# NEAC-10

## Model Description 2015

## Authors of the Document

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# 1 Introduction

The goal to make transport work in the interests of society is still a major challenge encountered at regional, national and European level. Effective solutions require approaches that reflect the cross-border and global nature of the modern transport system and the turbulent economic environment that drives change. Moreover, transport plays a key role in determining whether society can react to the global emergency of climate change.

As a derivative and supporting activity of the economy, on the one hand, and as a major source of greenhouse gas emissions on the other, transport and transport businesses become more and more important. Sustainable and cohesive mobility of goods and persons contribute positively to the good of society. Patterns of transport reflect, through patterns of transport and logistics activity, economic interactions between regions, countries and continents.

The European Single Market has triggered substantial growth in trade between Member States, and with the enlargement of Europe the process of change has been further accelerated. Today, Europe is increasingly regarded as a single economic area with free movement of people and goods. However, there are still substantial divergences in terms of economic growth, trade, and transport infrastructure. Many of the border regions which were peripheral to the European Union no longer are, and new peripheral regions have appeared. Over or under-utilisation of the existing transport infrastructure is no longer considered in narrow terms, but within the broader context of the economic competitiveness of regions.

In order to make a start in understanding these complex economic, trade and transport phenomena, it is necessary to be able to analyse the underlying trade relations and transport flows in an integrated manner. This is the basis for making a prognosis for future traffic flows and volumes at regional, national and European levels. All of these are necessary components of the "know-how" in finding reasonable, cost effective and sustainable solutions for the transport market and the economy as a whole.

With this document, the reader is introduced to a unique analytical system, NEAC, which sets out to provide transport data and a model for analysing flows at European scale, all in a single package. The current incarnation, NEAC-10 builds upon a long history of European transport research and consultancy carried out by NEA Transport Research and Training and parent company, Panteia BV since the 1990s, which is now being taken forward within Panteia's transport groups.

The production of this document was motivated by the willingness of the transport experts from Panteia B.V. to inform companies as well as regional, national, European authorities about the availability of specific expertise and powerful and flexible instruments which they could rely upon in their decision-making for the benefit of society.

## 1.1 NEAC Transport Simulation System: a Decision Support System in a multi-layered European Context.

Significant efforts have been made to model the inter-relationships between economic development, trade and transport. Normally transport models focus upon analysing detailed patterns of road traffic flows within limited regional scope; and this may extend to national transport models or cross-border "corridor" models. However, the main differentiating features of NEAC are that it addresses:

- Multimodal transport, at a
- Regional to European scale.

Therefore it is a suitable system for analysing medium to long-distance traffic flows, for analysing macro-economic impacts, global trade patterns, and for measuring wider-scale impacts such as greenhouse gas emissions. The system covers all of Europe and neighbouring countries, and provides the link between traffic and economic development across European regions. Applications typically focus upon forecasting, transport policy, transport infrastructure, port competition, containerisation, and environmental impacts of transport.

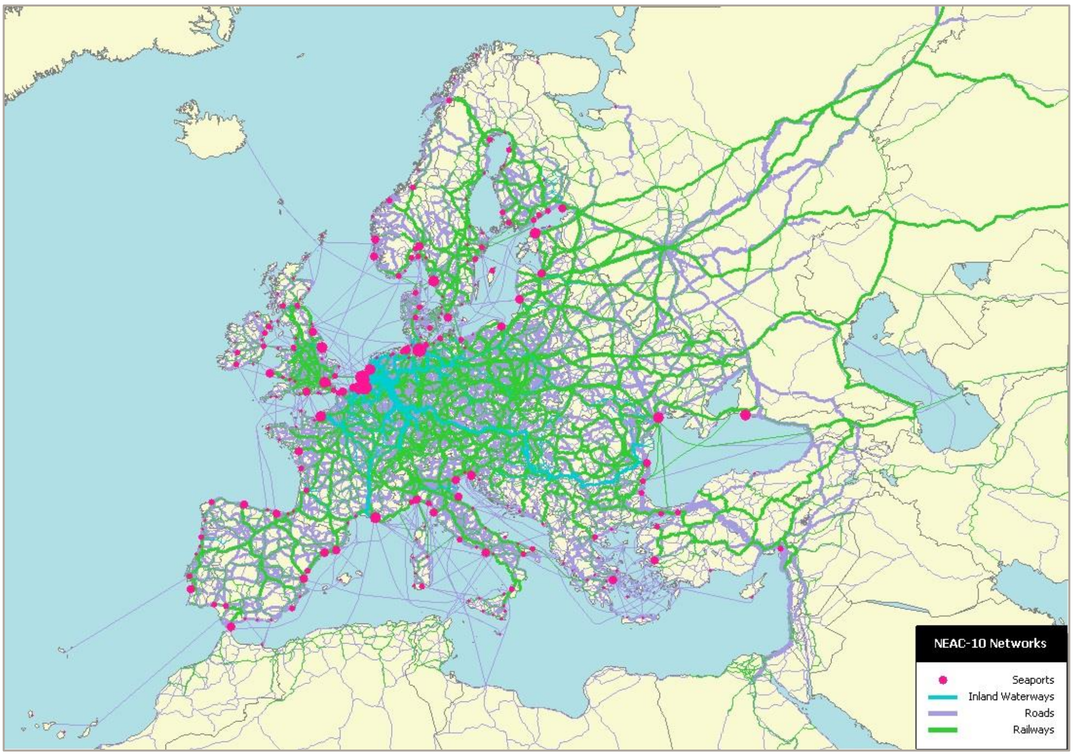
The basic units within the system are NUTS3 regions, and a multimodal transport network. Goods are traded between regions depending on their socio-economic needs and routed from origin to destination via the transport network. The volumes being traded, and the route/mode choices used determine the system's cost, measured as user (internal) and non-user (external) cost. Through a combination of exogenous and endogenous effects, the system can be modelled over time to produce forecasts.

Levels of economic development are linked to their levels of trade, which is constrained by transport costs, which increase over longer distances, resulting in the familiar pattern in which shorter distance traffics tend to dominate. The major trade routes connect urban centres, but flows are dispersed across thousands of links. Such a polycentric/dispersed pattern makes it difficult to develop new markets for transport systems such as rail and inland shipping which rely on scale economies. The development of European multimodal corridors is a way to focus the major flows onto priority routes which can be adapted in an efficient way to provide multimodal capacity and impact-amelioration methods in order to minimise internal and external costs.

The complexity of the spatial patterns of traffic flows are illustrated below in Figure 1. NEAC uses the extended networks developed by the WORLDNET project connecting to neighbouring regions in the Middle East, North Africa and Central Asia.

Ports have a special role within the system as the primary gateways for intercontinental traffic. Sea transport is included within the multimodal network structures in NEAC. Naturally, sea transport which offers high capacity and relatively low greenhouse gas emissions and low transport costs per tonne kilometre is a key element in NEAC. Port choice also has a major bearing upon inland patterns of goods distribution.

Figure 1: NEAC-10, Multi-layered European Transport Model



*Source: NEAC-10*

## 1.2 What Information is Available from NEAC?

NEAC allows users to analyse transport either at macro (pan-European) or at regional level, depending on the need.

The system illustrates the importance of traffic on the networks for every **region** considered:

- Current and future economic development per sector.
- Current and future traffic generated per region to and from every trading region.
- Accessibility to and from the region.
- Environmental impacts – energy consumption, emission levels.
- Levels and quality of infrastructure
- Impacts on traffic related to new investments in infrastructure.

NEAC illustrates the participation of regions in relation to their European **connections**:

- The role of regional distribution of goods in the organisation of transport chains, as the basis for multimodal transport.
- European infrastructure and regional development.
- Effects of measures at different levels – regional, national, European.

It addresses key areas of transport **policy**:

- Decision-makers are provided with detailed knowledge of the sources and the causality of traffic flows, a necessary condition for the optimisation of infrastructure use and planning.
- It is an instrument to measure the feasibility of new infrastructure projects such as new network links, or new ports or terminals.
- It helps to analyse or bench-mark a region or a country's position in Europe, to define cross-border co-operation and to manage development within a European context.
- It can be used to measuring the European interest of a regional project, e.g. removal of a bottleneck within a long-distance European corridor.

## 1.3 What level of detail does the system offer?

- The system applies a common regional structure (EZ2006-Level3), based on NUTS3, as developed for the ETISplus project (see below). Excluding the Russian Federation, there are 1585 regions defined in Europe. There are 2321 Level-3 regions worldwide.
- A core European area including all EU Member States, Norway, Switzerland, and neighbouring countries including Serbia, Bosnia, Albania, Montenegro, FYROM, Moldova, Ukraine, Belarus and Turkey.
- Worldwide flows to and from the core European area detailed by 52 product types (NSTR 2 Digit – see Annex).
- Cross-border and domestic flows within the European core area detailed by 52 product types (NSTR 2 Digit).
- Five transport modes for freight; road, rail, inland waterway, sea and others.
- 250 Seaports.
- 10,231 Railway links.
- 58,639 Road links.
- 2,005 Waterway links.

### *1.3.1 Regional detail*

(see ETISplus Final Specification [3], Section 4.3, p64 )

NEAC-10 uses the most detailed regional definition provided by the ETISplus database, equivalent to NUTS3 in EU Member States. It is a hierarchical zoning system allowing straightforward conversion from the more disaggregate Level 3 to intermediate Levels 2 and 1, back to Level 0 which is national.

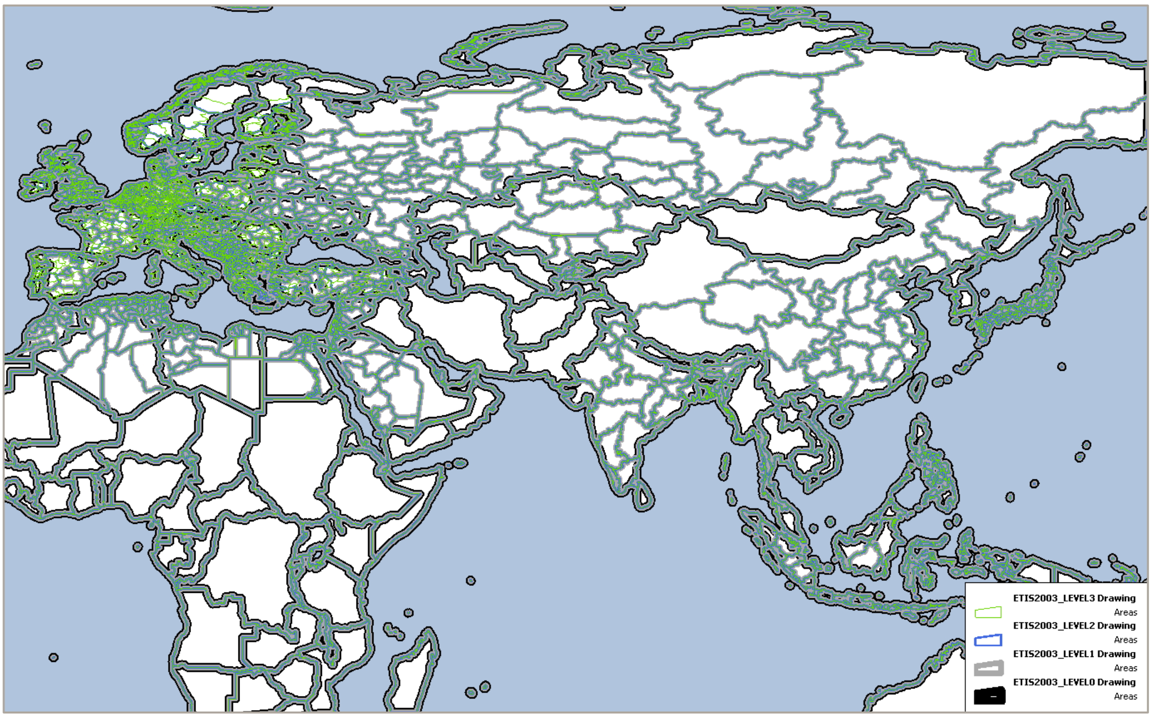
So whereas the NUTS3 system applies only to European Member States, the ETISplus system allows data from all over the world to be handled within a common set of definitions.

The maps below from the ETISplus Data Specification show how it is constructed, with two examples; one at a micro-level, and the other showing the worldwide zones.

Figure 2: Hierarchical ETISplus EZ2006-Level 3 Zoning – Inside Core European Area

*Source: ETISplus*

Figure 3: ETISplus EZ2006-Level 3 Zoning - Worldwide

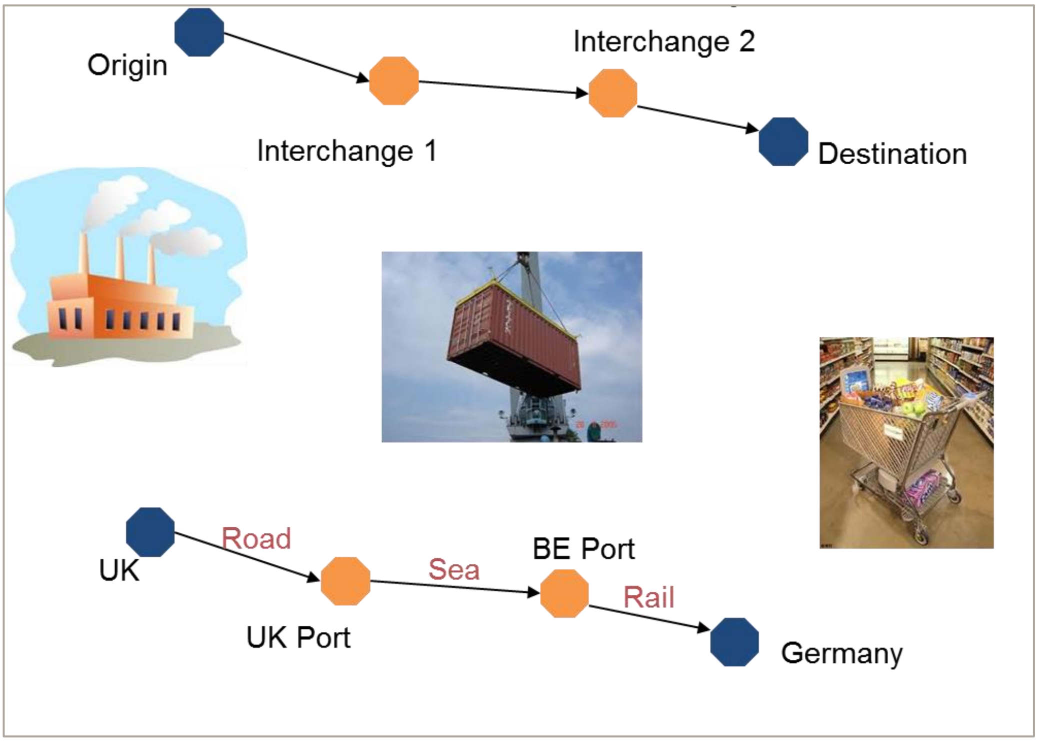


*Source: ETISplus*

## 1.4 Mode Chain Concept

One of the key features of the NEAC system is that it developed the concept of using mode chain structures within a transport model. This is a natural consequence of adopting a continental/worldwide scope. Europe trades with all regions of the world, and the most significant worldwide flows arrive by sea at European ports, at which point they are transhipped. When the goods enter the inland networks they switch to one of three inland modes; road, rail or inland navigation.

