PILOT ACTIVITY CONCEPT & LAUNCH REPORT

D.T2.2.3 PILOT #5

Work paper

Version 2.0

09.2020

1) Introduction

In this section, please briefly describe the need underlining the development of the pilot action: the challenges it tackles, how it was developed and why it fits the REIF project.

The Pilot Action aims at updating the regional freight transport model of Regione Emilia-Romagna expanding its modelling capabilities in order to estimate the effects of the solution of bottlenecks or the introduction of new transport flows.

The main challenges related to data collection and implementation of the new modelling capabilities. Please refer to section 3 for a more detailed description of the data required.

2) Pilot action description

PP involved	**Fondazione ITL (PP8), Regione Emilia-Romagna (PP10)**
Timescale (start/end date)	June 2020 – April 2021
Main actors/stakeholders involved	Main actors: Emilia-Romagna Region, ITL Foundation Stakeholders involved: member of cluster ERIC (see deliverable D.T2.2.4)
Pilot action launch *Please describe when and how the pilot action was launched*	The Pilot Action was launched in June 2020 with the start of the activity focussed on the updating of regional model. The first phases of pilot action (Bottleneck analysis and simulation) will take place in september/october.
Description of the activities to be done within the pilot action	• Updating and upgrading of the regional freight transport model; • Analysis of bottlenecks; • Estimate of potential demand for rail services.
Expected results	• Updated freight transport model; • Estimate of potential rail traffic
Potential risks of the successful outcome of the pilot action and the adopted strategies to overcome them	• Lack of likelihood of some hypothesis used during the input phase of scenario modelling.

3) Conclusion

See chapters in next pages.

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1. Introduction

This report outlines the methodology and the first results achieved by Pilot Action 5, aimed at updating the regional freight traffic model to assess the impacts of overcoming infrastructure and functional bottlenecks, which can increase the attractiveness and connectivity of the regional freight rail system with the trans-European transport network, and its priority corridors.

The report specifies, in particular:

1) the methodology used to update the model (Chapter 2)
2) the principles to build scenarios, aimed at overcoming bottlenecks (Chapter 3)

In particular, it should first be emphasised that activities to update the regional freight model are structured on two parallel levels, complementary to each other:

- ✓ on the one hand, the review and development of algorithms for generation/attraction, distribution and modal split of flows, according to the most recent European-level disciplinary advances[1];
- ✓ on the other hand, the integration of the (intermodal) supply modules, conducted using the large databases already present in the multi-modal and multi-scale model of the Italian transport system, i-TraM, developed by META srl with the Laboratory of Transport Policy (TRASPOL) of the Milan Polytechnic, in turn interfaced with the European model TransTools 3 (fig.1.1.1)[2].

[1] See: Ben-Akiva M.E., Meersman H., Van de Voorde E. (eds.) [2013] *Freight Transport Modelling*; Emerald; de Jong G., Tavasszy L.A. [2017] *Modelling Freight Transport*; Elsevier; Tavasszy L.A., de Bok M., Alimoradi Z., Rezaei J. [2019] "Logistics Decisions in Descriptive Freight Transportation Models: A Review"; Journal of Supply Chain Management Science, vol.1, n.1.

[2] For further deepenings, . Ben-Akiva e de Jong [2013], Cascetta ed al. [2013], Ivanova [2014], Meersman e Van de Voorde [2013].

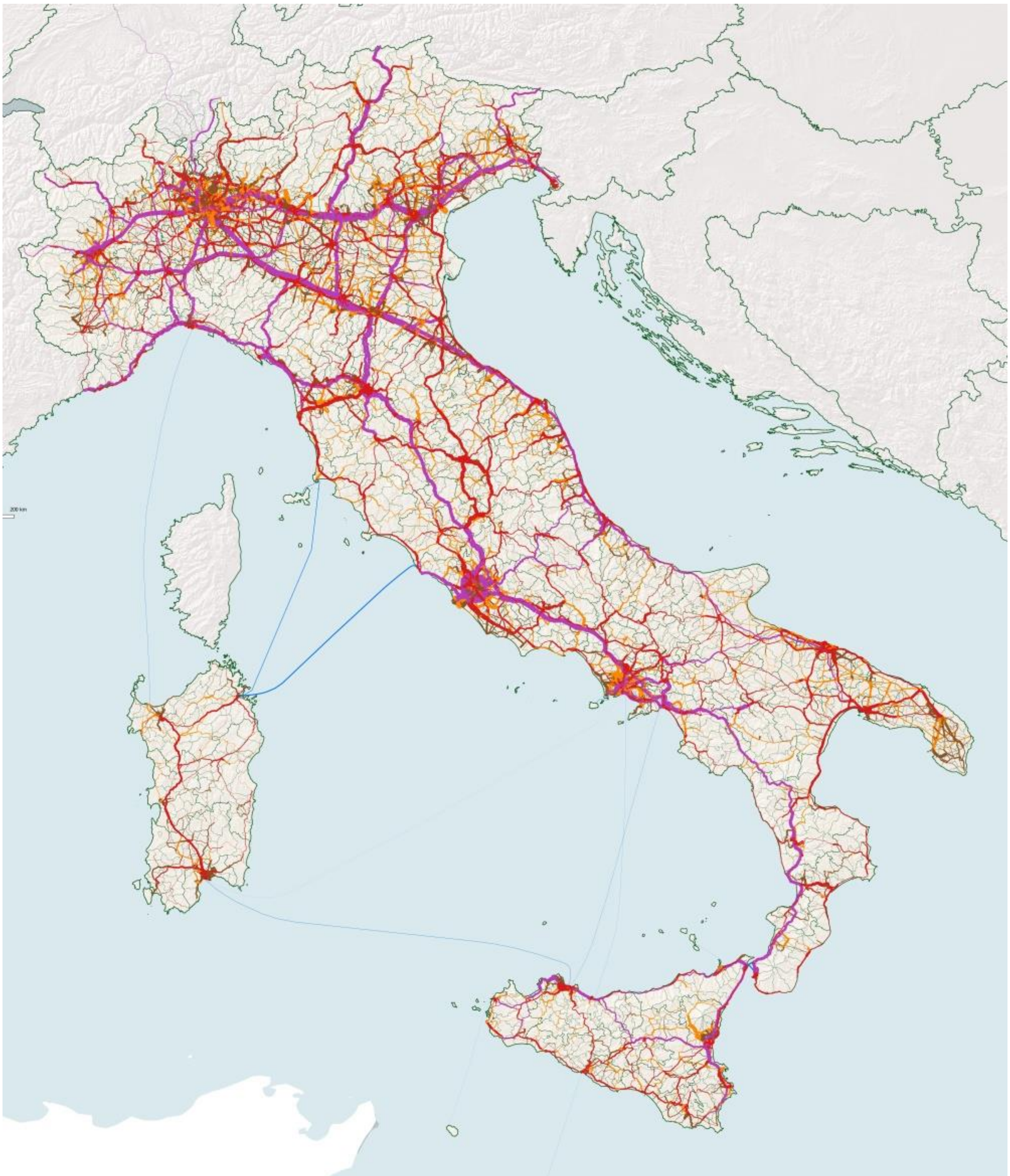


Fig.1.1.1. i-Tram model – national road traffic flows (light-heavy)

2. Updating of the regional freight transport model

2.1. Overview

The update of the regional freight model, which has been implemented according to the latest methodological innovations, affects three aspects of general interest:

1) the **demand estimation procedure**, which is reported to a fully multimodal framework, interfaced with the European matrix ETIS-Transtools, articulated by commodity categories and appropriately referred to an "end" description of the generation/attraction locations of goods flows within the territory of the Emilia-Romagna region;
2) the **process of describing the supply**, which is integrated through a schematization of the logistics chains belonging to the platforms present in the regional territory, in terms of both single-mode (road-road), and intermodal (road-rail, road-sea shipping, railway-sea shipping);
3) the **procedure for estimating the modal split of flows**, which is developed according to the recent algorithms of joint transport mode / shipment size choice, to take into account, in addition to the transport costs, also the inventory costs, combined in a Total Logistical Cost (TLC).

These aspects are best detailed in the chapter's follow-up. In particular, paragraph 2.2 is devoted to the estimate of demand, while paragraph 2.3 deals with the description of the supply, and paragraph 2.4 illustrates the modal split estimation. Taken together, these three innovations make it possible to estimate the O/D freight matrices, associated to the zoning of the regional traffic model, articulated by commodity category and by mode of transport (road, railway, sea shipping).

2.2. Demand estimation

2.2.1. Freight generation and Freight transport generation

The freight demand model is based on the well-established distinction between Freight Generation (FG) models and Freight Traffic Generation (FTG)[3] models. As is well known, the former refers essentially to the flows of goods, expressed in tons, while the latter relates rather to vehicle movements, expressed in vehicles.

This theoretical distinction allows to separate the processing phase of the multi-modal matrix of freight flows, from the estimation of matrices concerning vehicular movements related to the different modes of transport. The two phases differ both in the relationship with the territorial and traffic descriptors, and in the different meaning for the single infrastructure networks. Among them, the model includes some refinements in the description of the transport supply, aimed at improving the modelling of all-road and intermodal third-party services.

[3] See particularly: Holguin-Veras J., Jaller M., Destro L., Ban X.J., Lawson C., Levinson H.S. [2012] "Freight generation, freight trip generation, and the perils of using constant trip rates"; Association for European Transport and Contributors; 22 pp.

2.2.2. Generation / attraction of freight flows

The estimation of freight demand, expressed in terms of the multimodal O/D matrix *(Freight Generation* phase) uses as a starting point the ETISplus matrix, developed under the European TransTools project, aimed at simulating the operation of continental-scale freight transport (figure.2.2.1).

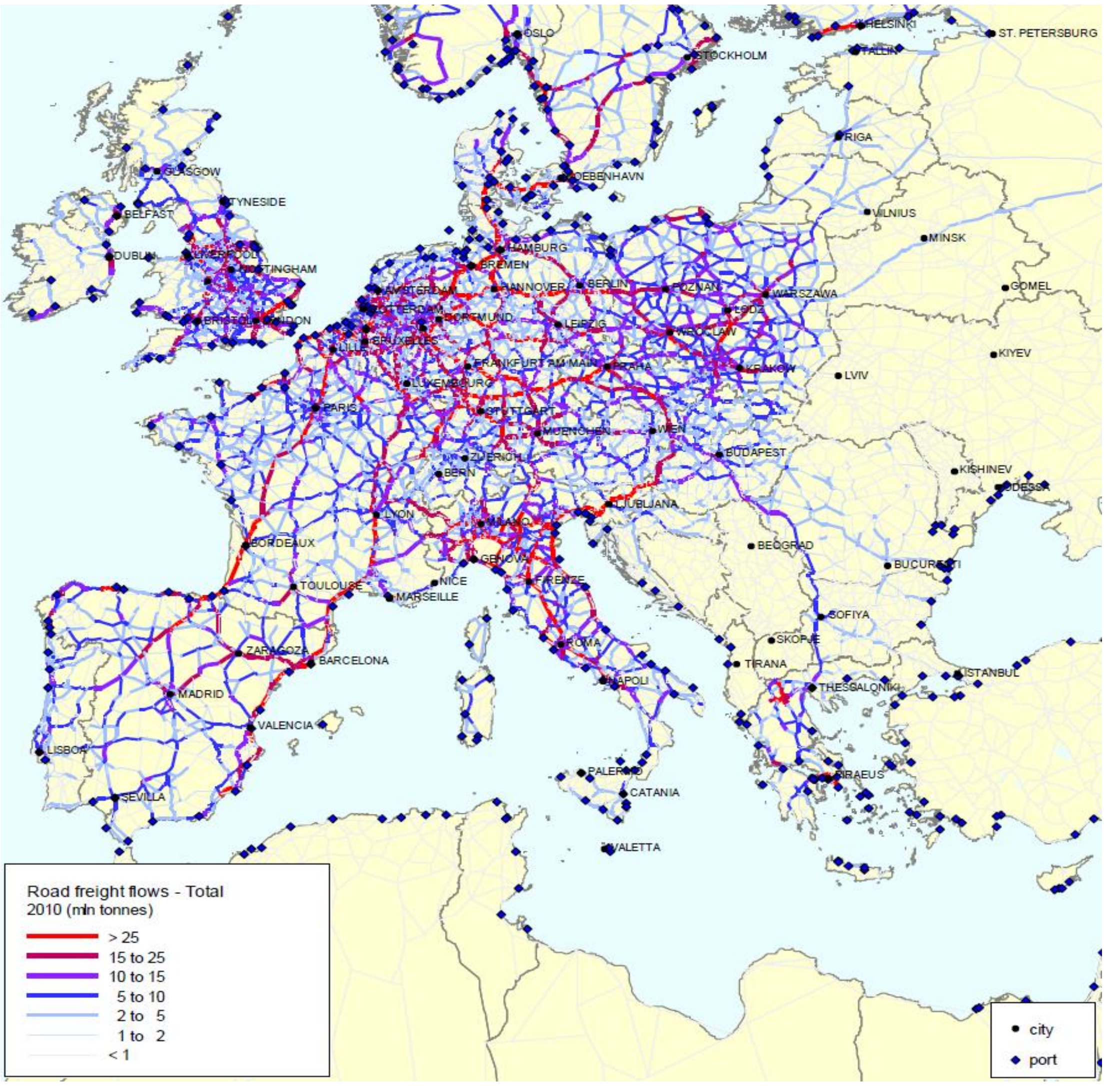


Fig.2.2.1. Transtools model: rail and road networks

This matrix returns the flows of goods, between transport zones corresponding to the NUTS3 areas, split into five modes of transport (road, rail, sea shipping, inland waterways, air) and in 10/18 product categories, depending on whether the NST/R 1967 classification or the NST/R 2007 classification is used (tab.2.2.1 and 2.2.2).

