components are generally a limited share of the overall mobility in the region under analysis, but they can be significant in specific situations, for instance in a metropolitan area with a large maritime port or a in a region attracting many visitors. Furthermore, traffic to and from outside the region or crossing traffic can have severe implications for specific types of infrastructure or services in the area, such as local public transport, interchange parking at the border or ring roads. Some travel surveys or ad-hoc data collection could provide quantification of this part of traffic, as well as large scale models which can help especially in terms of future projections.

In the other direction, given their spatial granularity, large-scale models do not treat local traffic or manage it in coarse way. This limited level of detail is consistent with the scope of strategic models. Nevertheless, if strategic models are expected to provide the overall picture of the transport activity, information that metropolitan/regional models can provide can be helpful.

At European scale, it should be considered the role of TEN-T corridors, which are backbones of the European network and link major nodes constituted by cities and metropolitan areas. The way that local traffic would evolve in the future in these nodes is then of great importance for studying the passenger and freight flows distribution along the different corridors of the TEN-T core and comprehensive network. In fact, cities are important points of transfer and last-mile connection within or between different transport modes on the TEN-T and it is important to ensure that neither capacity bottlenecks nor insufficient network connectivity within urban nodes can hamper multimodality along the trans-European transport network. In this sense, the new provisions introduced through the revised TEN-T Regulation require that by 2040, at least one multimodal passenger hub and one multimodal freight terminal allowing for sufficient transhipment capacity within or in the vicinity of the urban node is in place. In addition, by 2025, the 424 cities identified in the new TEN-T regulation must develop a Sustainable Urban Mobility Plan (SUMP) that includes measures to integrate the different modes of transport, and to promote zero-emission mobility.

In this respect, the following metropolitan areas involved in the HARMONY project are in the list of urban nodes on TEN-T corridors: Turin (Italy), Rotterdam (the Netherlands), Athens (Greece), Katowice (Poland).

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[1] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Passenger_mobility_statistics#Urban_trips

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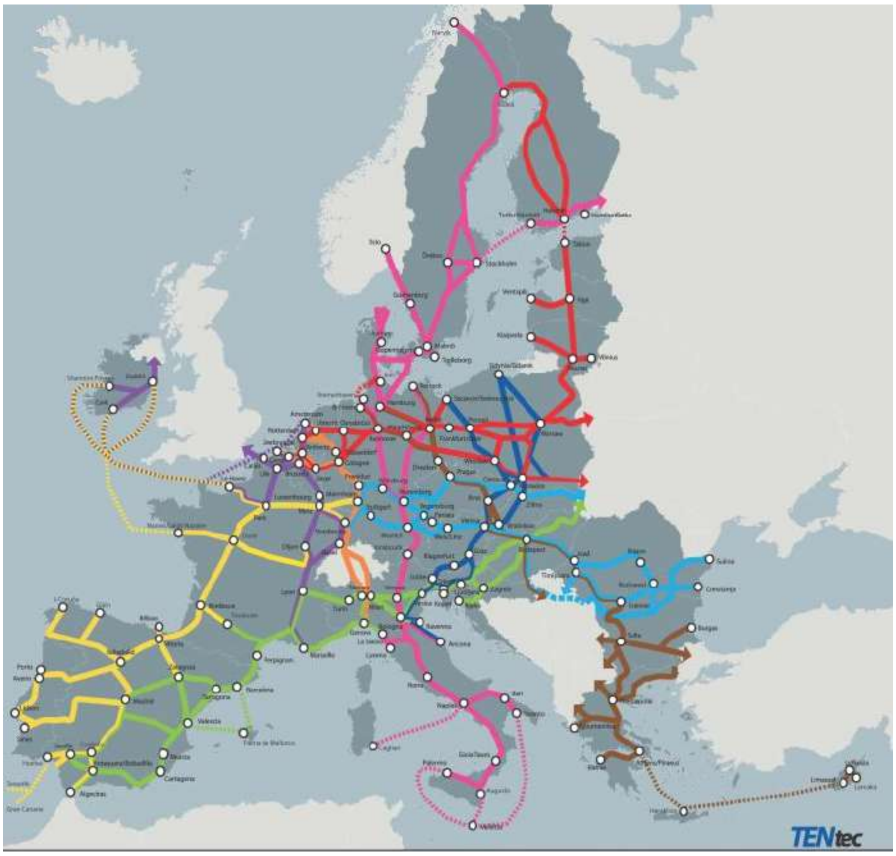

Figure 1 – The TEN-T network and urban nodes

2.2 Types of interaction

Large-scale models operating at regional, national or supranational scale (i.e. the EU and beyond) are used to study demand on corridors focusing on regional and long-distance traffic; usually they operate with a coarse zoning system, much more aggregated than the one adopted in metropolitan and regional models such as in the HARMONY MS.

As mentioned above, there is scope for an interaction between the HARMONY MS and large-scale models in two directions. On the one side, the HARMONY MS might offer useful information on the future development of local mobility within nodes in the context of the mobility transitions and innovation; on the other side the large-scale model might provide data on through traffic due to long distance movements that affect the metropolitan areas of interest.

Nevertheless, the integration of different demand models involves a significant investment and high data processing costs (Erhardt GD 2007, Horowitz A 2014, Llorca C 2018). The NCHRP Report 765 (Llorca C., 2018) warns about several issues during model integration, including the need of consistent network representations, consistency in input and outputs, the definition of points of connection between small and large-scale models, etc. In fact, there are not many examples for the integration of models of different scales in the literature, and they are mostly focused on the assessment of the benefits of adding external demand (Llorca C., 2019).

In this sense, the interaction between the two kinds of models cannot be conceived in terms of merging them into an interoperable tool, because the technical issues would be heavily challenging. The interaction can reasonably be foreseen as a matter of data exchange. The following table summarises the kind of information that could be exchanged in the two directions.

Table 1 – Types of interaction between large scale models and metropolitan models

From large scale models to HARMONY metropolitan models	From HARMONY metropolitan models to large scale models
Number of trips between the metropolitan area region and other regions by mode of transport	Intrazonal trips by mode of transport
Number of tonnes between the metropolitan area region and other regions by mode of transport	Intrazonal pass-km by mode of transport
Number of trucks between the metropolitan area region and other regions	Intrazonal road vkm
Medium/long distance traffic crossing road infrastructures in the metropolitan area	Load on road links generated by local transport activity
National GDP or employment trend as input for the Regional Economy Model	Transport cost and transport time variations on infrastructures in the metropolitan area with long-distance demand relevance

2.3 Challenges of operational applications

Even for the case where the interaction between metropolitan models and large-scale models is basically a matter of exchanging data, its practical implementation is normally challenging. As a matter of fact, any transport model is usually designed for specific purposes; it is conceived as an independent tool and the adopted methodological solutions are those more appropriate for the expected use of the model in its specific context. Therefore, linking two different transport models is generally problematic even when only “soft” links are envisaged. In this sense, the HARMONY MS is already an example of an integrated platform, where models of different nature and scope are linked, in a comprehensive tool, addressing the data exchange between different components[2].