Figure 4: Mode Chain Concept



NEAC builds mode chains describing not just the exchanges of goods between regions, but the interchanges at which the goods are transhipped. In the case, for example, of trade between the UK and Germany, NEAC handles the flow as a multi-modal sequence, indicating which modes of transport are used inland, connecting the origin and destinations to the seaports.

Working in this way has major benefits for the model system because it provides a specific link between economic (trade) relations and transport flows. Chinese economic growth may generate exports to Germany, but this indirectly increases activity around the European ports handling these flows. From a database perspective this allows the system to make use of trade and transport sources, and to combine them. Thus economic effects (trade patterns) can be estimated using the same data structures as transport effects (mode and route choice).

From a user perspective there is major advantage. One of the main themes in transport policy is the development of multi-modal networks. It is therefore necessary to model multimodality explicitly within the system. Thus, the system is specified to allow *complementarity* and *substitutability* between transport modes, whereas traditional approaches only allow for the latter (substitution). In a practical example, bringing traffic by sea to a port with a rail connection, may also have the impact of increasing rail shares inland.

To illustrate the versatility of this chain approach, and example is provided showing trade flows between the Iberian Peninsula and Germany.  In 2010, the database indicates:

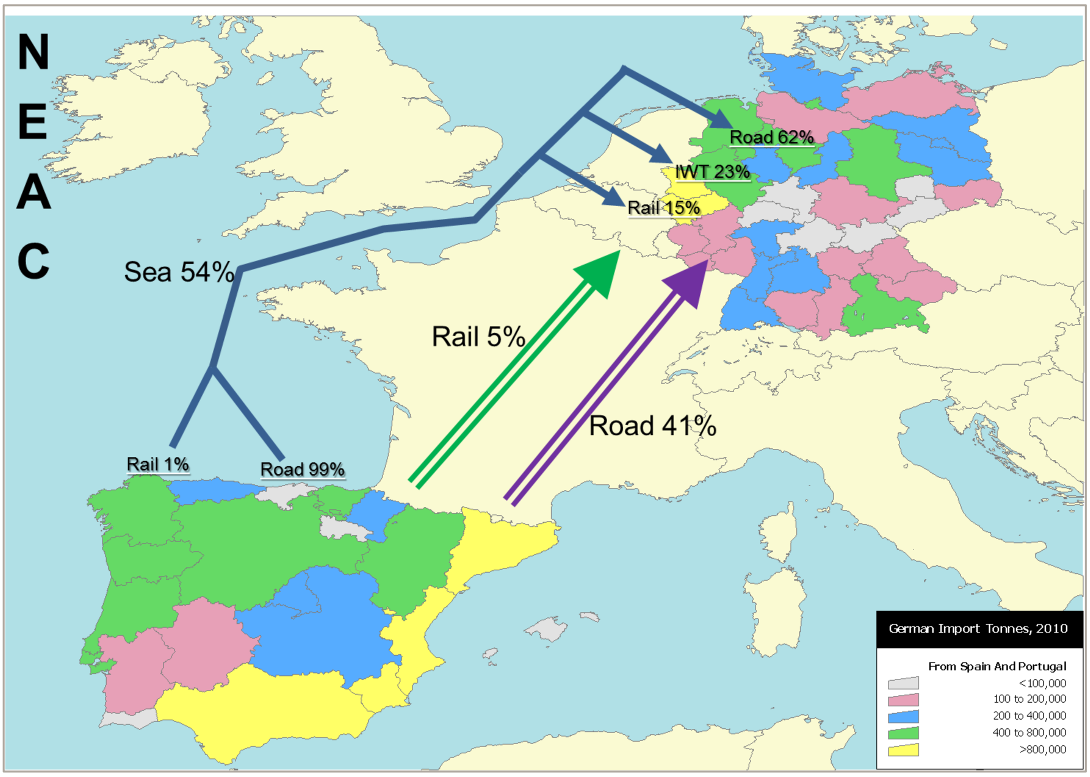
- 11.9 million tonnes exported from Spain and Portugal (combined) to Germany.
- This figure includes all commodities – unitised and bulk.

Mode split has been analysed according to the main (trunk) mode and for sea transport, the inland mode has also been split out.

Thus:

- Trunk mode shares are: Sea 54%, Road 41% and Rail 5%
- Iberian origin hinterland modes for sea flows are: 99% road, 1% rail.
- Hinterland modes at the destination are: 62% road, 23% waterway, and 15% rail.
- Note: Rail flows include road/rail combinations.

Figure 5: Segmentation of Traffic Flows from Iberia to Germany



*Source: NEAC-10*

The largest origin volumes in this example are found along the Mediterranean coastline of the Iberian peninsula, and the largest destination volumes are found in the Ruhr area of Germany.

The map shows that for any given corridor or trade flow, the traffic does not necessarily follow the shortest path (direct road in this example), but that a variety of routes and mode sequences are used, which can save either internal or external costs.

Such variations are also related to the fact that a high proportion of warehousing and logistical activity takes place in the Benelux region, thus linking towards inland waterway and sea options. The relatively low share of rail on this corridor is related to the fact that Iberian rail gauge (the width of the track) is wider than in France and Germany, so trains cannot run non-stop from inland regions of Spain to their destinations in Germany. Also, the fact that a high proportion of economic and trade activity takes place along the Iberian coastline (rather than the interior) helps to explain the high share for short-sea shipping, especially from Portuguese regions and the Atlantic regions of Spain.

As can be seen, a purely modal approach to transport analysis would miss important aspects of the pattern of freight flows within this corridor. A chain approach adds a high degree of extra complexity to the analytical process, but it is necessary to depict the relevant trade flows and forces shaping modal competition.

Compared to the traditional approach, in which only the direct road and flows would be visible, there are important differences in interpretation. If rail were seen as the only competitor for road, it might be concluded that possibilities for modal shift were limited, because otherwise rail flows would need to increase by more than 100% in order to make any significant difference. However, bearing in mind that sea offers a viable alternative, and that traffic arriving at seaports can also be captured by rail and waterway services, then it is clear that there is still considerable scope for modal shift from road, provided that the multi-modal options can serve a broad range of cargo types, such as fresh produce, which is an important Spanish export that is normally transported by road in refrigerated lorries.

In summary therefore, the mode chain concept, which is central to NEAC, offers clear advantages:

- Better representation of the complexity of the transport system.
- Reconciliation of the transport/regional-economics approach.
- Insight into the organisation of transport.
- Matching of transport policy to solving transport problems.

# 2 Model Concepts

## 2.1 Transport Systematics

Why attempt to model European transport? There are two straightforward answers to this question. The first is that data resources alone are far from ideal, and the second is that modelling, or the application of a set of simple behavioural rules, helps to provide an understanding of transport behaviour, or the dynamics of the system. In this way it is possible to develop the basis for a forecast or a scenario in which exogenous factors influence the outcome.

A useful set of guidelines to define the challenge of transport systems analysis were provided by Manheim in 1979.

| **Fundamentals of Transportation Systems Analysis** |
|---|
| The focus is on the interaction between the transportation and activity systems of a region. |
| The challenge is to conduct a systematic analysis in a particular situation which is valid, practical and relevant, and which assists in clarifying the issues to be debated. |
| The transport system must be viewed a single, multimodal system. |
| Transportation system cannot be separated from consideration of the social, economic and political systems of the region. |
| Total transportation system – the total trip, from point of origin to final destination, over all modes and facilities must be considered. |

*Source: Marvin Manheim, MIT, 1979 [5]*

Thus, the purpose behind model building is to be able to link the transport system to the economic activity systems, to allow an analysis to be made which helps to clarify the issues being debated. It needs to oriented towards what is relevant, and what is can be achieved in practice.

In the current context of analysing European transport flows, the main design goals for NEAC10 were:

- It should be possible to link economic activity via a trade model to traffic volumes.
- It should allow relevant policy and market variables, including transport costs to be modelled.
- It should be a multimodal model.
- It should be possible to estimate traffic impacts and externalities.
- It should be chain based, rather than with a conventional O/D.
- It should make good use of available data.

## 2.2 Modelling approaches

To a large extent transport modelling has developed in the field of local transport analysis, and in particular, for estimating or simulating vehicle movements in highly detailed network representations, typically road networks.

In general, there are two important categories of models that might be employed:

- Dynamic/simulation models, in which the system captures the behaviour of individual agents such as drivers and passengers, and how they interact with each other.

- Rational pipe models, in which 'blocs' of demand are estimated and then shared out, first between zones, then by transport mode, and then to links within given modal networks.

### 2.2.1 *Four Step Models*

A classical approach to rational pipe transport modelling, followed since the 1960s is the 'four-step' approach.

**Step 1: Generation** – the amount of traffic generated or attracted to/from a region.
**Step 2: Distribution** – the region to region flows.
**Step 3: Mode Split** – the region to region flows per mode of transport.
**Step 4: Assignment** – the traffic flows mapped onto (assigned to) a modal network structure.

In this way, with relatively limited data about the socio-economic characteristics of a zone and the transport choices available, it would be possible to develop a model showing estimated flows within e.g. the road network.

Four stage models have been popular, often because they can be developed with commonly available data and software tools, and also because they are scale-able to conurbation, national level or even European level. Zones and networks can always be scaled up by aggregation, but agents in dynamic models have to be recognisable entities such as individual drivers.

### 2.2.2 *Multimodal Modelling – Long distance transport*

As the model scope is scaled up however, the primary challenge becomes the estimation of the third step, transport mode, due to the greater likelihood for multi-modal trips. The problem is compounded by the lack of available data sources showing how transport modes are used in combination. It therefore shifts from a data analysis issue to a modelling issue, of how to predict what combinations of modes will be used in sequence. Modelling chains is similar conceptually to network assignment, so there is a tendency here for steps three (mode split) and four (assignment) to merge.

In the 1990s, there were several attempts to develop suitable structures for multimodal modelling. STEMM (Strategic European Multimodal Modelling) was a

Fourth Framework research project [6] to develop a methodology for modelling multi-modal chains for passenger and freight transport.

Rather than deriving transport chains empirically from statistical sources, the STEMM project focused specifically on estimating them within a model structure, using multi-modal transport networks and transport costs. In this way, the required demand databases were constructed with reference to a fixed representation of the supply side of the market, and then calibrated using network link counts, where they were known.

The STEMM freight model, developed by MDS-Transmodal, ITS-Leeds and IWW (KIT), could therefore be used to estimate transport chains. An important goal in STEMM was to understand the circumstances in which different transport modes were complements (choose x AND y) or substitutes (choose x OR y). Since STEMM, the multi-modal freight model concept was developed further by MDST in a UK context, as GBFM, part of the UK's national model [7]. Like STEMM, GBFM estimates all the traffic flows synthetically, builds multimodal chains and then compares its estimated flows with observed flows at those points where a comparison can be made e.g. seaports. Thus the model is calibrated to transport data, rather than derived directly from it.

The main advantage of multi-modal network based models like GBFM is their ability to work around substantial data gaps, to unify the processes of mode split and assignment, and to make the estimation of the base year essentially the same process as the estimation of a forecast or scenario. Their relative simplicity and transparency makes it easier for the user to trace the relationships between the inputs and the outputs.

During the WORLDNET project, these modelling concepts were applied to database construction. Projects such as ETIS-Base and TRANSTOOLS had made parallel developments in Europe-wide transport network databases and cost databases, making it possible to attempt the construction of a chain-based matrix of long-distance flows (European cross-border and Europe to/from the rest of the world), with relatively meagre data inputs.

This WORLDNET methodology is therefore the basis for the database construction in NEAC-10.

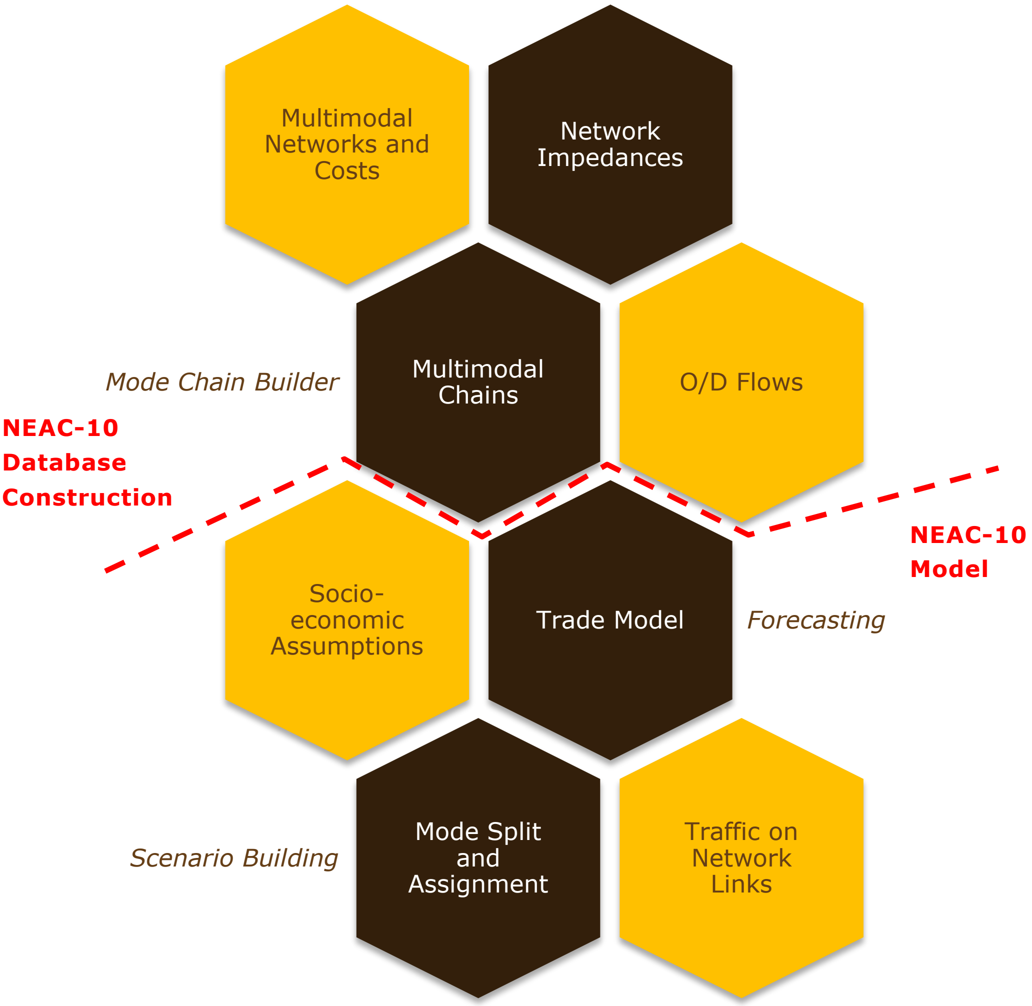
## 2.3 NEAC-10 – Overview Structure

NEAC-10 consists of two main parts:

- A database, including a mode chain database containing the base year traffic flows.
- A model for forecasting future demand, or transport scenarios.

