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# Deliverable D10.5

Final Report

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# Glossary

| | |
|---|---|
| **AngularJS** | A client framework to build web applications in JavaScript |
| **BAU** | Business as usual |
| **CO** | Confidential, only for members of the Consortium |
| **$CO_2$** | Carbon Dioxide |
| **DEM** | Demography module of the HIGH-TOOL model |
| **DG MOVE** | European Commission's Directorate-General for Mobility & Transport |
| **EC** | European Commission |
| **ECR** | Economy & Resources module of the HIGH-TOOL model |
| **EMC** | Expected Minimum Cost |
| **EMU** | Expected Maximum Utility |
| **ENV** | Environment module of the HIGH-TOOL model |
| **ETC** | European Transport Conference |
| **ETISplus** | European Transport Policy Information System |
| **EU** | European Union |
| **EU28** | 28 Member States of the European Union |
| **Eurostat** | Statistical Office of the European Union |
| **EXIOBASE** | A global, detailed Multi-Regional Environmentally Extended Supply and Use/Input-Output Database |
| **FRD** | Freight Demand module of the HIGH-TOOL model |
| **GDP** | Gross Domestic Product |
| **GHG** | Greenhouse Gas |
| **$NO_x$** | Nitric oxide and nitrogen dioxide |
| **NST** | Eurostat' Standard Goods Classification for Transport Statistics |
| **NUTS** | Nomenclature of Territorial Units for Statistics; A number assigned to it defines the level of granularity, such as 0 for the country level |
| **O/D** | Origin/destination |
| **PAD** | Passenger Demand module of the HIGH-TOOL model |
| **PostGIS** | An open source software programme that adds support for geographic objects to the PostgreSQL object-relational database |
| **PostgreSQL** | A object-relational database |
| **SAF** | Safety module of the HIGH-TOOL model |
| **Sails.js** | A server framework to build Node.js applications |
| **SESAR** | Single European Sky ATM Research Programme |
| **$SO_x$** | Sulfur oxide |
| **TEN-T** | Trans-European Networks for Transport |
| **TPM** | Transport Policy Measures |

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|---|---|
| **TRA** | European Transport Research Conference |
| **VES** | Vehicle Stock module of the HIGH-TOOL model |
| **VOC** | Volatile organic compound |
| **WCTR** | World Conference on Transport Research |
| **WCTRS** | World Conference on Transport Research Society |

# Executive Summary

Decisions concerning transport policy measures elaborated by the European Commission (DG MOVE) have important long-term implications for society, the environment and the economy. Transport policy measures can sequester capital for decades and result in manifold effects, both beneficial and detrimental. Policy measures may thus have large impacts, all the more if taken at the European level. To support the strategic assessment of transport policy options by the European Commission, the Project Consortium developed the HIGH-TOOL model.

The HIGH-TOOL model is an open source, high-level strategic assessment model for use by EU policy makers and policy analysts to assess economic, social and environmental impacts of transport policy measures. The model has two purposes. It can be applied to strategic assessment of transport policy options, and to support identification of policy options for further analyses by more detailed assessment instruments.

The HIGH-TOOL model has a modular structure and is based on existing tools, which, where necessary, were complemented by new models. The model has a modular structure, consisting of following modules: Demography, Economy & Resources, Passenger Demand, Freight Demand, Vehicle Stock, Environment, and Safety. Due to its character as a strategic high-level instrument it does not cover detailed networks. The core of the model are transport demand models for passenger and freight, following the structure of the classic transport model, however without assignment of flows on networks. The HIGH-TOOL model has a global scope. However, the main focus is attached to Europe, and particularly to the Member States of the European Union. The spatial scope is the level of NUTS-2 for all EU Member States (EU28), Norway and Switzerland, NUTS-0 for EU neighbouring countries, and country bundles for intercontinental transport. The tool's timeline are 5-years steps from 2010 to 2050. The year 2010 is the base year of the HIGH-TOOL model. The business-as-usual scenario of the HIGH-TOOL model is aligned with the EU Reference Scenario 2013 (European Commission, 2013).

The HIGH-TOOL model was introduced successively during the project under active participation of the future users of the tool. It provides a user-friendly interface, allowing intuitive model application and three different ways of policy selection. For each policy simulation, the tool creates a Policy Assessment Report which contains key results in Excel format in form of tables and diagrams.

The HIGH-TOOL model is an open source instrument, and does not require any commercial software products to be run. This pattern – which distinguishes the HIGH-TOOL model from other European transport policy assessment instruments – ensures thorough transparency of computations, allows the experienced user to modify calculation methodologies, and provides the basis for an efficient further development of the model in the future.

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| SIGNIFICANCE BV | Den Haag, Netherlands | http://www.significance.nl/ |
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## 1.4 Project Homepage

www.high-tool.eu

# 2 Publishable Summary

## 2.1 Project Context and Objectives

The European Commission's General Directorate Mobility & Transport (DG MOVE) follows a challenging objective: to develop transport policies that benefit all sectors of the Community. The European Commission's White Paper on Transport (European Commission, 2011a) addresses the challenges related to this mission by – among other things – presenting a 'vision for a competitive and sustainable transport system'. This vision includes targets such as decreasing the transport sector's Green House Gas (GHG) emissions by 60% until 2050, to develop an 'efficient core network for multimodal intercity travel and transport', to foster sustainability and competitiveness of the European air and maritime transport markets, and to support 'cleaner urban transport and commuting'. In the 'Roadmap for moving to a competitive low carbon economy in 2050', the transport sector's contributions to the objective are summarised by the key words 'fuel efficiency, electrification and getting prices right'.

Decisions concerning transport policy measures elaborated by the European Commission (DG MOVE) that are proposed by the European Union (EU), have important long-term implications for society, the environment and the economy. Transport policy measures can sequester capital for decades and result in manifold effects, both beneficial and detrimental. Policy measures may thus have large impacts, all the more if taken at the European level.

In this context, the Project Consortium has developed the HIGH-TOOL model. The HIGH-TOOL model is an open source, high-level strategic assessment model for use by EU policy makers and policy analysts to assess economic, social and environmental impacts of transport policy measures. The model has two purposes. It can be applied to strategic assessment of transport policy options, and to support identification of policy options for further analyses by more detailed assessment instruments.

## 2.2 Model Development Stages and User Involvement

The HIGH-TOOL model was introduced successively during the project in order to facilitate the active participation of the future tool users in the development process. Figure 3 provides an overview of the development process aligned with the various user involvement activities.

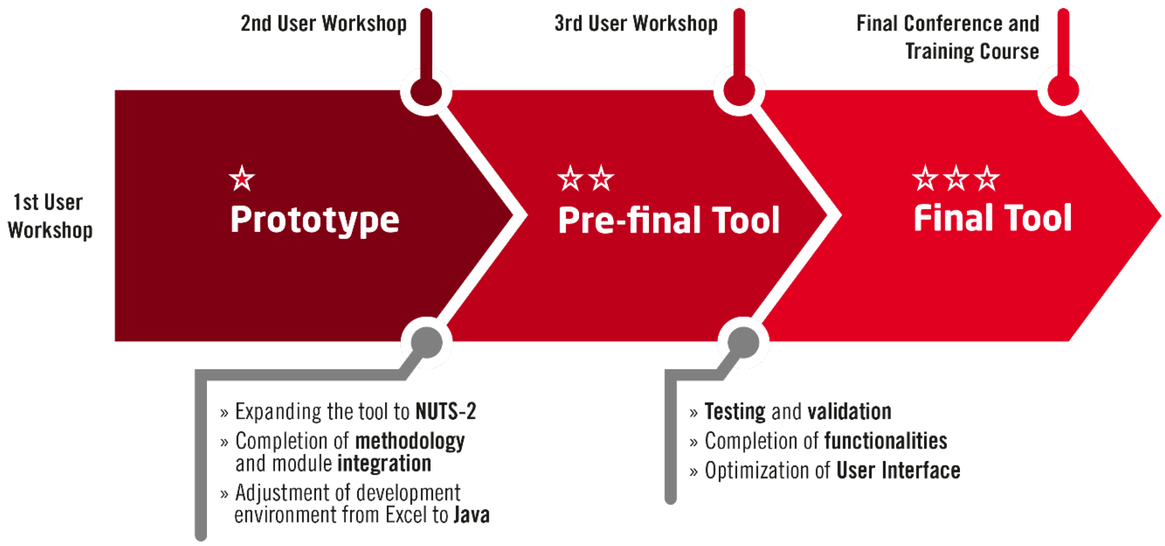



Figure 1: Development process of the HIGH-TOOL model and user involvement

The key user requirements for the tool were identified during the 1st User Workshop, supported by a complimentary internet-based survey.

The model development has been divided into three stages: prototype, pre-final version and final version.

The *prototype version* fulfilled following objectives: to establish a concrete basis for collecting comments and recommendations from the future tool users, and to allow the HIGH-TOOL Consortium to gain experiences in the modular tool development. The prototype version of the HIGH TOOL model was presented to the policy specialists of the European Commission and discussed at the 2nd User Workshop.

Under consideration of comments obtained with respect to the prototype, the *pre-final version* was elaborated. The pre-final version, running at NUTS-2 level, was a Java-based tool, and captured a wider field of transport policies. However, the pre-final model version was neither fully calibrated nor validated. The pre-final model was presented to EC policy specialist at the 3rd User Workshop.

Considering further comments by the future tool users on User Interface and Policy Assessment Report, the *final model version* was developed, after an extensive testing and validation phase. The final version of the model was presented to EC staff during the Final Conference, while application examples were elaborated and implemented in the Training Course. Finally, the User Guide was produced to allow easy access to the application of the HIGH-TOOL model.

## 2.3 General Model Features

**Model type**

The assessment tool is designed as a high-level strategic assessment tool which is partly based on existing tools, and, where necessary, complemented by new models. Due to its character as a strategic high-level instrument it does not cover detailed networks. The core of the model are transport demand models for passenger and freight, following the structure of the classic transport model, however without assignment of flows on networks. Integrating knowledge from several domains, such as demography, economy, transport demand, environment and safety, the HIGH-TOOL model constitutes an integrated assessment model.

**Geographical scope and time horizon**

The HIGH-TOOL model has a global scope. However, the main focus is attached to Europe, and particularly to the Member States of the European Union. The spatial scope is the level of NUTS-2 for all EU Member States (EU28), Norway and Switzerland, NUTS-0 for EU neighbouring countries, and country bundles for intercontinental transport. In total 314 modelling zones are considered.

The tool's timeline are 5-years steps from 2010 to 2050. The year 2010 is the base year of the HIGH-TOOL model.

**Demand segmentation**

Passenger demand is differentiated by following modes: air, rail, road (passenger car and powered 2-wheelers), and long-distance coach. The urban demand sub-module additionally considers urban bus, urban tram/metro, cycling and walking. The demand differentiation by trip purpose covers business, private, vacation, and commuting trips.

The freight transport modes are air, rail, road, inland waterways, and maritime transport. The demand is considered for NST-2 commodities (52 commodity groups).

The passenger and freight transport demand is further distinguished by vehicle types and fuel types. The model considers 60 vehicle types and 17 fuel technologies.

**Baseline**

To answer a key user requirement, the HIGH-TOOL baseline is aligned with the EU Reference Scenario 2013 (European Commission, 2013). Thus the forecasts of the HIGH-TOOL Baseline are largely consistent with those of the EU Reference Scenario 2013.

**Technical implementation**

The HIGH-TOOL model was largely developed in Java, thus ensuring platform independence. The User Interface was programmed as a stand-alone online application based on AngularJS and SailsJS, both free and open source software components programmed in JavaScript. The HIGH-TOOL Data Stock is realised as a PostgreSQL database with PostGIS extension.

## 2.4 Overview Structure of the HIGH-TOOL Model

The HIGH-TOOL model shows a modular structure. It consisting of three main elements:

- Core modules that represent the modelling framework
- Data Stock that facilitates the exchange of data
- User Interface for application of the model and providing access to the assessment results.

The model's overview structure is displayed by Figure 2.

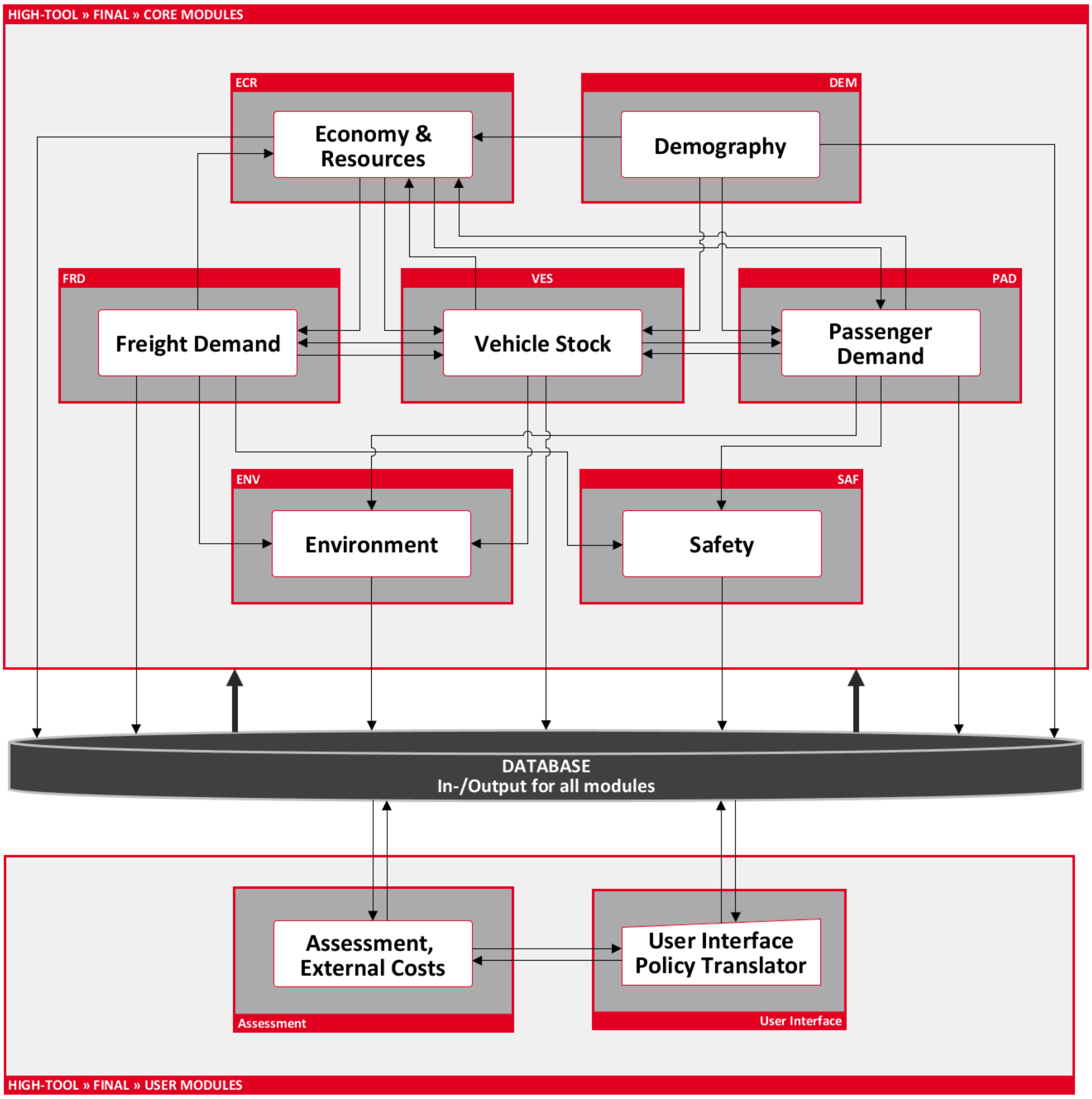



Figure 2: Overview structure of the HIGH-TOOL model

## 2.5 Core Modules

The HIGH-TOOL model comprises following modules:

- Demography (DEM)
- Economy & Resources (ECR)
- Passenger Demand (PAD)
- Freight Demand (FRD)
- Vehicle Stock (VES)

- Environment (ENV)
- Safety (SAF).

These modules interact sequentially with each other.

### 2.5.1 Demography Module

The Demography module (DEM) estimates the projected regional population and labour force in the 28 EU Member States and in Norway and Switzerland. UN projections are provided for other countries worldwide and are adapted to the geographic zoning system used in HIGH-TOOL.

The population and labour force are calculated at country level for the EU 28, Norway and Switzerland based on EU Reference Scenario assumptions on fertility rates, life expectancies at birth and net migration (European Commission, 2013). The projected population values are then disaggregated to geographic zones based on historical demographic trends. The net migration distribution per zone is based on socio-economic data, specifically historical data on income and employment. Population development at country level is simulated with a cohort component that incorporates the effects of demographic drivers and migration.

Regional disaggregation of the population excluding migration is based on the 2010 historical regional distribution. Net migration is regionally allocated using a distribution proxy based on income and employment rate. Labour force is estimated from the labour force percentage defined in the EU Reference Scenario and underlying assumptions.

### 2.5.2 Economy & Resources Module

The Economy & Resources module (ECR) comprises three components: Economy, Resources, and the combined component of GDP, Trade, Energy, Resources, and Production/Distribution.

The Economy sub-module estimates total output, capital stock and labour use in the economy, for which the general drivers (GDP, household income per capita and population) are exogenously defined by the EU Reference Scenario 2013. These drivers are disaggregated from country to zone based on ETISplus data (regional GDP, regional population, and labour force). The combined component (GDP, Trade, Energy, Resources, Production/ Distribution) estimates and projects employment, trade, resource consumption, and purchasing power under various transport policy measures. Resources component calculates environmental indicators (without combustion) using the EXIOBASE database for $CO_2$, $NO_x$, $SO_x$, PM, biomass, fossil fuel use, metal use, mineral use, wood use, and water use.