When models are very different in scope, such as a model simulating transport demand at European scale and a model focusing at urban level, the complexity is stronger, because it is even more likely that the features of the model are very different. As such, the most relevant challenges that should be addressed for operational applications of the interaction between metropolitan models and large-scale models are as follows:

- The **spatial scope** of a metropolitan model is probably comparable to one zone or very few zones of a large-scale model. A zone is defined as the unit of geography of the transport model and its size varies depending on the context of application. In fact, a zone of a metropolitan model could be in the range of as city blocks or buildings, while in a European scale model each zone would usually represents entire provinces. Therefore, in some cases, the zoning system of the latter model will hardly match the boundaries of the study area of the former model. The zone of the large-scale model can exceed the study area of the metropolitan model or cover just part of it. So, the transport activity (demand) modelled in one model cannot be immediately associated to the transport activity (demand) the other model. In some cases, absolute level of activity can be compared after some post-processing of model results. In other cases, only relative changes can be safely exchanged.
- Another aspect strictly related to the different level of detail of zones, is the different **density of networks**. The networks of large-scale models (at least the road network) are necessarily stylised; they include only a subset of existing roads (those relevant for trips between zones at the scale of the model). Especially close to urban areas, actual road networks become very dense, and several alternatives are available to move to and from the city. In a large-scale model, the density of the road network is not reproduced, only few road links are used and each one represents more roads, providing enough capacity to accommodate the modelled trips to and from the city. On the other hand, the road network of metropolitan models generally includes

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[2] See D2.2 - The HARMONY MS – First prototype

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most of or all links, with limited or even no aggregations. Therefore, traffic on links extracted from a large-scale model should be interpreted with care before considering it an information for a metropolitan model.

- The **segmentation of demand** is almost always different between metropolitan models focused on local trips and in large-scale models focused on medium and long-range mobility. In fortunate cases, the segments used in one model are sub-segments of the other model (e.g., the metropolitan model can distinguish shopping trips from leisure trips while the strategic model can put both under a "non-working" trip category) but in other cases segments will just be different.
- The **temporal scale of simulation** could also be a challenge. Large-scale models often work with yearly-based matrices, while metropolitan models often work with daily-based matrices. The conversion between yearly and daily trips is not necessarily a simple change of unit; the average day is normally considered as a working day, when the share of working trips is above the yearly average and the share of leisure trips is lower. For transferring data between models using a different time scale, this kind of aspects need to be carefully considered. If the metropolitan model works for a shorter time scale (e.g., morning peak) there is an additional complexity as yearly and daily matrices are generally symmetrical while matrices representing mobility of a few hours are not.
- Apart from the differences mentioned so far (spanning from different segmentation to spatial scope and detail), it should be underlined that the results of a large-scale model for a specific zone could not be really comparable to those of a metropolitan model for that zone. The reason is that large-scale models are usually calibrated against aggregated statistics at national level, rather than against observed data zone-by-zone. One good reason being that zone-by-zone data simply does not exist. Since large-scale models are **calibrated in aggregated terms**, their results at zone level could not be of good quality. A given aggregated activity can be reproduced compensating overestimation in one zone with underestimation in another zone. Within reasonable limits this is acceptable for a large-scale model, but it could be less acceptable for exchanging data with metropolitan models, at least in absolute terms.

As a further consideration, models are using information from various sources. These sources are not necessarily the same or fully consistent to each other (e.g., trip rates are drawn from travel surveys, traffic on links drawn from roads monitoring systems, aggregated passenger-km provided by transport operators, etc.). Data provided by another model adds another potential source of inconsistency. If this exogenous modelling data is used already in the calibration phase, the consistency can be handled together with the other sources, to derive a coherent set of comparable figures. But if the model is calibrated on other sources, there is the risk that a specific additional information drawn from a different model and used in a later stage can result inconsistent (even if it is reliable).

Abstracting from the challenges mentioned above, one large-scale model can be a source of useful inputs for one metropolitan model. The other way round (metropolitan models to large scale models) has little benefit. Receiving data from just one or few metropolitan models would provide a modest benefit even if the data is correct and consistent. Adjusting only one or few zones does not make a huge difference at the scale of analysis of national or European models. Nevertheless, if several metropolitan models were available their results could be associated to different types of regions and an attempt of generalising some statistics for each region type (e.g., average trip distances, share of public transport) could be made and support a more generalised improvement of the large-scale model.

To summarise, the linkage between large-scale models and metropolitan models presents several challenges even if conceived as an exchange of data, due to the different nature and scope of the applications. Therefore, when exploring their integration, the modeller should carefully evaluate the required steps to obtain a consistent exchange of information. The following sections provide the description of two use cases related to metropolitan areas where the HARMONY MS has been applied: Rotterdam (for freight demand) and Turin (for passenger demand). The use cases have been developed to present some examples of application, taking the opportunity of the linkage with the European network model TRUST (TRansport eUropean Simulation Tool). A detailed description of the TRUST model is reported in Annex 1.

3. Rotterdam case study: interaction with TRUST European network model

3.1 Introduction

This section describes the case study testing the interaction between large-scale and metropolitan model developed for Rotterdam, focusing on freight road transport demand. More in details, the interaction has been tested in terms of providing the metropolitan model with the demand matrix of long-distance demand for road freight resulting from a large-scale model.

3.2 Overview on the Rotterdam modelling application

Within the application for Rotterdam, the following models developed in the HARMONY project have been considered: the Firm Synthesizer (FS, WP4), Spatial Interaction Freight (SIF, WP4) and Tactical Freight Simulator (TFS, WP6). The application focuses on road freight transport. Specifically,[3]:

- The **Firm Synthesizer** discretises the regional employment per zone into individual firms using a firm size distribution per sector. Here we take the regional employment of the V-MRDH transport model provided by Gemeente Rotterdam.
- The **Spatial Interaction Freight** (SIF) produces a commodity demand matrix. For this purpose, it calculates zonal productions and attractions based on regional employment and uses an external commodity matrix per NSTR goods type as starting point for the shape of the matrix. It then uses an Iterative Proportional Fitting technique to match the initial matrix with the calculated productions and attractions. Here the external commodity matrix originates from BasGoed, the Dutch national strategic model for freight transport. At this stage, an interaction is already in place with a national model and could be replaced with an alternative source, i.e. the TRUST model.
- The **Tactical Freight Simulator** (TFS) then disaggregates this commodity demand matrix into individual shipments between firms and, subsequently, individual tours transporting these shipments.