NST/R 1967 CLASSIFICATION

It is still the most frequently used classification, based on 10 categories, one of which (number 9) is extremely wide and indefinite.

The reference to this classification remains necessary both for statistical continuity and because it represents the highest degree of detail available for some modes of transport (in particular, railway and sea shipping).

CLASSIFICAZIONE MERCEOLOGICA SECONDO LA NOMENCLATURA STATISTICA DEL TRAFFICO (NST/R) 1967 *in vigore fino al 2008*	
0	PRODOTTI AGRICOLI E ANIMALI VIVI 01 - cereali; 02 - patate; 03 - legumi freschi e frutti freschi; 04 - materie tessili naturali e sintetiche; 05 - legno e sughero; 06 - barbabietole da zucchero; 08 - animali vivi; 09 - animali o vegetali
1	DERRATE ALIMENTARI E FORAGGERE 11 - zuccheri; 12 - bevande; 13 - droghe e spezie; 14 - derrate alimentari non durevoli; 16 - derrate alimentari durevoli e luppolo; 17 - alimenti per animali e cascami alimentari; 18 - oleaginosi
2	COMBUSTIBILI MINERALI SOLIDI 21 - carbon fossile; 22 - lignite; 23 - coke; 24 - torba
3	PRODOTTI PETROLIFERI 31 - petrolio greggio; 32 - benzina; 33 - idrocarburi energetici; 34 - derivati non energetici; 35 - cherosene; 36 - gasoli, olii combustibili leggeri; 37 - olii combustibili pesanti
4	MINERALI E CASCAMI VARI PER LA METALLURGIA 41 - minerali di ferro; 44 - minerali di manganese e concentrati; 45 - altri minerali e cascami non ferrosi; 46 -cascami, scorie e piriti di ferro; 47 - altoforno
5	PRODOTTI METALLURGICI 50 - ferro/leghe; 51 - ghisa ed acciaio grezzi; 52 - semilavorati siderurgici laminati; 53 - laminati, profilati a caldo; 54 lamiere d'acciaio; 55 - tubi, getti e pezzi forgiati; 56 - metalli non ferrosi; 57 – altri semilavorati siderurgici; 58 - laminati e profilati a freddo, filo; 59 - altre lamiere e bande d'acciaio
6	MINERALI GREGGI O MANUFATTI E MATERIALI DA COSTRUZIONE 61 - sabbie, ghiaie, argilla e scorie: 62 - sale, piriti, zolfo; 63 - pietre, terre e minerali connessi; 64 - cementi, calce; 65 - gesso; 69 - materiali da costruzione manifatturati
7	CONCIMI 71 - minerali; 72 – manifatturati
8	PRODOTTI CHIMICI 81 - prodotti chimici di base; 82 - allumina; 83 - prodotti carbochimici; 84 - cellulosa ed avanzi; 89 - materie chimiche
9	MACCHINE E VEICOLI, OGGETTI MANUFATTURATI E MERCI DIVERSE 91 - macchine e materiale da trasporto; 92 - trattori, macchine, attrezzature agricole; 93 - altre macchine, motori e parti; 94 - articoli metallici; 95 – vetro, vetreria, prodotti della ceramica; 96 - cuoio, tessili, abbigliamento; 97 - articoli manifatturati diversi; 98 - armi e munizioni da guerra; 99 – transazioni speciali

Tab.2.2.1. NST/R 1967 commodity classification

NST/R 2007 CLASSIFICATION

Based on 18 categories (of which only 14 actually can be traced back to individual goods) it is certainly more adhering to the current freight flows framework, but it is not available for all means of transport.

CLASSIFICAZIONE MERCEOLOGICA SECONDO LA NOMENCLATURA STATISTICA DEL TRAFFICO (NST) 2007 *in vigore dal 2009*	
01	PRODOTTI DELL'AGRICOLTURA, DELLA CACCIA E DELLA SILVICOLTURA; PESCI ED ALTRI PRODOTTI DELLA PESCA 01A - Altre materie prime di origine animale; 01B – Pesci ed altri prodotti della pesca; 011 – Cereali; 012 – Patate; 013 – Barbabietole da zucchero; 014 – Frutta fresca ed altri ortaggi freschi; 015 – Prodotti della silvicoltura; 016 – Piante vive e fiori; 017 – Altre materie di origine vegetale; 018 – Animali vivi; 019 – Latte vaccino crudo e latte crudo di pecora e di capra
02	CARBONI FOSSILI E LIGNITI; PETROLIO GREGGIO E GAS NATURALE 021 – Carboni fossili e ligniti; 022 – Petrolio greggio; 023 – Gas naturale
03	MINERALI METALLIFERI ED ALTRI PRODOTTI DELLE MINIERE E DELLE CAVE; TORBA, URANIO E TORIO 031- Minerali di ferro; 032 – Minerali di metalli non ferrosi (esclusi i minerali di uranio e di torio); 033 – Minerali per l'industria chimica e concimi minerali (naturali); 034 – Sale; 035 – Pietre, ghiaia, sabbia, argilla, torba e altri prodotti delle miniere e delle cave n.c.a.; 036 – Minerali di uranio e di torio
04	PRODOTTI ALIMENTARI, BEVANDE E TABACCHI 041 – Carni, pelli gregge e prodotti a base di carne; 042 – Pesci trasformati e conservati e prodotti a base di pesce; 043 – Preparazioni e conserve di frutta e di verdura; 044 – Oli e grassi vegetali e animali; 045 – Prodotti lattiero-caseari e gelati; 046 – Prodotti della macinazione, amidi e fecole e alimenti per animali; 047 – Bevande; 048 – Altri prodotti alimentari n.c.a. e prodotti a base di tabacco (non trasportati tramite servizi di spedizione o raggruppati); 049 – Vari prodotti alimentari e prodotti a base di tabacco trasportati mediante servizi di spedizione o raggruppati
05	PRODOTTI DELL'INDUSTRIA TESSILE E DELL'ABBIGLIAMENTO; CUOIO E PRODOTTI IN CUOIO 051 – Tessili; 052 – Articoli di abbigliamento e pellicce; 053 – Cuoio e prodotti in cuoio
06	LEGNO E PRODOTTI IN LEGNO E SUGHERO (ESCLUSI I MOBILI); ARTICOLI DI PAGLIA E MATERIALI DA INTRECCIO; PASTA DA CARTA, CARTA E PRODOTTI DI CARTA; STAMPATI E SUPPORTI REGISTRATI 061 – Prodotti in legno e sughero (esclusi i mobili); 062 – Pasta da carta, carta e prodotti di carta; 063 – Stampati e supporti registrati
07	COKE E PRODOTTI PETROLIFERI RAFFINATI 071 – Prodotti di cokeria; mattonelle e combustibili solidi similari; 072 – Prodotti petroliferi raffinati liquidi; 073 – Prodotti petroliferi gassosi, liquefatti o compressi; 074 - Prodotti petroliferi raffinati solidi o in cera
08	PRODOTTI CHIMICI E FIBRE SINTETICHE E ARTIFICIALI; ARTICOLI IN GOMMA E IN MATERIE PLASTICHE; COMBUSTIBILI NUCLEARI 081 – Prodotti chimici minerali di base; 082 – Prodotti chimici di base organici; 083 – Concimi (esclusi i concimi naturali) e composti azotati; 084 – Materie plastiche e gomma sintetica in forme primarie; 085 – Prodotti farmaceutici e parachimici, inclusi i pesticidi e altri prodotti chimici per l'agricoltura; 086 – Articoli in gomma e materie plastiche; 087 – Combustibili nucleari
09	ALTRI PRODOTTI DELLA LAVORAZIONE DEI MINERALI NON METALLIFERI 091 – Vetro, oggetti di vetro, prodotti ceramici e in porcellana; 092 – Cemento, calce e gesso; 093 – Altri materiali da costruzione, manufatti
10	METALLI; MANUFATTI IN METALLO, ESCLUSE LE MACCHINE E GLI APPARECCHI MECCANICI 101 – Ferro, ghisa e acciaio di prima trasformazione e ferroleghe (esclusi i tubi); 102 – Metalli non ferrosi e relativi prodotti; 103 – Tubi, profilati, cavi e relative guarnizioni; 104 – Costruzioni metalliche; 105 – Caldaie, ferramenta, armi e altri manufatti in metallo
11	INFORMATICI, MACCHINE ED APPARECCHI ELETTRICI N.C.A.; APPARECCHI RADIOTELEVISIVI E APPARECCHIATURE PER LE COMUNICAZIONI; APPARECCHI MEDICALI, APPARECCHI DI PRECISIONE E STRUMENTI OTTICI; OROLOGI 111 – Macchine per l'agricoltura e la silvicoltura; 112 – Apparecchi per uso domestico n.c.a. (elettrodomestici bianchi); 113 – Macchine per ufficio, elaboratori e sistemi informatici; 114 – Macchine ed apparecchi elettrici n.c.a.; 115 – Componenti elettronici e apparecchi trasmittenti; 116 – Apparecchi riceventi per la radiodiffusione e la televisione; apparecchi per la registrazione e la riproduzione del suono o dell'immagine e prodotti connessi (elettrodomestici marroni); 117 – Apparecchi medicali, apparecchi di precisione e strumenti ottici; orologi; 118 – Altre macchine, macchine utensili e loro parti
12	MEZZI DI TRASPORTO 121 – Prodotti dell'industria automobilistica; 122 – Altri mezzi di trasporto
13	MOBILI; ALTRI MANUFATTI N.C.A. 131 – Mobili; 132 – Altri manufatti
14	MATERIE PRIME SECONDARIE; RIFIUTI URBANI E ALTRI RIFIUTI 141 – Rifiuti domestici e urbani; 142 – Altri rifiuti e materie prime secondarie
17	MERCI TRASPORTATE NELL'AMBITO DI TRASLOCHI (UFFICI E ABITAZIONI); BAGAGLI E ARTICOLI VIAGGIANTI COME BAGAGLIO ACCOMPAGNATO; AUTOVEICOLI TRASPORTATI PER RIPARAZIONE; ALTRE MERCI NON DESTINABILI ALLA VENDITA N.C.A. 171 – Traslochi di privati; 172 – Bagagli e articoli viaggianti come bagaglio accompagnato; 173 – Veicoli da riparare; 174 – Attrezzature per impianti, materiale per ponteggi; 175 – Altre merci non destinabili alla vendita n.c.a.
18	MERCI RAGGRUPPATE 180 – Merci raggruppate
19	MERCI NON INDIVIDUABILI; MERCI CHE PER UN QUALUNQUE MOTIVO NON POSSONO ESSERE INDIVIDUATE E QUINDI NON POSSONO ESSERE ATTRIBUITE AI GRUPPI 01-16 191 – Merci non individuabili in container o casse mobili; 192 – Altre merci non individuabili
99	ALTRE MERCI N.C.A. 990 – Altre merci non classificate altrove

Tab.2.2.2. NST/R 2007 commodity classification

In order to link the ETISplus matrix to the zoning used by the Emilia-Romagna region model, it is necessary to detail the spatial division of flows: this requires knowing their breakdown in terms of generation and attraction.

This step can be done using the inter-sector input-output economic scheme, already developed under the national i-TraM model, which allows the economic activities of individual industrial sectors -articulated according to the ATECO classification- to be linked with the flows of goods in and out of them, as described by the NST classification (Figure 2.2.2).