To generate economic output and environmental data, this module uses regional demographic and labour data provided by the Demography (DEM) module, transport costs by the Freight Demand (FRD) module, the type of vehicles purchased by the Vehicle Stock (VES) module, and passenger transport costs by the Passenger Demand (PAD) module. The economic and environmental indicators generated are used in the other modules.

Economic indicators are a key driver of passenger and freight demand, and demand for vehicle stock. Hence, there is feedback between these modules. The ECR module generates updated employment and income data used in the DEM module to ensure consistency of population distribution and spatial economic development.

### 2.5.3 Vehicle Stock Module

The Vehicle Stock module (VES) converts passenger and freight demand to vehicle fleet size, which is disaggregated to vehicle type and vehicle age cohort for calculation of emissions and energy use. Vehicle types include propulsion and fuel technologies, and the module includes 61 road and 12 non-road vehicle types. The vehicle age cohorts range from 0 to 29 years.

Fleet stock forecasts are provided for each of the 28 EU Member States and for each period (5-year intervals) up to 2050. The module also delivers forecasts of average fixed and variable generalised costs for each vehicle type, and total tax revenue per country.

Taking into account the transport demand and the vehicle stock in the previous period, as well as the vehicles that survived in current period, the demand for new vehicles and the average mileage per vehicle are calculated.

The logit and the stock dynamic model inside the Vehicle Stock module use the calculated average generalised costs to define the shares of the different types of new vehicles entering the market as well as their numbers. This calculation produces the detailed existing vehicle stock in the current period.

### 2.5.4 Passenger Demand Module

The Passenger Demand (PAD) module largely follows the classical four-step approach to transport demand modelling of generation, distribution, modal split and assignment. However, instead of the assignment step, the module translates number of trips into transport performance by the conversion.

The generation step estimates the trip demand for each origin. In the distribution step, the origin-destination trip matrix is computed and then further differentiated by transport modes. The conversion step derives transport performance indicators, such as passenger-kilometres and vehicle-kilometres.

Trip generation is carried out by a regression approach. The distribution and the model split components are integrated by using the Expected Minimum Cost (EMC) measure, which relies on the Expected Maximum Utility (EMU) or logsum measure. For the cost functions, the concept of generalised time is used in which the cost unit refers to minutes and not to monetary terms. The EMC values are computed using a Nested Logit model.

Road trips are split by car and powered two-wheelers, under the assumption of country-specific shares and motorisation levels.

A hypernet model linked to the core PAD module was developed for road and rail. It represents an optional submodule for simulating network effects in passenger transport, and allows a more realistic depiction of transport infrastructure policies.

The core PAD module is complemented by two additional modules. The first is the urban passenger demand module which follows a generic, elasticity-based approach. Since urban trips are a subset of intra-zonal trips, the generation step is linked to the core PAD module. The second is the intercontinental air passenger module, which uses a regression-based approach to estimate the number of flights between European regions and intercontinental destinations.

### 2.5.5 Freight Demand Module

The Freight Demand (FRD) module consists of four components: trade conversion, route choice, modal split and conversion. The trade conversion component converts trade values to volumes and extracts air demand from total trade between an origin and destination. The route choice and modal split components distribute demand across transport chains and perform a modal split on each leg of the transport chains, while applying the effects of measures. The conversion component derives other transport indicators, such as tonne-kilometres and vehicle-kilometres. The transport indicators relating to full-freight aircraft are determined in a subcomponent and feed into the conversion component.

The Freight Demand module together with the Economy & Resources module follow an analogue approach to the classical four-step methodology of generation, distribution, modal-split and assignment. The latter is replaced by calculation of performance indicators in the conversion component.

The module delivers trade in value per origin-destination (O/D), which is converted to volumes by applying volume density assumptions per O/D and commodity (assumed constant over time) extracted from ETISplus database.

The air demand base matrix extracted from ETISplus is adjusted according to growth in imports and exports delivered by the ECR module, and subtracted from total trade. This results in tonnes demand per commodity per Origin-Destination.

Each origin-destination is connected by route chains that have been extracted from the ETISplus database. These chains form up to three legs that connect origin and destination via up to two transhipment regions. For each leg, the modal split is calculated taking into account cost elements that can be influenced by the Vehicle Stock module. This is done to compute generalised cost per mode connecting an origin and destination of a leg through a multinomial logit function. Based on total generalised costs for route chains connecting origin and destination, demand is distributed across the route chains through transhipment regions by applying a multinomial logit.

The conversion step calculates tonne-kilometre and vehicle-kilometre performance indicators for the origin region and “on the territory” perspective. The latter is calculated by applying the share of distance in a leg in a country obtained, using data from ETISplus.

Finally, assumptions on full-freight share and capacity of airfreight transport are applied to extract airfreight transport by full-freight aircraft from the total demand for air.

### 2.5.6 Environment Module

The Environment (ENV) module calculates wheel-to-tank fuel consumption and emissions for each vehicle type. The key variables in this calculation are fuel consumption or fuel intensity, and emission factors or emission index. These factors are divided into technologies that are represented in the model by the age cohort or vintage.

The module generates estimates of $CO_2$ emissions and five other pollutants: CO, VOC, $NO_x$, $SO_2$ and PM2.5. Fuel consumption and emissions are calculated per origin country and disaggregated to zones based on the share of transport demand in each zone.

The Environment module receives input from the Passenger and Freight Demand modules and from the Vehicle Stock module (fleet size).

The module comprises two parts. Firstly, the predicted transport demand segmented by country, mode and fuel type is disaggregated by vehicle type and vehicle technology (represented by the vehicle age cohort). Secondly, fuel consumption and emissions are derived and calculated for each mode, vehicle type, fuel, and age cohort (technology) using the previously disaggregated transport demand, fuel consumption and emission factors.

Dataset on fuel consumption and emission factors for all vehicle age cohorts (technology) are available for the year 2010. For each period in the remaining simulation period (2015–2050), only factors of the new vehicles (vehicles between 0 and 4 years old) are available in the dataset. These factors are modifiable to enable policy simulation, such as introduction of new emission standards in a specific time or simulation period.

Fuel consumption by and emission factors of older vehicles (vehicles more than 4 years old) are derived from the dataset for the previous period.

### 2.5.7 Safety Module

The Safety module (SAF) assesses the impact of transport policy measures on safety, and yields predictions of the number of fatalities and injuries, and associated social costs.

The required input includes historical mobility data from the Data Stock, predicted mobility (from the Passenger and Freight Demand modules), and user input changes to safety risk and safety risk causal factors. Risk is defined as the number of occurrences (fatalities, injuries) per unit of mobility (in vehicle-kilometre or trips).

The module distinguishes road and non-road modes that are dealt with at different levels of detail. Road safety is treated in the most detail and predicts fatalities as well as serious and minor injuries. Road is further split into car, truck, powered two-wheelers, public transport, bike, and pedestrians. Non-road modes include rail, air, short sea shipping, and inland waterways.

The results are presented per country and time period.

For each transport mode, there are two components. The first is the Business-as-Usual (BAU), which calculates safety risks and makes predictions based on risk trend lines (from historical mobility and safety data) and mobility predictions (from the Passenger and Freight Demand modules). The second is the scenario component that adapts the BAU risks according to the anticipated effect of safety measures modelled. The effect is derived from changes in accident causal factors (which are the policy inputs) and the elasticities and equations relating these to changes in risk. Safety predictions for the scenario follow from these scenario risks and mobility predictions. Road fatalities, serious and minor injuries are predicted. For the other modes, the focus is on fatalities. For all modes the social costs are calculated.

## 2.6 Model Validation and Testing

The HIGH-TOOL model was subject to an extensive validation and testing approach.

Robustness tests were carried out to ensure that the model works correctly in the presence of invalid inputs or stressful environmental conditions.

Since the results of the HIGH-TOOL Baseline scenario required consistency with the forecasts of the EU Reference Scenario 2013, significant effort was spent to calibrate the HIGH-TOOL modules to this reference. Furthermore, the modules' reactions on changes in input variables were tested by sensitivity checks.

Finally, the HIGH-TOOL model was tested by following case studies:

- Post 2020 introduction of $CO_2$ standards for cars and vans
- Evaluation of corridor improvement for rail passenger transport via the hypernet
- Introduction of speed limits for light commercial vehicles
- Untapped potential of maritime ports related to liberalisation policies
- Cost sensitivity of the HIGH-TOOL model for passenger road mode
- Modules' stability in a given time-step
- Increase of public and private transport infrastructure investments
- Competition between high-speed rail and air.

## 2.7 User Interface and Policy Selection

The HIGH-TOOL model has been designed as a user-friendly policy-assessment tool, which can be operated by transport experts without a deep modelling background. Therefore, the User Interface of the HIGH-TOOL model is designed as a "user-centric" application, empowering users to make a productive and intelligent use of the HIGH-TOOL model. The User Interface supports users in thinking more systematically and in building consistent policy questions. On the other hand, the HIGH-TOOL User Interface is designed to reduce the risk of abusing models beyond their limits.

The key design principles applied in relation to user interaction are as follows: Anticipation, visible navigation, efficiency, consistency, explorable interfaces, learnability, readability and intuitiveness.

The HIGH-TOOL model offers three options to define policies to be assessed:

- Using a *single pre-defined Transport Policy Measure*
- Using *combinations* of pre-defined Transport Policy Measures
- Using a *customised policy package* of policy variables.

Policies and policy variables can be defined in terms of a temporal dimension (2015 to 2050) and geographical distribution (countries and regions in Europe).

## 2.8 Dissemination

A wide dissemination approach was applied within the HIGH-TOOL project. Besides the creation of a consistent visual identity for the project and the continuous update of the project homepage, three project leaflets were created and distributed.

The HIGH-TOOL project was presented on four major transport research conferences, on four major transport research conferences, the European Transport Conference (ETC) in Frankfurt, Germany (September 2015); the 6th European Transport Research Conference (TRA) in Warsaw, Poland (April 2016); the 14th World Conference on Transport Research (WCTR), Shanghai, China (July 2016) and the European Transport Conference (ETC) in Barcelona, Spain (October 2016).

Furthermore, the project was presented on the Workshop of the WCTRS Special Interest Group E1, Transport Systems Analysis & Economic Evaluation in Istanbul, Turkey (October 2015), on a Workshop of the German-Turkish Science Year Programme in Istanbul, Turkey (May 2015), to visiting delegations at KIT, as well as to national policy-makers and to students.

Three User Workshops were conducted to learn user requirements, to present the model, to raise awareness on the project, and to facilitate personal interaction between the model developers and the future users of the tool.

# 3 Project Context and Objectives

The European Commission's General Directorate Mobility & Transport (DG MOVE) follows a challenging objective: to develop transport policies that benefit all sectors of the Community. By assessing transport trends of the previous years, the European Commission concluded in 2011 that business as usual is not sustainable, because the following three key patterns of the European transport system had not sufficiently been addressed (European Commission, 2011b):

- Persistent oil dependency and expected long-term increase of oil prices
- increasing congestion and worsening accessibility of peripheral regions of the EU
- and deterioration of climate and local environment.

Thus there has been a clear need for EU transport policy to facilitate changes in trends. In the Commission Staff Working paper accompanying the Transport White Paper 2011 it is stated that past policies had failed to sufficiently address these three patterns. Four main reasons were identified which had prevented the EU transport system from becoming sustainable (European Commission, 2011c):

- Inefficient pricing: Most of the external costs of transport are not internalised and where existent, internalisation schemes are not coordinated between modes and Member States. Many taxes and subsidies which have been designed without the internalisation goal in view have a distorting effect on behaviour.
- Inadequate research policy: Despite promising results from research, fast deployment of technologies for sustainable mobility is constrained by market and regulatory failures.
- Inefficiency of transport services: Efficiency and competitiveness of multimodal and cross-border transport is hampered by a number of remaining regulatory and market failures such as regulatory barriers to market entrance or burdensome administrative procedures. Furthermore, the different modes of transport are still not sufficiently integrated, and the policy to develop Trans-European Networks for Transport (TEN-T) has lacked financial resources and a true European and multimodal perspective.
- Lack of integrated transport planning: Land-use planning and location decisions are taken at various spatial levels, ranging from the local to the continental level. Decision-makers do not necessarily properly take into account the consequences of their choices on the operation of the transport system as a whole, which typically generates inefficiencies.

In 2011, the European Commission issued the Transport White Paper "Roadmap to a Single Transport Area – Towards a competitive and resource efficient transport system", a strategic document that addresses long-term challenges of the transport sector and develops a policy framework for the coming years (European Commission, 2011a).

The key targets of European transport policy have been to facilitate European economic progress, supporting competitiveness and offering high quality mobility services while using resources more efficiently. Thus, transport has to decrease its energy consumption, use cleaner energy, and make more efficient use of the infrastructure.

The Transport White Paper's central target is the European Union's commitment to reducing greenhouse gas emissions from transport by 60% by 2050 with respect to the 1990 level. This target is a precondition to ensure consistency with the long-term requirements for limiting climate change to 2°C and the EU overall target of reducing emissions by 80 to 95% by 2050. In this context, the Transport White Paper proposed ten goals for a competitive and resource-efficient transport system, which are benchmarks for achieving the 60% GHG emission reduction target. In brief, the ten goals are as follows (European Commission, 2011a):

- Halving the use of 'conventionally-fuelled' cars in urban transport by 2030, phasing them out in cities by 2050, and achieving essentially $CO_2$-free city logistics in major urban centres by 2030.
- Reaching low-carbon sustainable fuels in aviation of 40% by 2050, and reduce EU $CO_2$ emissions from maritime bunker fuels by 40%.
- Shifting 30% of road freight over 300 km to other modes by 2030, and more than 50% by 2050, facilitated by efficient and green freight corridors.
- Completing a European high-speed rail network by 2050. Triple the length of the existing high-speed rail network by 2030 and maintain a dense railway network in all Member States. By 2050, the majority of medium-distance passenger transport should go by rail.
- Completing the fully functional and EU-wide multimodal TEN-T 'core network' by 2030, with a high quality and capacity network by 2050 and a corresponding set of information services.
- Connecting all core network airports to the rail network, preferably high-speed, by 2050; ensure that all core seaports are sufficiently connected to the rail freight and, where possible, inland waterway system.
- Deployment of the modernized air traffic management infrastructure (SESAR) by 2020 and completion of the European Common Aviation Area. Deployment of equivalent land and waterborne transport management systems and of the European Global Navigation Satellite System (Galileo).

- Establishing the framework for a European multimodal transport information, management and payment system by 2020.
- Moving close to zero fatalities in road transport by 2050, and halving road casualties by 2020.
- Moving towards full application of "user pays" and "polluter pays" principles and private sector engagement to eliminate distortions, generate revenues and ensure financing for future transport investments.

Transport policy measures addressing these challenging goals have important long-term implications for society, the environment and the economy. Transport policy measures can sequester capital for decades and result in manifold effects, both beneficial and detrimental.

In this context, the Project Consortium has developed the HIGH-TOOL model. The HIGH-TOOL model is an open source, high-level strategic assessment model for use by EU policy makers and policy analysts to assess economic, social and environmental impacts of transport policy measures. The model has two purposes. It can be applied to strategic assessment of transport policy options, and to support identification of policy options for further analyses by more detailed assessment instruments.

# 4 Model Development Stages and User Involvement

The HIGH-TOOL model was introduced successively during the project in order to facilitate the active participation of the future tool users in the development process. Figure 3 provides an overview of the development process aligned with the various user involvement activities.

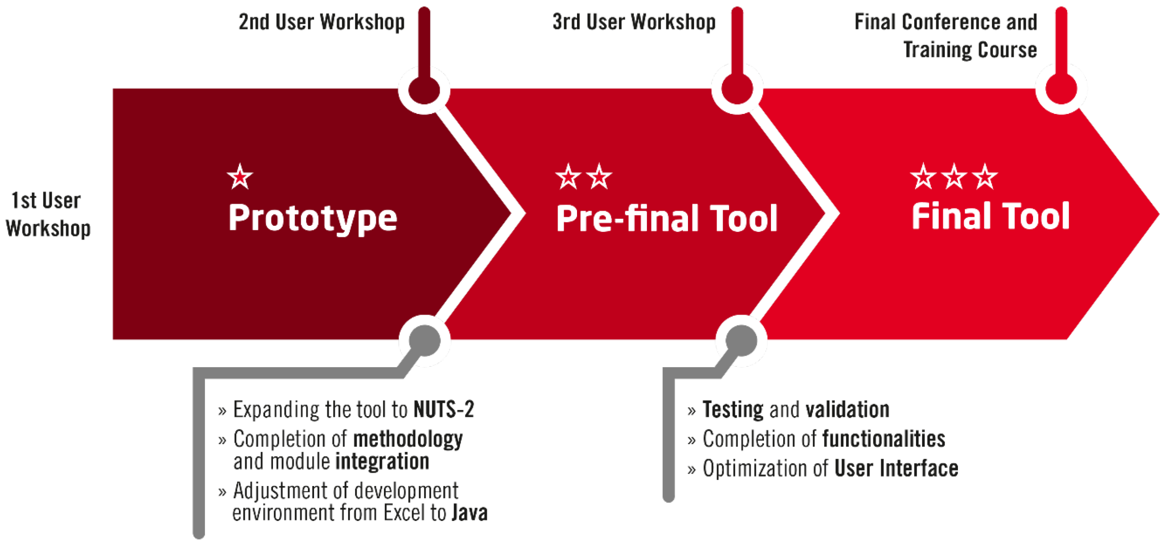



Figure 3: Development process of the HIGH-TOOL model and user involvement

After a careful analysis of the European Commission's White Paper on Transport (European Commission, 2011a) and the Impact Assessment Guidelines (European Commission, 2009), the key user requirements for the tool were identified during the 1st User Workshop, supported by a complimentary internet-based survey. The user needs are summarised by the HIGH-TOOL report on user requirements (Vanherle et al., 2016).