The study area for the development of the TFS is the province of South Holland in the Netherlands. This area is the most highly urbanized region in The Netherlands and has a population of 3.3 million, and 1.8 million jobs. One of the largest seaports in the world, the Port of Rotterdam is situated in the area.

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[3] The full description of these modelling components is available in Deliverables D4.2 and D6.2

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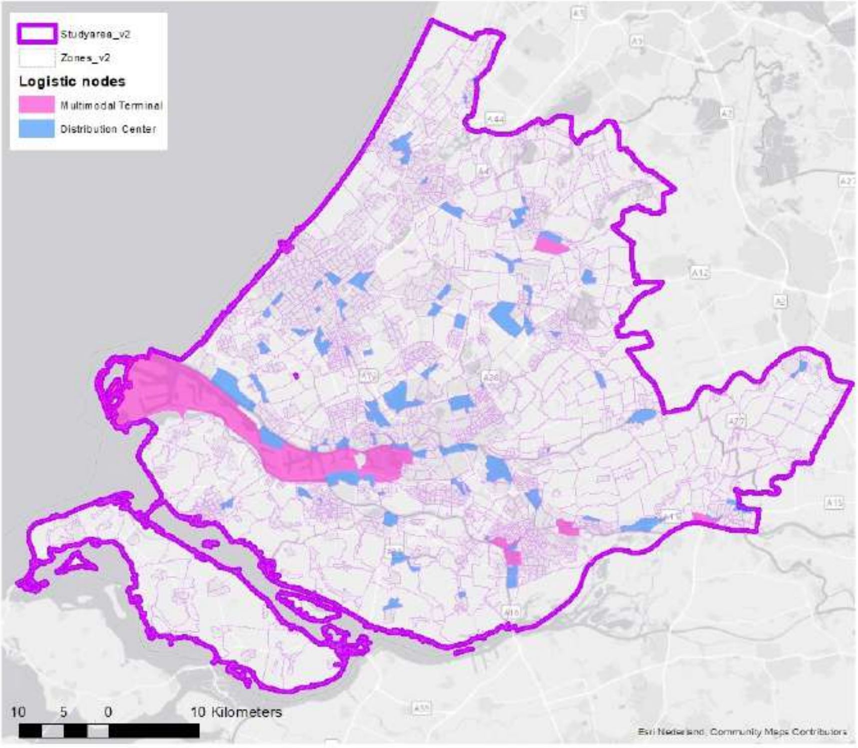

Figure 2 – Province of South Holland, the Netherlands

3.3 Overview of the TRUST model for freight

The TRansport eUropean Simulation Tool (TRUST) is a European scale transport model developed by TRT which simulates road, rail, air and, for freight, also maritime transport. TRUST covers the entire European Union and its neighbouring countries at the NUTS3 level of detail (about 1,600 zones) for passenger and freight demand.

TRUST can be used in the context of impact assessments and for supporting policy formulation and evaluation. It is particularly suitable for modelling road charging schemes for cars and heavy goods vehicles as well as policies in the field of infrastructure (e.g., completion of the core and comprehensive Trans-European Transport (TEN-T) network[4]).

More information on the TRUST model is provided in Annex 1.

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[4] https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

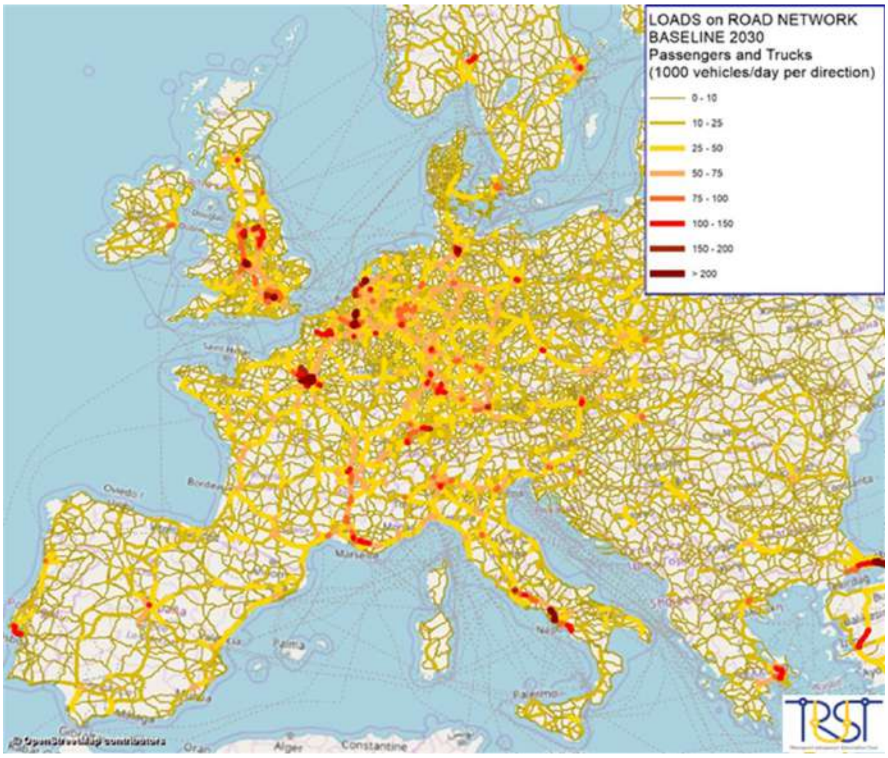

Figure 3 – example of road transport assignment in the TRUST model

With reference to freight transport demand, the following modes are covered in the TRUST model: trucks, rail, maritime and inland waterways (IWW).

The TRUST road network includes all the relevant links between NUTS3 regions, i.e. motorways, primary roads as well as roads of regional and sub-regional interest. Road network links are distinguished in different classes, each with specific features in term of capacity and free-flow speed. Additional corrections to the link characteristics are also applied to consider specific conditions, e.g. links in mountain areas are explicitly recognized. The European tolled road network is modelled on a country basis, i.e. national tolls are applied and those links where extra-tolls are levied (e.g. tunnels) are modelled case by case. Freight road demand is segmented in about 120 groups classified by origin country and distance bands.

The TRUST rail network covers basically the whole European network with the exception of local infrastructures. Different link types are used to distinguish the various parts of the network according to the maximum speed allowed and according to any specialisation (e.g. links reserved to High Speed services of links reserved to freight trains). Services between stations are not represented in terms of timetable or frequencies, but speeds on links are corrected to represent realistic commercial travel times between zones. Freight rail demand is segmented in conventional rail and intermodal transport.

The TRUST IWW module includes all the relevant canals among all the NUTS3 regions covered by the spatial area of the model. The inland waterway network includes the most relevant 70 inland ports across Europe from the point of view of the quantities of goods handled and their strategic role along the international routes. Freight IWW demand is segmented in conventional and intermodal transport.