However, these are integrated through the use of a common set of transport network structures, derived from the ETISplus project.

Figure 6: Overview of NEAC-10 Structure



The top half of the graphic represents the NEAC-10 database building process, resulting in a reference database of multimodal chains for the base year of 2010.

The lower half represents the NEAC-10 model, handling the dynamic aspects of the system, i.e. for estimating changes compared to the base year.

Methodologies for these two main components are set out in the following sections.

# 3 NEAC-10 Database

## 3.1 Overview

This section focuses on the methodology for estimating the long-distance origin-destination matrix used in the NEAC-10 model. Previous exercises of this nature e.g. ETIS-BASE and (1990s era) NEAC have tended to use methods focusing upon data combination to estimate transport chains. However, as the geographical areas being considered have grown, along with the associated data sourcing and harmonisation requirements, it has become impractical or indeed impossible to estimate a complete matrix at a suitable level of detail by simply combing available data.

On the other hand, as the availability and quality of digital transport networks has improved, it has become more feasible to use a modelling methodology as a matrix generator.

In short, we have developed a software package called the Mode Chain Builder (MCB) to combine available trade and transport data, and to estimate multimodal chains which are (1) calibrated and (2) fitted to known (unimodal) data.

A world trade database is used to estimate traffic generation at national level; a regional (NUTS3) distribution model is then applied to subdivide the trade flows into regions; and a multi-modal assignment procedure is then used to assign to multimodal transport chains. It is therefore a top-down process starting from trade data.

## 3.2 Terminology explanation

Since various textbooks and models use certain important terms interchangeably, it is useful to summarise the terminology used in this report.

Of particular importance is the understanding of the terms production/consumption (P/C) and origin/destination (O/D), because usage and understanding of these terms varies. Many transport or regional economic models are somewhat theoretical in nature, for example, those that apply text-book economic theories to estimate monetary trade between regions and industrial sectors. They then apply value/tonne densities to estimate traffic flows between points of production and consumption, or P/C matrices. Observing that these P/C matrices rarely resemble actual transport flows, they then add an intermediate fitting or logistics stage to convert P/C matrices into O/D matrices which can generally be compared and calibrated against known flows. Following this approach there are clear demarcations between P/C and O/D matrices.

In NEAC-10, there are some similarities with the above approach, but since the estimation steps are different, the interpretation of the NEAC-10 data structures also needs to be different. NEAC-10 splits (disaggregates) trade data (measured in tonnes) into multimodal NUTS3 chains, and all the data structures reflect this.

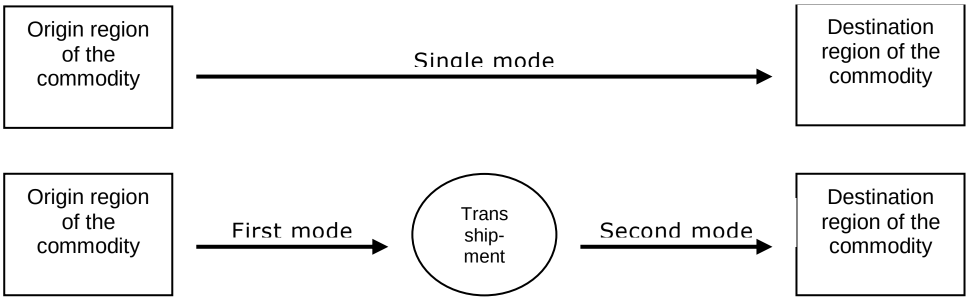
Table 1: Terminology

| ***Term*** | ***Meaning*** |
|---|---|
| Aggregate | Transport volumes measured at national level or higher. NUTS0. |
| Disaggregate | Transport models measured at sub-national levels e.g. NUTS3. |
| Trade | A buy/sell transaction. |
| Foreign Trade | Trade across international borders (import or export). |
| Consignment | A bundle of goods that is being sent as part of a single trade transaction. |
| Traffic | Relating to vehicle or vessel movements in a transport system. |
| Door to Door | From point of sale to point of purchase. |
| Quay to Quay | From transport facility to transport facility within a given mode. |
| Production | Relating to the transformation of resources into a product. |
| Consumption | Relating to the use of a product. |
| P/C matrix | A production/consumption matrix, i.e. one showing the entire journey from point of production to point of consumption. |
| Origin | The starting point for a flow. |
| Destination | The end point for a flow. |
| O/D matrix | An origin/destination matrix, showing trips between regions. |
| Chain | A sequence e.g. of traffic flows. |
| Trans-shipment | The exchange of a consignment between one ship (or other transport type) and another. |
| Modal Transfer | The exchange of a consignment between one mode of transport and another. |
| Mode Chain | The representation of a *trade* flow as a *chain* of *traffic* flows, identifying the intermediate *modal transfer* points. |
| Unimodal | Referring to a single mode of transport. |
| Calibration | Setting of exogenous model parameters to achieve a specific target value. |
| Fitting | Direct change/modification of an estimated value in order to match a specific data point. |

## 3.3 Mode Chain Data Structure in NEAC-10

In common with the 1990s era NEAC models, with ETIS, and with WORLDNET, the NEAC-10 database consists of chains rather than simple origin-destination relations. This concept is illustrated in Figure 7, in which an example of a transport chain with direct transport and a transport chain with indirect transport (including one transhipment region) is given:

Figure 7: Mode Chains with Direct and Indirect Transport



*Source: Smies L., Mode choice in European freight transport; the development of a modal-split model for the NEAC system.*

The inclusion of transport chains in the database makes it possible to model aspects of the interrelation between economic indicators and freight transport than would be possible by using traditional origin-destination matrices. Using transport chains implies that each trade relation can consist of more than one transport relation, since the possibilities of transhipment are taken into account explicitly. This in turn allows registering multimodal transport and transit flows in a more accurate way.

Also, the transport chain concept eliminates double counting. Transport that is transhipped in a harbour region is normally registered twice, in the international trade statistics as well as in the domestic transport statistics.

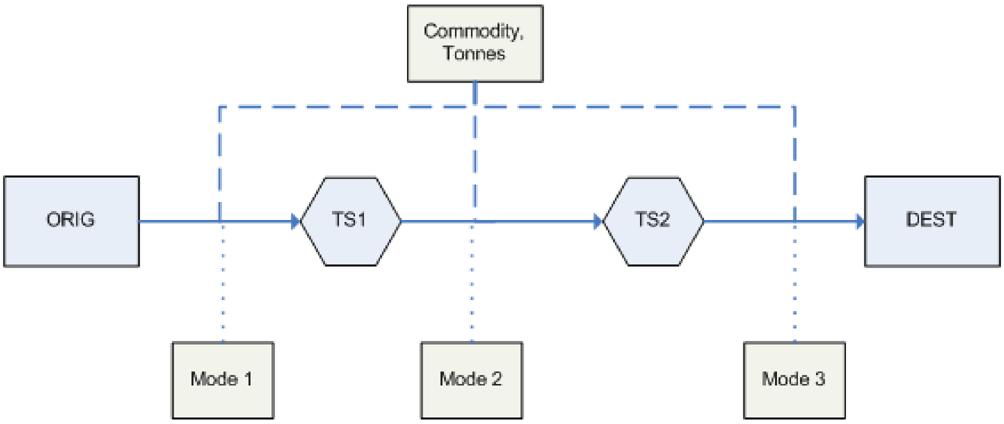
The actual data structure is listed below. It allows for two possible transhipment points, and therefore three separate transport relations within any given trade relation.

Table 2: Chain Data Structure in NEAC-10

| **Field** | **Type** | **Description** |
|---|---|---|
| DestinationZoneID | Long Integer | NUTS3 Region in Europe, Country elsewhere |
| OriginZoneID | Long Integer | NUTS3 Region in Europe, Country elsewhere |
| Transhipment1ZoneID | Long Integer | NUTS3 Region in Europe, Country elsewhere |
| Transhipment2ZoneID | Long Integer | NUTS3 Region in Europe, Country elsewhere |
| Stage1ModeID | Integer | Transport Mode at Origin |
| Stage2ModeID | Integer | Transport Mode between Transhipments |
| Stage3ModeID | Integer | Transport Mode at Destination |
| CommodityGroupID | Integer | NST Product Sector (2 Digit code) |
| Tonnes | Double | Traffic Volume in Tonnes |
| ContainerTonnes | Double | Container traffic volume in Tonnes |
| Container TEU | Double | Container traffic volume in twenty foot equivalent units (TEU), including empty containers. |
| SeaChain | Boolean | TRUE if chain involves sea transport |
| | | |
| *Base Year = 2010* | | |

Graphically, this can be pictured as a path through a network with (up to) three links and two intermediate modal interchanges (TS1 and TS2).

Figure 8: Graphical representation of mode chain structure in NEAC-10

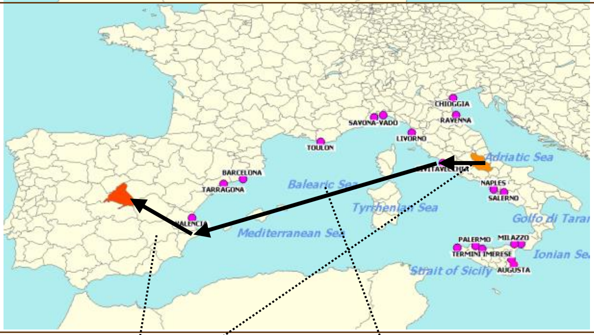
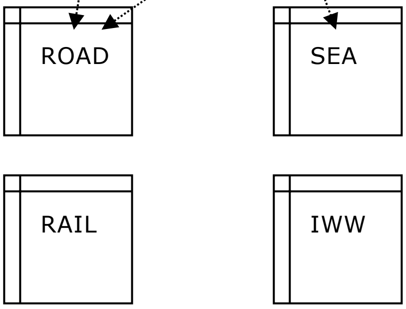


## 3.4 Mode Chain Builder

One of the key software elements within NEAC-10 is the Mode Chain Builder (MCB) which converts trade records (national level) into estimated NUTS3 mode chains.

The top-down estimation process can be exemplified graphically:

Figure 9: Mode Chain Builder

| | |
|---|---|
| **1. National Level**<br>Trade Data<br>e.g. Italy to Spain, Tonnage by product. 2010 |  |
| **2. Regional Split**<br>Regional Trade Data<br>e.g. Italy NUTS3 to Spain NUTS3, Tonnage by Product. 2010 |  |
| **3. Mode/Route Choice**<br>Mode Chain Data<br>e.g. Italy NUTS3 via Italian Port to Spanish Port to Spain NUTS3, Road, Sea, Road, Tonnage by Product.<br>2010 |  |
| **4. Transport Matrices**<br>O/D Data per Mode<br>Mode Chain Links are mapped into modal O/D matrices.<br>2010 |  |

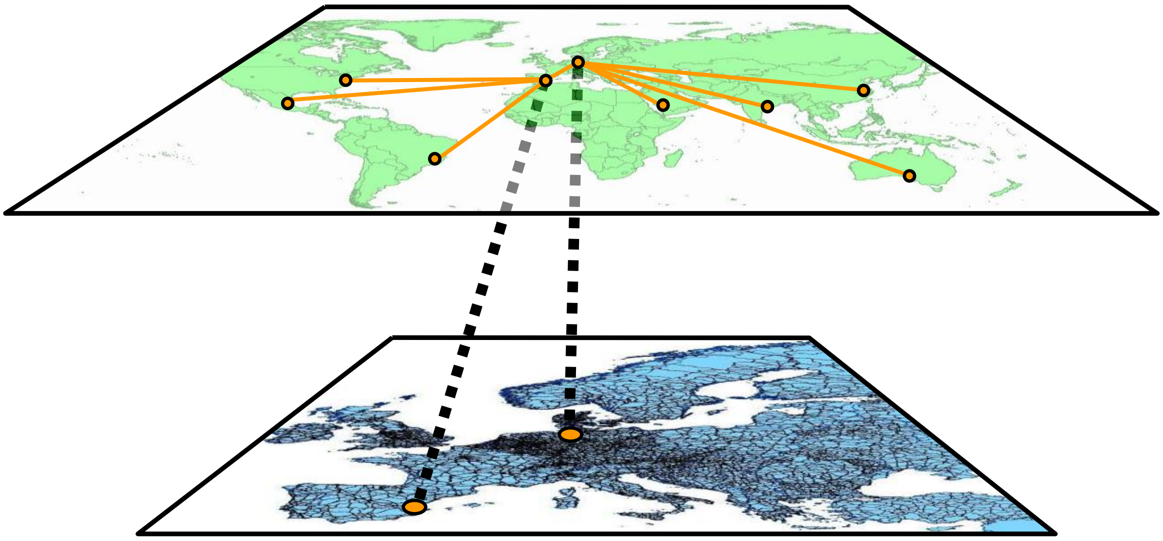
### 3.4.1 Methodology

Conceptually, the mode chain building process is straightforward. Trade data records which are derived from observed trade databases are split by region, and then the region to region flows are assigned to a multimodal network, in order to build a set of mode chains. Each leg of the mode chain represents a trip within a given mode, so by copying these chain segments into uni-modal O/D tables, it is possible to build transport matrices which can be compared against known quantities.

However, searching for multi-modal paths within highly detailed infrastructure networks covering a large area, for example those used within NEAC-10, an exhaustive method for enumerating possible paths, would generate a vast choice set. Given that the path enumeration process needs to be repeated for each consignment in a NUTS3 regional matrix with over twenty million entries, reducing path search space and complexity at this stage is imperative.

Therefore a two layer process was developed, so that the multimodal path search can be done by using hyperlinks through the unimodal networks.

Figure 10: Connecting terminals and networks – multimodal approach

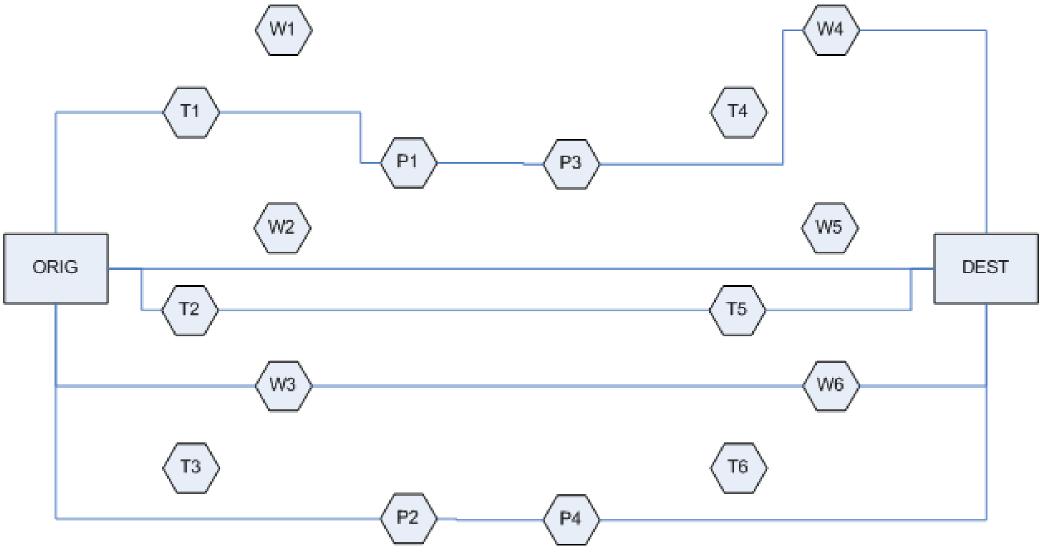


*Source: IWW, Worldnet Beijing Seminar, 2008*

First, a set of short path impedances are calculated for each of the unimodal networks (lower layer). Then a high-level multimodal graph (upper layer) is constructed using the unimodal impedances as inputs. In the diagram it shows how a worldwide transport chain might be constructed containing a single hyperlink connecting Spain to Denmark. That hyperlink itself would represent an entire journey by road. Its impedance summarises the characteristics of a much more detailed underlying road network.