The model development was divided into three stages: prototype, pre-final version and final version.

The *prototype version* fulfilled following objectives: to establish a concrete basis for collecting comments and recommendations from the future tool users, and to allow the HIGH-TOOL Consortium to gain experiences in the modular tool development. The prototype version of the HIGH-TOOL model was presented to the policy specialists of the European Commission and discussed at the 2nd User Workshop.

Under consideration of comments obtained with respect to the prototype, the *pre-final version* was elaborated. The pre-final version, running at NUTS-2 level, was a Java-based tool, and captured a wider field of transport policies. However, the pre-final model version was neither fully calibrated nor validated. The pre-final model was presented to EC policy specialist at the 3rd User Workshop.

Considering further comments by the future tool users on User Interface and Policy Assessment Report, the *final model* version was developed, after an extensive testing and validation phase. The final version of the model was presented to EC staff during the Final Conference, while application examples were elaborated and implemented in the Training Course. Finally, the *User Guide* was produced to allow easy access to the application of the HIGH-TOOL model.

Although three model versions were developed within the project, the model descriptions and contents in this report refer to the final version of the HIGH-TOOL model.

# 5 Description of the HIGH-TOOL Model

## 5.1 General Model Features

### Model type

The assessment tool is designed as a high-level strategic assessment tool which is partly based on existing tools, and, where necessary, complemented by new models. Due to its character as a strategic high-level instrument, it does not cover detailed networks. The core of the model are transport demand models for passenger and freight, following the structure of the classic transport model, however without assignment of flows on networks. Integrating knowledge from several domains, such as demography, economy, transport demand, environment and safety, the HIGH-TOOL model constitutes an integrated assessment model.

### Geographical scope and time horizon

The HIGH-TOOL model has a global scope. However, the main focus is attached to Europe, and particularly to the Member States of the European Union. The spatial scope is the level of NUTS-2 for all EU Member States (EU28), Norway and Switzerland, NUTS-0 for EU neighbouring countries, and country bundles for intercontinental transport. In total 314 modelling zones are considered.

The tool's timeline are 5-years steps from 2010 to 2050. The year 2010 is the base year of the HIGH-TOOL model.

### Demand segmentation

Passenger demand is differentiated by following modes: air, rail, road (passenger car and powered 2-wheelers), and long-distance coach. The urban demand sub-module additionally considers urban bus, urban tram/metro, cycling and walking. The demand differentiation by trip purpose covers business, private, vacation, and commuting trips.

The freight transport modes are air, rail, road, inland waterways, and maritime transport. The demand is considered for NST-2 commodities (52 commodity groups).

The passenger and freight transport demand is further distinguished by vehicle types and fuel types. The model considers 60 vehicle types and 17 fuel types.

### Baseline

To answer a key user requirement, the HIGH-TOOL baseline is aligned with the EU Reference Scenario 2013 (European Commission, 2013). Thus the forecasts of the HIGH-TOOL Baseline are largely consistent with those of the EU Reference Scenario 2013.

**Technical implementation**

The HIGH-TOOL model was largely developed in Java, thus ensuring platform independence. The User Interface was programmed as a stand-alone online application based on AngularJS and SailsJS, both free and open source software components programmed in JavaScript. The HIGH-TOOL Data Stock is realised as a PostgreSQL database with PostGIS extension.

## 5.2 Overview Structure of the HIGH-TOOL Model

HIGH-TOOL model consists of three main elements:

- Core modules that represent the modelling framework
- Data Stock that facilitates the exchange of data
- User Interface for application of the model and providing access to the assessment results.

While Figure 3 shows the overview structure of the HIGH-TOOL model, Figure 5 displays the detailed structure of the model, also depicting the structure within the core modules.

The model structure is explained in detail by the HIGH-TOOL report on the model structure (Mandel et al., 2016).

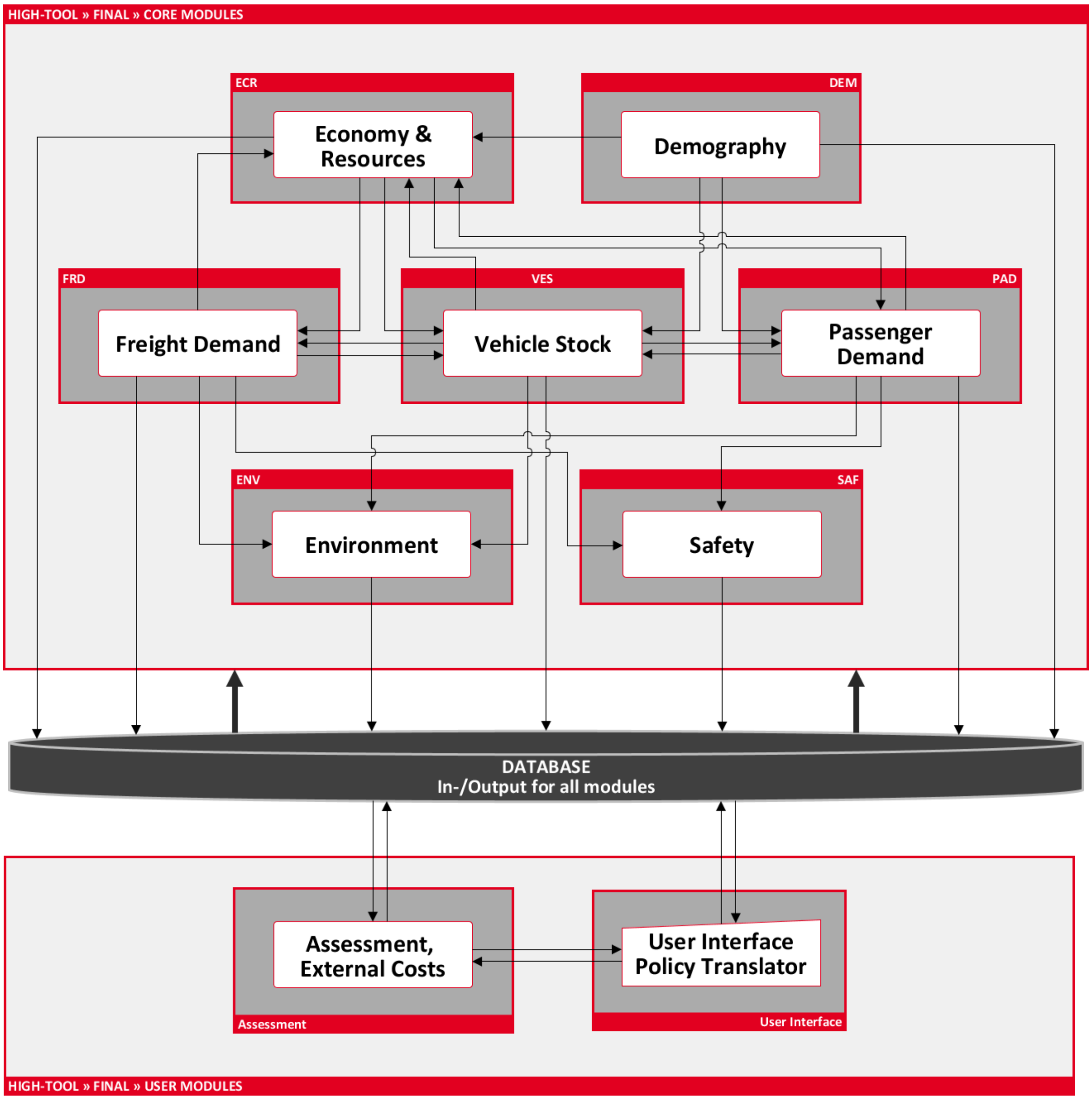



Figure 4: Overview structure of the HIGH-TOOL model

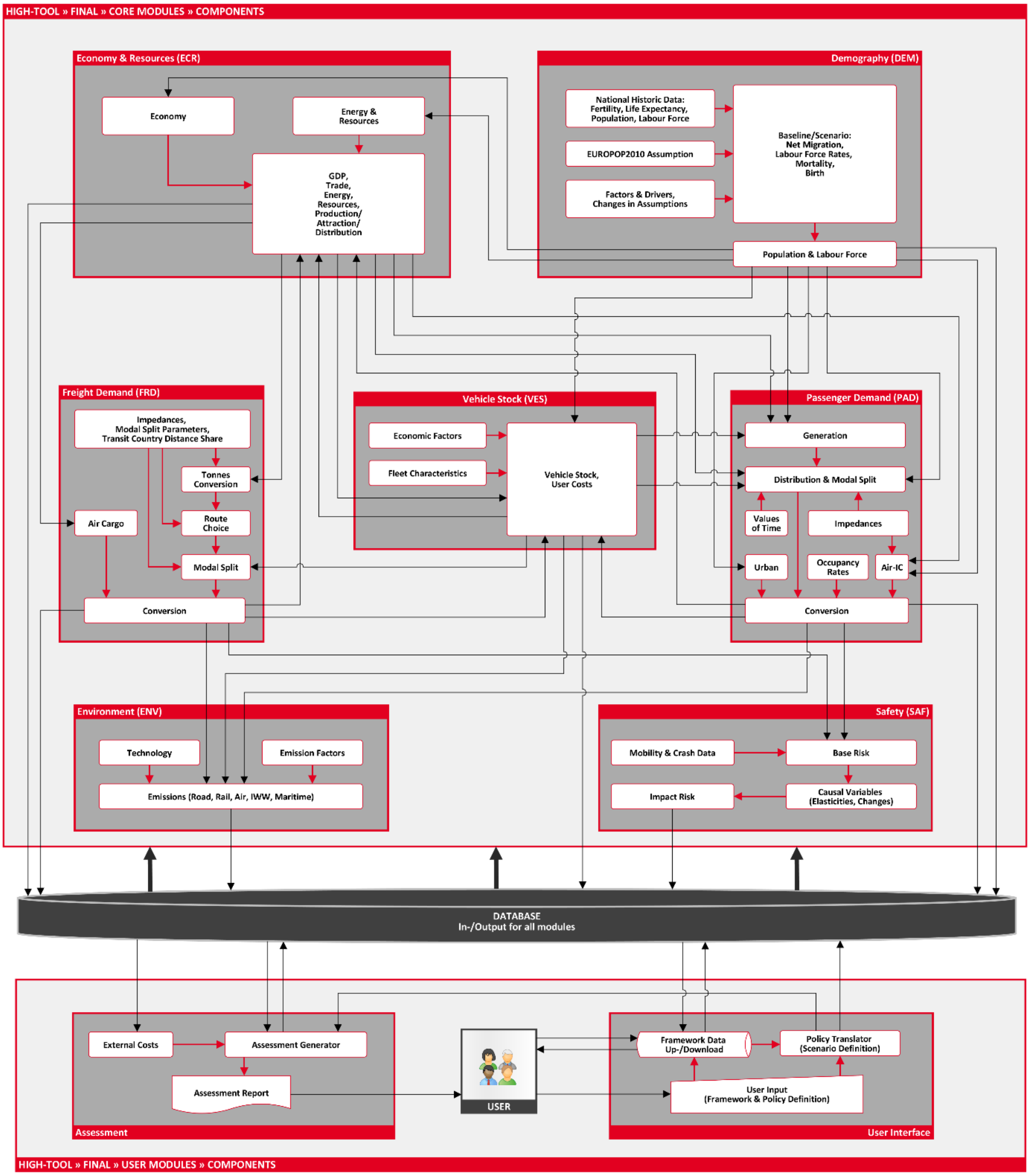



Figure 5: Detailed structure of the HIGH-TOOL model

## 5.3 Core Modules

The HIGH-TOOL model comprises following core modules:

- Demography (DEM)
- Economy & Resources (ECR)
- Passenger Demand (PAD)

- Freight Demand (FRD)
- Vehicle Stock (VES)
- Environment (ENV)
- Safety (SAF).

These modules interact sequentially with each other. The methodologies of these core modules are briefly summarised in the following paragraphs. A detailed description of the methodology is presented in the HIGH-TOOL report on elasticities and equations (van Grol et al., 2016).

### 5.3.1 Demography Module

The Demography module (DEM) estimates the projected regional population and labour force in the 28 EU Member States and in Norway and Switzerland. UN projections are provided for other countries worldwide and are adapted to the geographic zoning system used in HIGH-TOOL.

The population and labour force are calculated at country level for the EU 28, Norway and Switzerland based on EU Reference Scenario assumptions on fertility rates, life expectancies at birth and net migration (European Commission, 2013). The projected population values are subsequently disaggregated to geographic zones based on historical demographic trends. The net migration distribution per zone is based on socio-economic data, specifically historical data on income and employment. Population development at country level is simulated with a cohort component that incorporates the effects of demographic drivers and migration.

Regional disaggregation of the population excluding migration is based on the 2010 historical regional distribution. Net migration is then regionally distributed using a distribution proxy based on income and employment rate. Labour force is estimated from the labour force percentage defined in the EU Reference Scenario and underlying assumptions.

Figure 6 provides an overview of the structure of the Demography module.

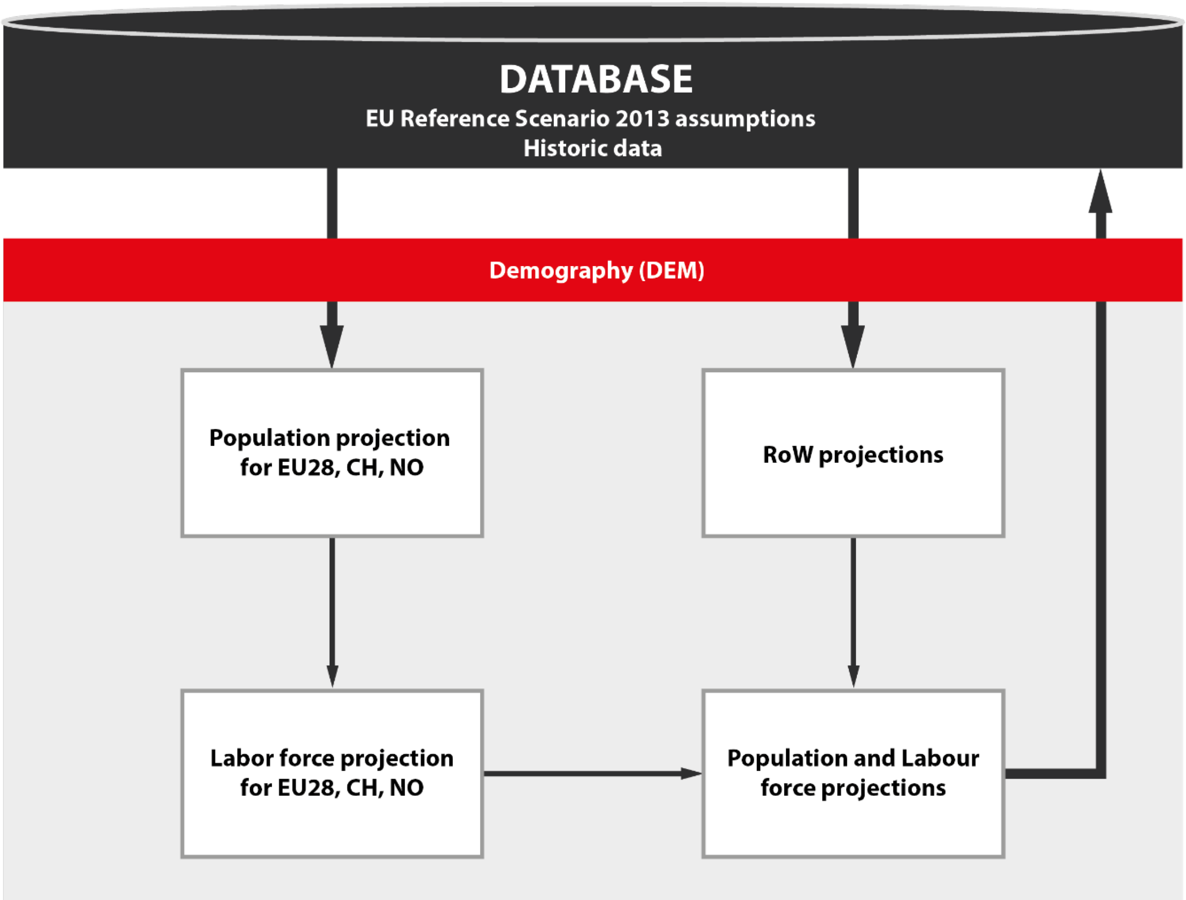



Figure 6: Structure of the Demography module

### 5.3.2 Economy & Resources Module

The Economy & Resources module (ECR) comprises three components: Economy, Resources, and the combined component of GDP, Trade, Energy, Resources, and Production/Distribution (see Figure 7).

The Economy sub-module estimates total output, capital stock and labour use in the economy, for which the general drivers (GDP, household income per capita and population) are exogenously defined by the EU Reference Scenario 2013. These drivers are disaggregated from country to zone based on ETISplus data (regional GDP, regional population, and labour force). The combined component (GDP, Trade, Energy, Resources, Production/ Distribution) estimates and projects employment, trade, resource consumption, and purchasing power under various transport policy measures. Resources component calculates environmental indicators (without combustion) using the EXIOBASE database for $CO_2$, $NO_x$, $SO_x$, PM, biomass, fossil fuel use, metal use, mineral use, wood use, and water use.