The TRUST Maritime Module is a multi-modal assignment model that allows to describe freight maritime transport by cargo type. Three main cargo types are considered separately: bulk (BLK), unitized (UNT) and general cargo (GCG).

The TRUST model deals with two of the four stages of traditional four-stage transport models, i.e. modal split and assignment. Demand generation and distribution are not derived in TRUST, with the model to be using base year Origin-Destination (OD) matrices derived from elaborations and updates of the matrices originally developed in the European research project ETISplus[5]. These matrices are updated in TRUST when the base year is changed. The update consists of revising O-D pair trips in order to reproduce observed passengers-km and tons-km by country and mode as reported by the European transport in Figures. Matrices for future years are obtained by applying to the base year matrices growth rates of transport activity. The growth rates of the 2020 EU Reference Scenario are currently used in the model for future trends at 2030, 2040 and 2050. Modal split is modelled by means of the application of a multinomial logit model. Also, the model considers demand between zones, while demand within zones is not treated explicitly.

The assignment algorithm used is Equilibrium Assignment which distributes demand for each origin/destination pair among available alternative routes, according to Wardrop first principle. This principle assumes that each traveller / shipment is identical, non-cooperative and rational in selecting the shortest route, and knows the exact generalised travel time (including therefore also cost) that will be encountered.

3.4 Description of the interaction and scenarios

As anticipated above, the modelling application within the HARMONY MS developed for Rotterdam includes 3 components from strategic (Firm Synthesizer and Spatial Interaction Freight) to tactical level (Tactical Freight Simulator). The linkage with a large-scale national model is already in place for the SIF model, which then provides input to the TFS for the disaggregation of the commodity demand matrix into individual shipments.

The use case testing the linkage with the TRUST network model is designed to use an exogenous demand matrix related to road freight transport, replacing the existing exogenous input used in the model and taken from the BasGoed model, the Dutch national strategic model for freight transport.

As reported in Section 2, the interaction between the two models – although in the form of data exchange – requires some preliminary work to be performed. In particular, challenges related to the zoning system and demand segmentation have been addressed. On the one hand the TRUST zoning system had to be adapted to the SIF zoning system, on the other hand the information about demand evolution from TRUST had to be elaborated to be consistent with the SIF model segmentation.

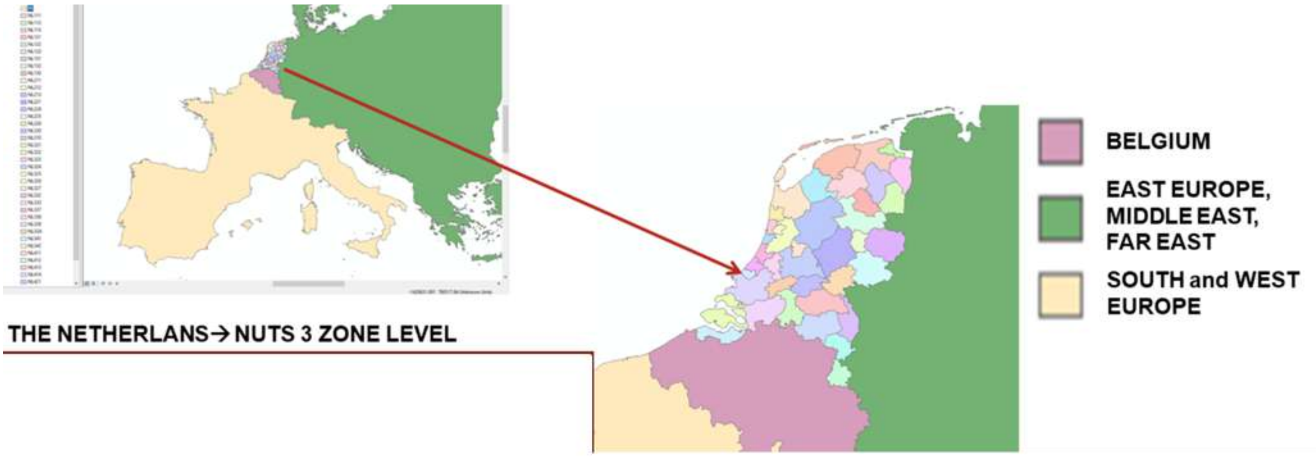

Figure 4 – Correspondence at zoning system level between SIF Rotterdam and TRUST model

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[5] https://cordis.europa.eu/project/id/233596

Concerning the zoning system, the TRUST zones (NUTS3) of the other countries have been aggregated to reproduce the external zones of the model for Rotterdam. In the Netherlands, the NUTS3 zoning system has been used, being already aligned with the requirement of the model for Rotterdam.

With respect to demand segmentation, TRUST doesn't differentiate by commodity once the mode split has been performed. Therefore, after preliminary checks of consistency between the two matrices, assumptions have been made to derive the demand segmentation of the Spatial Interaction Freight module (see below).

After having prepared a consistent set of demand matrices for the base year and the projection year 2030, two different scenarios for the forecast year were tested. In the first scenario the commodity demand from the national model BasGoed has been used as the external commodity demand for the Spatial Interaction Freight module, and in the second scenario the road freight demand from the TRUST model has been used in a similar way.

The BasGoed model provides a commodity demand matrix at the level of NUTS3-zones for 13 commodity types. These commodity types have a close relation to the NSTR commodity types used in the Spatial Interaction Freight module. For the forecast year 2030, a road charge per vehicle-km is implemented in the model with a flat toll of 0.15 €/km on the highway network and main secondary roads of the Netherlands (de Bok et al., 2021). In general, the assumptions of the forecast scenario are based on the national guidelines of the WLO scenarios coordinated by the Dutch government institutes PBL and CPB (CPB & PBL, 2015). This includes a variety of developments in, for example, costs, employment, population, and logistic efficiency. The 2030 "high" scenario which assumes a relatively high economic growth has been used.

From the TRUST model a commodity demand matrix at the level of NUTS3-zones is available, but without commodity type segmentation. To add this dimension to the TRUST matrix, the growth rate of the TRUST matrix from base year to forecast year has been applied per OD-pair to the base year matrix of BasGoed model. This preparation procedure is also necessary as the TRUST-matrix does not contain intrazonal flows within NUTS3-zones which, at the much more disaggregate modelling level of the TFS, are crucial for an accurate representation of local freight demand.

With the aim of consistency, the TRUST model has been run at 2030 under the assumption of a road charging policy for freight, with the same flat toll of 0.15 €/km on all roads in the Netherlands and, in other European countries, a rate diversified by vehicle type (i.e., CO_2 emissions of vehicle stock), road type (motorway or main roads) and country. Also, the TRUST scenario includes the assumption that the projects of the core network are completed by 2030 for road, rail and IWW[6] (under Regulation (EU) No 1315/2013).