The design of the high-level multimodal graph, and the degree of abstraction is therefore crucial to the resulting characteristics of the system. A schematic is shown below.

Figure 11: Mode Chain Builder - Multimodal Graph Design



*Source: WORLDNET*

ORIG, and DEST are specific origin and destination regions connected by a freight flow. The nodes P1-P4 are seaports, T1-T6 are rail terminals, W1-W6 are inland ports. Some paths have been traced out within this array of possible nodes. There is a simple road path connecting the origin and destination directly, an intermodal rail path via T2 and T5, an intermodal waterway path via W3 and W6, a road-sea-road path via P2 and P4, and a road-rail-sea-waterway-road path via T1, P1, P3 and W4.

To arrive at this construction, the system needs to generate sets of interchange nodes and then try to connect them into multimodal paths.

The origin and destination are given, fixed points. The single-mode networks can be used to find a sensible short list of accessible inland rail, waterway terminals and seaports for the origin and destination respectively. In the diagram, only a few nodes are shown, but in practice there will be several hundred. Node selection can also be linked to the commodity type to refine the choice process.

Mathematically, all nodes could be connected to all other nodes by all possible modes, but in practice this is not necessary. Origins and destinations connect to anything by road, (except in the special case where the origin and transfer node coincide). Origin rail terminals connect to destination rail terminals by rail. Origin rail terminals also connect to seaports by rail. Origin ports connect to destination ports by sea, and so on.

Following this method, it is possible to elaborate the graph structure in a realistic, hierarchical way, and then with reference to the underlying networks, the system can test whether a given link exists, and what its impedance is.

In this way, impossible connections are eliminated (e.g. Cyprus to Malta by road). Improbable, but possible connections are allowed, but they will be discarded later if their impedance is too high (e.g. Austria to Germany via Piraeus and Gdansk by sea) relative to other options.

The main value of this approach is that a simplified graph of hyperlinks prevents the feasible path set from expanding beyond a predictable level, and that simplification allows the model to enumerate all the paths, not just one optimal one. The model can then assign to the best ‘k’ paths, which is far more realistic.

A related benefit is that the system cannot produce paths with more than three links (two transhipment points). Additionally, one of the main problems with multimodal assignment can be avoided. An unconstrained multimodal assignment process can produce unrealistic chains with too many links.

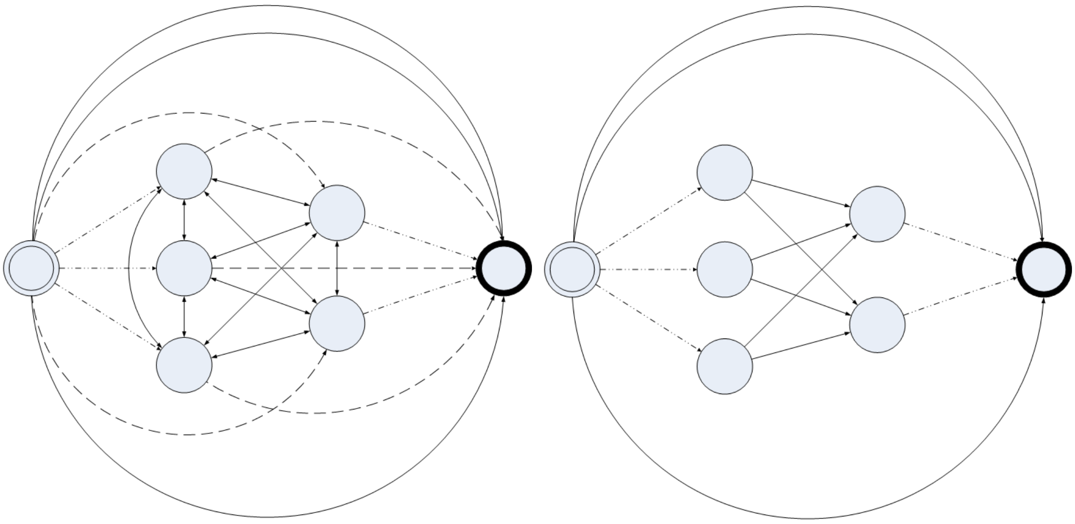
The key challenges have been limiting the size of the graph within the full-scale application and developing a one-size-fits-all structure that is equally applicable for intra- and inter-island flows as well as more straightforward continental journeys. In practice there is a limitation imposed by the need to build a transport chain with only two transhipment points, when four might be a more realistic option for inter-continental transport, but the approach has been to include the sea leg and the main inland link at each end if more links are found.

### 3.4.2 *Port Choice*

A particular problem has been the selection of sea ports. While transfers to rail and inland waterway are likely to occur close to the origin or destination, different heuristics needed to be developed in order to create a realistic choice set for sea ports. This is partly because sea transport can involve significant detours, partly because certain ports specialise in certain traffics, and partly because different combinations of distance and travel time apply differently for different cargo types. Additionally short-sea and deep-sea flows behave differently.

One mathematical possibility is to allow the optimisation to consider routes via ll possible port combinations. In reality this would take too much space and time to be computable, and most paths would not be allocated any traffic due to their sub-optimality. This can be illustrated below.

Figure 12: Finding maritime paths within a multi-modal network



Source: WORLDNET

Figure 12 displays a network connecting an origin (leftmost node) and a destination (rightmost node). This network contains five sea ports (centre nodes). The dashed links represent connections between nodes.

The figure on the left displays an “ideal” network where origin and destination are connected to all ports, and the ports are fully connected to each other.

The figure on the right displays a network with a heuristic applied to limit the number of port to port connections. Here the ports are divided into two sets, one close to the origin and one close to the destination. Any single port may appear in one or both sets.

Due to the method used to select ports the sets of ports will not intersect too much, reducing the potential number of paths.

Table 3 Number of paths arising from different network sizes

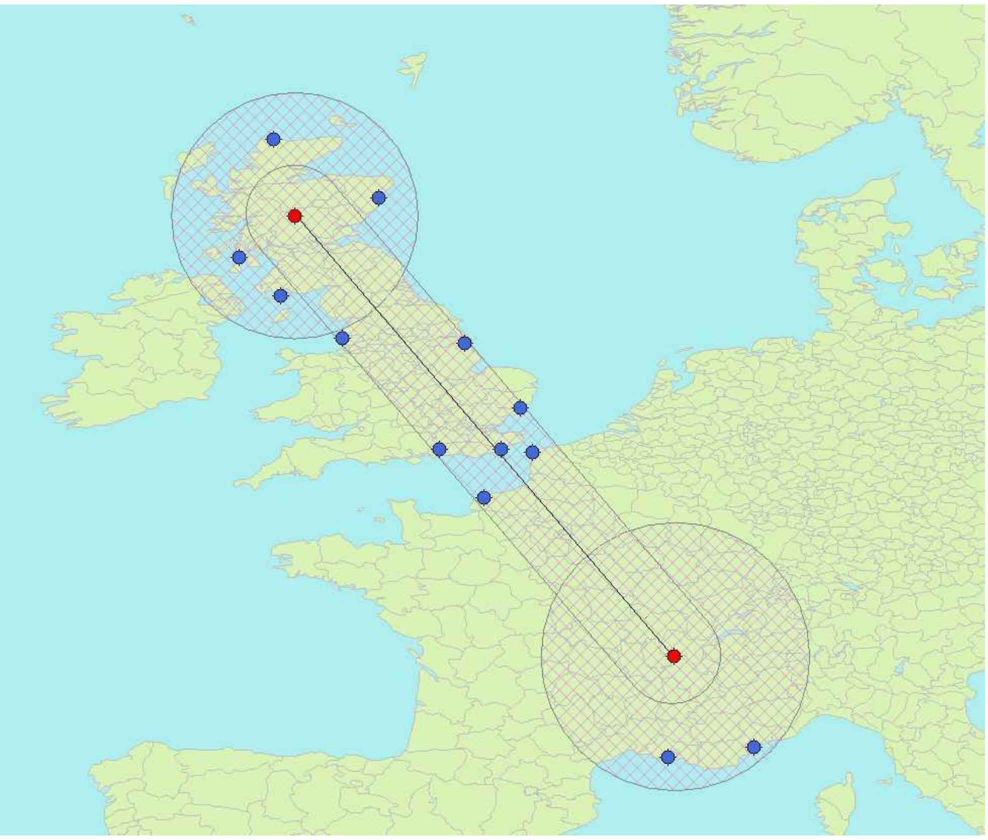
| ***Ports*** | ***"Exhaustive"*** | ***Heuristic*** |
|---:|---:|---:|
| *1* | 12 | 12 |
| *2* | 39 | 12 |
| *3* | 138 | 21 |
| *4* | 539 | 39 |

The table displays the amount of possible paths in networks for a given origin and destination. The figures given for the heuristic approach are for the scenario where the sets of ports are distinct and of equal size.

Beyond four ports, the calculation time expands at a factorial rate using the exhaustive search. The heuristic method however allows a set of paths to be found which is on the one hand large enough to be representative of the main (and likely) route options, and on the other, not so large as to require unreasonable calculation time. Finding this balance has been an important element in being able to carry out a detailed network search for a very large set of traffic flows.
The system now selects the nearest ‘n’ ports to the origin, the nearest ‘m’ ports to the destination, and the ‘p’ ports that deviate least from a straight line between origin and destination.

See example below:

Figure 13: Bounding Box for Port Selection



Source: WORLDNET

By controlling 'm', 'n' and 'p' it is possible to set absolute limits on the number of ports entered as transhipment points in the network, and at the same time ensure that different types of paths are entered.

Considering a traffic flow from Central Scotland to Central France, the system would enter the nearest Scottish ports, the English South Coast ports directly en-route to France, the French Channel ports, and the Mediterranean ports closest to the destination. Thus, the path enumerator would then be able to compare the costs of a trip with a high proportion of overland transport e.g. Glasgow-Portsmouth-Le Havre-Lyon with a trip with a high proportion of sea transport e.g. Glasgow – Clydeport – Marseilles – Lyon.

Since the attractiveness is only known after all the paths are enumerated the key concern is to create enough diversity in the port choice mechanism to ensure that structurally different routes can be compared. The system can be improved by filtering the port choice to match the cargo's mode of appearance to the facilities at the ports. Thus crude oil would not be diverted via a ferry port.

Having generated the best 'k' paths, the system allocates traffic to them using a multinomial logit function. The size of the bounding box and the value of 'k' are set to permit feasible calculation times.

### 3.4.3 Calibration

The mode chain builder runs iteratively, comparing its results against known transport data, and then adjusting its parameters to fit the results to the available data. As might be expected, calibration of the NEAC-10 database is a highly problematic area.

Key issues are:

- Matrix size, and the resulting processing time required for each iteration.
- Lack of multi-modal data against which the results can be corroborated.
- Local exceptions – it is unknown in advance if different choice function parameters are required to take account of specific local preferences.

Matrix size limits the number of model iterations which it is feasible to perform. Lack of data, or unreliability thereof, makes it difficult to compare modelled results with reality. Localisation is a potential hazard if calibration is limited to certain parts of the territory where good data can be found, e.g. France or Spain.

A related problem is that in order to compare the mode share results with national statistics for transport performance (t.Km), the transport chains have to be assigned to the detailed single-mode networks, adding time to the process.

Ports also provide a calibration point. Multimodal chains identify modal interchange points (at least they identify the NUTS3 regions containing the interchange points). If port volumes within these regions are also known, the estimates can be compared with the actual tonnages. Some simplification is also required because within EUROSTAT, port volumes are typically aggregated by mode of appearance (e.g. RORO, LOLO, liquid bulk), and not by NST commodity.

In practice therefore, the calibration iterations are carried out by reducing the matrix size, sampling records according to a heuristic which will ensure a representative range of records, and then gradually increasing the matrix size as the iterations start to converge.

## 3.5 Containerisation Estimation

All of the analysis and database construction carried out within the Mode Chain Builder, as described above, represents traffic flows as tonnages, as the lowest common denominator for all product categories. The calibration is carried out with reference to national figures for tonne kilometres. However, it is also necessary to be able to separate containerised volumes, and to convert these into expected volumes of twenty foot equivalent units (TEUs).

The system uses a three step calculation:

1. Identification of commodities and flows (tonnages) which can be containerised.
2. Conversion of these tonnages into TEU's using commodity densities (cubic metres per tonne)
3. Estimation of load factors – loaded, empty and partially loaded containers.

Under the current specification, only chains including sea transport are converted into estimated container volumes. However, this also means that the hinterland journeys for these sea chains are converted too.

## 3.6 Chain Fitting

An extra 'fitting' step is performed after the chain matrix has been calibrated. Mode Chain Builder outputs are calibrated against tonne kilometres per combination of country, commodity and mode and therefore not as region-region flows. Fitting the calibrated outputs to disaggregated O/D data (where available) potentially improves the database considerably.

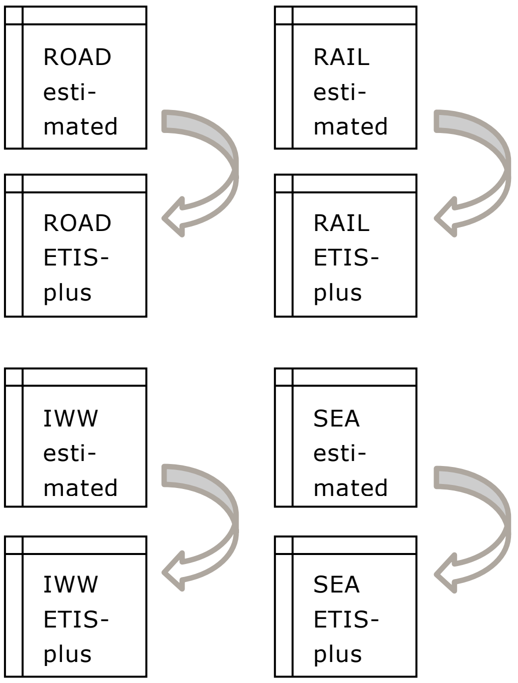
The individual transport matrices, derived from the chain are compared against the unimodal transport data from ETISplus database. This validation step fits the estimated traffic matrices to the transport data, by which the modal split balance on country level is adjusted. The country level traffic performances (tonne-kilometres, EUROSTAT) are used to check these adjustments.