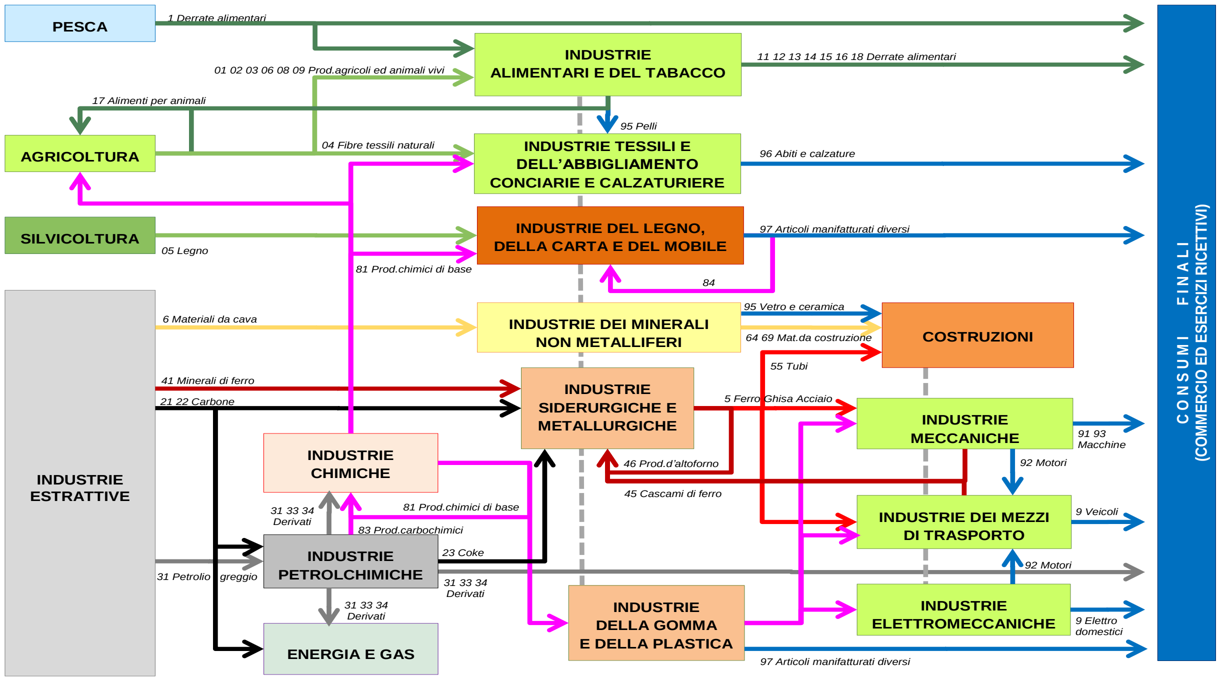


Fig.2.2.2. Inter-sector input-output economic diagram

The description of the levels of operation of local units in the individual industrial sectors is based on the number of employees, as recorded by the Industry Census and the ASIA archive and, on the other hand, on the electricity consumption monitored by Terna. The use of the two sources requires a harmonisation of the two sectoral classifications of industrial activities, similar but not identical to each other.

The estimate is developed in a first phase at the provincial level (NUTS3 for Italy) and then at the municipal/sub-communal level.

The availability of ISTAT/ASIA data makes it quite easy to reconstruct the performance of employees on a per-industry basis, at the municipal level, for the all years from 1971 to 2011 and then on an annual basis (as exemplified in The Figures 2.2.3, 2.2.4 and 2.2.5 related to the construction of transport vehicles). However, the actual estimation activities are only based on the year of the last census (2011) and that of the most recent update of the ASIA archive (2017).

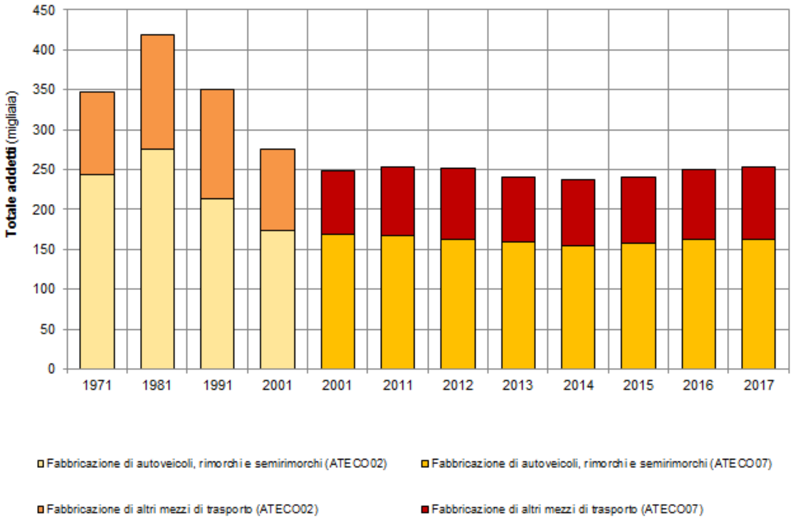


Fig.2.2.3. Construction of transport vehicles: total employees (1971-2017)

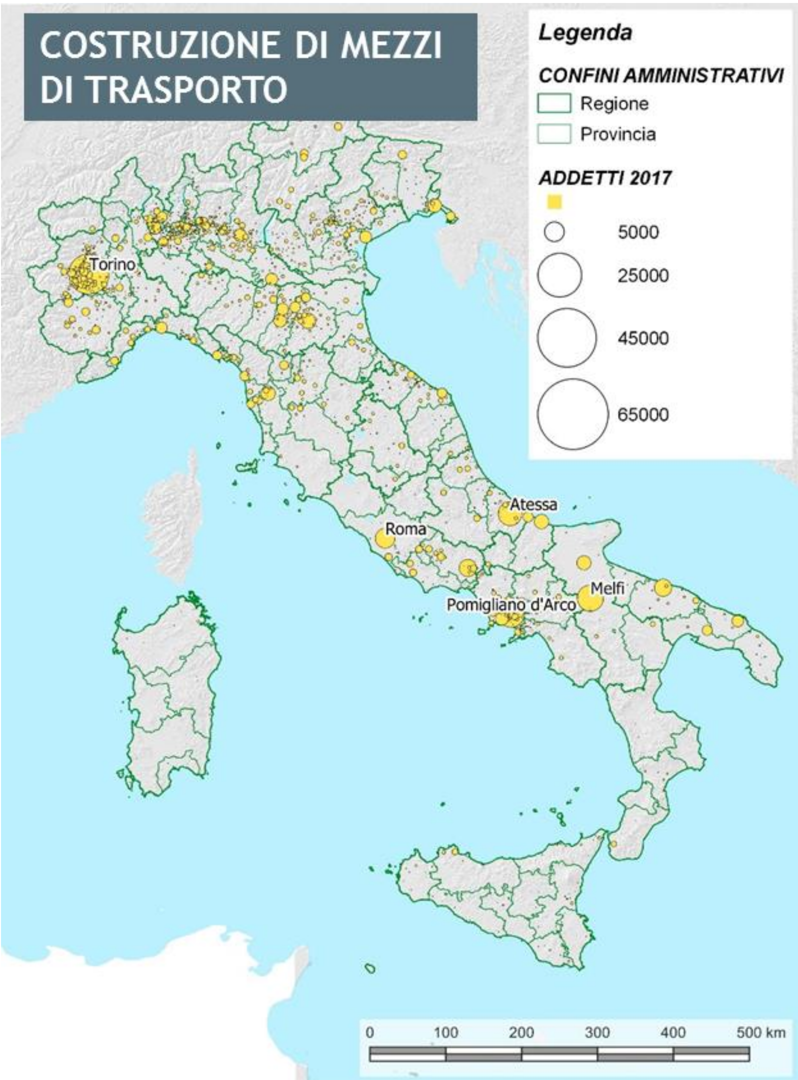


Fig.2.2.4. Construction of transport vehicles: employees per municipality – total Italy (2017)

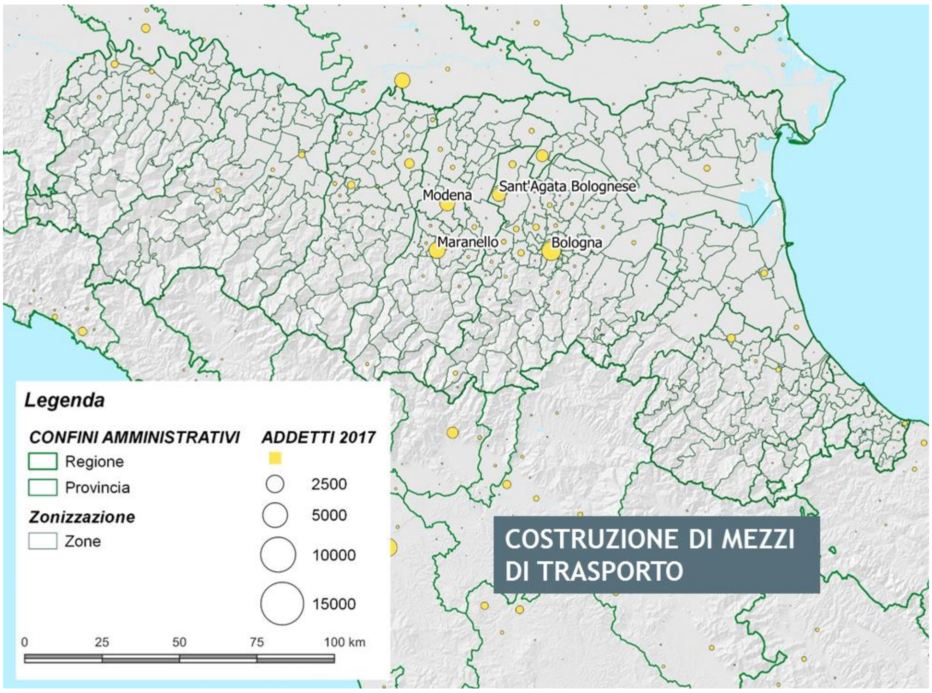


Fig.2.2.5. Construction of transport vehicles: employees by municipality– Emilia-Romagna (2017)

On the other hand, the ENEL/Terna statistics allow to reconstruct, for each sector of economic activity, the trend of electricity consumption at the provincial level for the whole period 1978-2018 (fig.2.2.6, 2.2.7).

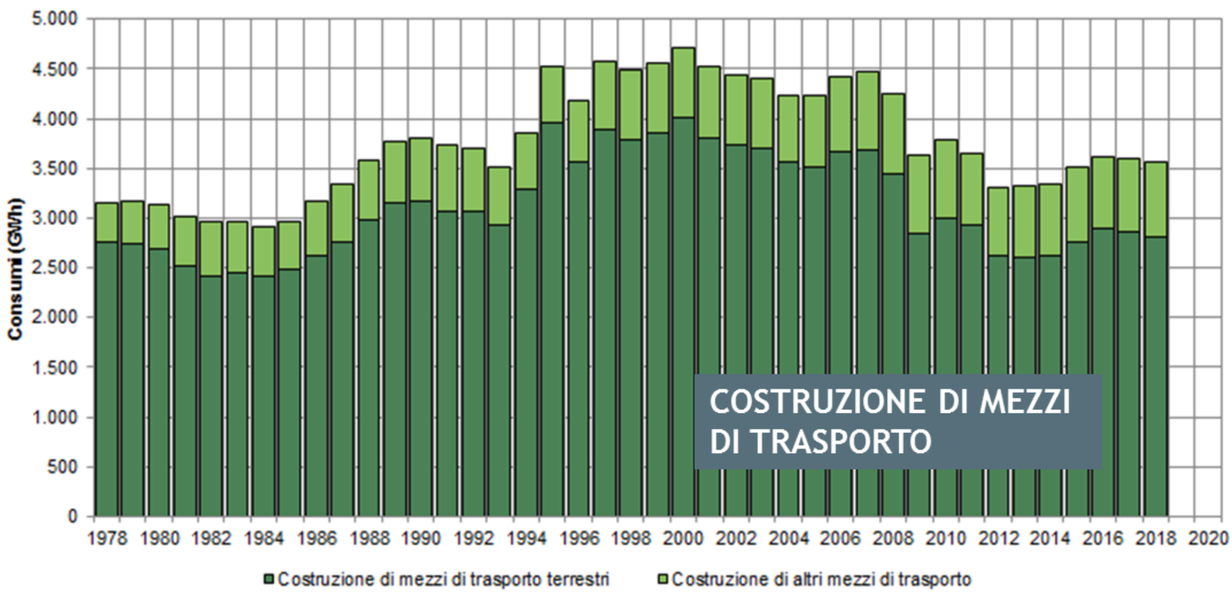


Fig.2.2.6. Construction of transport vehicles: electricity consumption – total Italy (1978-2018)

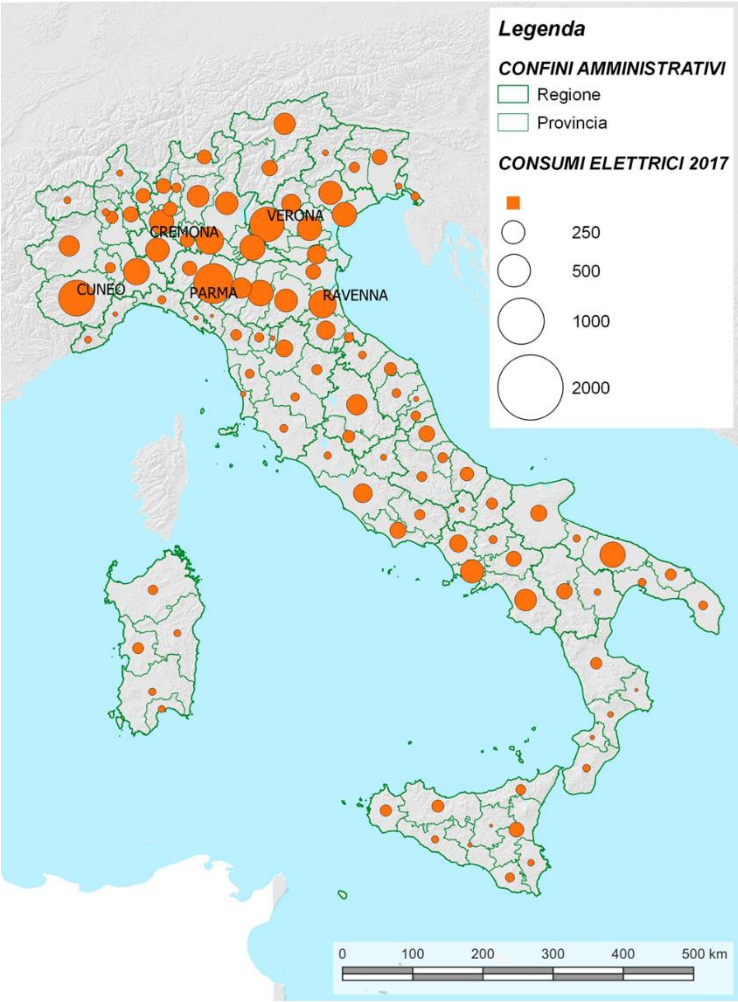


Fig.2.2.6. Construction of transport vehicles: electricity consumption by province (2017)

By comparing the performance of the workers with that of electricity consumption on a provincial scale, it is possible to reconstruct the operating performance of the individual industrial activities in relation to the workforce employed. This comparison makes it difficult to estimate the share of the workforce actually engaged in activities directly related to the production of industrial goods (operational employees), distinguishing it from the share of employees engaged in management or administrative tasks, which can also take place in local units not affected by the generation/attraction of physical flows.