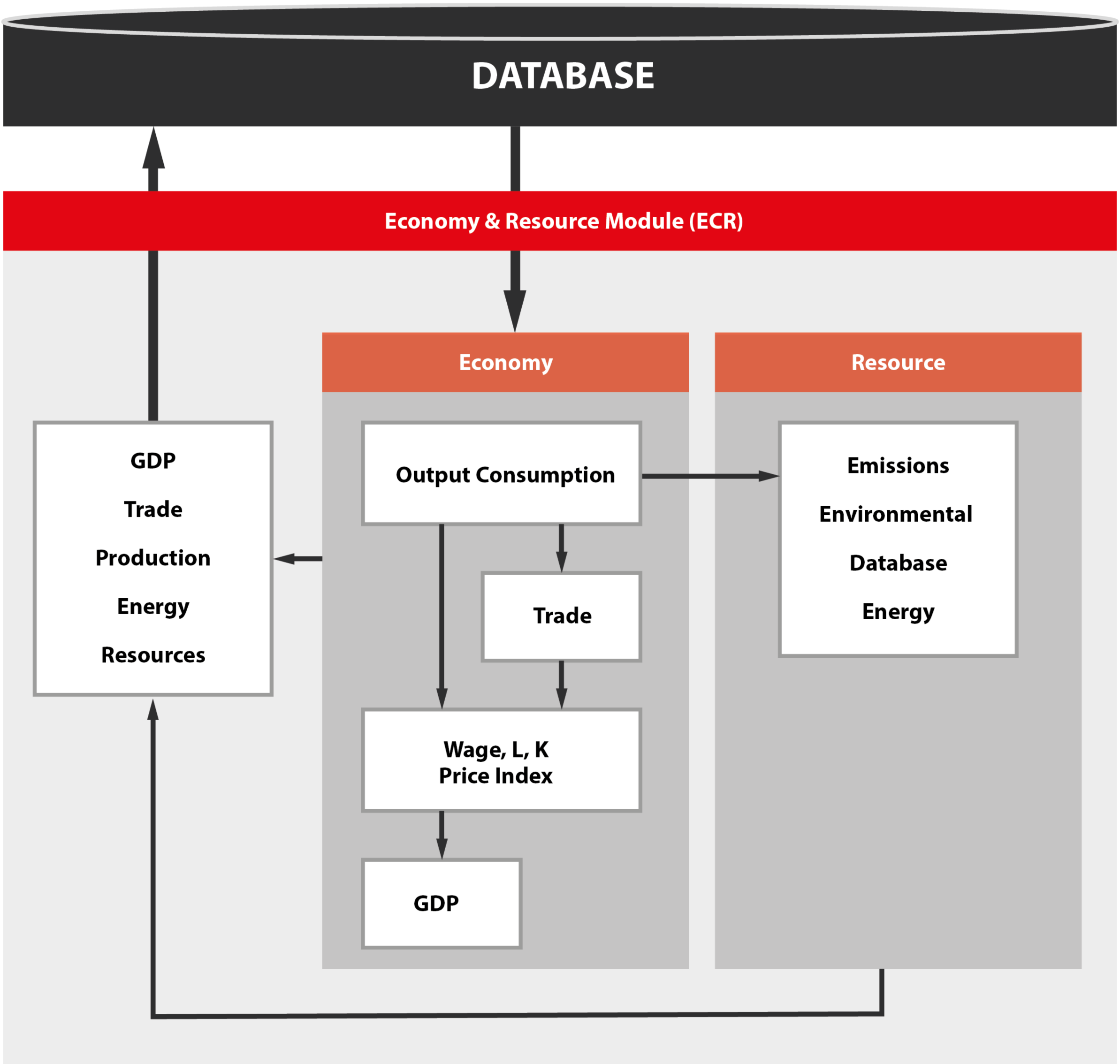



Figure 7: Structure of the Economy & Resources module

To generate economic output and environmental data, this module uses regional demographic and labour data provided by the Demography (DEM) module, transport costs by the Freight Demand (FRD) module, the type of vehicles purchased by the Vehicle Stock (VES) module, and passenger demand by the PAD module. The economic and environmental indicators generated are used in the other modules.

Economic indicators are a key driver of passenger and freight demand, and demand for vehicle stock. Hence, there is feedback between these modules. The ECR module generates updated employment and income data used in the DEM module to ensure consistency of population distribution and spatial economic development.

### 5.3.3 Vehicle Stock Module

The Vehicle Stock module (VES) converts passenger and freight demand to vehicle fleet size, which is disaggregated to vehicle type and vehicle age cohort for calculation of emissions and energy use. Vehicle types include propulsion and fuel technologies, and the module includes 61 road and 12 non-road vehicle types. The vehicle age cohorts range from 0 to 29 years.

Fleet stock forecasts are provided at country and region for each of the 28 EU Member States and for each period (5-year intervals) up to 2050. The module also delivers forecasts of average fixed and variable generalised costs for each vehicle type, and total tax revenue per country.

Taking into account the transport demand and the vehicle stock in the previous period, as well as the vehicles that survived in current period, the demand for new vehicles and the average mileage per vehicle are calculated.

The logit and the stock dynamic model inside the Vehicle Stock module use the calculated average generalised costs to define the shares of the different types of new vehicles entering the market as well as their numbers. This calculation produces the detailed existing vehicle stock in the current period.

The structure of the module is shown by Figure 8.

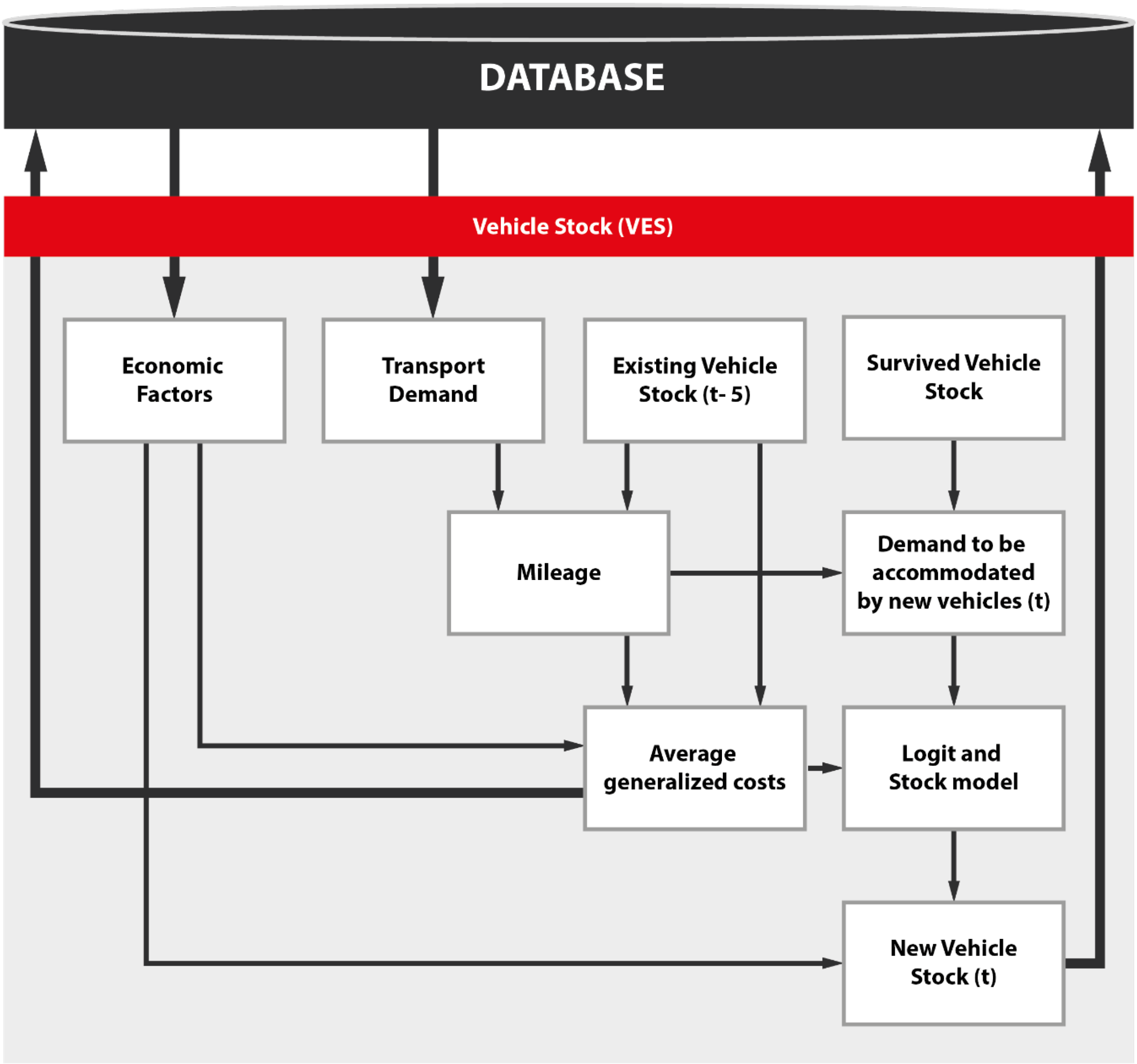



Figure 8: Structure of the Vehicle Stock module

### 5.3.4 Passenger Demand Module

The Passenger Demand (PAD) module largely follows the classical four-step approach to transport demand modelling of generation, distribution, modal split and assignment (Ortúzar and Willumsen, 2011). However, instead of the assignment step, the module translates number of trips into transport performance by the conversion.

The generation step estimates the trip demand for each origin. In the distribution step, the origin-destination trip matrix is computed and then further divided in the modal split step into transport modes. The conversion step derives transport performance indicators, such as passenger-kilometres and vehicle-kilometres.

Trip generation is carried out by a regression approach. The distribution and the model split components are integrated by using the Expected Minimum Cost (EMC) measure, which relies on the Expected Maximum Utility (EMU) or logsum measure. For the cost functions, the concept of generalised time is used in which the cost unit refers to minutes and not to monetary terms. The EMC values are computed using a Nested Logit model. Road trips are split by car and powered two-wheelers, under the assumption of country-specific shares and motorisation levels.

A hypernet model linked to the core PAD module was developed for road and rail. It represents an optional submodule for simulating network effects in passenger transport, and allows a more realistic depiction of transport infrastructure policies.

The core PAD module is complemented by two additional modules. The first is the urban passenger demand module which follows a generic, elasticity-based approach. It covers following modes of transport: cars, powered two-wheelers, tram/metro, bus, cycling, walking. Since urban trips are a subset of intra-zonal trips, the generation step is linked to the core PAD module. The second is the intercontinental air passenger module, which uses a regression-based approach to estimate the number of flights between European regions and intercontinental destinations.

Figure 9 displays the structural overview of the Passenger Demand module.

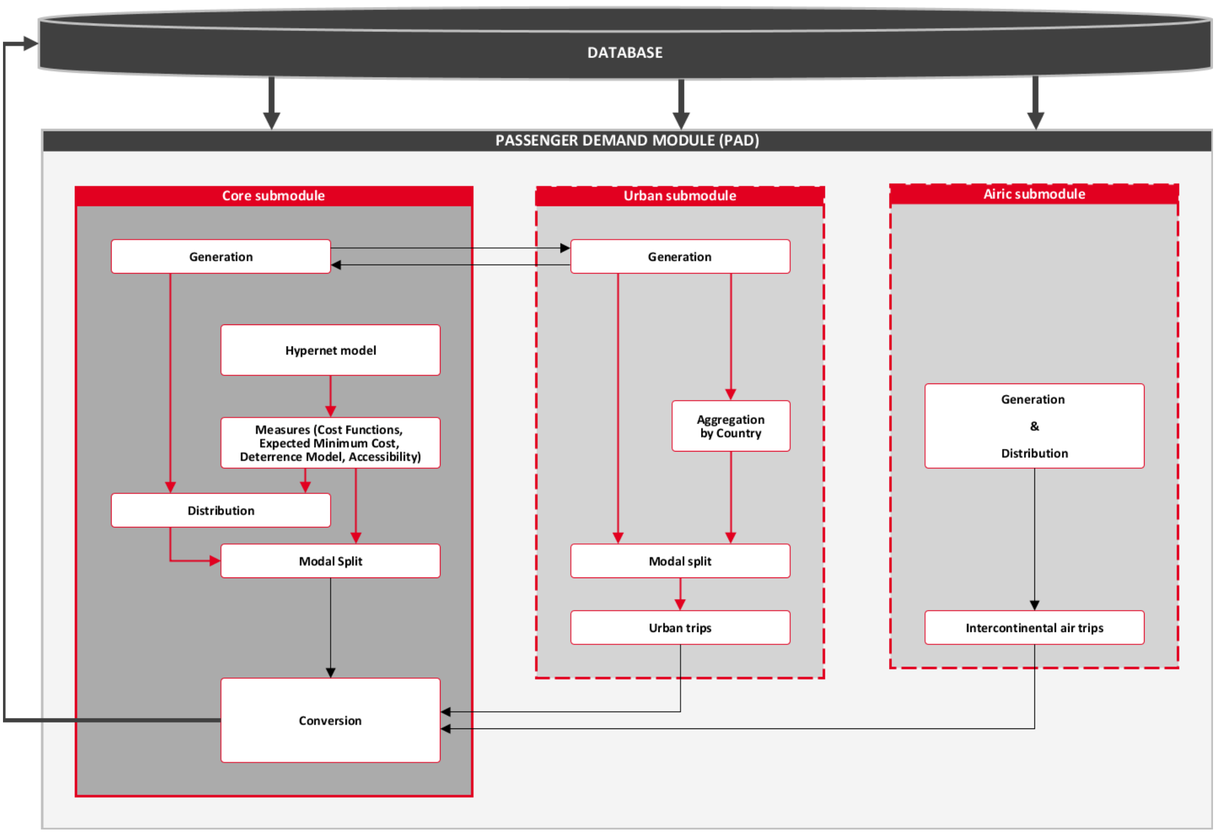



Figure 9: Structure of the Passenger Demand module

### 5.3.5 Freight Demand Module

The Freight Demand (FRD) module consists of four components: trade conversion, route choice, modal split and conversion. The trade conversion component converts trade values to volumes and extracts air demand from total trade between an origin and destination. The route choice and modal split components distribute demand across transport chains and perform a modal split on each leg of the transport chains, while applying the effects of measures. The conversion component derives other transport indicators, such as tonne-kilometres and vehicle-kilometres. The transport indicators relating to full-freight aircraft are determined in a subcomponent and feed into the conversion component. An overview of the module is provided by Figure 10.

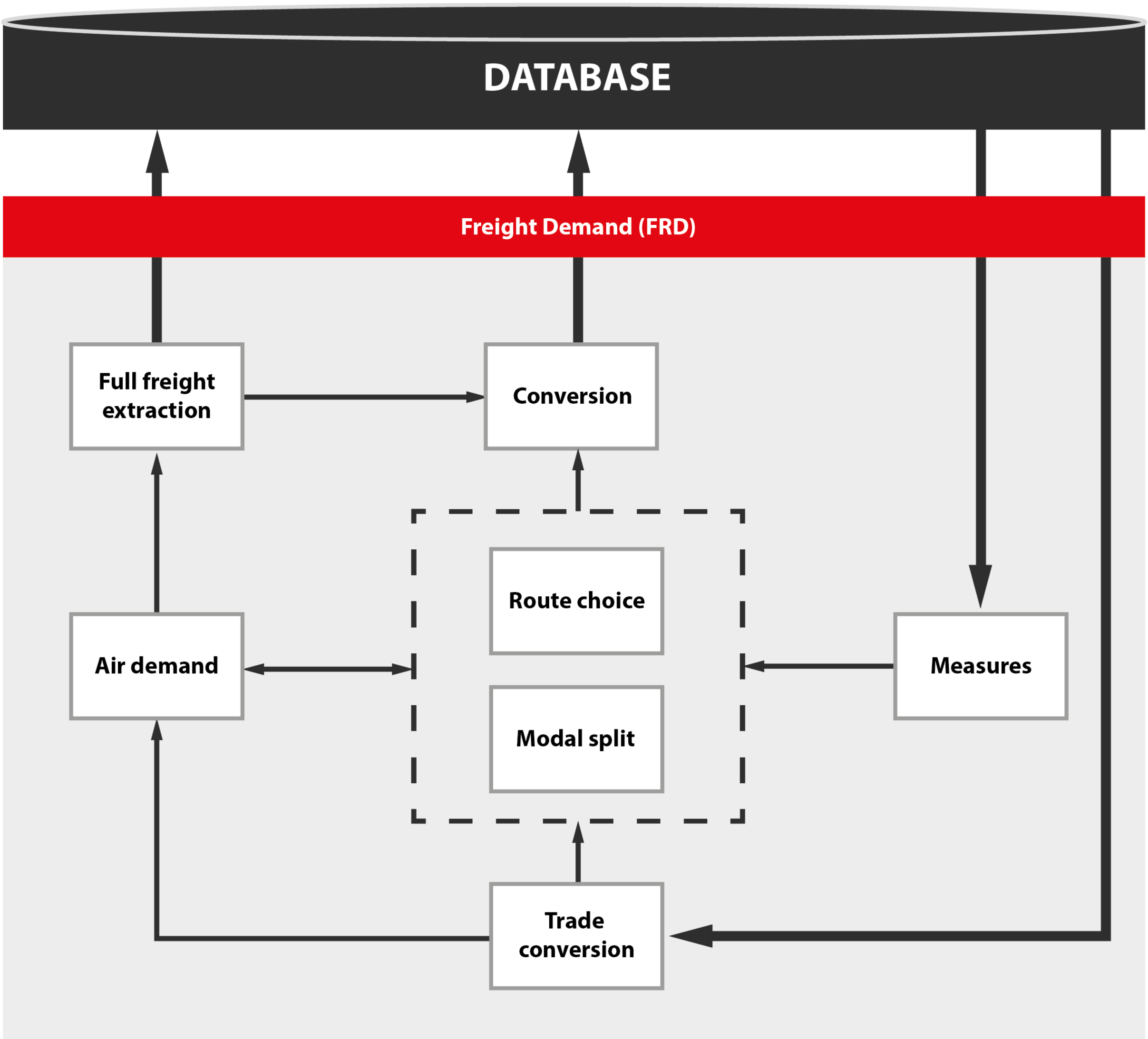



Figure 10: Structure of the Freight Demand module

The Freight Demand module together with the Economy & Resources module follow an analogue approach to the classical four-step methodology of generation, distribution, modal split and assignment. The latter is replaced by calculation of performance indicators in the conversion component.