This iterative fitting process takes place at regional (NUTS2) and commodity NST1 level because of the un-reliability of European transport data beyond this level of detail. For all modes and commodities the absolute differences are calculated and sorted by the corresponding volumes.

Figure 14: Chain Fitting Step

**Chain Fitting**

Unimodal O/D matrices 2010 derived from Mode Chain links are compared against the ETISplus 2010 transport matrices, and factors are calculated to fit the chains to the observed flows.

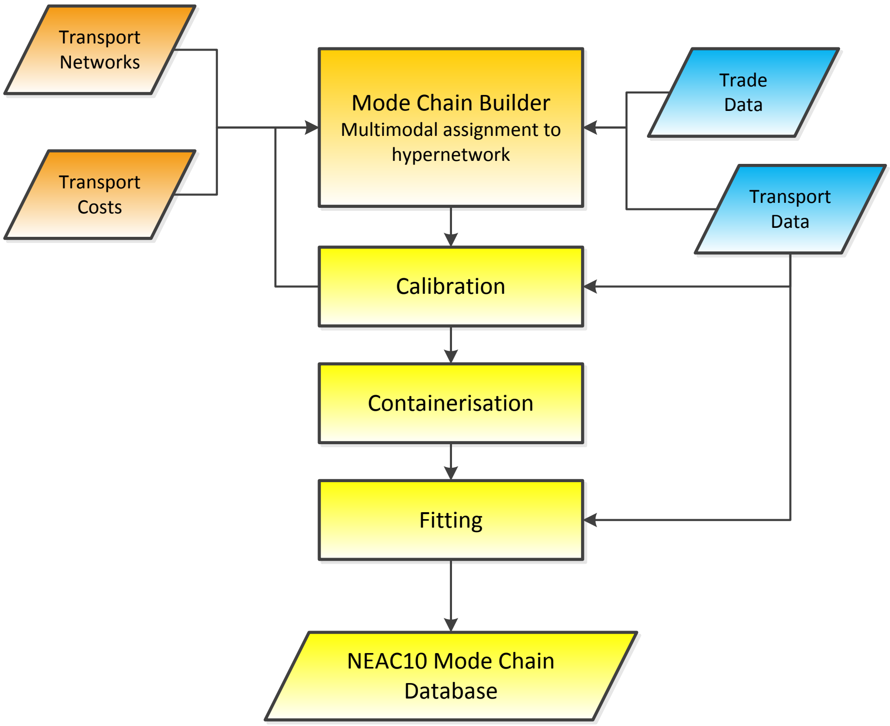


The correction factors (calculated at O/D/Mode level) are determined by the largest differences and are applied at chain level. This is complicated by the fact that O/D/Mode combinations have dependencies because of the chain structures. Factoring a chain record with both road and rail links affects both road and rail volumes, so an iterative process is required to solve these dependencies. Fitting allows new cells to be created in the resulting matrix, and also for chain segments to be swapped by mode. The factoring process is therefore dynamic. Re-running the routine, feeding the output back as input (iteration) improves the overall fit.

The final outcome is that the fitting process has the effect of changing the P/C relations compared to the original trade data. The changes in P/C balance are monitored during this iterative process at a country level.

## 3.7 Summary

Figure 15: Summary of Mode Chain Database Construction



# 4 NEAC-10 Model

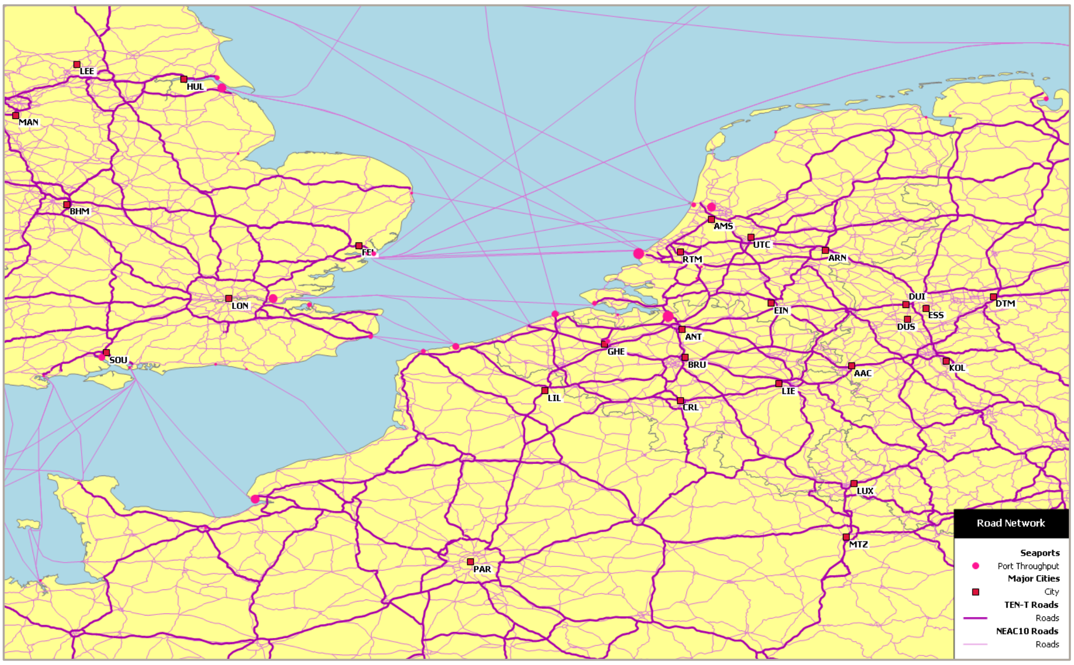
## 4.1 Transport Networks

NEAC-10 is a network-based transport model, meaning that the supply side of the transport industry is represented as a set of network structures connecting the trading regions in the model. Changes in networks influence accessibility and cost, traffic routeing patterns, and ultimately external costs.

NEAC-10 utilises the 2010 European networks published by the ETISplus project[1]. These have evolved via projects such as ETIS-Base, Transtools and Worldnet, and are designed to be suitable for analysis of transport at a range of scales from European level (TEN-T) down to NUTS3 level.

An example is shown below, comparing the NEAC10 network (thinner lines) to the European TEN-T network[2] (darker lines). Whereas the TEN-T network focuses on the main inter-urban links, the NEAC network include the main intra-urban links, as well as more of the supporting rural infrastructure.

Figure 16: Road Network in NEAC-10



A network structure with this level of detail is suitable for analysing transport flows of about 50km and upwards, which means that it is suitable for regional, national, corridor and pan-European models, but less suitable for urban or project level analysis.

At pan-European level, the network covers all countries including non-EU countries, and it has a full set of links to the neighbouring countries and beyond.

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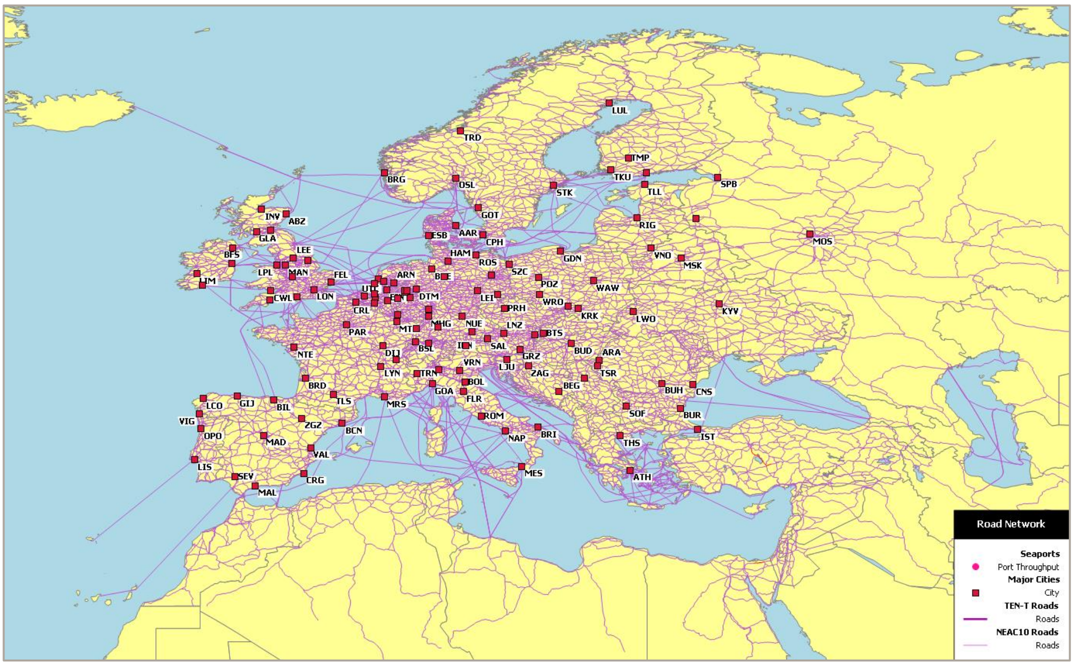
[1] ETISplus, WP7, Karlsrühe Institute of Technology (KIT).

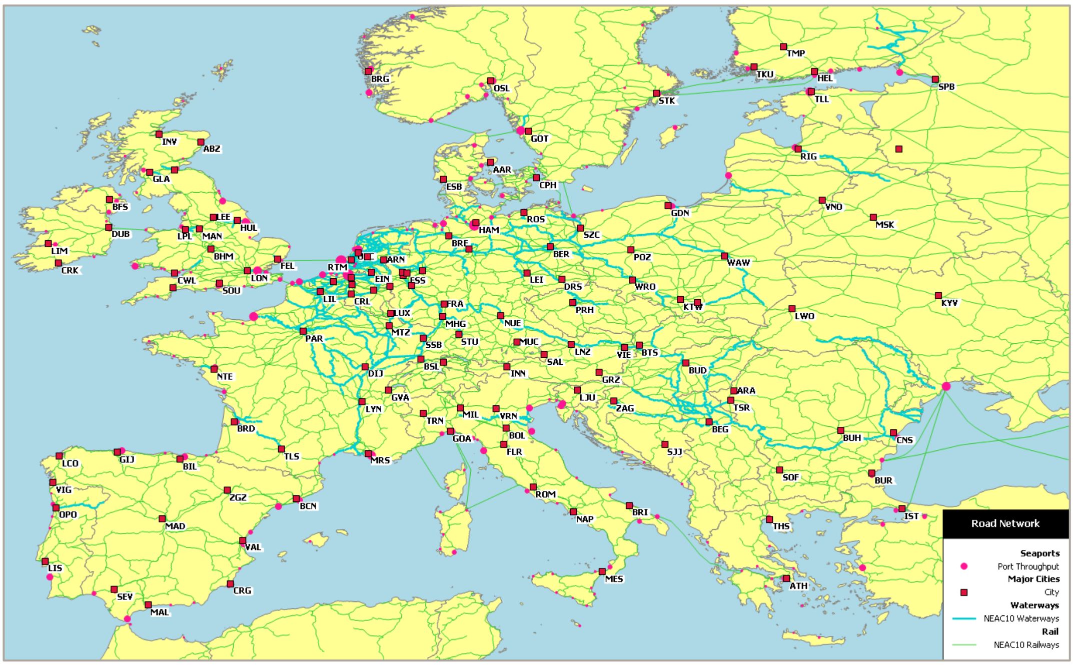
[2] TENtec, European Commission, DG-MOVE.

Figure 17: Full Extent of Road Network



Road and waterway networks are less dense in coverage, but the cover an equivalent area incorporating all European countries.

Figure 18: Extent of Rail and Waterway Networks in NEAC-10



## 4.2 Transport Costs

Modelling transport demand and estimating transport costs are closely related. However, estimating transport costs within a large scale model such as this involves a high degree of simplification, especially for transport modes such as rail and waterway where specialised transport options exist for specific commodities. Cost structures for unitised and bulk cargo are different. Relatively little exists in systems such as TRANSTOOLS to indicate preferred methods for calculating transport costs.

In NEAC10, the approach for estimating transport costs is to model the cost of operating a vehicle for a specific time period (e.g. a year) with an assumed rate of activity (hours working or annual mileage). These annual costs can then be averaged per kilometre or per hour. However, it is not necessarily straightforward to apply such costs inside a model. A vehicle making frequent short trips would have a different productivity level to one making infrequent trans-continental trips because it spends a greater part of the year travelling empty, part loaded or being loaded.

In a model it is typically necessary to distinguish between **fixed costs** such as terminal loading/unloading, **time-based costs** such as equipment hire and wages, purely **distance based costs** such as fuel and **link-based costs** such as road tolls.

The estimation procedure in NEAC10 is based on the approach adopted in ETIS-Base (MDS-Transmodal, AJI-Europe), and updated for the Transalpine Multi-Modal Model (TAMM, NEA).

### NEAC10 Cost Model

The cost formula is generic for different modes, consisting of five basic elements:

- Track or infrastructure
- Traction or haulage
- Equipment; wagons, containers etc.
- Terminals or transhipment/loading points
- Service

For road or rail, these elements would be:

| | **Road Network** | **Rail Network** |
|---|---|---|
| **Track** | Road tolls | Infrastructure/track charges |
| **Traction** | Haulage | Locomotive |
| **Equipment** | Trailer | Wagon hire |
| **Terminals** | Loading/Unloading | Loading/Unloading |
| **Service** | Profit margin | Profit/Subsidy |

Cost items are termed “Variable” if they depend on distance, and “fixed” if not. Costs such as wages and capital costs are considered fixed because they are time based rather than distance based.