The estimation procedure consists essentially of three successive steps:

1) Estimation of **per-capita consumption of non-operational employees;**
2) Estimation of **the incidence of non-operational employees by industrial sector and** province;
3) Determination, by difference, of **the operational employees,** taken as a parameter to share at the municipal level the flows of goods generated/attracted at the provincial level.

ESTIMATION OF PER-CAPITA CONSUMPTION OF NON-OPERATIONAL EMPLOYEES

Per-capita consumption of non-operational employees is determined assuming that they correspond to the average value found in the banking sector (credit and insurance). In fact, this sector, in addition to requiring only management or administrative activities (no "operational" employees) has also a good correlation between the number of employees and consumption detected on a provincial scale, both in 2011 and in 2017 (fig.2.2.7).

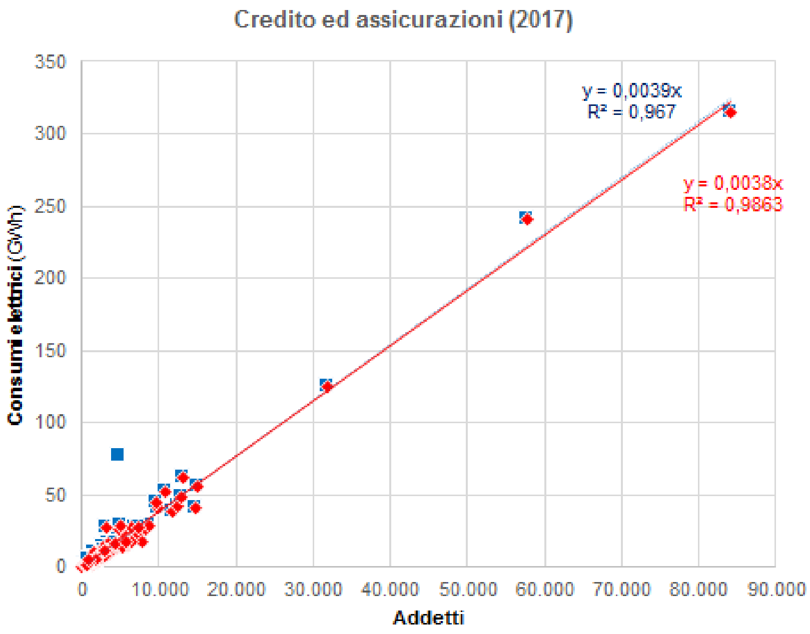


Fig.2.2.7. Electrical consumption correlation: credit and insurance(2017)

Using this correlation, it is possible to refer to the per-capita consumption of a non-operational worker(e_{nop}), employed in any industry, a value equal to 4.259 kWh in 2011 and 3.769 kWh in 2017.

ESTIMATION OF THE INCIDENCE OF OPERATIVES BY SECTOR AND PROVINCE

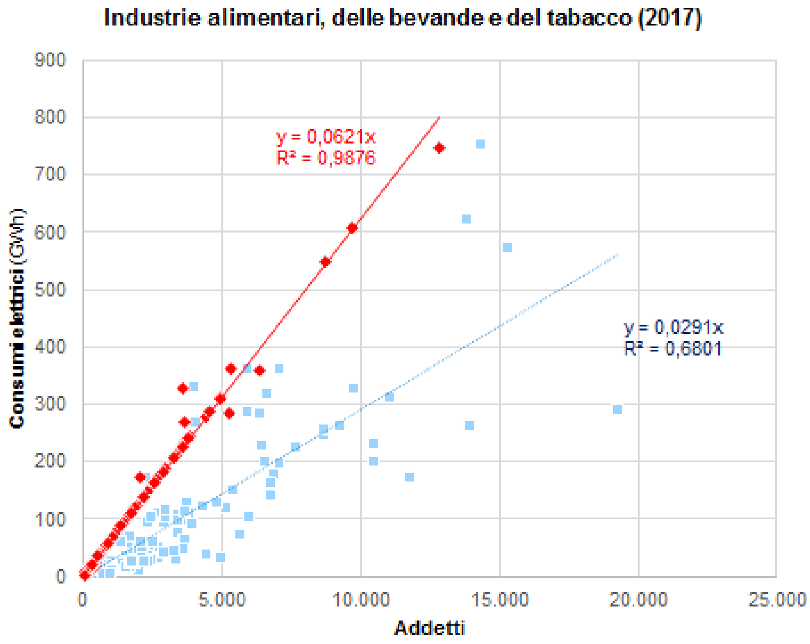
Once the per-capita consumption of non-operational employees has been estimated, it is possible to estimate the impact of the operational staff on the total workforce by sector and province by requiring that total consumption result from the sum of two defined elements:

$$E_{TOT} = e_{nop} \cdot add_{nop} + e_{op} \cdot add_{op}$$

Where e_{op} represents the unitary consumption of employees, differentiated by industrial sector. By specifying the percentage of *non-operational* employees with p plus add_{nop}/add_{TOT}, it is possible to write:

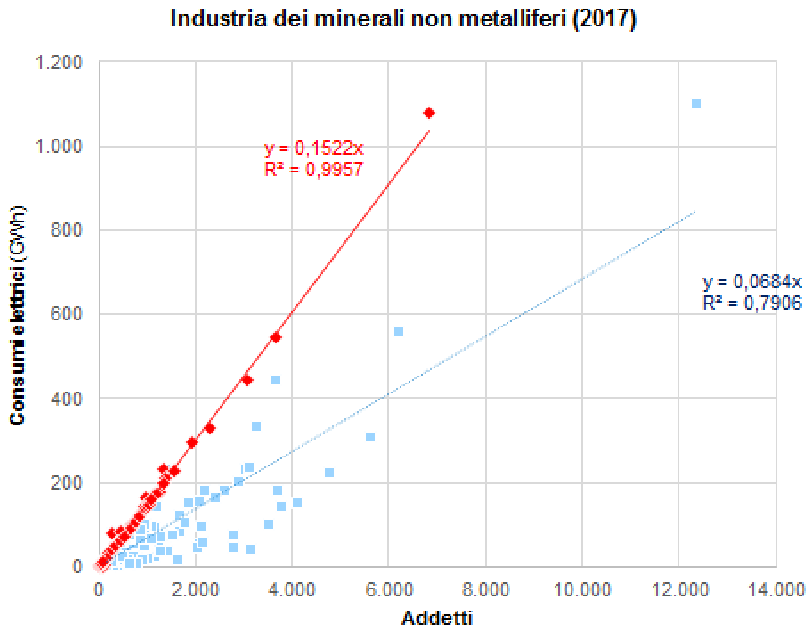
$$E_{TOT} = [e_{nop} \cdot p + e_{op} \cdot (1-p)] \cdot add_{TOT}$$

Given add_{TOT}, E_{TOT} ed e_{nop}, p and e_{op} are determined by searching for p-values that minimize the average standard deviation of regression between the monitored/estimated electrical consumption. The results for the different sectors (figg.2.2.8, 2.2.9, 2.2.10) appear to be statistically robust: therefore, the use of the "operational workers" indicator as a descriptor of the differences in operation between local industrial units at the local level can be considered appropriate.



Consumo pro capite addetti operativi: 62.100 kWh/addetto

Fig.2.2.8. Determination of per-capita power consumption by operational workers: food industries (2017)



Consumo pro capite addetti operativi: 152.300 kWh/addetto

Fig.2.2.9. Determination of per-capita power consumption by operational workers: non-metallic minerals industries(2017)

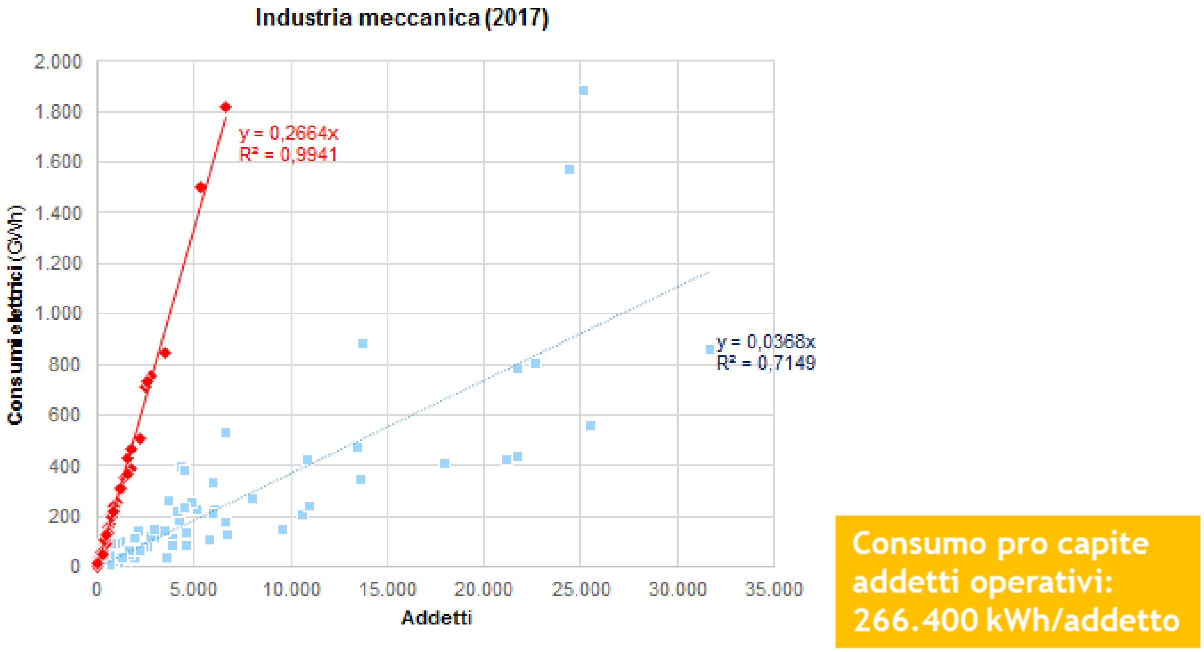


Fig.2.2.10. Determination of per-capita power consumption by operational workers: mechanical industries (2017)

ESTIMATION OF THE INCIDENCE OF OPERATIONAL WORKERS BY SECTOR AND PROVINCE

In the model the operating workforce is the key descriptor of the levels of operation of local units with physical handling of goods.

The detailing the operation of local units at the municipal level can be developed in two different ways:

1) Applying a procedure at the municipal level identical to the one shown at the provincial level
2) Ranking local units according to the socio-demographic characteristics of the corresponding census section.

The first solution is certainly more precise, but it requires electricity consumption data by industry at the municipal level (under review). The second solution, however, allows to articulate production at the municipal level taking into account existing territorial constraints (for example, the reduced probability of operational activities being established in the historic centers), but it is certainly less precise, also because it can be conducted on a figure available only for the year 2011 (the results will be extrapolated to the year 2017).