3.5 Results

When comparing the two scenarios after applying the TFS (using demand from the TRUST model or the BasGoed model), the total road freight demand at 2030 in tonnes is almost identical. This is consistent with the endogenous structure of the SIF module where productions and attractions of each zone are calculated, setting the row and column totals of the commodity matrix. In fact, the external commodity matrix merely determines the shape, given the row and column totals.

However, looking at comparison in terms of tonnes-kilometres in the table below, we can observe some differences. On one hand, this might be caused by different model designs and cost elasticities between BasGoed and TRUST, on the other hand the different assumptions related to the road charging policy scenarios and TEN-T network have an impact on the shape of the matrix. In fact, in the BasGoed scenario, no charge is implemented on roads outside the Netherlands, while in the TRUST scenario road charging is applied and the TEN-T network for other modes is also improved. This will cause

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[6] https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

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international road transport demand to be less attractive in the TRUST model compared to BasGoed, and hence in the external commodity matrix of the TRUST model there will be a smaller share of long-distance international shipments with the area of the Rotterdam model.

Table 2 – Comparison of results for the use case in Rotterdam

Scenario	**Ton-kilometres**
Base year	38,838,975
Forecast 2030 (with BasGoed external matrix)	57,477,527 (+47.99%)
Forecast (with TRUST external matrix)	54,117,445 (+39.34%)

It can be concluded, though, that it is feasible to use the outcomes of the TRUST model as input for the SIF module of WP4 and the TFS of WP6. The tonnes and ton-kilometres of the TFS are similar in their magnitude when either BasGoed or TRUST model is used to provide the external commodity matrix. For this purpose, however, some data preparations are needed to add information about goods types and intrazonal flows to the TRUST commodity matrix. In general, we can conclude that the SIF module and TFS are flexible for different sources of input data regarding regional commodity flows.

4. Turin case study: interaction with TRUST European network model

4.1 Introduction

This Section describes the case study testing the interaction between large-scale and metropolitan model developed for Turin, focusing on passenger transport demand. More in details, the interaction has been tested in terms of providing the metropolitan model with the demand matrix of long distance passenger demand by mode resulting from a large-scale model.

4.2 Overview on the Turin modelling application

This section describes the case study related to interaction between large-scale and metropolitan model developed for Turin, focusing on passenger transport. Within this application, the existing VISUM network model extended and enhanced in the HARMONY project (WP7, at operational level) has been considered (since the Agent based model for the same area was not yet available for testing purposes). A more detailed description of the model is provided in Deliverable D7.1 and D7.6.

The study area is the Turin Functional Urban Area (FUA) which includes the municipality of Turin and 87 municipalities within the province of Turin. The total population of the FUA is about 1,75 million inhabitants (as of 2018), of which about 870,000 inhabitants live in the Municipality of Turin. The following figure shows the administration boundaries for Turin Municipality, FUA area, Turin province and the Region Piemonte.

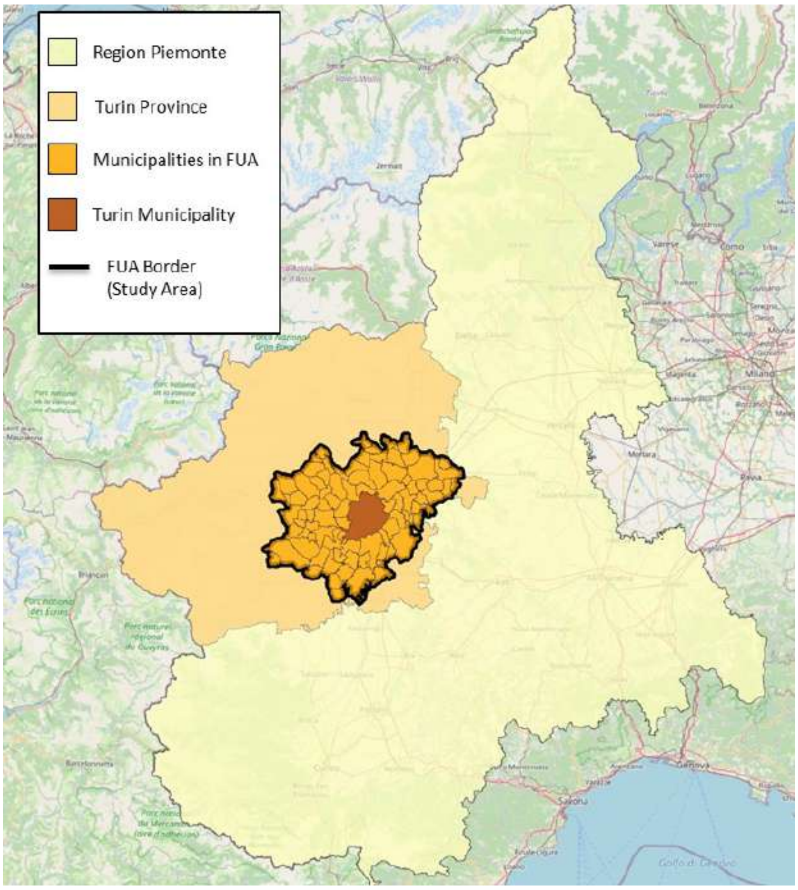

Figure 5 – The Turin Urban Functional Area, Italy

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The total number of zones in the network model is 270 (183 zone within Turin plus 87 municipalities of the FUA).

A multimodal land network model performs the assignment of both private and public transport demand, therefore including the representation of various transport modes and services. The following are considered for the application of the use case:

- Private: car, bike, moped scooters,
- Public Transport: bus, tram, metro, train,
- Sharing mobility services: car sharing, bike sharing, shared e-scooters, shared moped scooters.