The module delivers trade in value per origin-destination (O/D), which is converted to volumes by applying volume density assumptions per O/D and commodity (assumed constant over time) extracted from extracted from ETISplus (Szimba et al, 2013).

The air demand base matrix extracted from ETISplus is adjusted according to growth in imports and exports delivered by the ECR module, and subtracted from total trade. This results in tonnes demand per commodity per origin-destination.

Each Origin and Destination is connected by route chains extracted from the ETISplus database. These chains form a set of up to three legs that connect an origin and destination through up to two transhipment regions. For each of the legs obtained modal-split is performed in the modal-split component. The Modal split component considers various cost elements influenced by the VES module that can be affected by policy measures to compute generalised cost per available mode M connecting an Origin and Destination of a leg through a multinomial logit function according to TRANS-TOOLS (Burgess et al., 2008; NEA, 2007).

Subsequently based on total generalised costs for route chains connecting the trade relation's Origin and Destination, demand is distributed across the route chains connecting Origin and Destination through transhipment regions T in the Route choice component by applying a multinomial logit.

The conversion step calculates tonne-kilometre and vehicle-kilometre performance indicators for the origin region and “on the territory” perspective. The latter is calculated by applying the share of distance in a leg in a country obtained, using data from ETISplus.

Finally, assumptions on full-freight share and capacity of airfreight transport are applied to extract airfreight transport by full-freight aircraft from the total demand for air.

### 5.3.6 Environment Module

The Environment (ENV) module calculates wheel-to-tank fuel consumption and emissions for each vehicle type. The key variables in this calculation are fuel consumption or fuel intensity, and emission factors or emission index. These factors are divided into technologies that are represented in the model by the age cohort or vintage.

The module produces estimates of $CO_2$ emissions and five other pollutants: CO, VOC, $NO_x$, $SO_2$ and PM2.5. Fuel consumption and emissions are calculated per origin country and disaggregated to zones based on the share of transport demand in each zone.

The Environment module receives input from the Passenger and Freight Demand modules and from the Vehicle Stock module (fleet size).

The module comprises two parts (see Figure 11). Firstly, the predicted transport demand segmented by country, mode and fuel type is disaggregated by vehicle type and vehicle technology (represented by the vehicle age cohort). Secondly, fuel consumption and emissions are derived and calculated for each mode, vehicle type, fuel, and age cohort (technology) using the previously disaggregated transport demand, fuel consumption and emission factors.

Dataset on fuel consumption and emission factors for all vehicle age cohorts (technology) are available for the year 2010. For each period in the remaining simulation period (2015–2050), only factors of the new vehicles (vehicles between 0 and 4 years old) are available in the dataset. These factors are modifiable to enable policy simulation, such as introduction of new emission standards in a specific time or simulation period.

Fuel consumption by and emission factors of older vehicles (vehicles more than 4 years old) are derived from the dataset for the previous period.

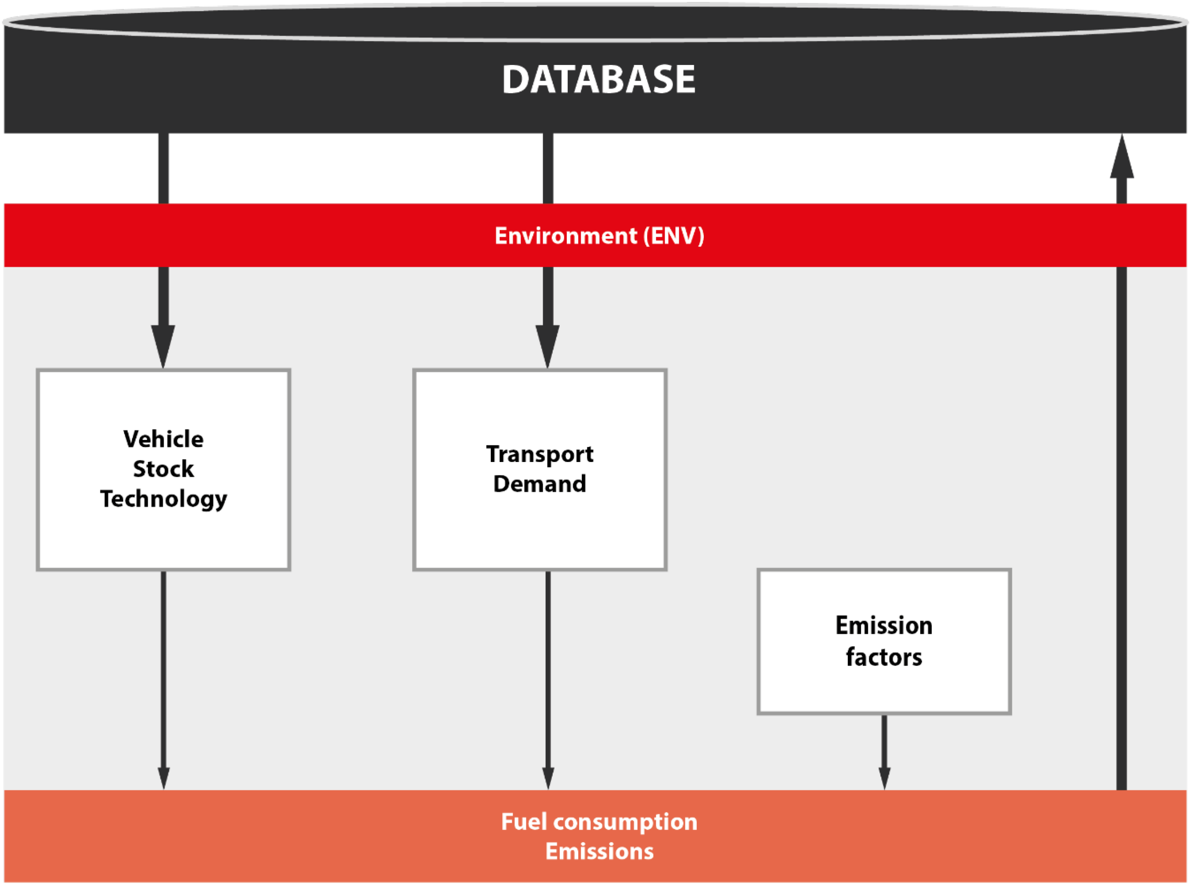



Figure 11: Structure of the Environment module

### 5.3.7 Safety Module

The Safety module (SAF) assesses the impact of transport policy measures on safety, and yields predictions of the number of fatalities and injuries, and associated social costs.

The required input includes historical mobility data from the Data Stock, predicted mobility (from the Passenger and Freight Demand modules), and user input changes to safety risk and safety risk causal factors. Risk is defined as the number of occurrences (fatalities, injuries) per unit of mobility (in vehicle-kilometre or trips).

The module distinguishes road and non-road modes that are dealt with at different levels of detail. Road safety is treated in the most detail and predicts fatalities as well as serious and minor injuries. Road is further split into car, truck, powered two-wheelers, public transport, bike, and pedestrians. Non-road modes include rail, air, short sea shipping, and inland waterways.

The results are presented per country and time period.

For each transport mode, there are two components. The first is the Business-as-Usual (BAU), which calculates safety risks and makes predictions based on risk trend lines (from historical mobility and safety data) and mobility predictions (from the Passenger and Freight Demand modules). The second is the scenario component that adapts the BAU risks according to the anticipated effect of safety measures modelled. The effect is derived from changes in accident causal factors (which are the policy inputs) and the elasticities and equations relating these to changes in risk. Safety predictions for the scenario follow from these scenario risks and mobility predictions. Road fatalities, serious and minor injuries are predicted. For the other modes, the focus is on fatalities. For all modes the social costs are calculated.

Figure 12 shows the Safety module's structure.

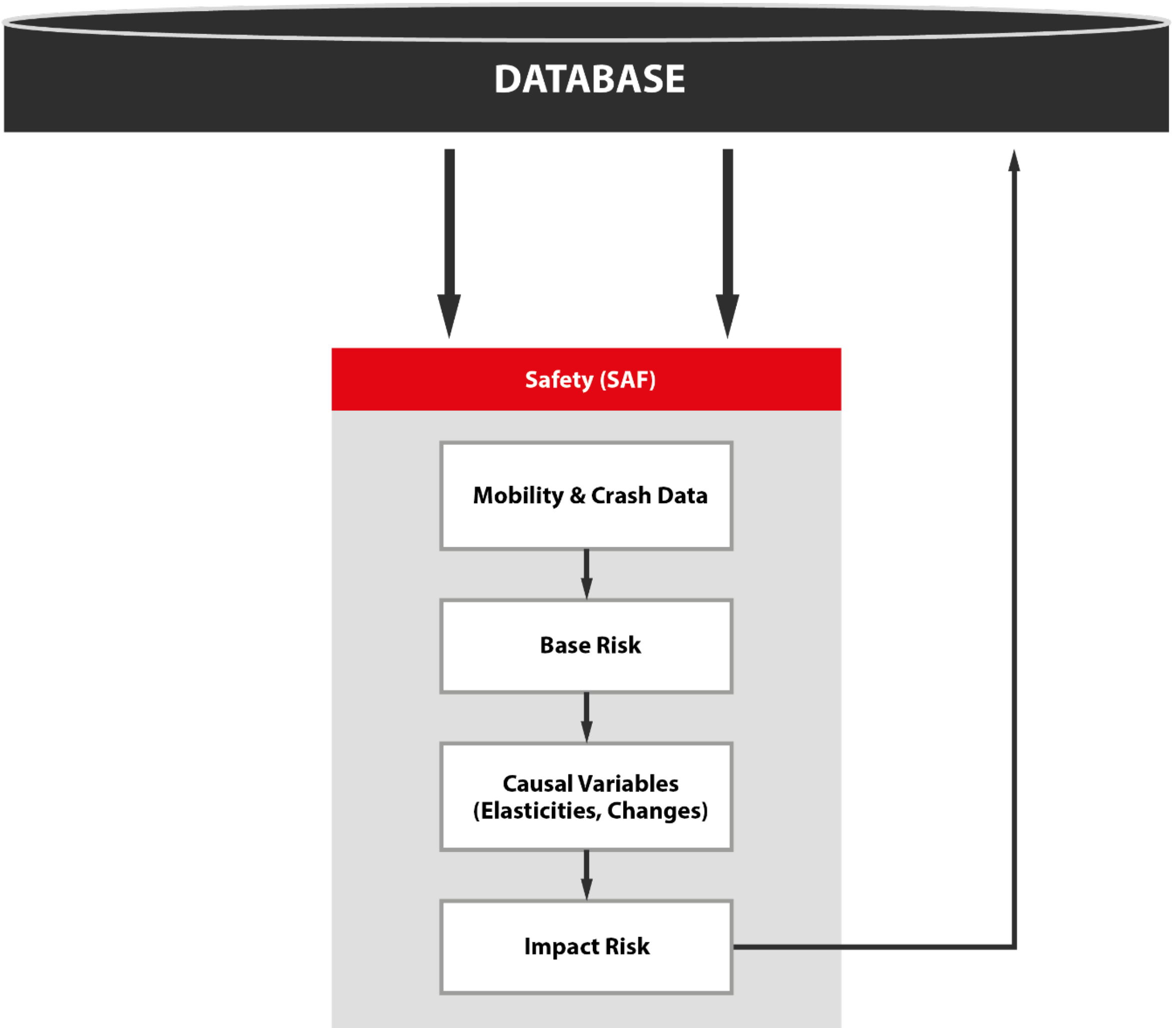



Figure 12: Structure of the Safety module.

## 5.4 The HIGH-TOOL Data Stock

The Data Stock ensures data exchange between the modules, provides exogenous input to the modules, and stores intermediate and output data. Thus, the main focus of the Data Stock is the identification of the necessary input and output data, their definition, dimensions and sources. For each module, data requirements have been identified, and the set of input and output variables have been elaborated, together with data dimensions. The database approach is documented and further explained by the HIGH-TOOL report on the Data Stock (Kiel, Smith and Laparidou, 2016).

## 5.5 Interaction between Core Modules

The core modules interact sequentially with each other. The sequential solution reduces the computation loops, as results for a period t are passed to computations in t+1. An iterative process would be much more time consuming as the modules would interact, re-compute, store and read data several times until the results for a certain time period become available and the model can move forward to the next time period. The sequence starts with DEM to produce demographic outputs for all forecast years 2015–2050. Subsequently ECR is run, fed by DEM results of time step t and by VES, PAD and FRD outputs of time step t-1. Afterwards VES is activated, on the basis of DEM/ECR (step t), and PAD/FRD (step t-1) outputs. Subsequently, PAD and FRD are run, using results from DEM/ECR/VES, and ECR/VES, respectively. Finally, results by PAD, FRD and VES are delivered for all years to ENV for the computation of the environmental impacts and by PAD and FRD to SAF for the computation of the safety impacts. The tool's base year is 2010. Thus, the first time step 2015 is partly driven by 2010 results, and 2020 by 2015 results etc.

The interaction scheme is shown by Figure 13.

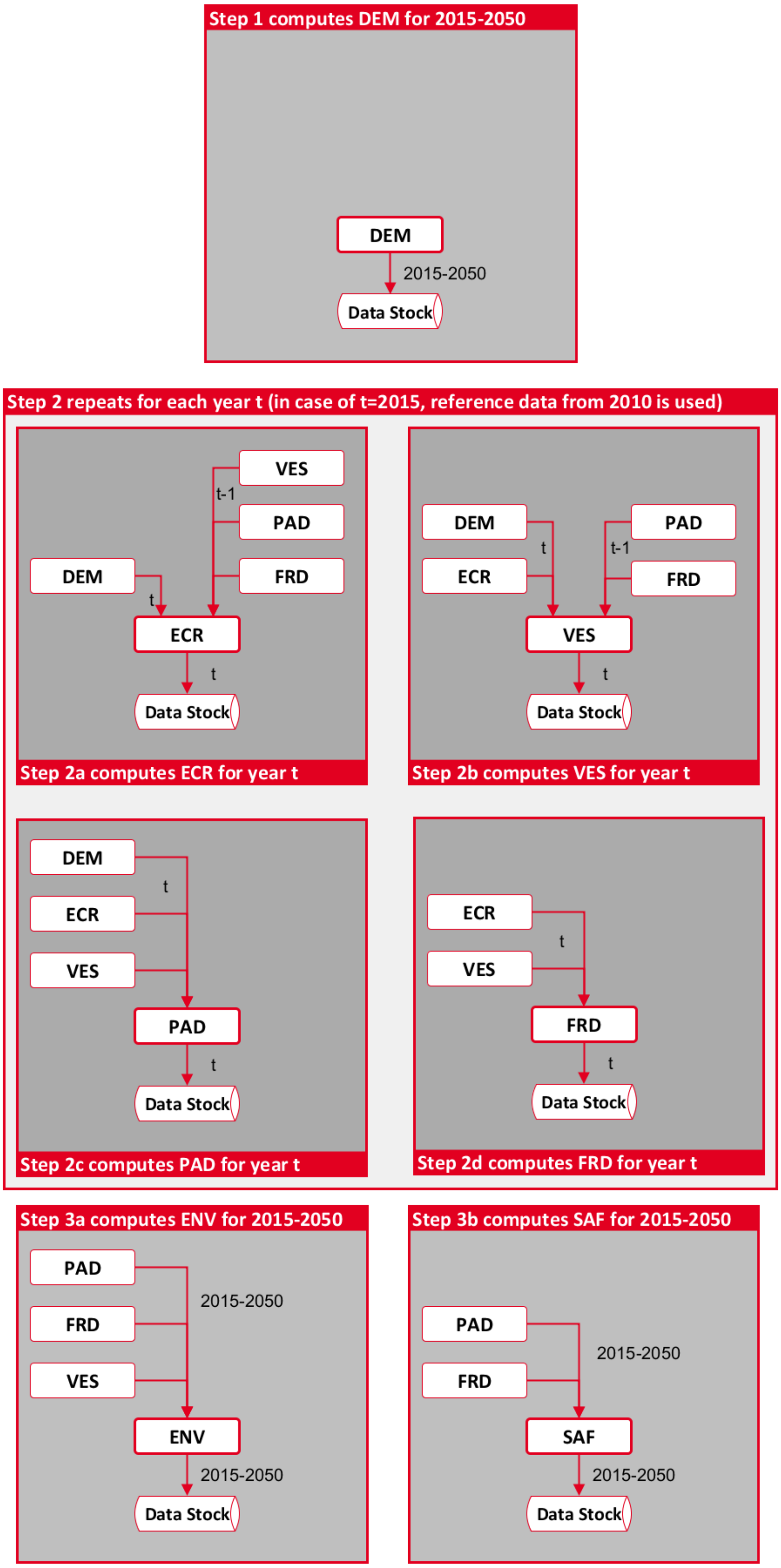



Figure 13: Model execution order

# 6 Model results, Validation and Testing

## 6.1 The HIGH-TOOL Baseline

Following the requirements by the EC, the HIGH-TOOL "Baseline", i.e. the "business-as-usual"/"do-nothing" scenario, was calibrated to and validated against the EU Reference Scenario 2013 (European Commission, 2013).