Once the detailed picture of municipal and provincial operations can be reconstructed, it will be possible to update to 2017 the unit coefficients of generation/attraction of goods flows, already developed by the i-TraM model with reference to the 2011 figure (fig.2.2.11)

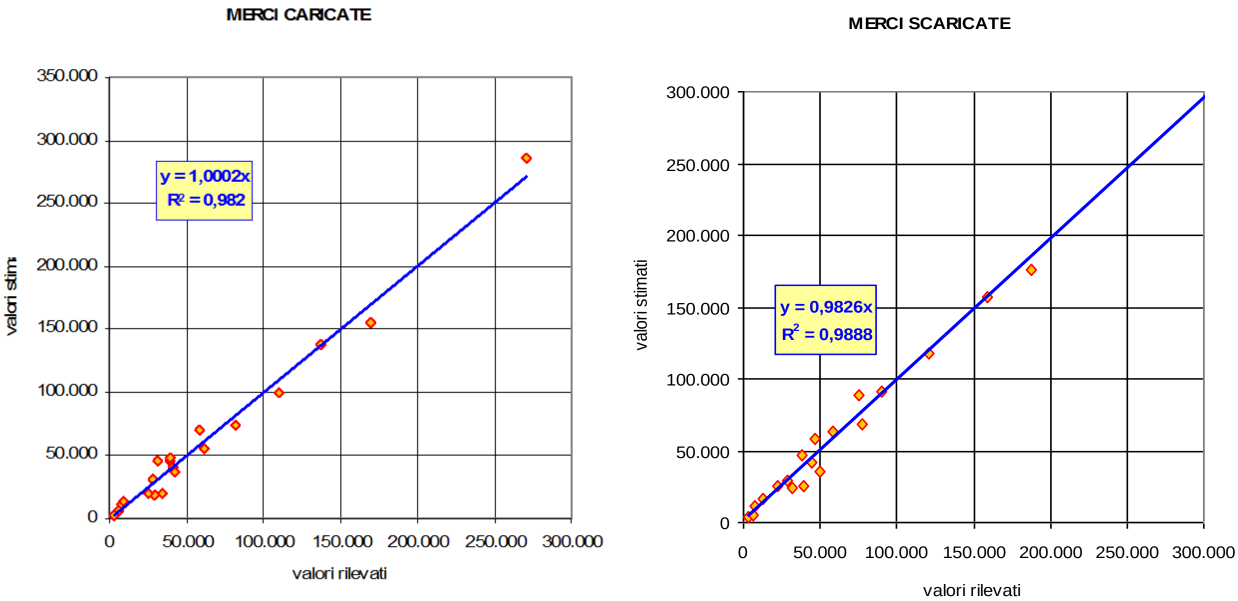


Fig.2.2.11. i-TraM national model: calculation of generation/attraction coefficients (2011)

These coefficients can be used to split the ETISplus matrix in order to reconstruct the total flows of goods generated/attracted by each municipality, articulated by commodity category, assuring the algebric consistency with the overall O/D matrix.

2.2.3. Freight distribution

Due to the intrinsic characteristics of the freight demand, which is mainly oriented on medium and long trips, the distribution of flows by sources/destinations detailed at the municipal level is achieved through a simple bi-proportional estimation procedure.

2.3. Freight transport supply

2.3.1. General structure

The second element of innovation, introduced in the regional model, relates to the description of transport supply. In fact, the current modelling configuration confined itself to replicating the infrastructure supply in relation to the different route choices, entrusting the reconstruction of the vehicle flows to an allocation on the paths of minimum general cost. This approach, which is adequate for own account transport of goods, is not appropriate for third-party freight services, which by now cater for major share of demand.

In this regard, the description of the infrastructure network will be supplemented by a "fine" description of the third-party transport services supplied by logistic firms, which in the light of the most recent scientific advances[4], seems most necessary to adapt the simulations to the real logic of allocation of flows by the different logistics providers.

This will result:

- on the one hand, in an analysis of **rail freight services,** programmed on the national network, and/or available paths, as modelled by the timetable database of the i-TraM model, which replicates the entire national rail traffic down to the detail of each single station (fig.2.3.1);

Fig.2.3.1. National model i-TraM: Planned rail circulations on the rail network (2017)

[4] See: Ha D.-H., Combes F. [2015] "Building a Model of Freight Generation with a Commodity Flow Survey"; 2nd Interdisciplinary Conference on Production Logistics and Traffic, Dortmund, Germany; 17 pp.; Combes F., Tavasszy L.A. [2016] "Inventory theory, mode choice and network structure in freight transport"; European Journal of Transport and Infrastructure Research, n.16, pp.38-52.

- on the other hand, in the development of a specific module aimed at replicating the distribution/transport supply of the main third-party logistics operators, by mapping the existing logistics platforms in the region and in the neighbouring regions, as well as their reciprocal connections within individual corporate networks, with the preparation of supply schemes obtained by chaining inter-platform "line" services (defined in function of the company' organization)(fig.2.3.2).

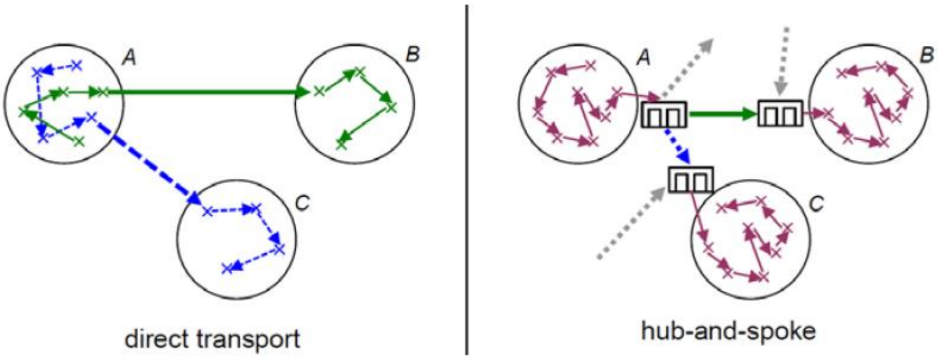


Fig.2.3.2. Description of third-party logistic supply at regional level (da Combes e Tavasszy [2016])

2.3.2. Structure of road logistic chains

The reconstruction of the logistics chains associated with the activities of the different operators is functional to replicate, in a schematic way, the logic of flow bundling/unbundling in intermediate platforms, also road/road platforms, typically put in place by third party transport operators, that induce important changes in the real configuration of the vehicular movements[5].

This reconstruction is obtained by selecting logistics operators operating in Emilia-Romagna on the basis of two separate and complementary sources:

- ✓ AIDA data provided by ITL;
- ✓ the list of the 500 largest Italian logistics operators, compiled by CONFETRA and illustrated by the technical press (selecting the first 20 national operators and all firms based in Emilia-Romagna).

For each operator, the network of platforms in use is reconstructed, as described by the various available sources (including their websites, supplemented by detailed checks using digital mapping). Figg. 2.3.3. and 2.3.4 show examples for four distinct operators.

[5] For further details see Ben-Akiva, Bolduc e Park [2013], Friedrich, Tavasszy and Davydenko [2014], Liedtke, Schröder and Zhang [2013], Pettersen and Strandenes [2013].

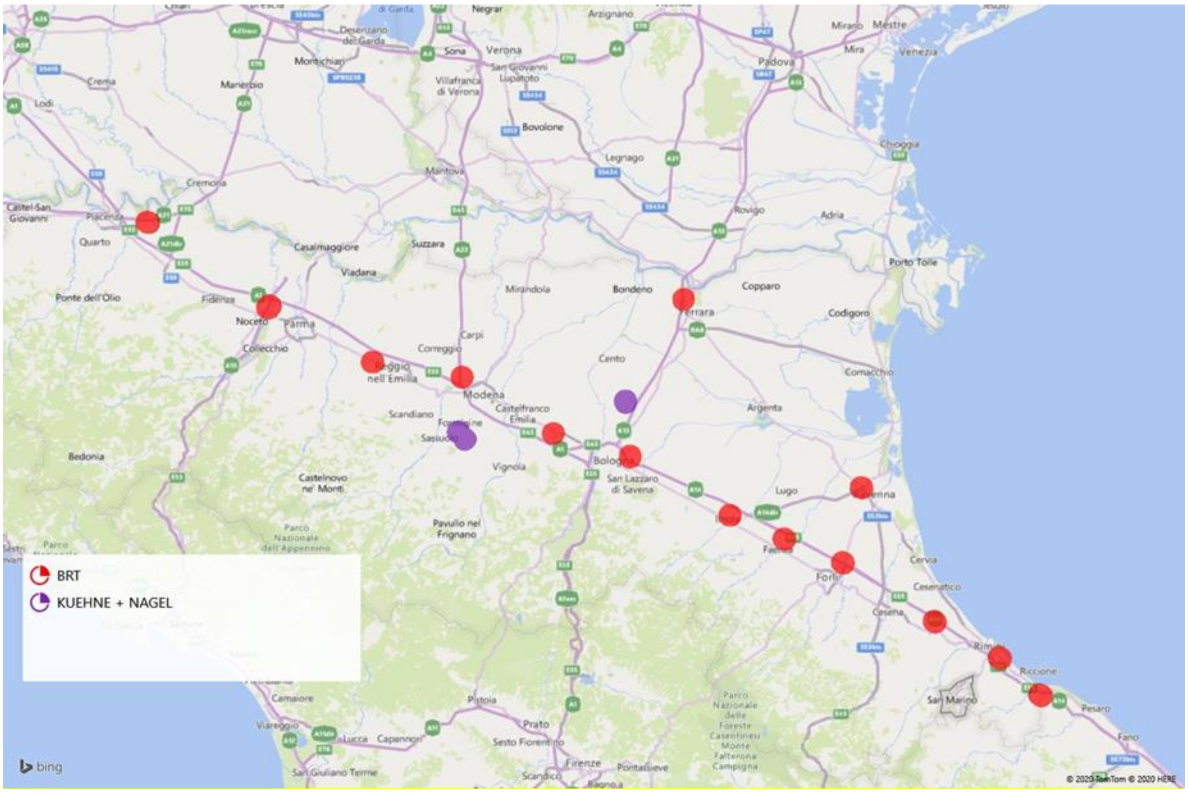


Fig.2.3.3. Locations of BRT and Kohne-Nagel locations in Emilia-Romagna

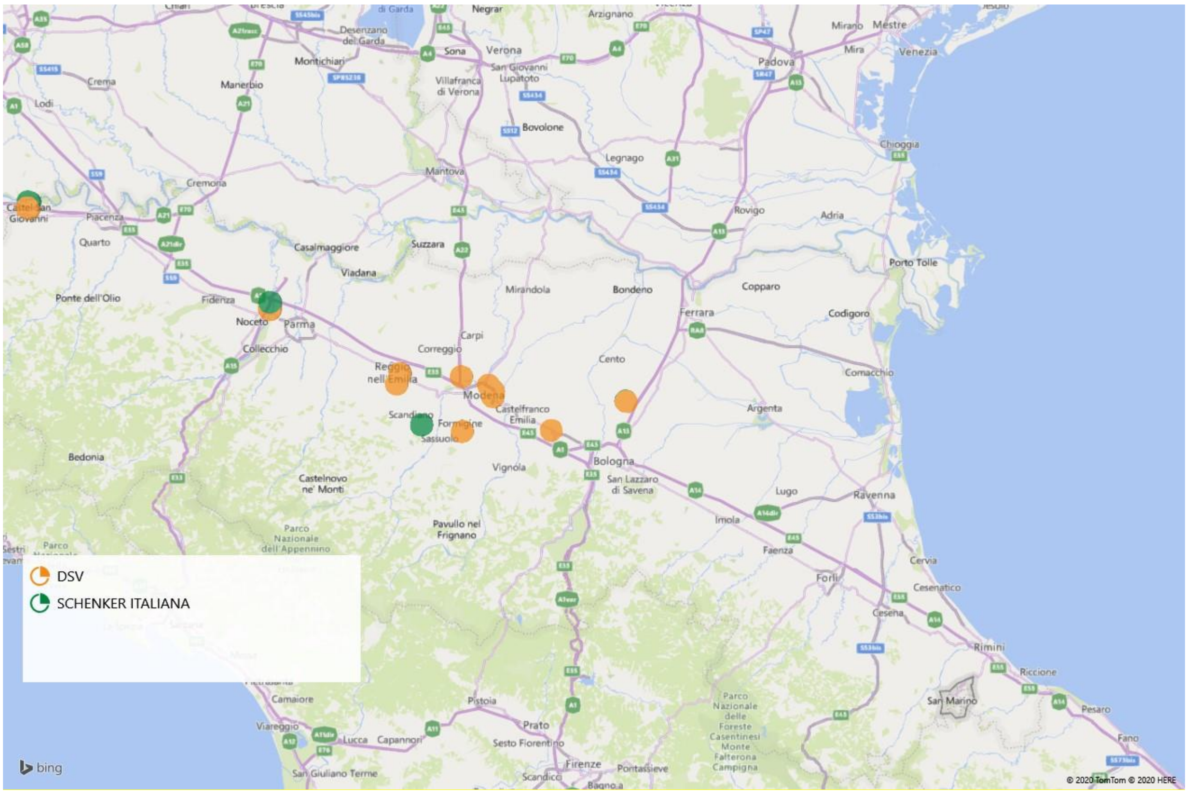


Fig.2.3.4. Locations DSV and Schenker Italian locations in Emilia-Romagna

All information relating to the individual platforms and the corresponding logistics chains is contained in the Geographical Information System (GIS) developed *ad hoc* within the project.

In particular, with reference to its main implementation features, its **inputs** are:

- a **cost matrix for lorries**, resulting from the Emilia Romagna Region Transport Model;
- a list of the **main companies of the logistic sector** operating in the area. In particular, the 20 companies with the highest revenues have been selected[6];
- a list of the **transit points** belonging to the companies selected. Different goods categories may be specified for each transit point.

As far as concern the **transit points**, the list includes:

- all the transit points within the Emilia Romagna region;
- one transit point per company for the provinces of Lombardy, Tuscany and Veneto;
- one transit point per company for all other Italian regions.

Fig.2.3.5. shows an example of the transit points belonging to a specific company in Emilia-Romagna.