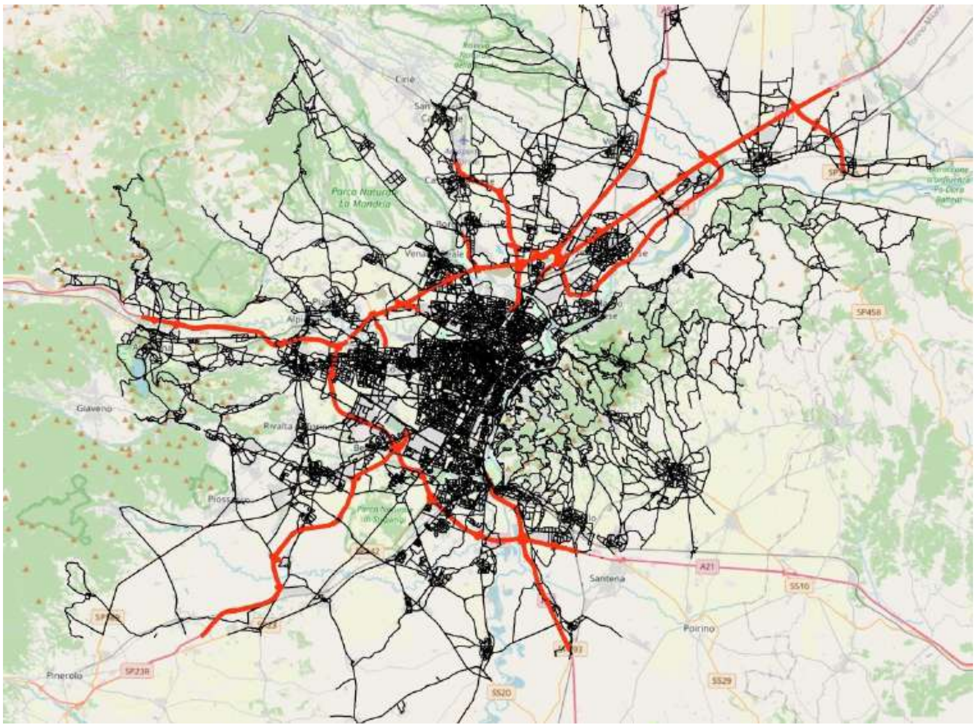

Figure 6 – The road network of the Turin FUA model in the HARMONY MS

The operational model focuses only on the assignment phase of transport demand by mode, since the mode choice process within the HARMONY MS is performed by the tactical passenger simulator, with an agent-based model providing the output to the network model in terms of matrices by mode. The matrices are disaggregated for two time periods - morning peak hour (8:00-9:00) and off-peak hour (e.g., 11:00-12:00) – and four different purposes - commuting, study, other and return home.

4.3 Overview of the TRUST model for passenger

As explained in Section 3, the TRansport eUropean Simulation Tool (TRUST) is a European scale transport model developed by TRT which simulates for passenger the demand on the following transport network: road, rail and air. TRUST covers the entire European Union and its neighbouring countries at the NUTS3 level of detail (ca. 1’600 zones) for passenger and freight demand (see also Section 3.2 and Annex 1 for more information.

. Concerning road passengers, demand is segmented in 124 groups, classified by origin country and trip purposes, namely: short commuting trips, short trips non commuting and long-distance trips. Short trips are always regarded as interzonal trips and are not represented at the scale of the model.

Rail passenger demand is segmented in regional passengers', Intercity train passengers' and High-Speed passengers' demand. The Air-transport mode is used only for the mode choice process. There is no air network in TRUST, but only Time and Costs skim matrices that are used to build utility functions for the logit algorithm (performing the mode choice). Thus, air demand share is calculated but not assigned. The Bus mode is represented in a very simplified way, with the support of exogenous dataset and sources.

The TRUST scenario at the year 2030 (used also for passenger demand) includes the assumption that the projects of the core network are completed by 2030 for road, rail and IWW[7] (under Regulation (EU) No 1315/2013).

4.4 Description of the interaction and scenarios

As mentioned above, the modelling application within the HARMONY MS developed for Turin and use for testing the linkage with large-scale models includes only the operational level (network model) due to the current availability of modelling components. As a further step, a linkage involving also the tactical level (the agent based model under development for Turin) could be foreseen.

The use case testing the linkage with the TRUST network model is designed to use exogenous demand related to passenger transport by mode and focusing on the infrastructure and service connecting the Turin airport. The interaction between the two models – although in the form of data exchange – requires some preliminary work to be performed. In particular, challenges related to the zoning system, the temporal scale and demand segmentation have been addressed.

First of all, the zoning system of TRUST and demand matrices had to be adapted to be consistent with the Turin model zoning system. In this sense, some external zones have been created in the Turin model, then the TRUST demand has been aggregated accordingly (as shown in the figure below).

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[7] https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

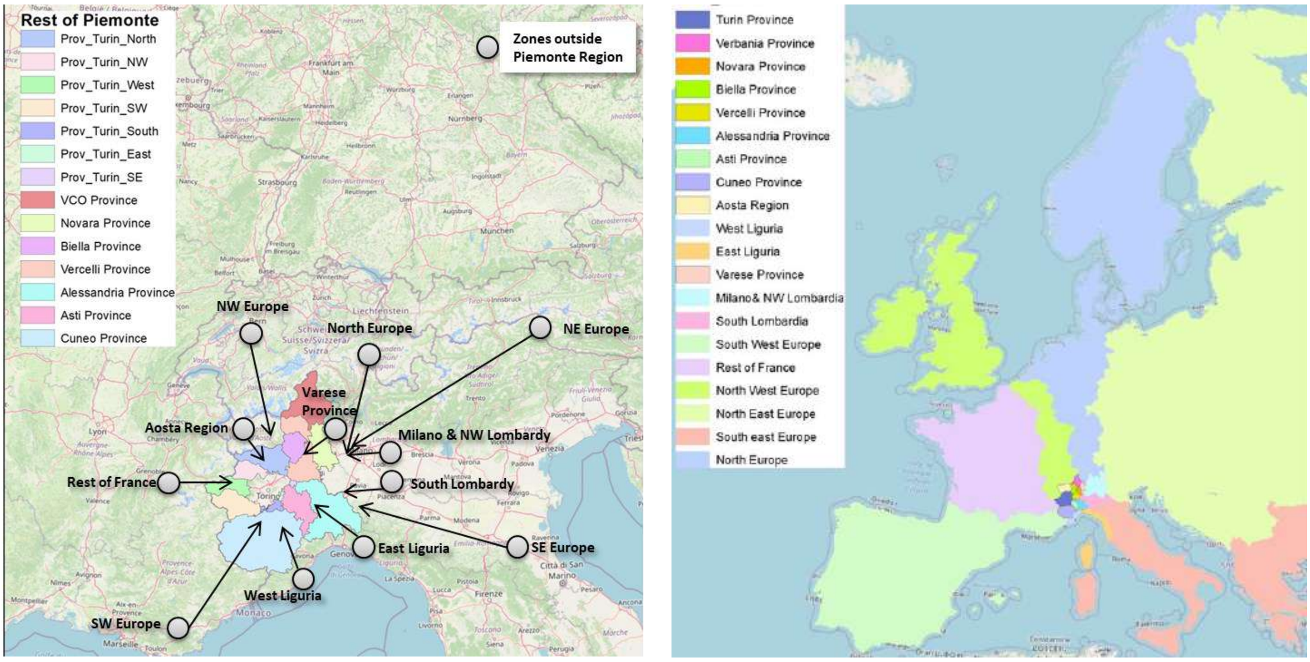

Figure 7 – External zones of the Turin network model in the HARMONY MS

Nevertheless, the zoning system of the Turin model is more detailed than the TRUST model for the metropolitan area of the FUA: in fact, it correspond to a single zone (NUTS3). Therefore, road, rail and air demand from TRUST has been distributed within the Turin zoning system using the popualtion by zone as proxy variable.