The EU Reference Scenario 2013 is portrayed as follows (European Commission, 2013):

*"[The EU Reference Scenario 2013] determines as core element the development of the EU energy system under current trends and adopted policies. It includes* ***current trends on population and economic development*** *including the latest 2010 statistics and takes into account the highly volatile energy import prices environment of recent years.* ***It portrays economic decisions, which are driven by market forces and technology progress in the framework of concrete national and EU policies and measures adopted until spring 2012 and which are or will be implemented over the next years.*** *The Reference 2013 scenario* ***includes all binding targets set out in EU legislation*** *regarding development of renewable energies and reductions of greenhouse gas (GHG) emissions, as well as the latest legislation promoting energy efficiency."*

The transport policy elements assumed for the EU Reference Scenario were carefully taken into account, and significant effort was spent to calibrate the HIGH-TOOL modules to this reference.

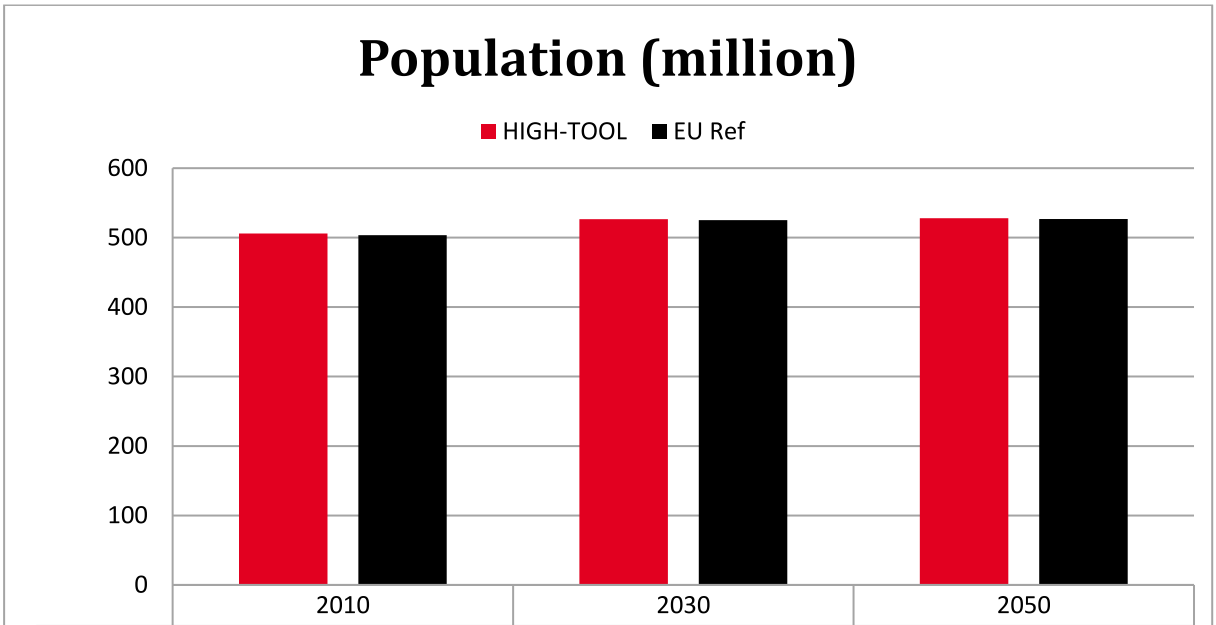
Thus in the validation approach, results of HIGH-TOOL outputs were compared to the trends of the EU Reference Scenario 2013. The validation approach, as described by van Meijeren et al. (2016), embraced both the validation of each module as stand-alone module and the validation of the integrated tool, in which all modules are interconnected with each other.

## 6.2 HIGH-TOOL Baseline Results

In this sub-chapter the results of the HIGH-TOOL baseline are compared to the EU Reference Scenario 2013. The comparison embraces following areas: Demography, economy, passenger demand, freight demand, vehicle stock, as well as environment. This validation approach refers to the baseline dated 14 September 2016.

### 6.2.1 Demography

The demographic development at EU28 level shows a moderate increase until 2050. The results of the HIGH-TOOL model show only marginal deviations from the results of the EU Reference Scenario (see Figure 84).

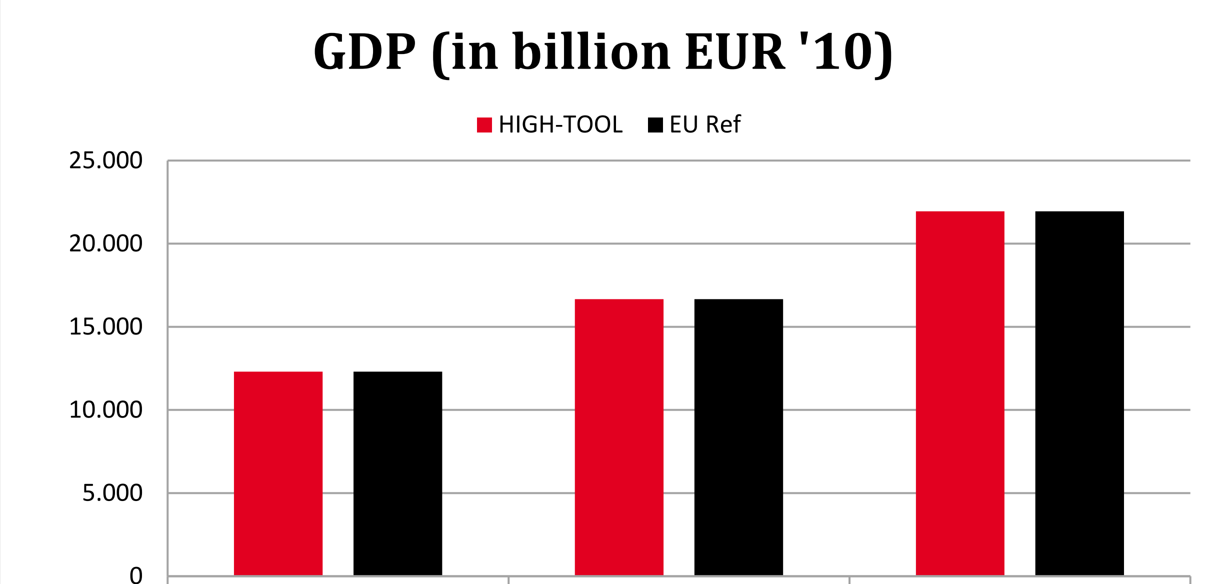



| | 2010 | 2030 | 2050 |
|---|---|---|---|
| HIGH-TOOL | 505 | 527 | 528 |
| EU Ref | 504 | 525 | 527 |

Figure 14: Demographic developments HIGH-TOOL vs. EU Reference Scenario

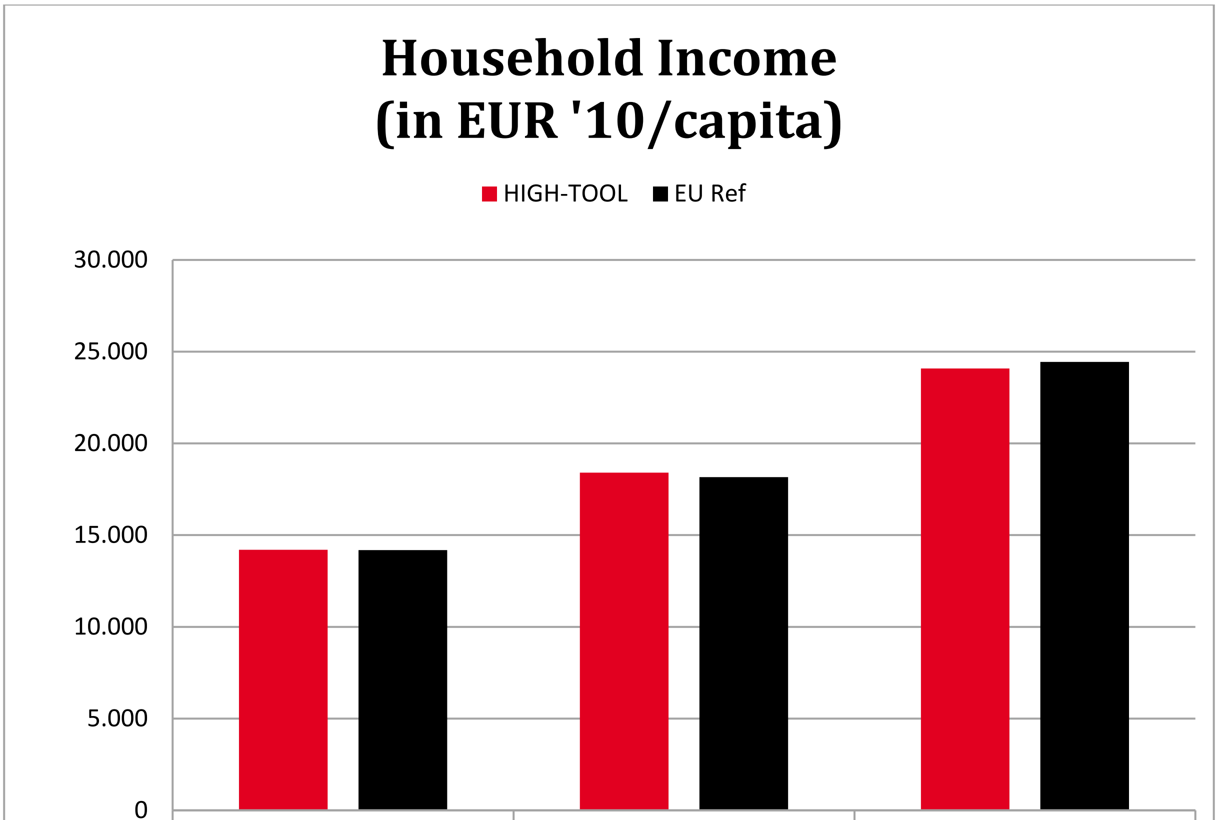
### 6.2.2 Economy

The development of GDP is expected to show average annual growth rates of around 1.5% for EU28. The HIGH-TOOL results are aligned with the forecasts of the EU Reference Scenario 2013 (see Figure 15). Also the development of GDP per capita, a combination of demographic and economic forecasts, reveals a very high level of consistency (see Figure 16).




| | 2010 | 2030 | 2050 |
|---|---|---|---|
| HIGH-TOOL | 12.302 | 16.668 | 21.944 |
| EU Ref | 12.302 | 16.668 | 21.944 |

Figure 15: GDP development, HIGH-TOOL vs. EU Reference Scenario




| | 2010 | 2030 | 2050 |
|---|---|---|---|
| HIGH-TOOL | 14.203 | 18.405 | 24.082 |
| EU Ref | 14.187 | 18.162 | 24.439 |

Figure 16: Development of household income, HIGH-TOOL vs. EU Reference Scenario

### 6.2.3 Passenger Demand

The development of the total passenger transport demand in EU28 (measured in pkm) shows a very high level of consistency between HIGH-TOOL and the EU Reference Scenario 2013 (see Figure 17).

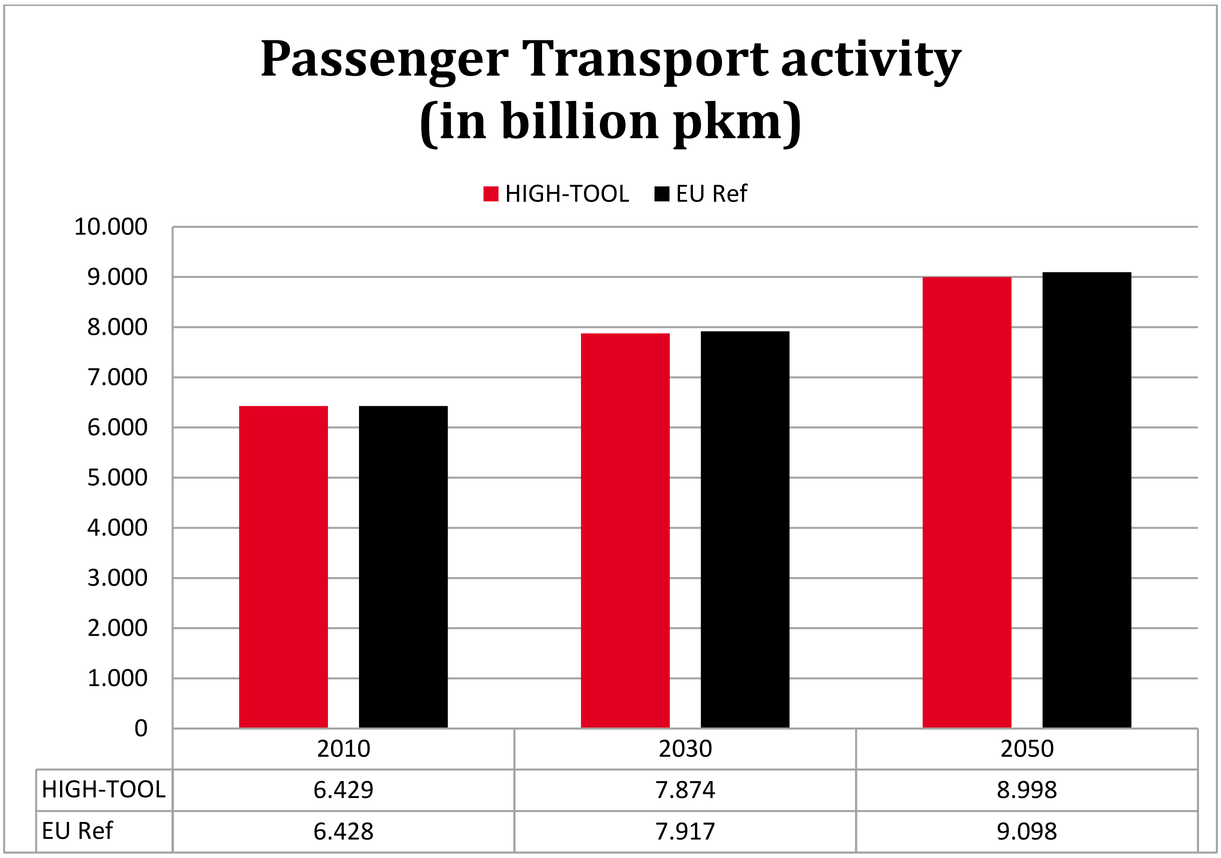
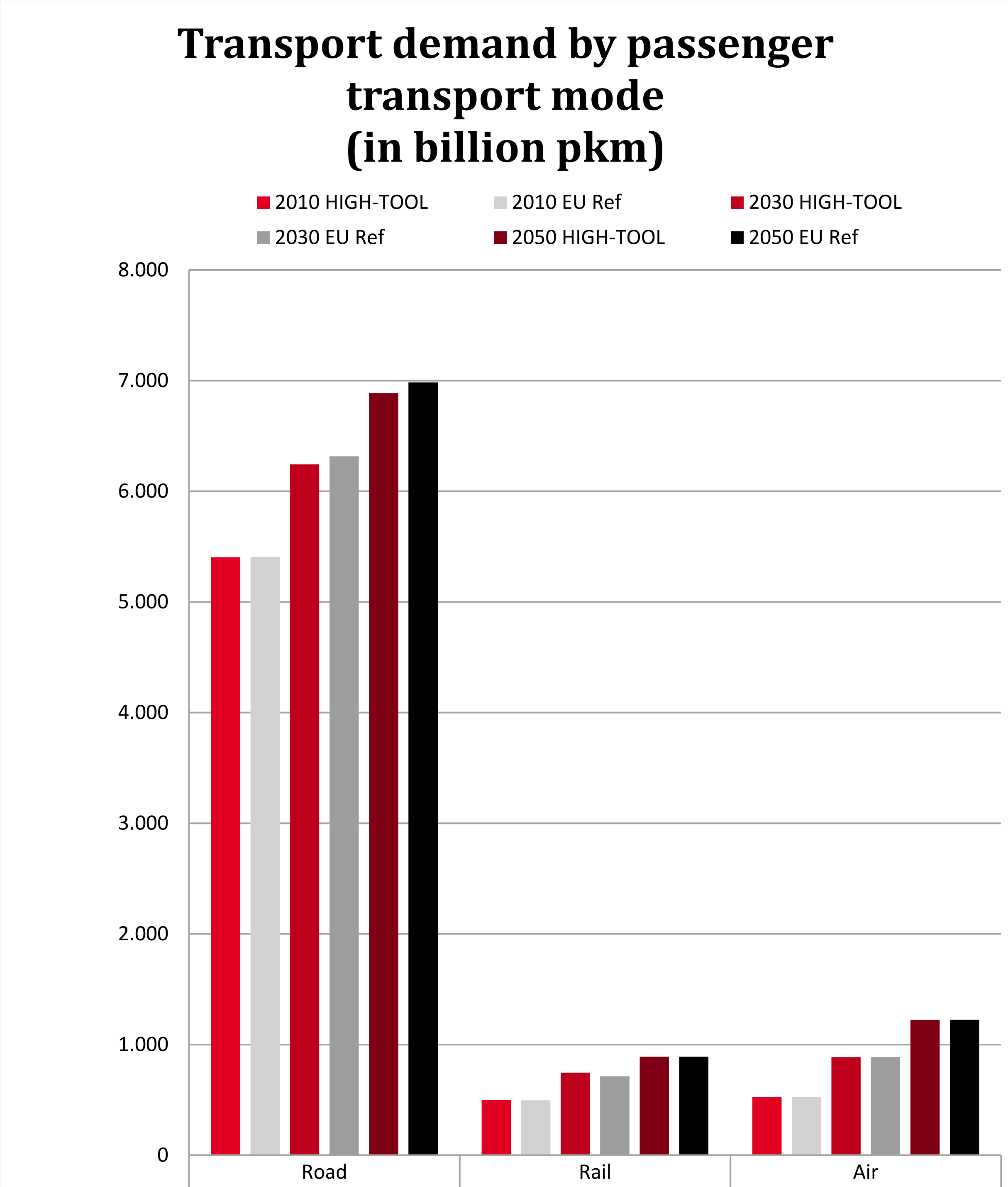