### Road Costs

An example is provided showing how road costs are calculated for a given journey:

| Cost Item | Basis | Example | Example Rate |
|---|---|---|---|
| Track Variable | Per Km | Road Toll | 0.05€/km |
| | | | |
| Traction Variable | Per Km | Haulage. Mainly (95%) fuel | 0.35€/Km |
| Traction Fixed | Per Min | Haulage, including wages and capital costs. | 0.50€/Min |
| | | | |
| Equip Variable | Per Km | Wear and tear on trailer. | 0.03€/Km |
| Equip Fixed | Per Min | Capital costs of trailer. | 0.04€/Min |
| | | | |
| Terminals Fixed | Per Load | Hours spent waiting, loading and repositioning. | 150€ per HGV load. |
| | | | |
| Service Fixed | Per Min | Profit margin | 0.25€/ Min |

Thus a complete journey of 1000km, at an average speed of 50kph, implying a door to door time of 20 hours (1200 minutes) would cost:

Table 4: Example road costs for 1000km trip

| Cost Element | Calculation |
|---|---|
| Track | 1000km * 0.05 = 50€ |
| Traction Variable | 1000km * 0.35 = 350€ |
| Traction Fixed | 1200min * 0.50 = 600€ |
| Equipment Variable | 1000km * 0.03 = 30€ |
| Equipment Fixed | 1200min * 0.04 = 48€ |
| Terminal Fixed Costs | 150€ |
| Service | 1200min * 0.25 = 300€ |
| TOTAL per HGV door to door | €1528 |
| Rate per Km | 1.528€/km |

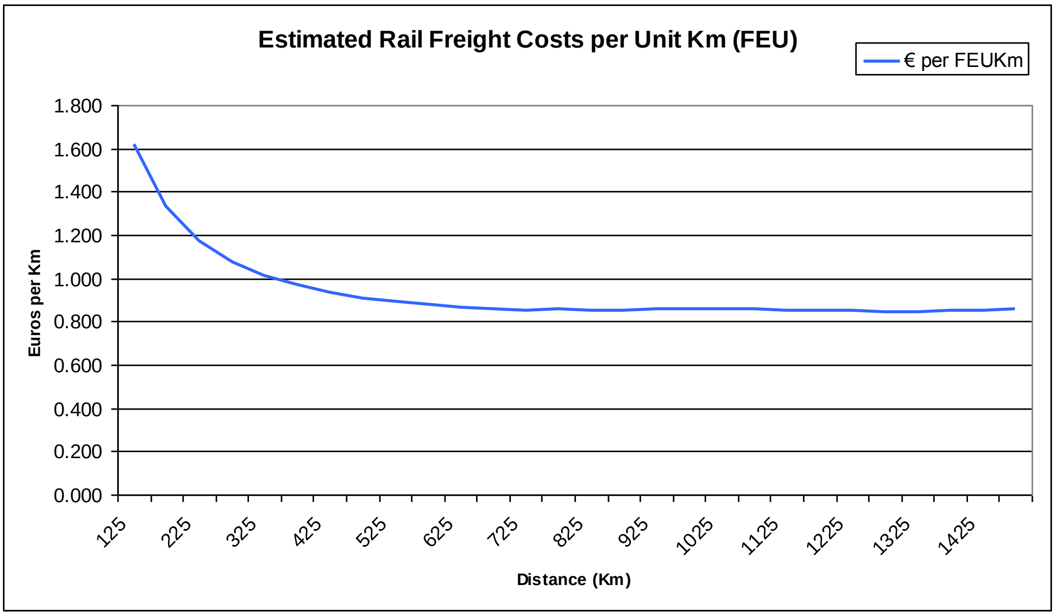
### Rail Costs

Estimating a single value for rail costs between two regions is less straightforward than the road example. While it is possible to assume that most long distance road transport takes place using standard 40 tonne or 44 tonne lorries and broadly comparable tractor-trailer combinations, there is greater variation for rail.

In NEAC10, rail is treated as a homogenous mode, without any differentiation between bulk and unitised transport. Cost estimations are based on unitised rail freight (containers and swap-bodies), since these are most relevant for modal shift, and these rates are applied to all forms of rail freight.

Average cost rates per unit (FEU)[3] km, as implemented inside NEAC-10 are shown below. Road costs average 1.525 Euros per vehicle km, whereas rail cost per FEU km tends towards 0.85 Euros.

Figure 19: Rail Costs per Unit (FEU) Km



### Basis for Rail Calculation

The most important assumptions underlying these cost curves are:

| **Cost Element** | **Assumption** |
|---|---|
| Train Type | Combined transport: unaccompanied forty foot (12m) freight unit. See example in photograph below. |
| Train Length | 600 metres trailing length.<br>30 Wagons (each one can hold one FEU and one TEU) |
| Average Load | 24 FEU (approx. 400 tonnes) |
| Avg Loco Km per Year | 150-200000 |
| Track Cost | Typically 0.05 to 0.15 Euro per FEU km (1.20 EUR to 3.60 EUR per train km) |
| Traction Cost | Typically:<br>8 to 12 Euros per FEU per hour ( around 240 Euro per train hour), PLUS<br>0.1 Euros per FEU per km (around 2.4 Euro per train km) |
| Wagon Hire Cost | Typically around 1 Euro per FEU per hour |
| Terminal Cost | Typically around 50 Euro per lift (load or unload) |
| Service/HQ Cost | Typically around 10 Euros per FEU |

For a journey of 1000km, taking 36 hours terminal to terminal, with four additional hours required for train preparation, the cost would therefore be:

---

[3] One FEU (forty foot equivalent unit) is roughly equivalent to a standard road trailer in volume, and equal to two TEUs.

Table 5: Example rail costs for 1000km trip

| **Cost Element** | **Rate** | **Cost per FEU** | **Cost per Train** |
|---|---|---|---|
| Track | 0.1 EUR per FEU km | 100 EUR | 2400 EUR |
| Traction fixed | 10 EUR per FEU per hour | 400 EUR | 9600 EUR |
| Traction variable (per km) | 0.1 EUR per FEU per km | 100 EUR | 2400 EUR |
| Wagon Hire | 1 EUR per FEU per hour | 40 EUR | 960 EUR |
| Terminal Cost | 50 EUR per lift | 100 EUR | 2400 EUR |
| Service Cost | 10 EUR per FEU | 10 EUR | 240 EUR |
| TOTAL Costs (EUR) | | 750 EUR | 18000 EUR |
| Cost Per Km | | 0.75 EUR | 18 EUR |
| Cost per TKm | | 0.05 EUR | |

These figures use round numbers to explain the calculation. Some of these rates vary per country, so on average, and also taking into account delays at borders, the average cost rises to 0.85 Euros for all possible O/Ds.

They imply that rail is cheaper than road for long distances, and they also indicate potential for cost reduction through longer and faster trains, since much of the cost arises through the productivity of the locomotive.

### Inland Waterway Costs

Waterway costs also under a high degree of simplification. Apart from differentiation arising from different modes of appearance (liquids, dry bulks, containers), costs will vary significantly according to vessel size. So whereas it is possible to make reasonable assumptions about typical lorry weights and train lengths, it is important to be able to handle different vessel configurations for waterways.

One of the relatively recent additions (2015) to NEAC-10 has been to include different cost structures for different CEMT class vessels.

Table 6: Example waterway costs for a 1000km trip (CEMT 4)

| **Cost Element** | **Rate** | **Cost per FEU** | **Cost per Vessel** |
|---|---|---|---|
| Track | 0.013 EUR per FEU km | 13 EUR | 351 EUR |
| Traction fixed | 2.94 EUR per FEU per hour | 294 EUR | 7929 EUR |
| Traction variable (per km) | 0.143 EUR per FEU per km | 143 EUR | 3872 EUR |
| Wagon Hire | | | |

| Cost Element | Rate | Cost per FEU | Cost per Vessel |
|---|---|---|---|
| Terminal Cost | 50 EUR per lift | 100 EUR | 2700 EUR |
| Service Cost | 10 EUR per FEU | 10 EUR | 270 EUR |
| TOTAL Costs (EUR) | | 560 EUR | 15122 EUR |
| Cost Per Km | | 0.56 EUR | 15 EUR |
| Cost per TKm | | 0.037 EUR | |

## 4.3 Transport Impedances

Impedances are calculated by combining the network information with the transport cost calculations to estimate point to point costs through the network. Times, distances and costs are calculated for all connected pairs of origin and destination (Level 3) regions.

The calculation procedure selects a node from the given network (e.g. road) as the loading point for the origin region and another as the unloading point in the destination region. An optimal path is selected from the network that provides a balance of travel time and distance.

Distances and times per O/D depend upon the selection of loading points and the criteria for choosing from a set of network paths. For the road network, which is relatively dense compared to an average region, a loading point is selected as the node closest to the geometric centroid of the region.

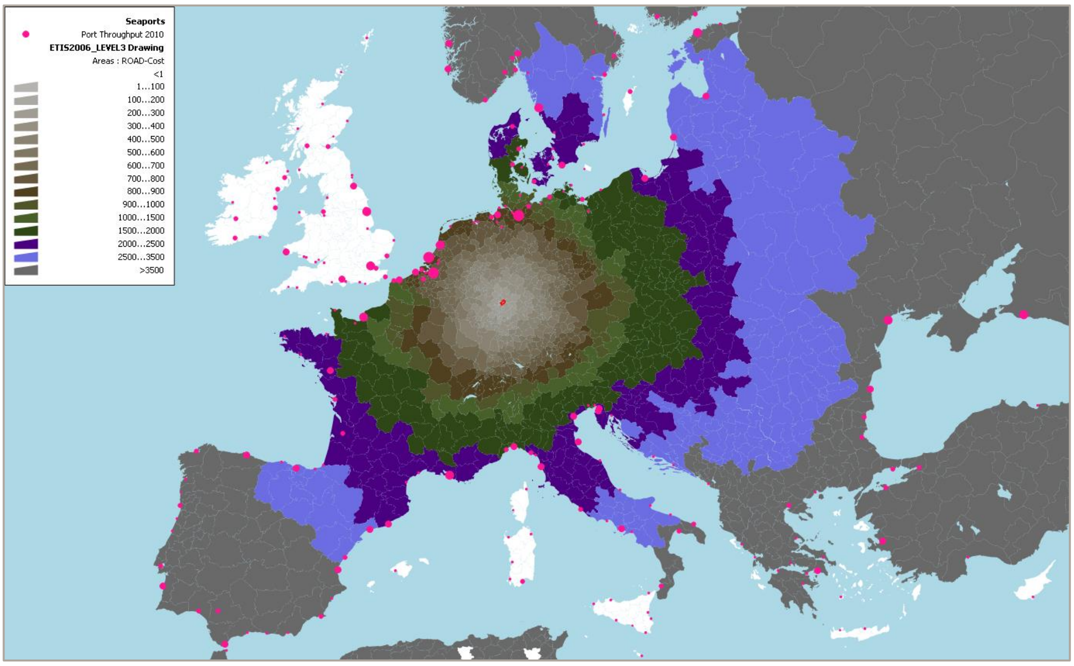
For rail, the network is less dense so it may be the case that the node nearest to the centre of the region is not inside the region. This may also be the case even if rail links pass through the region, because the links' end-points (nodes) lie outside. For rail therefore a loading point may be selected which is in an adjacent region.

For waterway, the network is again less dense, and there is a particular issue caused by the fact that rivers often define the boundary between regions. Thus is it quite likely that two adjacent regions load traffic at the same waterway node, and also that loading points will be situated by the edges of a region and not the centre. The algorithm for the selection of loading points therefore looks for waterway nodes close to region vertices as well those close to the centroid.

As a general rule, region to region O/Ds are only computed if the journey can be completed within a single mode, so that trips between the Continent and island regions are not estimated. In the case of the UK, it is assumed that rail connections can be made via the Channel Tunnel to Continental Europe, but not road connections, since that would entail a switch from road to rolling motorway (rail).

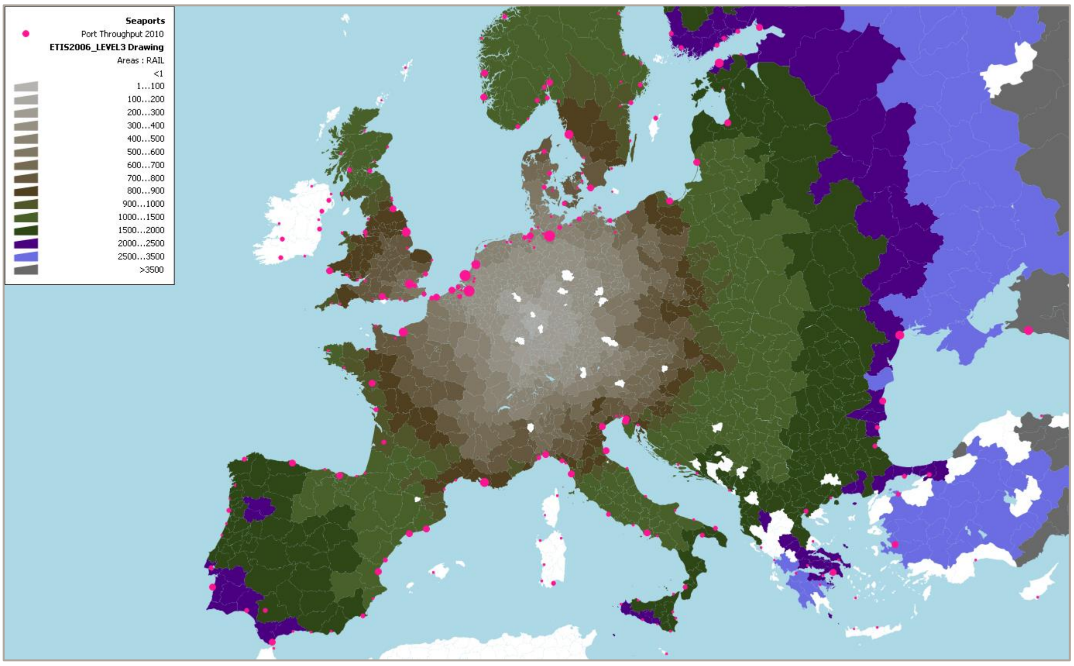
Examples are illustrated in the following figures, showing estimated impedances from the NUTS3 region containing the city of Frankfurt, for road, rail, and inland waterway.

Figure 20: Road Impedances – Frankfurt to the rest of Europe



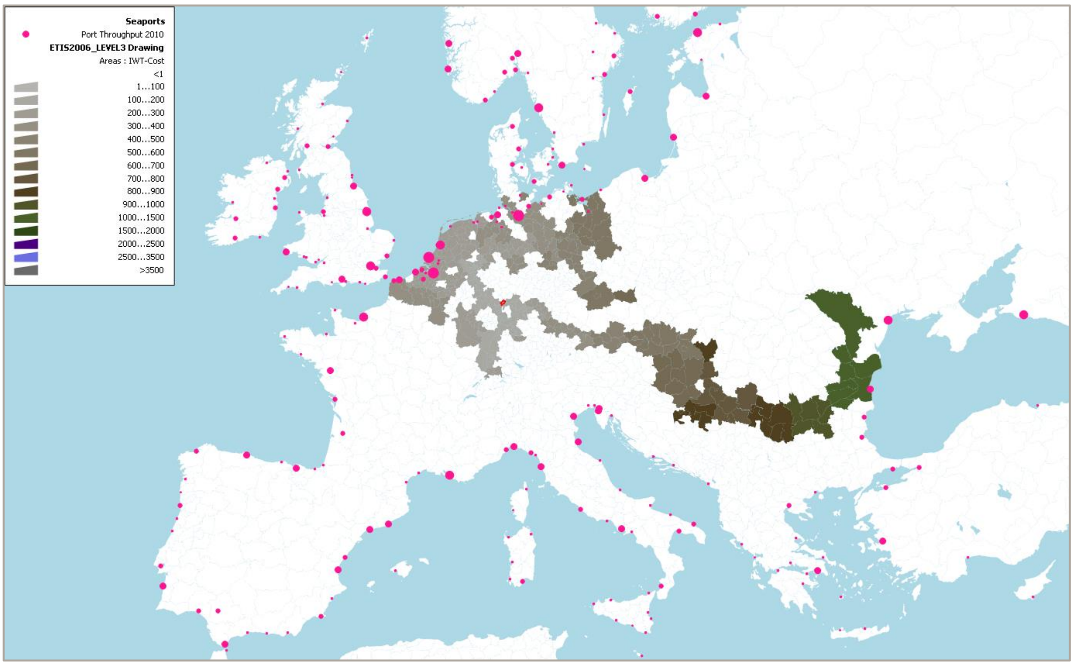
Source: NEAC10

Figure 21: Rail Impedances – Frankfurt to the rest of Europe



Source: NEAC10

Figure 22: Waterway Impedances – Frankfurt to the rest of Europe.