Furthermore, TRUST passenger demand is expressed in terms of daily trips, while the Turin network model assignement is performed for morning peak and off-peak hours. Therefore, the daily demand has been distributed among the hours of the day under the hypothesis that most of the long distance demand take place outside the peak-hour.

In terms of demand segmentation, the long-distance demand of the TRUST model has been added to the demand segment of the Turin model defined as “other purposes” (i.e., other then Commuting, Study, Home).

As a result, the daily long distance demand of the TRUST model added to the Turin model at the base year 2030 is shown in the following table and corresponds to about 1.5% of the passenger demand in the FUA of Turin.

Table 3 – Daily long-distance passenger demand by mode in Turin at 2030 (TRUST model)

Mode	Passengers/day
Car	26,000
Air	7,000
Rail	5,000
Total	38,000

A preliminary test has been done to check the effects of adding the long distance demand to the network model of the Turin FUA.

Then, demand matrices by mode at 2030 including the long distance trips have been assigned in the Use Case 1 (named below as Reference Scenario) and in a test scenario derived from Use Case 1, where the new rail connection to the airport is supposed not to be completed (Alternative Scenario).

The use case 1 is designed considering the following infrastructures:

- the urban and suburban public transport network, including:
  - Extension of the Metro Line n. 1 o West towards Rivoli-Cascine Vica
  - The new Metro Line n. 2, from Rebaudengo Fossata / Pescarito to Orbassano (North to South-West of Turin)
  - Extension of Tram line 3 to piazzale Toselli
  - Extension of Tram line 4 to Stupinigi
  - Extension of Tram line 15 to Grugliasco
- the Metropolitan Railway System (SFM), including:
  - The new SFM3 line, which will connect the Porta Susa railway station with the Caselle International Airport Sandro Pertini.
  - The SFM5 line, which will connect the Torino Stura railway station to the City of Orbassano. Three new railway stations will be built in this line: Orbassano Ospedale S.Luigi, Grugliasco – Le GRU and Torino-San Paolo.

Furthermore, the following land-use developments and relocation (related to offices, university, hospital) are considered:

- Torino, Lingotto area:
    - offices (Regional administration headquarter),
    - hospital (Città della Salute)
    - health research area, university (Città della Salute)
- Grugliasco: university extension
- Moncalieri e Chieri: closing hospitals
- Trofarello: new hospital

The following figure shows the rail line from the city centre to the Caselle airport that is suppressed in the Alternative scenario.

Figure 8 – The new SFM3 line connecting Porta Susa railway station with the Caselle International Airport in Turin

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4.5 Results

The total matrices (including long distance demand) have been assigned in the Reference and Alternative scenario. For the reference scenario, since the network model's run have been done using the model as stand-alone application without the connection with the mode choice model (agent based), the distribution of trips by mode to/from the airport is based on exogenous assumptions building on available data. For the same reason, when simulating the Alternative Scenario, the mode shift for these trips from rail mode to the other modes has been defined on the basis of elasticity parameters. The following tables summarise the comparison of results in terms of passenger-km by mode.

Table 4 – Comparison of passenger-km by mode in FUA of Turin at 2030 (linkage with TRUST model)

Mode	Reference Scenario	Alternative Scenario	% Variation
Car	19,954,335	19,968,750	0.1%
Bus	3,212,904	3,219,310	0.2%
Rail	1,500,265	1,445,657	-3.6%
Total	24,667,504	24,633,717	-0.1%

Table 5 – Comparison of passenger-km by mode within the city of Turin at 2030 (linkage with TRUST model)

Mode	Reference Scenario	Alternative Scenario	% Variation
Car	9,052,533	9,040,457	-0.1%
Bus	2,522,073	2,518,019	-0.2%
Rail	653,991	684,967	4.7%
Total	12,228,597	12,243,444	0.1%

Beside the result of the scenario' comparison, it can be concluded that also the passenger model developed for Turin allows the linkage with a large-scale model as the TRUST model. Again, data preparations and specific assumptions are needed to address the challenges of linking different models, related to the nature of the models themself. Nevertheless, the linkage is worth to be developed especially for evaluating specific scenarios involving long-distance demand.

5. Conclusions

The results of the analysis and of the two use cases implemented for freight and passengers demand show that the potential linkage and flexibility of the HARMONY MS with respect to different sources of input data. For this purpose, however, data preparations and specific assumptions are needed to address the challenges of linking different models, such as the zoning system, demand segmentation, temporal scale, etc.

Nevertheless, the potential integration of large scale and metropolitan models is especially useful for exploring scenarios involving long distance demand or to analyse mobility in metropolitan areas where external or crossing transport demand plays a relevant role.

Annex 1 – The TRUST network model

TRUST (TRansport eUropean Simulation Tool) is a European scale transport network model developed and maintained by TRT and simulating road, rail, inland waterways and maritime transport activity.

TRUST covers the whole Europe and its neighbouring countries and it allows for the assignment of passenger and freight origin-destination matrices at NUTS3 level of detail (about 1600 zones) on the multimodal transport network. Based on Eurostat data, national statistics and ETISPLUS database (CORDIS RCN : 92896), TRUST is calibrated to reproduce tonnes-km and passengers-km by country consistent to the statistics reported in the DG MOVE Transport in Figures pocketbook.

TRUST can be used in the context of impact assessments and for supporting policy formulation and evaluation. It is particularly suitable for modelling road charging schemes for cars and heavy goods vehicles as well as policies in the field of infrastructure (e.g., completion of the core and comprehensive Trans-European Transport (TEN-T) network). The model is currently used in the DG MOVE Framework Contract regarding the elaboration of long-term policy scenarios and variants for the transport system of all 27 Member States of the European Union with the time horizon of 2050. Coupled with the ASTRA strategic model[8], TRUST has been used for many impact assessment studies on behalf of DG MOVE (e.g. The impact of TEN-T completion on growth, jobs and the environment, Support Study for the Impact Assessment Accompanying the Revision of the Eurovignette Directive (1999/62/EC), Study on the Deployment of C-ITS in Europe, Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities).

Further information on TRUST is available on http://www.trt.it/en/tools/trust/

Details on TRUST structure and approach

TRUST is a transport network model for the assignment of Origin-Destination matrices at the NUTS3 level of detail for passenger and freight demand on the multimodal transport network of Europe. Road rail, inland waterways and maritime transport modes are covered in separate modules, each with its own matrices, that are then assigned simultaneously on the multimodal transport network. The current version of the TRUST model does not deal with modal split and its main output is the load on road network links in terms of vehicles per day and on non-road links in terms of either passengers or tonnes per day.