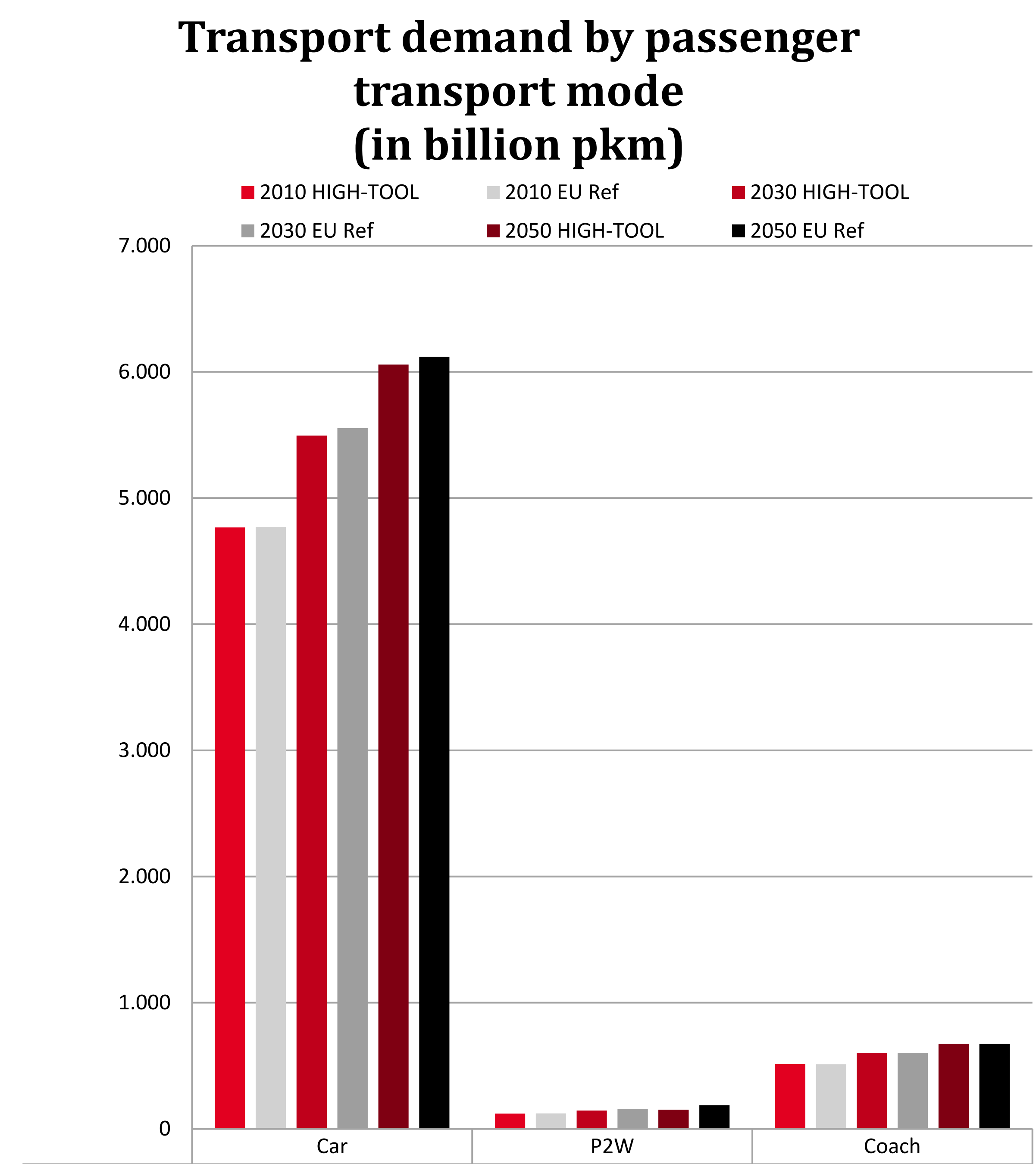

Figure 17: Development of passenger demand, HIGH-TOOL vs. EU Reference Scenario (EU28)

Also the evolution of passenger transport demand by mode of transport reveals a high level of consistency between HIGH-TOOL and the EU Reference Scenario 2013 (see Figure 18). The same holds true for the evolution of the individual road modes – passenger car, powered two-wheelers and coaches (see Figure 19).




| | Road | Rail | Air |
|---|---|---|---|
| 2010 HIGH-TOOL | 5.403 | 499 | 527 |
| 2010 EU Ref | 5.406 | 496 | 526 |
| 2030 HIGH-TOOL | 6.242 | 746 | 887 |
| 2030 EU Ref | 6.316 | 714 | 887 |
| 2050 HIGH-TOOL | 6.885 | 890 | 1.223 |
| 2050 EU Ref | 6.984 | 890 | 1.224 |

Figure 18: Development of passenger demand by mode of transport, HIGH-TOOL vs. EU Reference Scenario (EU28)

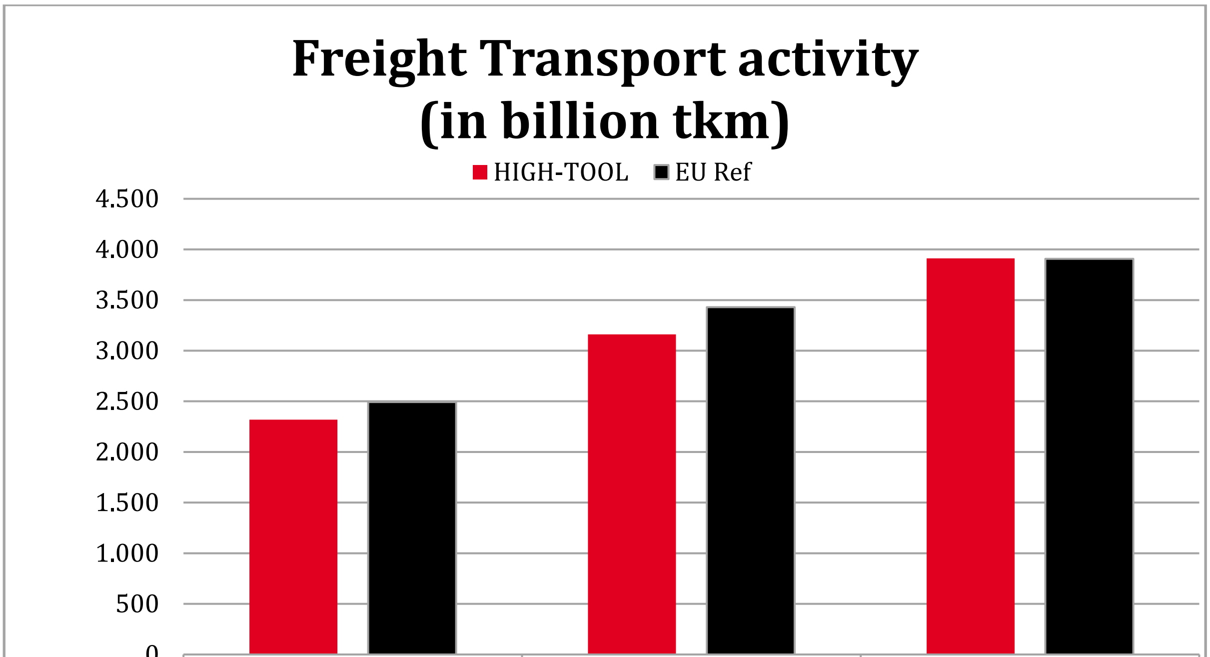



| | Car | P2W | Coach |
|---|---|---|---|
| 2010 HIGH-TOOL | 4.768 | 122 | 514 |
| 2010 EU Ref | 4.771 | 122 | 513 |
| 2030 HIGH-TOOL | 5.496 | 145 | 601 |
| 2030 EU Ref | 5.555 | 159 | 602 |
| 2050 HIGH-TOOL | 6.058 | 152 | 675 |
| 2050 EU Ref | 6.121 | 188 | 675 |

Figure 19: Development of passenger demand by road modes, HIGH-TOOL vs. EU Reference Scenario (EU28)

### 6.2.4 Freight Demand

The overall evolution of freight demand at EU28 level shows a high level of consistency between HIGH-TOOL and the EU Reference Scenario 2013 (see Figure 90).

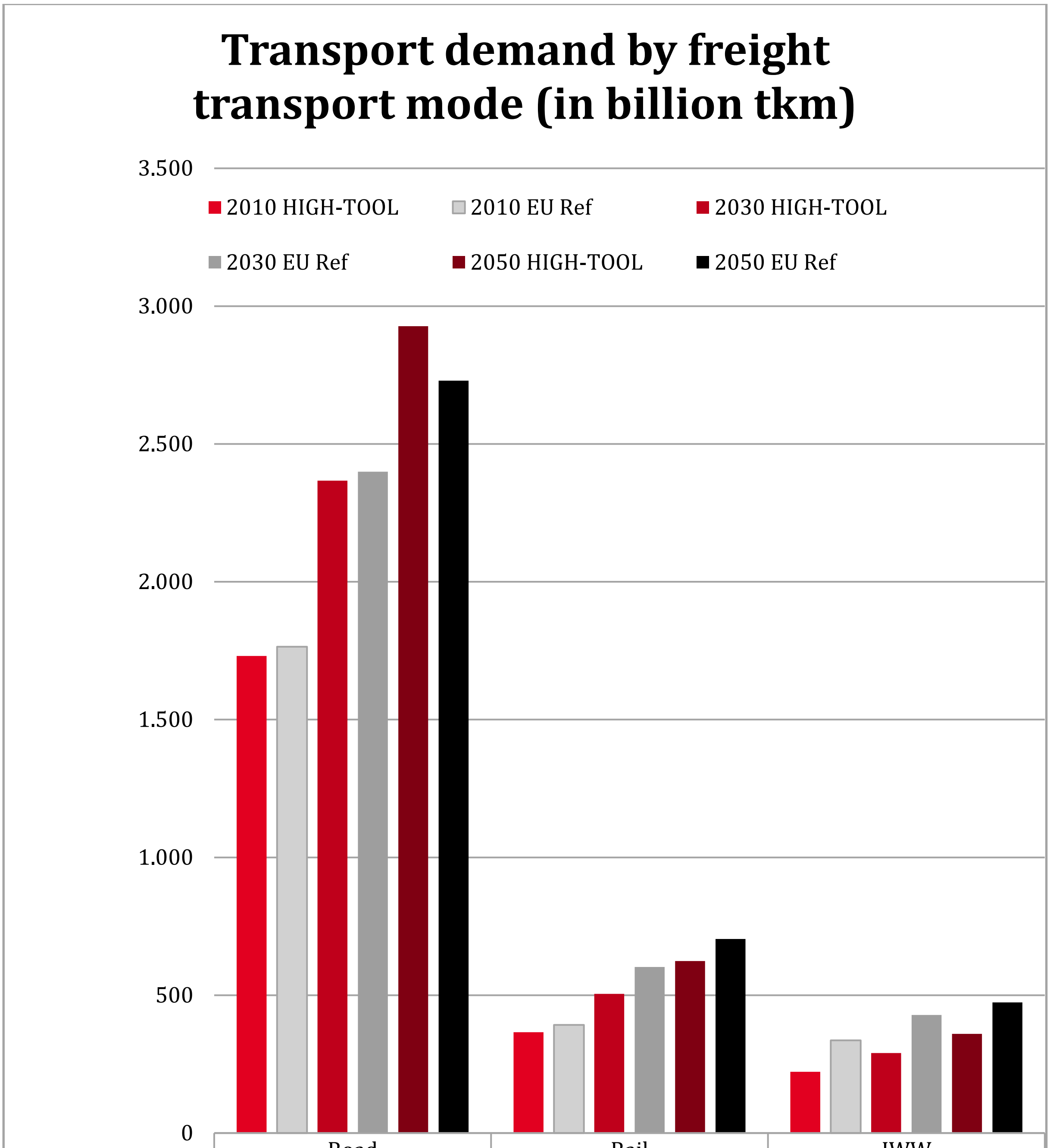



| | 2010 | 2030 | 2050 |
|---|---|---|---|
| HIGH-TOOL | 2.319 | 3.162 | 3.911 |
| EU Ref | 2.493 | 3.430 | 3.908 |

Figure 20: Development of freight demand, HIGH-TOOL vs. EU Reference Scenario (EU28)

When it comes to the comparison of demand evolution per mode of transport (see Figure 21), it needs to be considered that there are two definition differences between HIGH-TOOL and the EU Reference Scenario: For Inland Navigation the forecasts of the EU Reference Scenario contain an unknown quantity of short-sea/coastal shipping, while in HIGH-TOOL the strict definition of Inland Navigation is applied, i.e. navigation on rivers and channels. For road freight transport, the forecasts by the EU Reference Scenario represent haulage by vehicles registered in the country, while the HIGH-TOOL values refer to haulage on the territory.

Thus for inland navigation, the HIGH-TOOL values are below the values of the EU Reference Scenario 2013. For road transport the forecasts are largely consistent; only for 2050 the HIGH-TOOL forecasts are about 7% lower than the forecasts of the EU Reference Scenario 2013. In case of rail transport, the HIGH-TOOL forecasts tend to be below the forecasts of the EU Reference Scenario 2013, but follow the same trend.

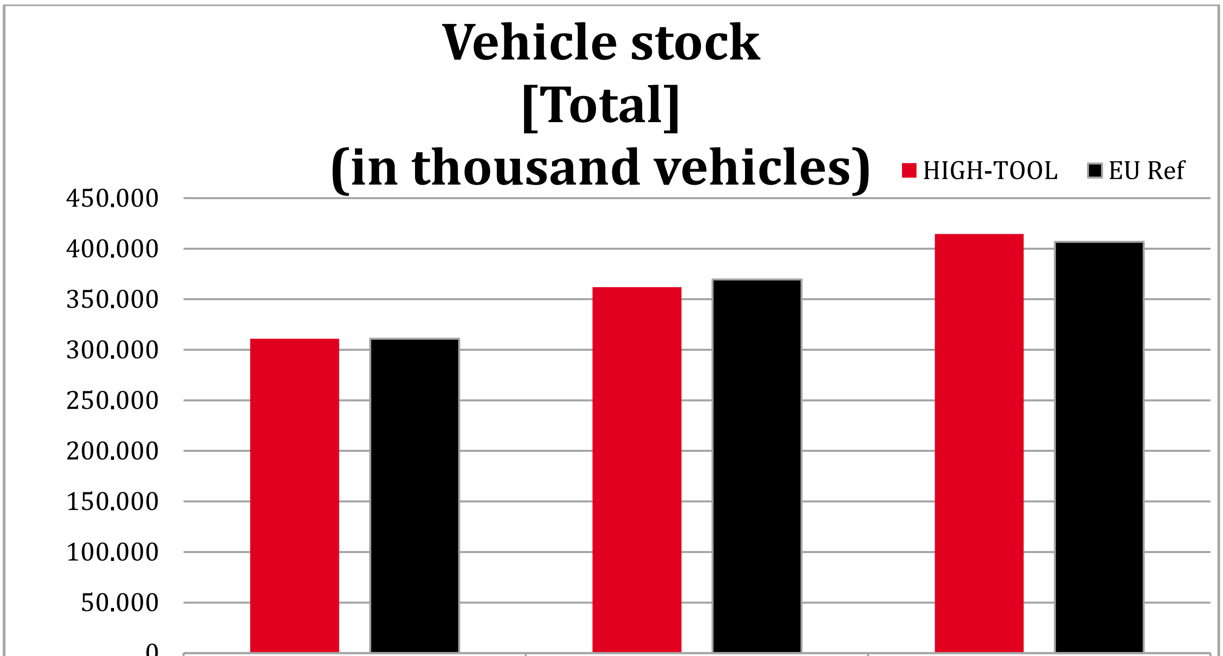



| | Road | Rail | IWW |
|---|---|---|---|
| 2010 HIGH-TOOL | 1.731 | 366 | 222 |
| 2010 EU Ref | 1.764 | 392 | 337 |
| 2030 HIGH-TOOL | 2.367 | 505 | 290 |
| 2030 EU Ref | 2.399 | 602 | 429 |
| 2050 HIGH-TOOL | 2.927 | 624 | 360 |
| 2050 EU Ref | 2.730 | 704 | 474 |

Figure 21: Development of passenger demand by modes, HIGH-TOOL vs. EU Reference Scenario (EU28)