Source: NEAC

## 4.4 NEAC Trade Model

The purpose of the trade model inside NEAC is to relate changes in economic activity and changes in the transport system to transport volume.

A gravity model formulation has been used in which the trade between countries/regions is explained by the supply factors of the exporting country/region and the demand factors of the importing country/region.

Mathematically, the trade model formulation is:

***Equation 1*** *The functional form of the trade model for international trade flows*

$$T_{ijg} = \alpha 1 * P_{ig}^{\alpha 2} * A_{jg}^{\alpha 3} * D_{ij}^{\alpha 4} * e^{\alpha 5 * DUMMY}$$

wherein,

| | | |
|---|---|---|
| $T_{ijg}$ | : | the trade of a commodity between region i and j in tonnes; |
| $P_{ig}$ | : | the added value (GVA) of the sector that supplies (produces) the commodity in country/region i; |
| $A_{jg}$ | : | the added value (GVA) of the sector that consumes (attracts) the commodity in country/region j; |
| $D_{ij}$ | : | the economic distance (cost of transport) between region i and j; |
| DUMMY | : | a dummy variable that captures economic co-operation between countries/regions or a specific position of (a group of) countries/regions; |
| $\alpha 1, \alpha 2, \alpha 3, \alpha 4, \alpha 5$ | : | the model parameters. |

The model, expressed in log-linear form was estimated for the trade of each commodity group:

Equation 1 can be rewritten in log-linear form as equation 2:

***Equation 2*** *The log-linear regression equation of the trade model*

$$\log T_{ijg} = \overline{\beta 1} + \overline{\alpha 2} * \log P_{ig} + \overline{\alpha 3} * \log A_{jg} + \overline{\alpha 4} * \log D_{ij} + \overline{\alpha 5} * DUMMY$$

in which:

$\beta 1 = \log \alpha 1$

Equation 2 was estimated with Ordinary Least Squares (OLS) on the basis of cross section data. The expected co-efficient ranges were:

$\alpha 2 > 0$, $\alpha 3 > 0$, $\alpha 4 < 0$, and $\alpha 5 > 0$ (or in some cases $\alpha 5 < 0$),

which can be translated into the following statements:

1) a larger value added of the producing sector in the exporting country should have a positive effect on trade ($\alpha 2 > 0$),
2) a larger value added of the attracting sector in the importing country should have a positive effect on trade ($\alpha 3 > 0$),

3) a larger distance between the exporting and the importing country should have a negative effect on trade ($\alpha 4 < 0$),

4) Depending of the dummy variable in consideration the value can either be positive or negative.

In use, NEAC-10 applies this trade model structure to each transport chain:

- Origin and destination regions define which economic growth rates are chosen.
- The routeing determines the total transport cost from origin to destination, and thus the value of 'D' which represents the economic distance between the regions.
- The product category determines which economic sectors are selected as the relevant production (P) and attraction (A) sectors in the given region. For example, trade in agricultural produce responds to growth of the agricultural sector in the origin region, and food consumption in the destination region.
- The combination of origin and destination regions determines which model is used. There are different elasticities estimated for domestic, intra-EU and extra-EU flows.

To make a forecast scenario, a set of economic growth rates, per NUTS3 region and per economic sector need to be provided as assumptions. In practice these will be estimated using reference forecasts of economic growth.

***Equation 3*** *The form for estimating future traffic flows.*

$$T^{f}_{ijg} = T^{b}_{ijg} * \left(\frac{P^{f}_{ig}}{P^{b}_{ig}}\right)^{\alpha 2} * \left(\frac{A^{f}_{jg}}{A^{b}_{jg}}\right)^{\alpha 3} * \left(\frac{D^{f}_{jg}}{D^{b}_{jg}}\right)^{\alpha 4} * e^{\alpha 5\,(DUMMY(f)-DUMMY(b))}$$

In the model, changes in production and attraction rates between the base year (b) and the forecast year (f), as well as changes in the economic distance. These ratios are then applied to the base year traffic volumes to estimate the future volumes.

## 4.5 NEAC Mode Split Model

NEAC10 uses the mode split methodology devised for the TRANSTOOLS model. A multinomial logit model has still been used:

***Equation 4*** *Multinomial Logit Model*

$$P_{m|cij} = \frac{e^{V_{m|cij}}}{\sum_{l \in M} e^{V_{l|cij}}}$$

$$with: V_{m|cij} = \beta_{m0} + \sum_{k} \beta_{mk} x_{cijmk}$$

Where:

*M*: Set of available modes.

$P_{m|cij}$: Choice probability of mode *m* given commodity group *c* and OD relation *ij*.

$V_{m|cij}$: Systematic utility of mode *m* given commodity group *c* and OD relation *ij*.
$x_{cijmk}$: Level of service *k* for mode *m* given commodity group *c* and OD relation *ij*.
$\beta_{mk}$: Logit parameter for mode *m* and level of service *k*.

This formula calculates the probability that a given mode is chosen by comparing estimated utilities for all available modes, for a specific origin-destination and for a specific commodity.

NEAC10 is a chain-based model, meaning that traffic flows are stored as sequences of modes (mode chains). As described above, the trade model, which predicts overall volumes works by analysing changes in the economic profiles of the trading regions (production and consumption). However, this mode split model is applied to the individual links within the chain and not to the chain itself which is likely to contain more than one mode. Furthermore, sea transport, and therefore port choice is not considered within this mode split process[4] . It therefore only applies to:

- Road
- Rail
- Waterway transport.

Mode choice within this formula reacts to changes in the utilities associated with each available mode. Increasing the utility (lowering the cost) for one mode will make it more attractive than the available alternatives, so the function will shift traffic towards this mode.

To be effective within the overall modelling structure, a scenario needs to be defined in which there are changes in the cost structures or in the new networks. For each combination of origin, destination, and commodity, a set of probabilities needs to be estimated for the base case (default or unchanged utilities) and for the scenario. By comparing the two sets of probabilities, a shift per mode can be estimated. Therefore this mode split model calculates changes[5] in mode between time periods rather than the absolute mode shares.

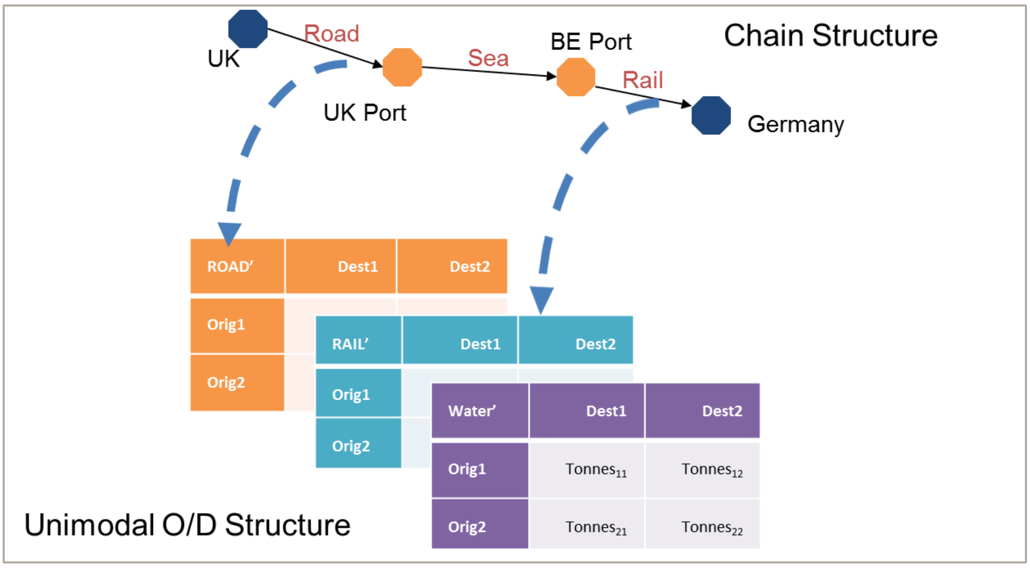
Thus, each mode chain is split into links, and each link is aggregated into a unimodal O/D table per commodity. The mapping of data from the chains to unimodal O/Ds is illustrated below in Figure 23 .

---

[4] In order to model shifts within the whole chain, the Mode Chain Builder (MCB) process scan be used instead. See **Error! Reference source not found.**.

[5] Whereas the Mode Chain Builder (MCB) calculates absolute mode shares by multimodal assignment to a hyper-network.

Figure 23:Mapping of Chain Structure into Unimodal O/D



| Water' | Dest1 | Dest2 |
|---|---|---|
| Orig1 | $\text{Tonnes}_{11}$ | $\text{Tonnes}_{12}$ |
| Orig2 | $\text{Tonnes}_{21}$ | $\text{Tonnes}_{22}$ |

When all of the chains have been unpacked in this manner, it is possible to quantify the modal shares per O/D and per commodity.

When the mode split model is applied, traffic can be shifted from one of the three unimodal O/D layer to the others depending upon changes in their relative utilities.

Details of the utility function specification and its parameters are shown in the annex.

## 4.6 NEAC Traffic Assignment Model

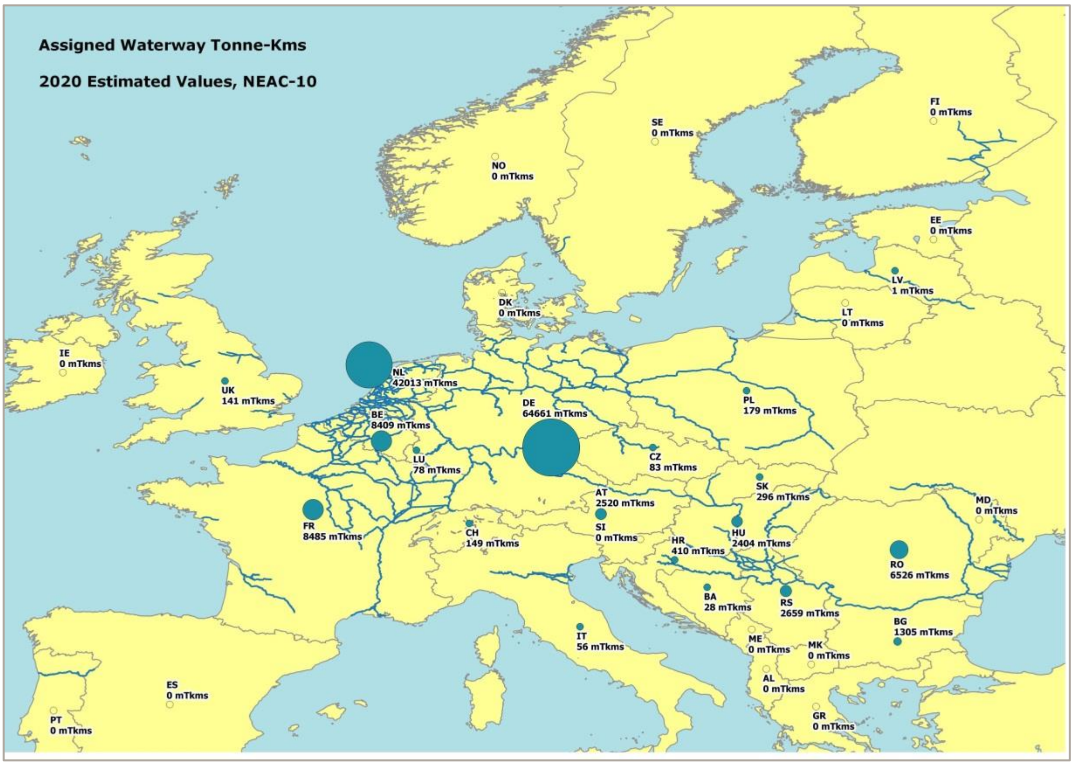
The final step of the model is to assign the unimodal O/D flows produced by the mode split model to the respective networks, thus completing the process by relating the estimated transport demand back to the supply side. Networks and cost functions used for assignment are the same of used for other steps in the model, so there is consistency with the assumptions used by the trade model and mode split model.

Traffic assignment maps the tonnages stored as O/D flows into link flows, but searching for efficient paths in the transport network connecting the origin to the destination. In the simplest case, all the traffic per O/D, within a given mode, will be assigned to a single efficient path, the so-called "all-or-nothing" approach. The path is chosen as the one which minimises total cost. There is an option to use "incremental" assignment, in which a congestion function is used to modify link speeds as traffic builds up, thus simulating the effect of traffic detouring onto longer but less congested routes.

Figure 24: Traffic Assignment, 2010, Inland Waterways

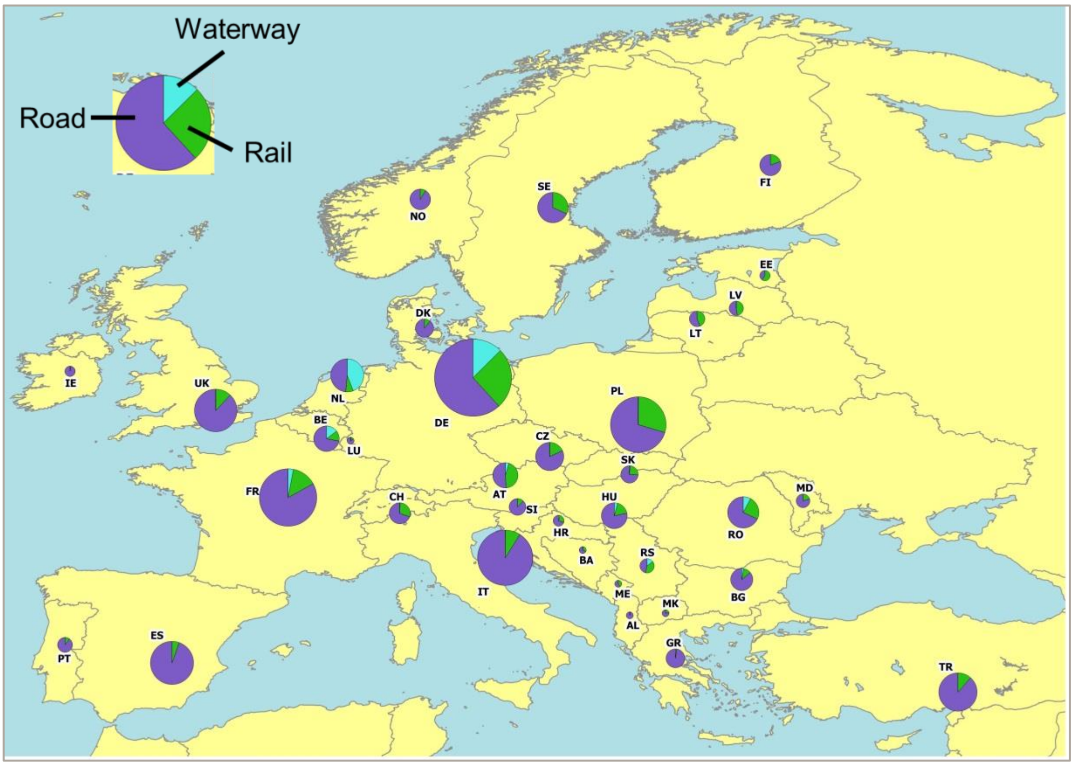
The same results can be visualised as national tonne-kms, as shown below.