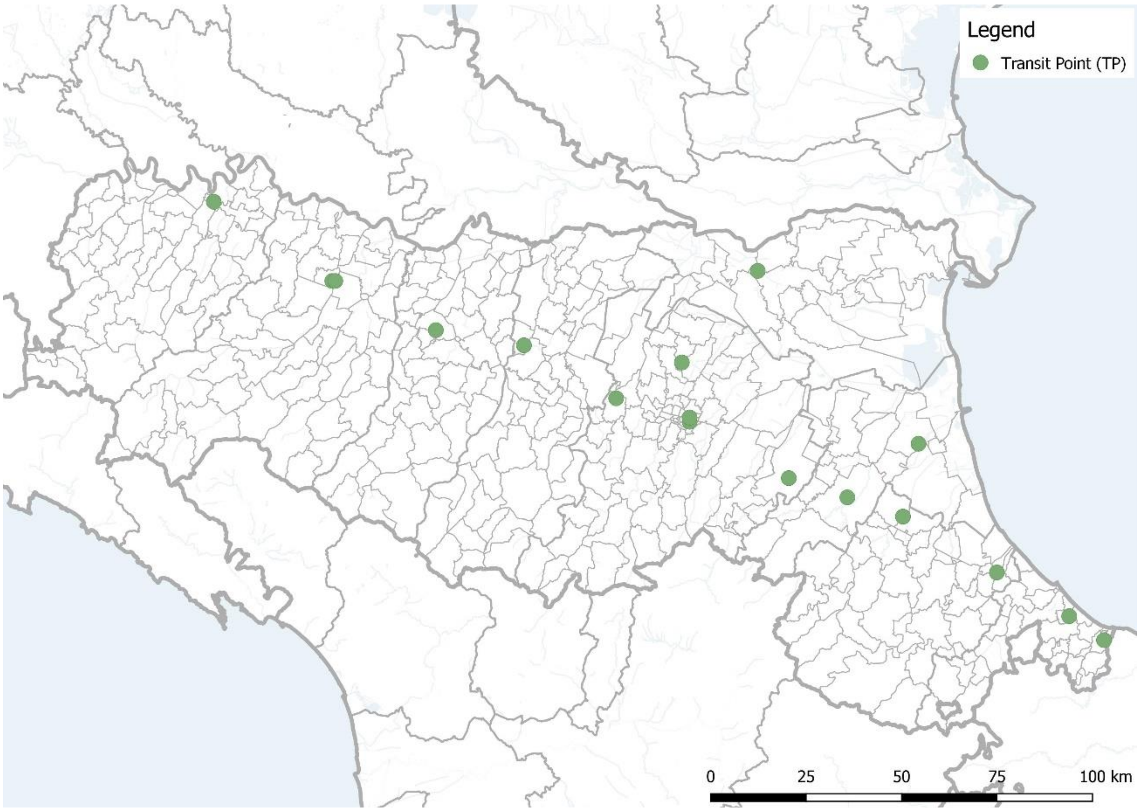


Fig.2.3.5. Example of logistics operator platforms' localisation

Given these inputs, the first output resulting from the GIS is the **network of connections existing between transit points**. Moreover, thanks to the availability of the cost matrix, **a generalized cost is provided for each connection** (fig.2.3.6)

[6] Data provided by Fondazione ITL

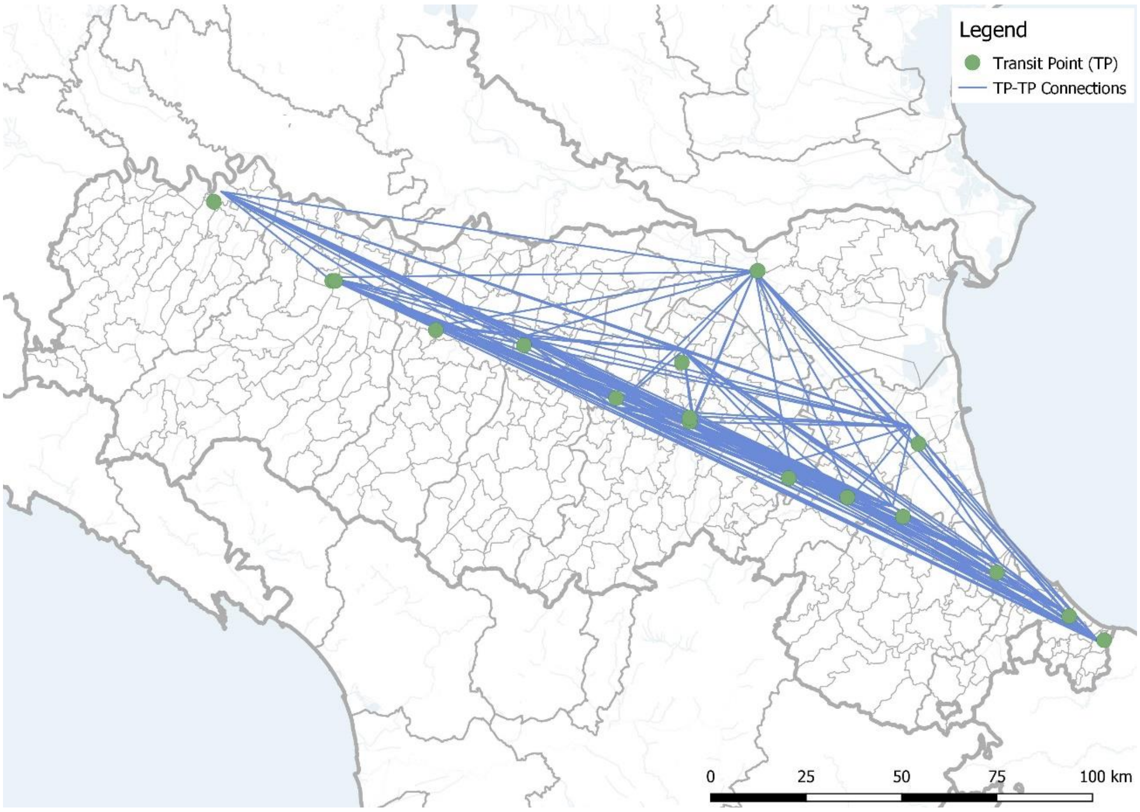


Fig.2.3.6. Relationships between logistic platforms

Finally, **connectors have been calculated**. The connectors link each zone of the model to transit points, computing their travel cost from the cost matrix. The travel cost associated to each connector has been capped to a limit, which is company-specific.

In fig.2.3.7 and fig.2.3.8 two examples are shown[7]. In the first one, the selected company has most of its transit points along the Via Emilia and manages to cover most of the regional territory. The only areas that are not served by the company are the inner areas in the Appennines.

On the contrary, in the second example, the selected company has just two transit points located within the region, far away from each other.

[7] The figures do not represent the network of an actual firm and have just an illustrative purpose

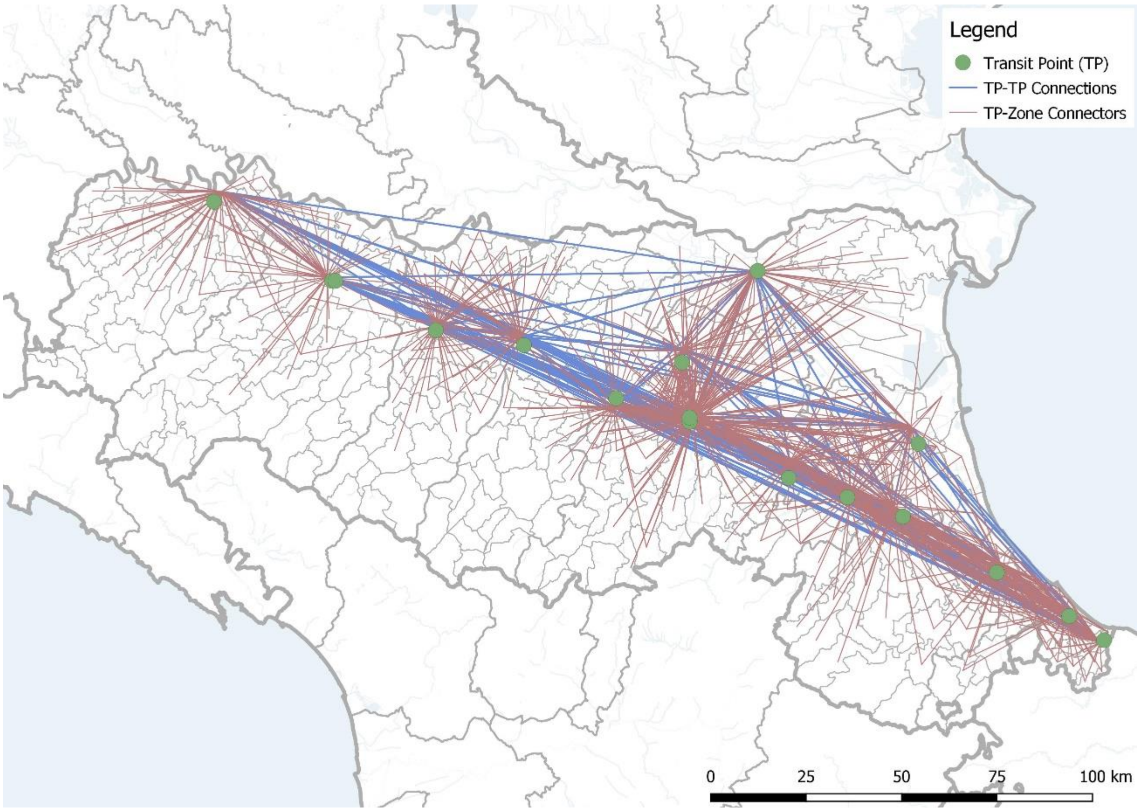


Fig.2.3.7. Relationship between platforms and catchment areas

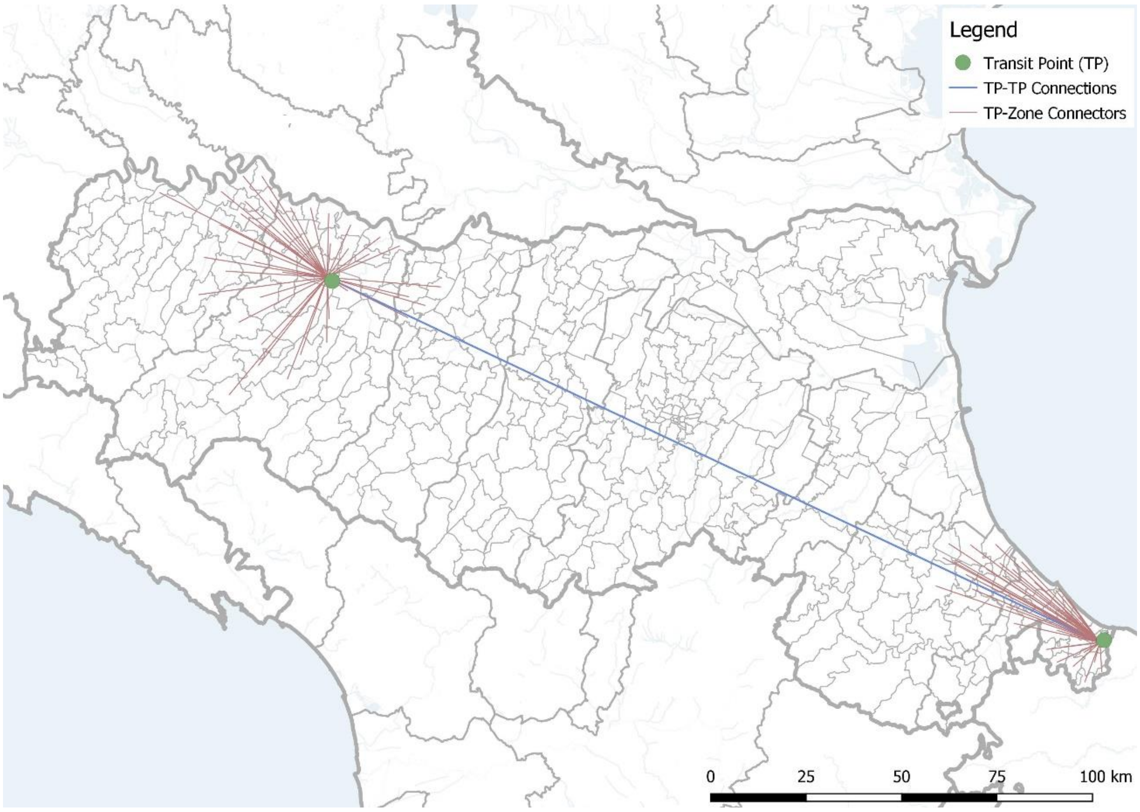


Fig.2.3.8. Construction of an O/D relationship

2.3.3. Structure of intermodal logistic chains

The logical structure used to reconstruct the road/road supply remains unchanged even in the case of intermodal supply, with the only change of the transport mode for inter-platform movements.

Therefore, the Geographical Information System shown in the previous paragraph can also be used to describe:

- Rail relations between to the Bologna and Parma freight villages and other intermodal terminals in the region or in its immediate vicinity (particularly along the Milan-Verona-Padova corridor)
- The sea shipping services at the port of Ravenna

2.3.4. Matrices of transport costs

As a result of the different description of the logistics supply, the model will be able to refer to three different matrices of transport costs, defined as:

- ✓ single-modal transport (all road), own account transport;
- ✓ single-modal transport (all road) third-party account transport;
- ✓ intermodal transport (road-railway or road-sea shipping) on a third-party account.