TRUST is built in PTV-VISUM software environment. The assignment algorithm used is Equilibrium Assignment which distributes demand for each origin/destination pair among available alternative routes, according to Wardrop first principle. This principle assumes that each traveller is identical, non-cooperative and rational in selecting the shortest route, and knows the exact travel time he/she will encounter. If all travellers select routes according to this principle the road network will be at equilibrium, such that no one can reduce their travel times by unilaterally choosing another route of the same OD pair. This principle has been extended to consider generalised travel cost instead of travel time, where generalised travel cost can include the monetary cost of in-vehicle travel time, tolls, parking charges and fuel consumption costs. The impedance function is defined in terms of generalised time from an origin O to a destination D. Travel costs are defined separately by link types using combinations of fixed, time-dependent and distance-dependent parameters. Travel time is estimated endogenously by the model as result of the assignment. Speed-flow functions are used to model the impact of traffic on free-flow speeds, given links capacity. The model iterates until a pre-defined convergence criterion for equilibrium is reached.

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[8] ASTRA (ASsessment of TRAnsport Strategies) is an integrated assessment system dynamic model at European scale, applied for strategic policy assessment in the transport and energy field (http://www.astra-model.eu/)

TRUST road transport module

The TRUST road module deals with the assignment of road transport O-D matrices for both passenger (cars) and freight (trucks>3.5t). The road network includes all relevant links between the NUTS3 regions, i.e. motorways, primary roads as well as roads of regional and sub-regional interest. Also ferry connections (Ro-Ro services) between European regions and between European regions and North Africa are explicitly modelled with their travel time and fare.

Road transport demand is modelled in TRUST by means of origin/destination matrices between NUTS3 zones. Intra-NUTS3 demand is not part of the matrices as it is not assigned to the network, but implicitly considered as pre-load on network links. For some non-EU countries (e.g. Russia or Ukraine) domestic demand is not part of the matrices. The passenger matrix includes car trips (coach trips are not modelled) and is segmented into three groups:

- Short distance (< 100 km) commuting
- Short distance (< 100 km) non-commuting
- Long distance (> 100 km)

The freight matrix includes vehicles above 3.5 tonnes between NUTS3 zones and is segmented into the following demand groups:

- Domestic Short distance (<=50 km)
- Domestic average distance (50 –150 km)
- Domestic Long distance (>= 150 km)
- International.

This segmentation allows us to apply dedicated parameters (e.g. considering that short distance domestic transport usually is made of lighter trucks than long distance international transport) and to measure the contribution of the typical vehicles of each segment to link loads. In addition, each demand group is further divided by considering the origin country (the are 242 flows in total) as this allows for the differentiation of fuel costs for the vehicles. Base year (2017) matrices are derived from those estimated in the ETISplus project with further revisions to match Eurostat statistics on road traffic. For forecasting purposes, future matrices are estimated exogenously by applying demand growth rates taken from available sources (e.g. EU Energy and transport trend, ASTRA model, etc.).

Speed-flow functions in TRUST are used to simulate congestion on road links. Since the model assigns daily matrices the speed-flow curves implemented as attributes of the road links are adjusted to take into account that congestion is more hardly recognisable if demand and supply are compared on a 24 hour basis. Speed-flow functions depends on link type, speed and flow/capacity ratio.

Fuel consumption and emissions factors for road modes build on COPERT IV functions but with a relevant modification. Basically, the convex form of the COPERT function has been modified to consider that in real traffic conditions average speeds (the assignment model provides average speeds) are most likely the result of repeated stop-and-go. An average speed of e.g. 70 km/h on motorways means that there is more traffic than when average speed is 110 km/h so one should expect more fuel consumption rather than less fuel consumption as implied by original COPERT functions. Since COPERT functions are different by vehicle type, an average fleet composition is considered to derive the parameters used in TRUST. When the model is run for forecasting purposes for future years, the emission factors are updated considering projections regarding the evolution of fleet in the selected year.

TRUST rail transport module

TRUST rail module does not consider capacity restrictions and follows an AON (All or Nothing) assignment of origin/destination matrices on the minimum path available on the network. This means that the transport volume on the rail links are computed irrespective of the availability of rail services and of transport chains.

The rail network includes different link types according to technical elements (number of tracks, electrification, maximum speed allowed, etc.) as drawn from the ETISplus database. Links dedicated to some type of traffic (e.g. high-speed service or freight trains) are distinguished as well as links where some types of train are not allowed. The rail network is linked to the road network as intermodal transport is modelled. Rail supply includes intermodal terminals where loads are transferred between road and rail. There are 917 intermodal terminals across the EU countries. In case of passenger transport the interchange links between local/intercity services and high-speed services and transfer between car feeder and local/intercity services are modelled as well.

Rail demand is segmented according to types of traffic which correspond to different train types in terms of occupancy of rail capacity. For passenger demand, three segments based on train type are used:

- Regional Trains
- Intercity Trains
- High Speed Trains (or similar, like the German ICE trains)

Two different types of freight trains are considered:

- intermodal trains,
- conventional trains (conventional block trains or single wagon load trains), which is further split into three groups:
    - conventional trains 700 tonnes
    - conventional train 1200 tonnes
    - conventional train 2900 tonnes.

TRUST maritime transport module

The maritime network includes several ports throughout Europe. Fictitious maritime links provide sea routes to link ports and allows the model to compute travel distances of maritime connections.

Maritime ports are classified into three categories: bulk ports, container ports and general cargo ports. Most of the ports belong to more than one category but some ports have only one or two specialisations; ports can host only demand for those freight segments (e.g. if one port is classified as a bulk port only, maritime routes for general cargo and container demand cannot go through that port). For zones without ports there is no direct access to ship mode, which in turn can be accessed through feeder modes (truck, rail or inland waterway according to existing infrastructures). As a consequence, rail, road and inland waterway networks are also used in the TRUST maritime model because trains, trucks and barges are used as feeder modes to connect inland zones with ports and allow a full path between the origin and the final destination of freight shipment.

Maritime demand consists of origin/destination matrices segmented according to the three categories of bulk, container and general cargo. Matrices are in terms of tonnes per year and each segment of demand has its matrix that is assigned independently to the network.

TRUST inland waterway transport module

TRUST inland waterways (IWW) network includes all the relevant canals among all the NUTS3 regions covered by the spatial area of the model. The network includes 70 main inland ports across Europe selected on the basis of the quantities of goods handled or on their strategic role along the international routes. Each IWW network link has specific features in term of free-flow speed. Specific flags are used to identify links belonging to the Core TEN-T Network, to each TEN-T Corridor and to the comprehensive network. Therefore, results can be provided for these subsets of the network. Demand Origin-Destination matrices are segmented according to two main freight categories: container and non-container. Matrices are based on ETISplus project and further refined on Eurostat statistics.

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