Figure 25: Traffic Assignment, 2010, Inland Waterway Traffic, National Tonne-Kms



Combining the assignment results for all modes, it is possible to estimate modal shares by territorial area. In the following map this is shown as pie-charts per country.

Figure 26: Estimated Modal Shares - NEAC-10 Traffic Assignment



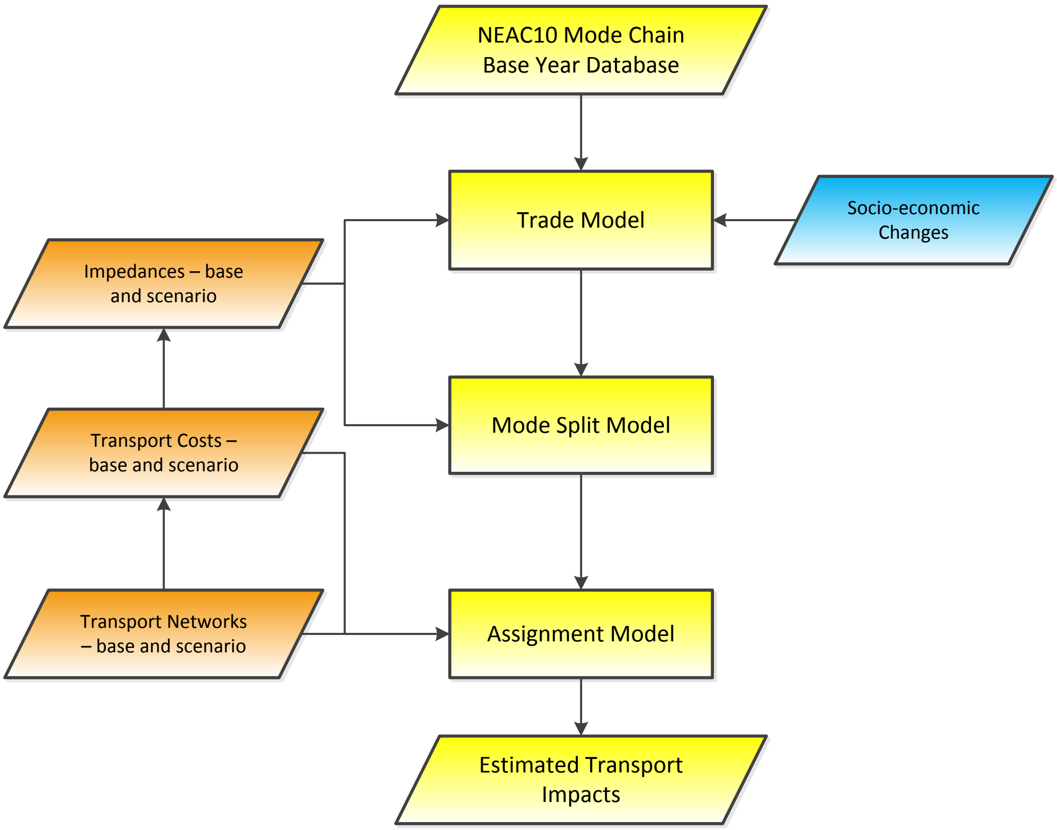
Naturally, these assignment results can be refined to highlight particular corridors, certain commodities, modes of appearance (e.g. containers), port-hinterland traffic and so on.

Assignment results can be combined with external costs to derive transport **impacts**.

## 4.7 Summary of NEAC-10 Model

In overview, the structure of the model can be represented as a flow chart. Base year flows are input from the NEAC model chain database, as described earlier in this document. By combining flow data with socio-economic forecasts, and with network and cost data, the model predicts traffic growth, mode shares and traffic impact levels for freight transport across Europe.

Figure 27: Summary of NEAC-10 Model



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# Annex: Commodity Definitions in NEAC-10

NST2 (2 digit codes)

| Code | Description |
|---|---|
| 0 | Live animals |
| 1 | Cereals |
| 2 | Potatoes |
| 3 | Other fresh or frozen fruit and vegetables |
| 4 | Textiles textile articles and man-made fibres |
| 5 | Wood and cork |
| 6 | Sugar-beet |
| 9 | Other raw animal and vegetable materials |
| 11 | Sugars |
| 12 | Beverages |
| 13 | Stimulants and spices |
| 14 | Perishable foodstuffs |
| 16 | Other non-perishable foodstuffs and hops |
| 17 | Animal food and foodstuff waste |
| 18 | Oil seeds and oleaginous fruit and fats |
| 21 | Coal |
| 22 | Lignite and peat |
| 23 | Coke |
| 31 | Crude petroleum |
| 32 | Fuel derivatives |
| 33 | Gaseous hydrocarbons liquid or compressed |
| 34 | Non-fuel derivatives |
| 41 | Iron-ore |
| 45 | Non-ferrous ores and waste |
| 46 | Iron and steel waste and blast furnace dust |
| 51 | Pig iron and crude steel |
| 52 | Semi-finished rolled steel products |
| 53 | Bars sections wire rod railway and tramway track construction material of iron or steel |
| 54 | Steel sheets plates hoop and strip |
| 55 | Tubes pipes iron and steel castings and forgings |
| 56 | Non-ferrous metals |
| 61 | Sand gravel clay and slag |
| 62 | Salt iron pyrites sulphur |
| 63 | Other stone earths and minerals |
| 64 | Cement lime |
| 65 | Plasters |
| 69 | Other manufactured building materials |
| 71 | Natural fertilisers |
| 72 | Chemical fertilisers |
| 81 | Basic chemicals |
| 82 | Aluminium oxide and hydroxide |
| 83 | Coal chemicals |
| 84 | Paper pulp and waste paper |
| 89 | Other chemical products |

| Code | Description |
|---:|---|
| 91 | Transport equipment |
| 92 | Tractors |
| 93 | Other machinery apparatus and appliances engines parts thereof |
| 94 | Manufactures of material |
| 95 | Glass glassware ceramic products |
| 96 | Leather textiles and clothing |
| 97 | Other manufactured articles |
| 99 | Miscellaneous articles |

# ANNEX: NEAC Mode Split Utility Function

## NEAC Mode Split Utility Function

The definition of the utility functions per transport mode is given below:

U(road) =
ArailE*dcrailE + AiwwE*dciwwE + AseaE*dcseaE
+ ArailWE*dcrailWE + AiwwWE*dciwwWE + AseaWE*dcseaWE
+ b_road*road
+ bcost*totcost
+ bcroadE*costE
+ bcroadWE*costWE

U(rail) = a_rail
+ ArailE*dcrailE + AiwwE*dciwwE + AseaE*dcseaE
+ ArailWE*dcrailWE + AiwwWE*dciwwWE + AseaWE*dcseaWE
+ b_rail*rail
+ bcost*totcost
+ bcrailE*costE
+ bcrailWE*costWE

U(inlww) = a_inlww
+ ArailE*dcrailE + AiwwE*dciwwE + AseaE*dcseaE
+ ArailWE*dcrailWE + AiwwWE*dciwwWE + AseaWE*dcseaWE
+ bcost*totcost
+ bciwwE*costE
+ bciwwWE*costWE

U(sea) = a_sea
+ ArailE*dcrailE + AiwwE*dciwwE + AseaE*dcseaE
+ ArailWE*dcrailWE + AiwwWE*dciwwWE + AseaWE*dcseaWE
+ bcost*totcost
+ bcseaE*costE
+ bcseaWE*costWE
+ bc5sea*c5sea

List of coefficients:

| | |
|---|---|
| a_rail | Constant |
| a_inlww | Constant |
| a_sea | Constant |
| | |
| ArailE | dummy rail, East Europe |
| AiwwE | dummy inland waterways, East Europe |
| AseaE | dummy sea, East Europe |
| | |
| ArailWE | dummy rail, inter Europe (W <-> E) |
| AiwwWE | dummy inland waterways, inter Europe (W <-> E) |

| | |
|---|---|
| AseaWE | dummy sea, inter Europe (W <-> E) |
| | |
| b_road | dummy road parameter |
| b_rail | dummy rail parameter |
| | |
| Bcost | generalized cost parameter |
| | |
| bcroadE | specific cost parameter for road, East Europe |
| bcrailE | specific cost parameter for rail, East Europe |
| bcinlwwE | specific cost parameter for inland waterways, East Europe |
| bcseaE | specific cost parameter for sea, East Europe |
| | |
| bcroadWE | specific cost parameter for road, inter Europe (W <-> E) |
| bcrailWE | specific cost parameter for rail, inter Europe (W <-> E) |
| bcinlwwWE | specific cost parameter for inland waterways, inter Europe (W <-> E) |
| bcseaWE | specific cost parameter for sea, inter Europe (W <-> E) |
| | |
| bc5sea | extra cost parameter for port regions (table 1) |

List of explanatory variables:

| | |
|---|---|
| dcrailE | dummy constant for rail, East Europe. Value is 1 if origin and destination are both in area 2 (East Europe) and transport mode is rail. Otherwise value is 0. |
| dciwwE | dummy constant for inland waterways, East Europe. Value is 1 if origin and destination are both in area 2 (East Europe) and transport mode is inland waterways. Otherwise value is 0. |
| dcseaE | dummy constant for sea, East Europe. Value is 1 if origin and destination are both in area 2 (East Europe) and transport mode is sea. Otherwise value is 0. |
| | |
| dcrailWE | dummy constant for rail, inter Europe (W <-> E). Value is 1 if origin is in West Europe (W) and destination in East Europe (E), or vice versa (origin in E, destination in W). and transport mode is rail. Otherwise value is 0. |
| dciwwWE | dummy constant for inland waterways, inter Europe (W <-> E). Value is 1 if origin is in West Europe (W) and destination in East Europe (E), or vice versa (origin in E, destination in W). and transport mode is inland waterways. Otherwise value is 0. |
| dcseaWE | dummy constant for sea, inter Europe (W <-> E). Value is 1 if origin is in West Europe (W) and destination in East Europe (E), or vice versa (origin in E, destination in W). and transport mode is sea. Otherwise value is 0. |
| | |

| | |
|---|---|
| Road | dummy road parameter (border resistance): Dummy for waiting times at EU (including Norway + Switzerland) outside borders for road transport; Value is 1 if origin EU and destination non-EU or if origin is non-EU and destination is EU and mode is road, otherwise value is 0. |
| Rail | dummy rail parameter (border resistance): Dummy for gauge-width differences for rail transport; Value is 1 if origin and destination region have different gauge-widths, otherwise value is 0. |
| | Standard gauge: All TRANSTOOLS regions in the countries: AL, AT, BE, BA, BG, CZ, CH, DK, DE, FR, GR, HR, HU, IT, MD, NL, NO, PL, RO, SE, SI, SK, TR, UK (except 15230000 = UKN) and YU.<br>Irish gauge: In the TRANSTOOLS regions: 9000100, 9000200 and 15230000 (= IE and UKN).<br>Iberian gauge: All TRANSTOOLS regions in the countries: ES and PT.<br>Russian gauge: All TRANSTOOLS regions in the countries: BY, EE, FI, LT, LV, MD, RU and UA. |
| Totcost | Total cost |
| | |
| costE | specific cost variable for East Europe transport. costE = totcost if origin and destination are both in East Europe. Otherwise value is 0. |
| costWE | specific cost variable for inter Europe transport. costWE = totcost if origin is in West Europe (W) and destination in East Europe (E), or vice versa (origin in E, destination in W). Otherwise value is 0. |
| | |
| c5sea | extra cost variable for port regions. c5sea = totcost, if origin or destination region is a port region (see table 1) and distance > 500, zero otherwise. |

### Estimation of Model Parameters – Mode Split Model

Table 7: Mode Split Model Parameters

| | nstr0 | nstr1 | nstr2 | nstr4 | nstr5 | nstr6 | nstr7 | nstr8 | nstr9 | nstr10 |
|---|---|---|---|---|---|---|---|---|---|---|
| A_RAIL | -1.9225 | -3.1145 | -1.0756 | -1.6209 | -0.8901 | -2.7242 | -2.6939 | -2.3372 | -1.8668 | -1.3862 |
| A_INLWW | -2.0620 | -2.6490 | -0.4265 | -1.4461 | -2.7086 | -1.2998 | -0.8092 | -2.9036 | -3.7000 | -0.9052 |
| A_SEA | -0.4138 | -0.4076 | 0.6971 | 0.0731 | 0.5149 | 0.0063 | -0.5515 | 0.2736 | 0.0835 | 0.9607 |
| ARAILE | 5.2743 | 2.8520 | 1.7196 | 1.0463 | 3.4922 | 3.1458 | 2.5742 | 3.1979 | 2.0749 | 2.4966 |
| AIWWE | -2.1590 | | -4.2746 | -4.5100 | -1.0760 | -3.1421 | | | | |
| ASEAE | -1.7732 | -1.7764 | -2.3677 | | -2.6656 | -2.1006 | | -1.4949 | -2.2051 | -1.0672 |
| ARAILWE | 5.2397 | 2.5573 | 3.8239 | 3.7283 | 2.9102 | 2.0834 | 3.9495 | 4.0129 | 0.6811 | 2.3404 |
| AIWWWE | -0.6044 | | | | | | 1.9336 | -0.8149 | -1.5599 | |
| ASEAWE | 0.3403 | | 1.5127 | | -0.8794 | | 2.9763 | -0.0936 | -0.9325 | 0.4747 |
| B_ROAD | | -0.6850 | | | | | | | -0.3768 | |
| B_RAIL | -1.4129 | -0.7757 | -2.5009 | -2.4415 | -0.7071 | -1.2590 | -1.7007 | -1.2655 | -0.7522 | -1.5663 |
| BCOST | -0.0061 | -0.0048 | -0.0051 | -0.0143 | -0.0041 | -0.0093 | -0.0257 | -0.0044 | -0.0052 | -0.0061 |
| BCROADE | -0.0079 | -0.0084 | -0.0304 | -0.0205 | -0.0163 | -0.0216 | | -0.0057 | -0.0067 | |
| BCRAILE | -0.0306 | -0.0237 | -0.0503 | -0.0265 | -0.0159 | -0.0879 | | -0.0260 | -0.0052 | -0.0388 |
| BCIWWE | | | | | | | | | | |
| BCSEAE | x | x | x | x | x | x | x | x | x | x |
| BCROADWE | | | | | -0.0062 | -0.0027 | | | | |
| BCRAILWE | -0.0334 | -0.0334 | -0.1266 | -0.1364 | -0.0147 | -0.0697 | -0.0897 | -0.0603 | -0.0047 | -0.0606 |
| BCIWWWE | | | | | | -0.0661 | | | | |
| BCSEAWE | x | x | x | x | x | x | x | x | x | x |
| BC5SEA | -0.0083 | | -0.0411 | | -0.0074 | -0.0092 | -0.0321 | -0.0108 | -0.0163 | |