2.4. Economic order quantity and modal split

2.4.1. Introduction

The third and last innovation introduced on the regional freight simulation model concerns modal choice algorithms. Based on some recent modelling developments, integrating of *inventory theory* at this modelling stage[8], a joint algorithm of choice shipment size / mode of transport is developed. This algorithm aims to describe the choices of shippers according to the well-known *Economic Order Quantity* (EOQ) theory, based on the minimization of the Total Logistic Cost (TLC) function. The TLC is given by the sum of:

- ✓ **inventory costs,** which in turn relate to the value of the goods per unit of weight or volume;
- ✓ **generalised transport costs,** in turn a function of operating costs, travel times, as well as modal constants dependent on the levels of safety and reliability of the different modes[9].

The output of the proposed procedure allows to estimate not only the quantity of goods *Q(m,i,j,k)* belonging to product category *m*, which in a given time interval move from zone *i* to zone *j* with mode *k*, but also the frequency of shipments, in relation to the chosen mode of transport. This translates into the ability to take into account the capacity of the vehicles, distinguishing the smaller ones (vans, trucks) from larger ones (trains, ships), with obvious advantage for the study of traffic type that can be collected by intermodal services.

2.4.2. The algorithm for the joint Economic Order Quantity and transport mode choice

Traditional freight models, developed similarly to passenger transport models, model **the transport of material goods from a production place A to a consumption place B as a continuous flow *Q*** (Fig.2.4.1).

Fig.2.4.1. Conventional model of freight flows

Apart from a few exceptions, this description is unrealistic, because in general **the transport takes place intermittently, that is, with separate shipments.** Therefore, industrial firms need to manage stocks of goods **departing and arriving,** equipping themselves with warehouses and/or storage areas starting from the production sites and/or arriving to the sites of consumption of the goods transported (Fig.2.4.2).

[8] See i.e. De Jong G., Ben-Akiva M. [2007] "A micro-simulation model of shipment size and transport chain choice"; Transportation Research B, vol.41; pp.950-965; Abate M., de Jong G. [2014] "The optimal shipment size and truck size choice-the allocation of trucks across hauls"; Transportation Research A, vol.59(1), pp. 262–277; Combes F., Tavasszy L.A. [2016] "Inventory theory, mode choice and network structure in freight transport"; European Journal of Transport and Infrastructure Research, 16(1); pp.38-52.

[9] For more insights on the concept of Total Logistics Cost, see Abate e Kveiborg [2013], and Holguín-Veras et al. [2014a, 2014b].

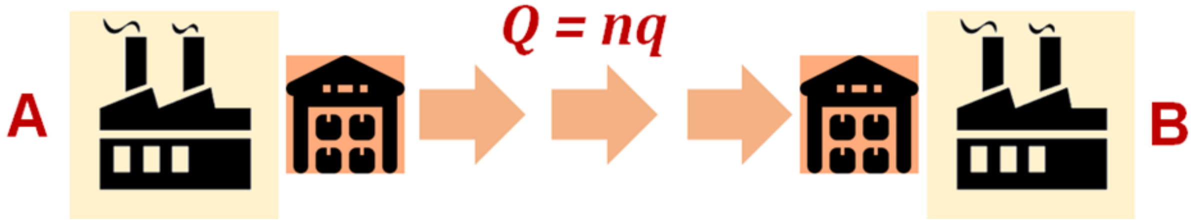


Fig.2.4.2. Advanced freight flow model

As already mentioned, the choice of mode of transport is differentiated by product sector and is based on the concept of Total **Logistic Cost,**or ***TLC***, in turn obtained as a sum **of:**

- **Inventory cost**
- **Transport cost**

The **unitary transport costs,** determined as the sum of a fixed quota and a variable one depending on the weight transported, **tend** to grow according to the number **of shipments,** and therefore, for a set overall flow Q, to decrease according to the size of the shipping lot.

Conversely, **unit** inventory **costs,** proportional to the average inventory of the goods, **tend to** decrease according **to the number of shipments,** and therefore, *Q* being equal, to grow according to the size of the shipments.

Generally, the sum of inventory and transport costs gives a function with a typical U-shape, showing the existence of an optimal size of shipments, or economic order quantity, which minimizes the Total Logistic Cost.

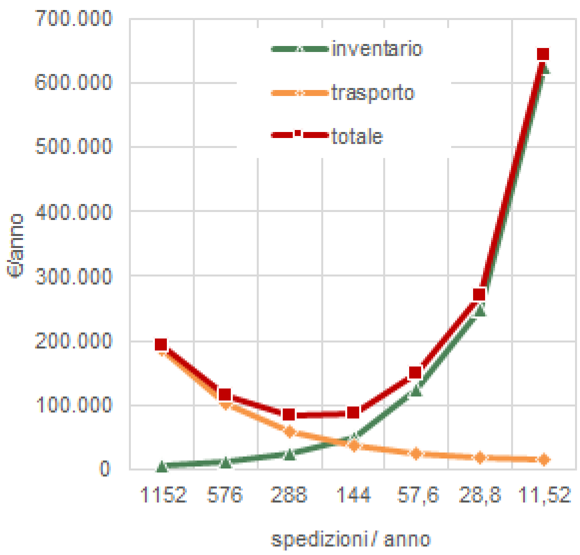


Fig.2.4.3. Inventory cost, freight cost, and total logistics cost

The algorithms of joint choice shipment size / mode of transport assume that all shippers behave minimizing the function of Total Logistics Cost, that is, by sizing their shipments in relation to the economic order quantity.

Clearly, different modes of transport, characterized by varied cost functions, determine, for the same price, different economic order quantity: for example, small vehicles, characterized by fixed shipping costs but low economies of scale, are associated with optimal shipments which are smaller than those generated by the use of larger means of transport, characterized by higher fixed costs but also by greater economies of scale (fig.2.4.4).

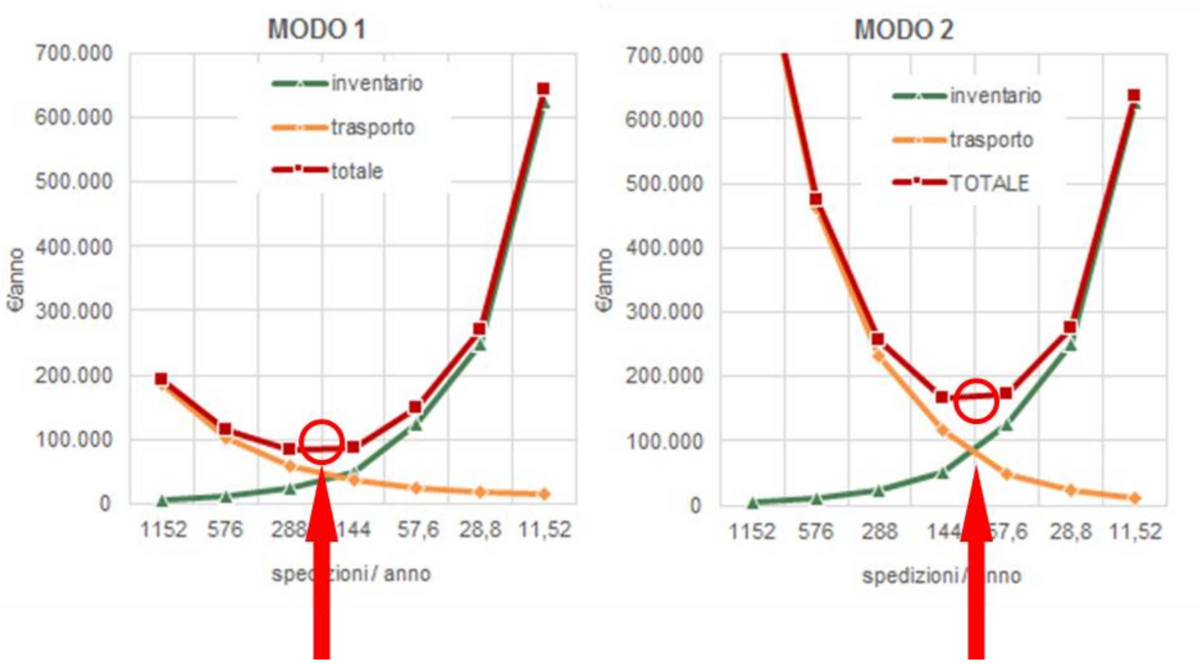


Fig.2.4.4. Determining the economic lot for different modes of transport

On the other hand, the shipping lot also varies depending on the unit value of the goods, as the inventory costs of high-value-added goods per unit of weight/volume make it cheaper to operate with frequent and small shipments, compared to the case of low value added goods per unit of weight/volume, whose immobilization can be a minor economic problem.

In any case, the algorithms of joint choice of shipment size / transport mode assumes that shippers choose the transport mode providing the lowest Total Logistics Cost (fig.2.4.5).

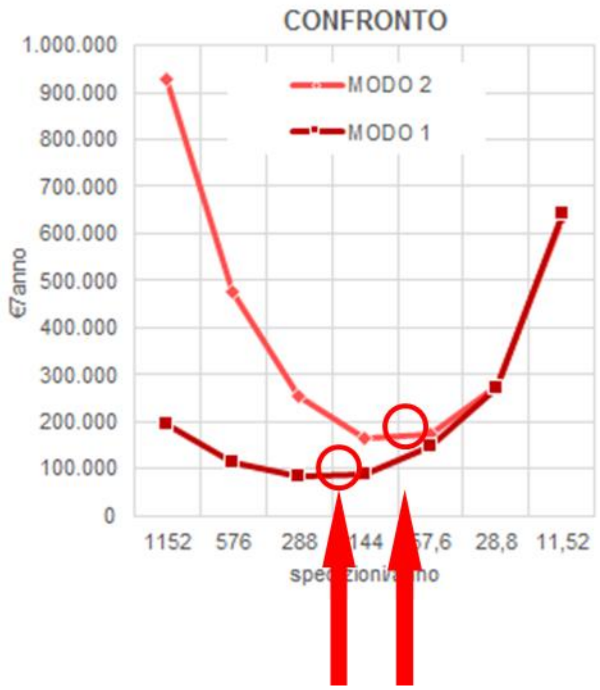


Fig.2.4.5. Joint choice of shipment size and transport mode

2.4.3. Estimating the unit value of freight

An important consequence of the new approach is that the choice of mode of transport depends on the product characteristics of freight, for example:

- size
- unit weight
- value by unit of weight (volume)
- perishability
- obsolescence

All these parameters, in fact, affect the inventory cost of the product and, therefore, the economic order quantity.

As a result, the modal choice model will have to be supplied with average parameters, referred to each product category. From this point of view, it will be necessary to proceed by referring to some specific products, such as to allow the determination of the physical-chemical and merchandise parameters.

On the other hand, with regard to the value of goods, it is proposed to operate using, for each commodity category, the weighted average of the unit values of import/export by category NST/R 2007 in 2011 and 2017, as results from the Italian Foreign Trade Statistics.

Categoria merceologica NST/R 2007	**Valori unitari** €/t a prezzi concatenati 2010	
	2011	*2017*
01-Prodotti dell'agricoltura, della caccia e della silvicoltura; pesci ed altri prodotti della pesca	672,1	636,5
02-Carboni fossili e ligniti; petrolio greggio e gas naturale	274,9	419,8
03-Minerali metalliferi ed altri prodotti delle miniere e delle cave; torba; uranio e torio	119,1	114,4
04-Prodotti alimentari, bevande e tabacchi	1.487,8	1.200,3
05-Prodotti dell'industria tessile e dell'industria dell'abbigliamento; cuoio e prodotti in cuoio	16.935,0	14.746,7
06-Legno e prodotti in legno e sughero (esclusi i mobili); articoli di paglia e materiali da intreccio;	873,1	867,9
07-Coke e prodotti petroliferi raffinati	405,2	569,1
08-Prodotti chimici e fibre sintetiche e artificiali; articoli in gomma e in materie plastiche; combust	2.997,4	2.720,8
09-Altri prodotti della lavorazione di minerali non metalliferi	738,9	649,4
10-Metalli; manufatti in metallo, escluse le macchine e gli apparecchi meccanici	1.588,3	1.802,5
11-Macchine ed apparecchi meccanici n.c.a.; macchine per ufficio, elaboratori e sistemi informati	12.679,7	11.946,6
12-Mezzi di trasporto	9.315,0	7.386,3
13-Mobili; altri manufatti n.c.a.	7.607,7	6.576,7
14-Materie prime secondarie; rifiuti urbani e altri rifiuti	469,1	452,3

Tab.2.4.1. Average value of goods per tons – NST/R 2007 ***classification***

2.4.4. Multimodal aspects

One of the main advantages of using the joint choice algorithm of shipment size / transport mode, together with the explicit description of the third-party transport supply, is that it already integrates the typical problems of intermodal transport, without the need to introduce additional parameters.

In fact, an intermodal transport chain will simply be modelled as a third-party transport service in which the inter-terminal flows are by rail and the delivery circuits are by road.

Therefore, the attraction of freight transport demand to intermodal services will be assessed taking into account both the unit transport costs supplied by bundling flows on a limited number of terminals, as well as the inventory costs induced on the overall logistics chains, in relation to the goods treated.

2.4.5. Summary of the modal split process

Taken as a whole, the mode choice model will take the form of a 2/3-level nested logit procedure, defined as follows[10]:

1) Choice between own account and third party transport;
2) In the case of transport in own account, choice of vehicle (van, truck, lorry, with variable capacity depending on the goods transported, taking into account the empty returns); in the case of third-party transport, choice of operator and/or reference logistics network (including intermodal services);
3) In the case of third-party transport, choice of vehicle (van, truck, lorry, block train, with variable capacity depending on the goods transported and the management of the directional imbalances typical of the chain examined), associated to the description of the corresponding supply chain.

[10] For further details, cfr.Combes [2014], Combes, Ruijgrok and Tavasszy [2013], de Jong [2014], Friedrich and Balster [2013].

2.5. Road transport assignment

2.5.1. Introduction

Once the matrices of freight flows, split by mode, are estimated, the last remaining modelling stage is the assignment to infrastructure networks.

This step will be implemented differently depending on the mode.

2.5.2. Assignment and validation of road flows

The assignment of road flows will be done simply by assigning the O/D matrix, expressed in vehicles, possibly divided by type (van, truck, lorry/semi-trailer), on routes of minimum generalized cost (Toledo ed al. [2013]).

This operation will be developed directly on the regional road graph and can be validated according to the road traffic monitoring carried out by the Emilia-Romagna Region and others.

2.5.3. Assignment and validation of railway flows

Allocation of rail flows will be implicitly based on the timetabling of the services on fixed routes.

The attraction potential of rail services, intermodal and rail only, can be assessed either at the level of a simple matrix, identifying the lines and goods for which the costs supplied by the railway service appear able to change the modal split, or by assuming the programme of train movement, thus proceeding to a new assignment of freight flows.

2.5.4. Assignment and validation of maritime flows

Due to the characteristics of the regional model, the allocation of maritime flows will be implemented only with reference to the port of Ravenna, described as an external route of the model.

In other words, the port will be modelled as a set of terminals, associated with several logistics chains operating on long-haul transport (national or international), and its capacity to attract flows to the different routes will be assessed.

3. Scenario building

3.1. Main goals

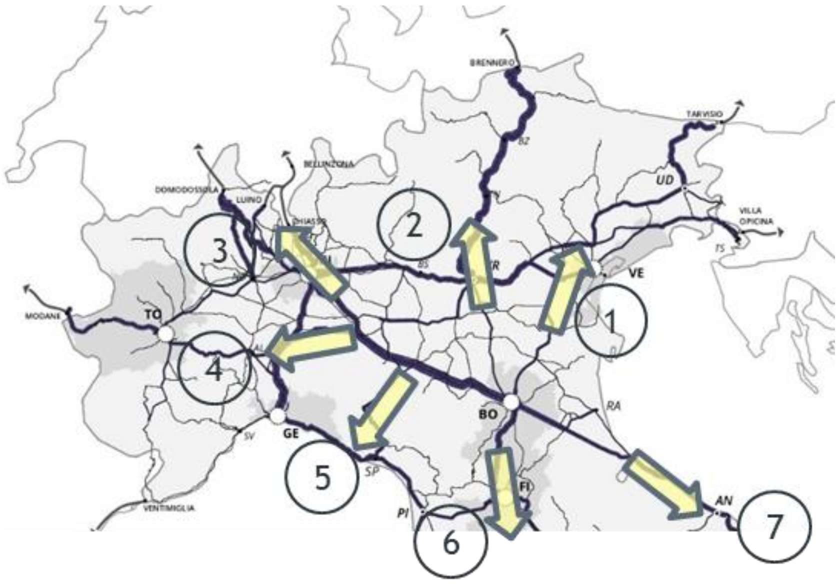
The development of the simulation model is aimed primarily at verifying the "bottlenecks" (infrastructural and functional) present on the regional rail network, and assessing possible actions to increase the attractiveness of intermodal services.

From this point of view, the immediate perspective for the model is to build a reference situation, based on the policy framework, with respect to which to examine the potential for the development of rail traffic, possibly by introducing hypotheses relating to the development of new services originated/destined to the regional terminal system.

3.2. Reference scenario

The baseline scenario will take into account first of all the policy framework of the upgrades of the rail network on all regional routes.

The infrastructure upgrades will be discussed along seven axes illustrated in the following picture and listed below.



1. North-West (Padova-Venezia-Trieste-SL/Udine-Tarvisio-AT)
    a. Reinstatement of the Linea dei Bivi at Venezia Mestre
    b. Upgrade of the Venezia Trieste line
    c. Infrastructural and technological upgrade of the Trieste-Divača line
    d. Doubling of the Udine-Cervignano line

    The recent opening of the Koralm base tunnel in Austria will also be discussed since it solved a bottleneck North of the Tarvisio border crossing
2. North (Verona-Brenner-AT)
    a. New Brenner line
3. North-West (Milan-Gotthard/Simplon-CH)
    a. Upgrade along the Rhine-Alpine TEN-T corridor
    b. Quadrupling of the Monza-Chiasso line
    c. Upgrade of the Gallarate-Rho line

4. West (Voghera-Genova/Torino-Modane-FR)
    a. Upgrade of the Tortona-Voghera
    b. Redevelopment of the railway node of Genova and new Terzo Valico line linking Genova to the North of the Apennines
    c. Torino railway by-pass and connection to the new Torino-Lyon (FR) line
    d. New Torino-Lyon (FR) line
5. South-West (La Spezia-Livorno)
    a. Upgrade of the Pontremolese line
    b. Upgrades at Thyrrenian ports
6. South (Florence-Rome)
    a. Upgrade along the Scan-Med TEN-T corridor, including loading gauge upgrades along the tunnels through the Apennines
7. South-West (Ancona-Bari)
    a. Infrastructural and technological upgrade of the line along the Adriatic Sea and toward the Ionian Sea
    b. Alignment upgrade and speed increase of the Bologna-Lecce axis
    c. Doubling of the Termoli-Lesina line

3.3. Bottleneck analysis

An initial survey of existing infrastructure bottlenecks in Emilia-Romagna was conducted separately from the Integrated Regional Transport Plan (PRIT) and the ERIC expert group.

In the first case, the analysis identified some railway lines that are not adequate to serve the expected demand, as well as a number of nodes lacking in terms of functionality for the movement of freight trains (tabb.3.2.1 and 3.2.2). The cases identified affect the Pontremolese line, the Reggio Emilia-Sassuolo line, the Bologna node and the connections between Ferrara and the Adriatic line, as well as the railway nodes of Ravenna, Ferrara, Faenza, Fidenza, Piacenza and the terminal of Villa Selva in Forlì.

	Bottleneck	Goals	Actions
1	The single-track Reggio Emilia-Sassuolo line is the only link to Dinazzano terminal; and it is crowded during daytime due to the coexistence of freight and passenger traffic	Increase freight traffic capacity towards Dinazzano	Upgrading speed and allowed train length and crossing station. Electrification
			New line Dinazzano-Marzaglia
2	A new North-South route is needed between Ferrara and Adriatic line, in order to reduce traffic on the Ravenna-Rimini line	Increase freight traffic capacity between Ferrara and the Adriatic Line, reducing traffic on the Ravenna-Rimini line (TRC)	Electrification of Granarolo Faentino.Lugo-Lavezzola line.
3	High saturation level of Bologna bivio S.Vitale-Castel Bolognese section	Enhance traffic management reducing conflicts between freight and passenger trains, in order to develop suburban railway services.	Four-tracking of the section
4	An upgrade of Pontremolese line is needed	Improve the links between La Spezia port and industrial areas of Emilia-Romagna, with particular reference to Parma freight village and the Tirreno-Brennero (Ti.Bre) route	Completion of track-doubling

Tab.3.2.1. Bottlenecks identified in PRIT (lines)

	Bottleneck	Goals	Actions
1	**Ravenna port**. Low capacity and high operation costs of the railway links between station and harbours. High terminal times and conflicts with heavy road traffic.	Eliminate conflicts between road and railway traffic, looking at the increase of modal split of railway in port traffic.	New over- and underpasses and infrastructural upgradings
2	**Ravenna port**. Acceleration of manouvres between the railway station and the two links (Left/right) with the harbour. Use of Candiano freight yard	Upgrading of Candiano terminal; transfer of 70% of operations from the railway station. New tracks dedicated to Right railway link with the harbour	Upgrading of Candiano terminal, new railway links with the harbour, possible new connexion with national rail network.
3	**Ferrara station**. A direct connexion on the route Ravenna-Ferrara-Poggio Rusco is needed.	Avoid train manoeuvres in Ferrara station	Completion of new direct link.
4	**Faenza station**. A direct connexion on the route Ferrara-Faenza-Rimini is needed.	Increase rail traffic capacity between Ravenna/Ferrara and the Adriatic line.	New single track electrified link between Granarolo-Faenza and Faenza-Rimini lines.
5	**Fidenza station**. A direct connexion on the route Fornovo-Fidenza-Bologna is needed.	Upgrading of connexions between La Spezia port and Parma freight village	New single track electrified link between Fornovo-Fidenza and Fidenza-Bologna lines.
6	**Villa Selva terminal**. Completion of works.	Completion of works.	Completion of works.
7	**Piacenza terminal**. Increase of rail traffic capacity.	New spur line in Piacenza Le Mose area	New terminal and connexions.
8	**Faenza freight yard**. It is located into the urban area.	Conservation of rail traffic capacity by relocation of the yard outside the urban area.	New Faenza terminal (private initiative)
9	**Ferrara station**. The passenger station intercept freigh traffic, too	Avoid passenger/freigh traffic conlicts.	New direct link between Ravenna and Poggio Rusco

Tab.3.2.2. Bottlenecks identified in PRIT (nodes)

In the second case, the focus was on the terminal system, highlighting some shortcomings in Dinazzano, Bologna, Villa Selva, Rubiera, Ravenna and Parma (tab.3.2.3)

	Bottleneck	Impacts	Suggested actions
1	**Dinazzano terminal**. The performances of Reggio-Dinazzano line area low.	The line is close to saturation.	Electrification and upgrading of allowed train length in Scandiano station Double tracking New line Dinazzano-Marsaglia
2	**Dinazzano terminal**. The existing spaces are saturated.	Few possibility to increase railway traffic.	Yard widening (3 tracks with a length of 750 m)
3	**Bologna freight village**. Arrival/departure tracks are lacking.	No possibility of additional operation during the more requested time intervals (6-9 AM, 6-9 PM)	Two new tracks.
4	**Lotras (Villa Selva) terminal**. allowed train length of Incoronata-Villa Selva section is limited to 575 m.	Reduced economic efficiency.	More efficient trains.
5	**Lotras (Villa Selva) terminal**. Terminal tracks are uneletrified.	Longer operation times.	Electrification.
6	**Rubiera terminal**. The loading gauge of Bologna-Firenze-Spezia links is limited.	Loss of traffic (diverted on the road transport)	Speeding of upgrading of the lines.
7	**Rubiera terminal**. Frequent conflicts with manteinance works on the main line.	=	Find alternative solutions.
8	**Rubiera terminal**. No possibility to operate train with a length of 500 m and a weight of 1.600 t.	=	Upgrade of spur lines.
9	**Sapir terminal**. Freight traffic must cross Ravenna passenger station.	=	=
10	**Sapir terminal**. The branch with national rail network is not electrified.	=	=
11	**CEPIM**. New tracks for locos and manoeuvres are needed.	Loss of coeherence between private and public investments	New tracks for locos and trains manoeuvres.

Tab.3.2.3. Bottlenecks identified by ERIC group

The above cases are the starting point for analysing the network functionality at the regional/superregional level and for the subsequent construction of the scenarios.

3.4. Scenario building

Once the existing bottlenecks have been identified, the product sectors and the most promising routes for attracting traffic to the railway hubs will be identified, developing possible supply schemes to serve them.

The identification of potentials can already be conducted at the demand description level, verifying the shape of the O/D matrices for individual goods, in terms of sensitivity to possible changes in rail transport costs.

As regards possible supply patterns, they can be developed in terms of:

- **Logic of bundling/unbundling of traffic** in intermediate logistics nodes, both mono- and inter-modal (in a broad sense, including not only *inland terminals* but also ports and railway stations where single wagonload freight traffic is operated);
- **railway production technique** (block-trains, collection/delivery of single wagonload traffic, liner trains);
- affected **interchange nodes**;
- **frequencies of service** supplied to end customers (and, therefore, services supplied to the demand expressed by the shippers in terms of EOQ).

These options will be described in terms **of rail or intermodal services that complement** the framework of the transport supply modelled in the current scenario, in order to generate a number of intervention scenarios, which are not necessarily alternative to each other.

These scenarios can then be simulated with the goal of quantifying their impact in terms of:

4) demand attracted to the railway mode;
5) demand diverted the road mode (e.g. with elimination of all-road routes, but addition of collection/distribution routes between the plant and inland terminal);
6) increases in traffic on the rail network.

These scenarios can also be added together, in order to appreciate their overall impact and/or mutual compatibility, in particular by referring to the remaining available capacity of the rail network and, therefore, to the emergence of possible conflicts of allocation of tracks at individual infrastructure "bottlenecks".

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