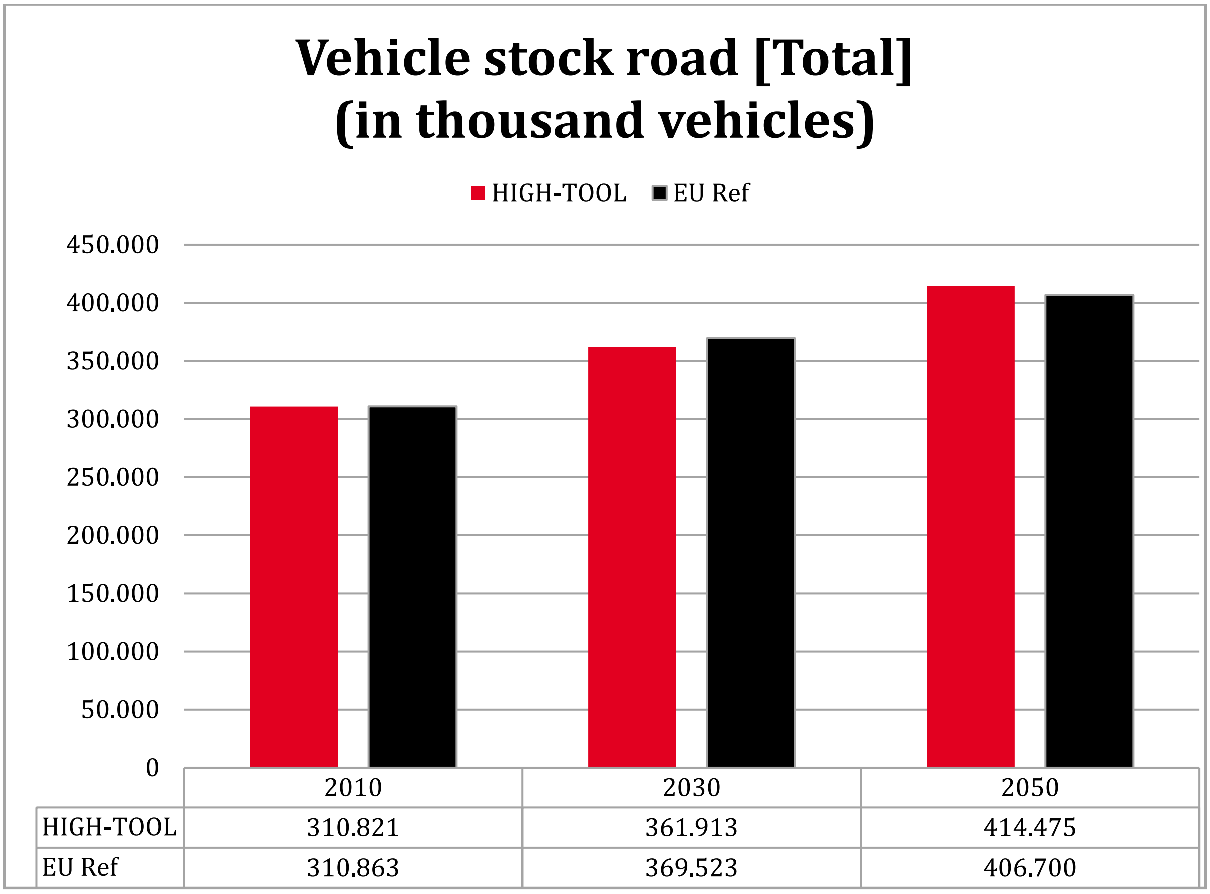
### 6.2.5 Vehicle Stock

The total vehicle stock covering all modes of transport (road, rail, inland navigation and air) reveals a high level of consistency between HIGH-TOOL and the EU Reference Scenario 2013 (Figure 22) at EU28 level. Also the mode-specific vehicle stock reveals a high level of consistency for road (Figure 23), rail (Figure 24) and air (Figure 25). For inland navigation the differences are higher because of different data definitions in HIGH-TOOL and the EU Reference Scenario, as explained in the previous paragraph (Figure 26).



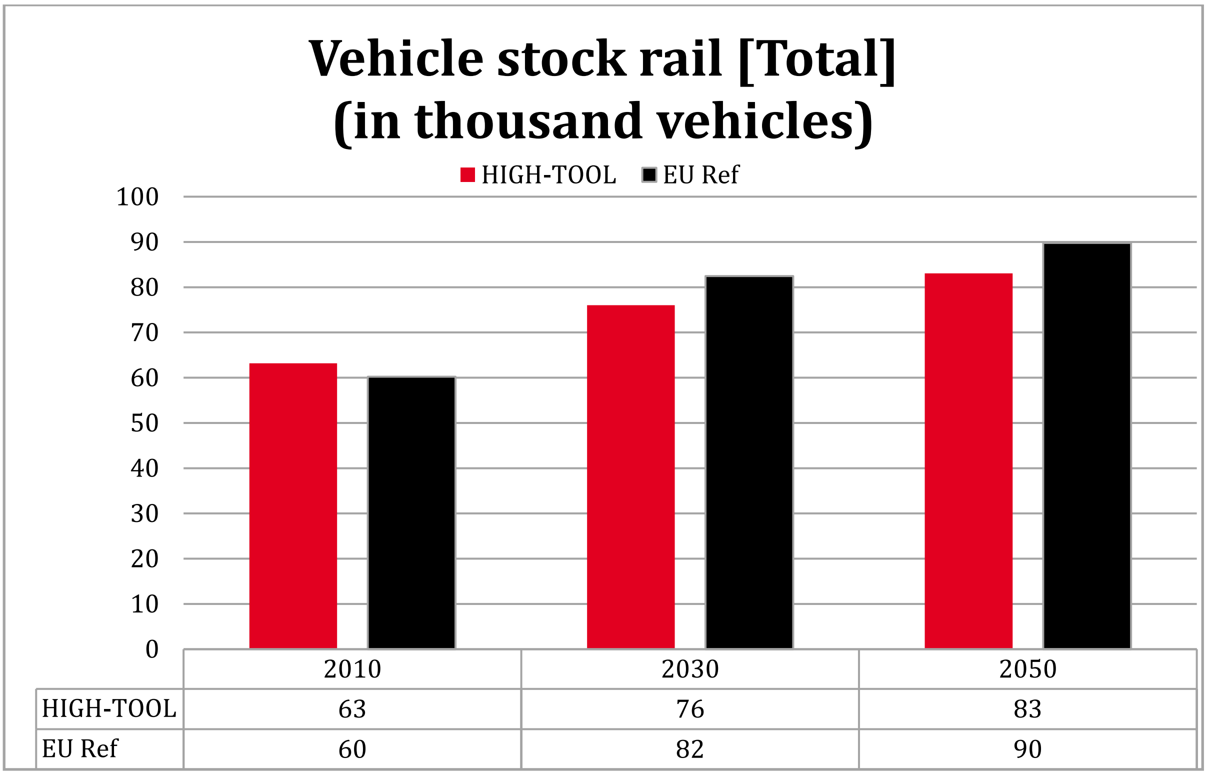

| | 2010 | 2030 | 2050 |
|---|---|---|---|
| HIGH-TOOL | 310.895 | 362.003 | 414.575 |
| EU Ref | 310.940 | 369.627 | 406.815 |

Figure 22: Development of total vehicle stock, HIGH-TOOL vs. EU Reference Scenario (EU28)




| | 2010 | 2030 | 2050 |
|---|---|---|---|
| HIGH-TOOL | 310.821 | 361.913 | 414.475 |
| EU Ref | 310.863 | 369.523 | 406.700 |

Figure 23: Development of road vehicle stock, HIGH-TOOL vs. EU Reference Scenario




| | 2010 | 2030 | 2050 |
|---|---|---|---|
| HIGH-TOOL | 63 | 76 | 83 |
| EU Ref | 60 | 82 | 90 |

Figure 24: Development of rail vehicle stock, HIGH-TOOL vs. EU Reference Scenario

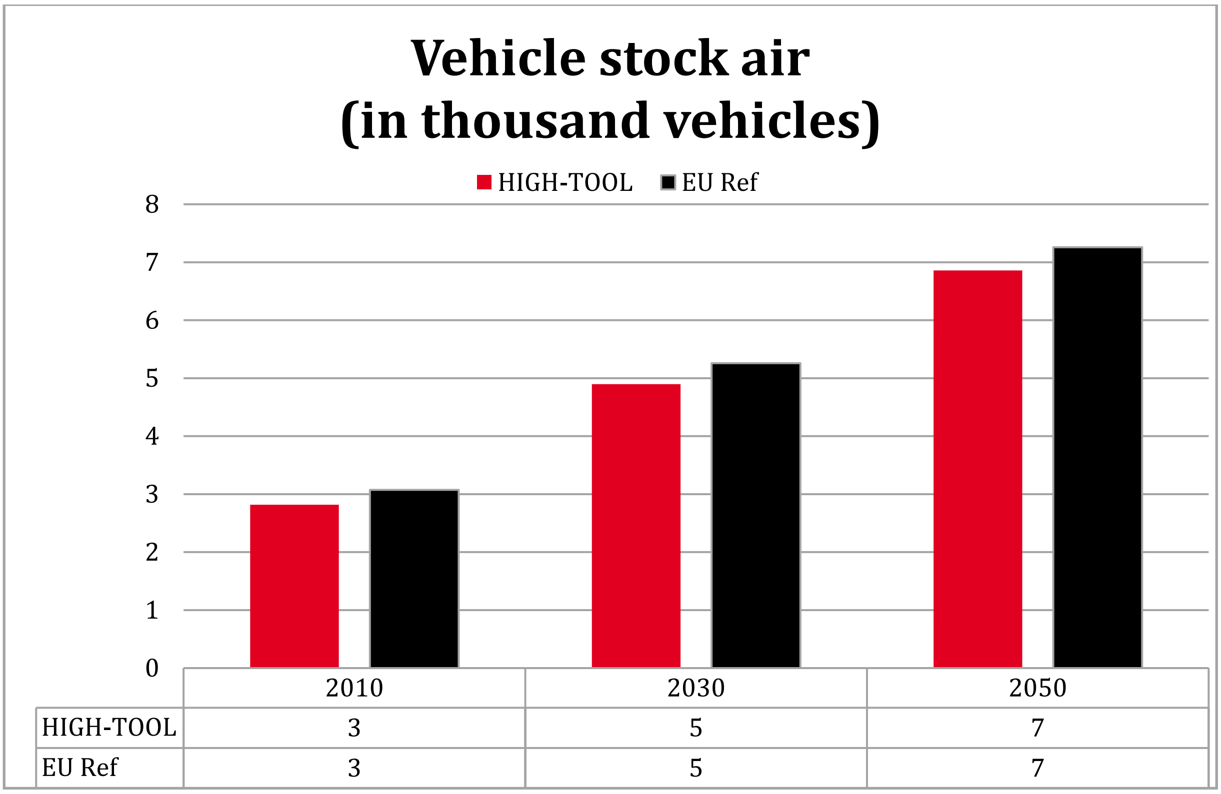



Figure 25: Development of air vehicle stock, HIGH-TOOL vs. EU Reference Scenario

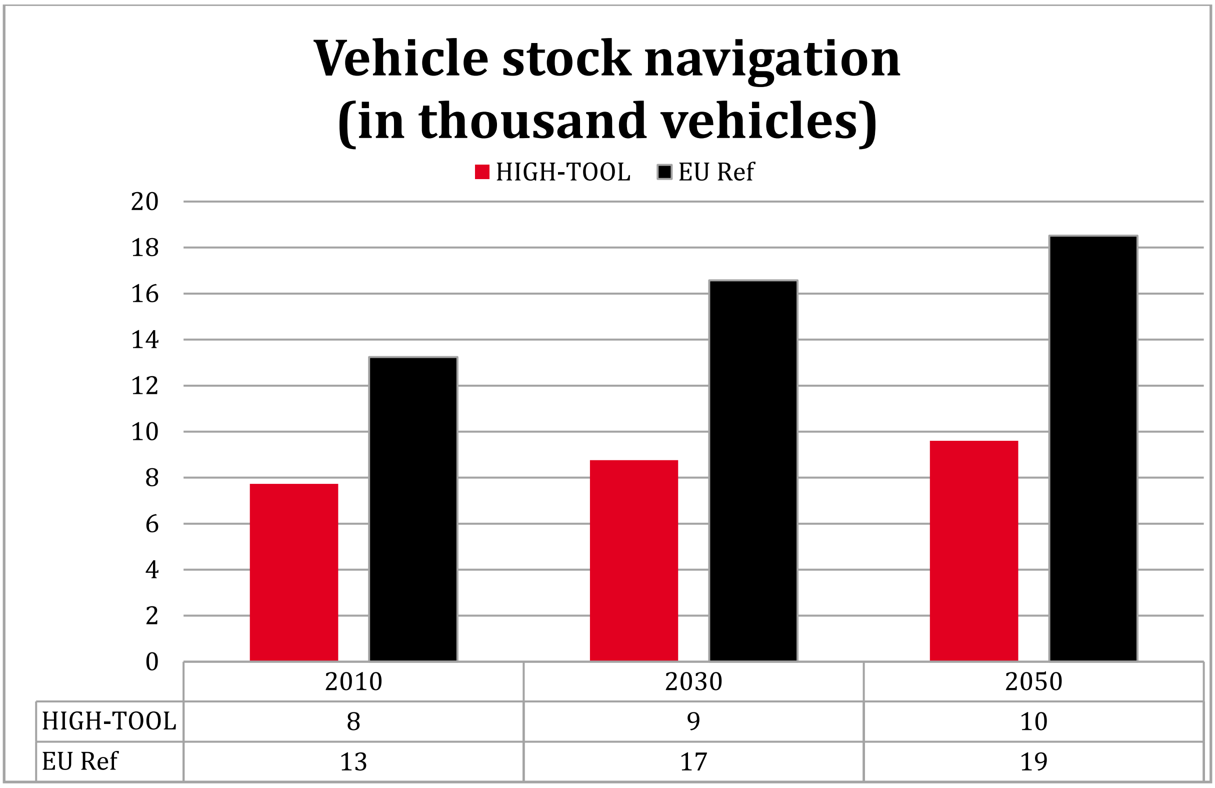



Figure 26: Development of inland navigation vehicle stock, HIGH-TOOL vs. EU Reference Scenario

### 6.2.6 Environment

The evolution of the energy consumption by the transport shows a rather stable trend over time, both for HIGH-TOOL and the EU Reference Scenario 2013 (see Figure 27).

Also the evolution of transport $CO_2$ emissions (Figure 28) shows a high level of consistency between HIGH-TOOL and the EU Reference Scenario 2013.

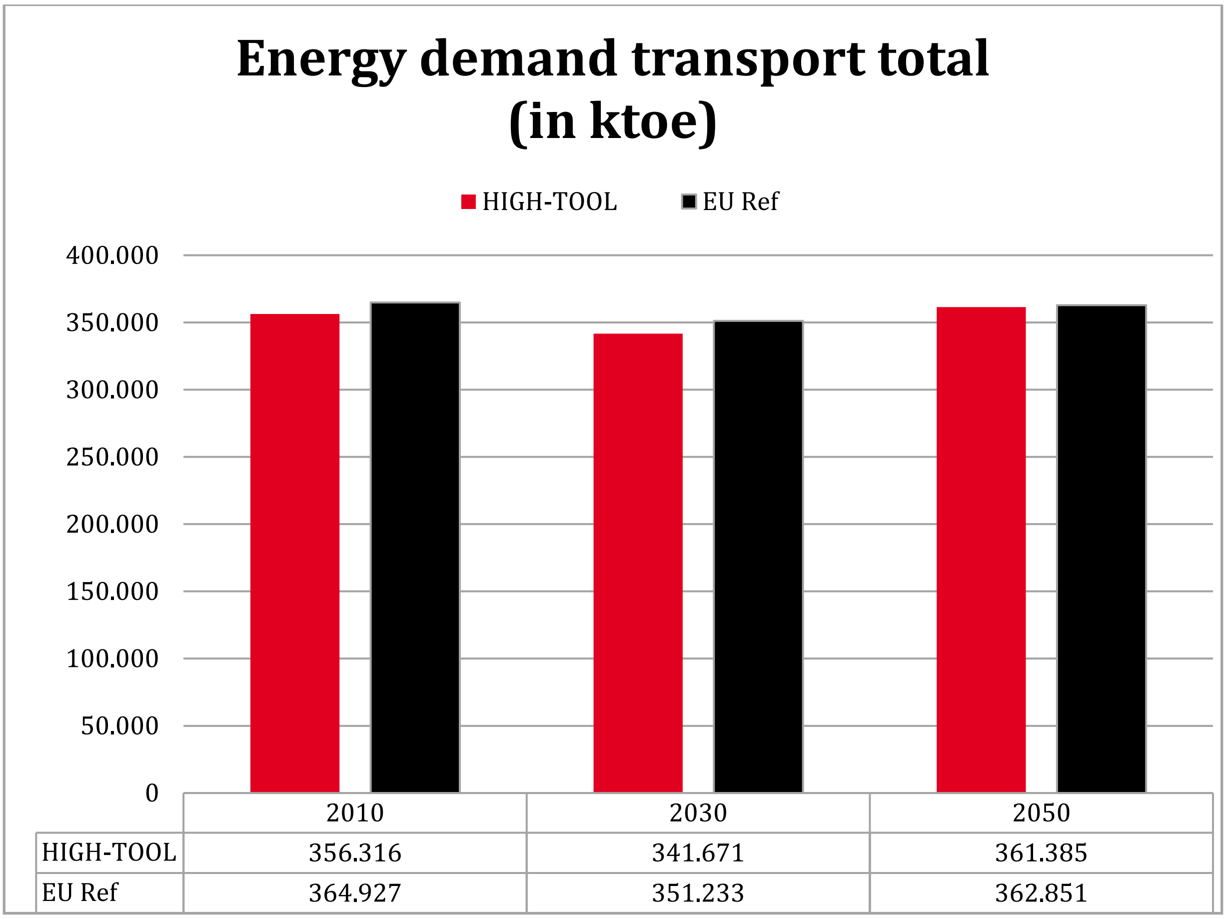



Figure 27: Development of transport energy demand, HIGH-TOOL vs. EU Reference Scenario (EU28)

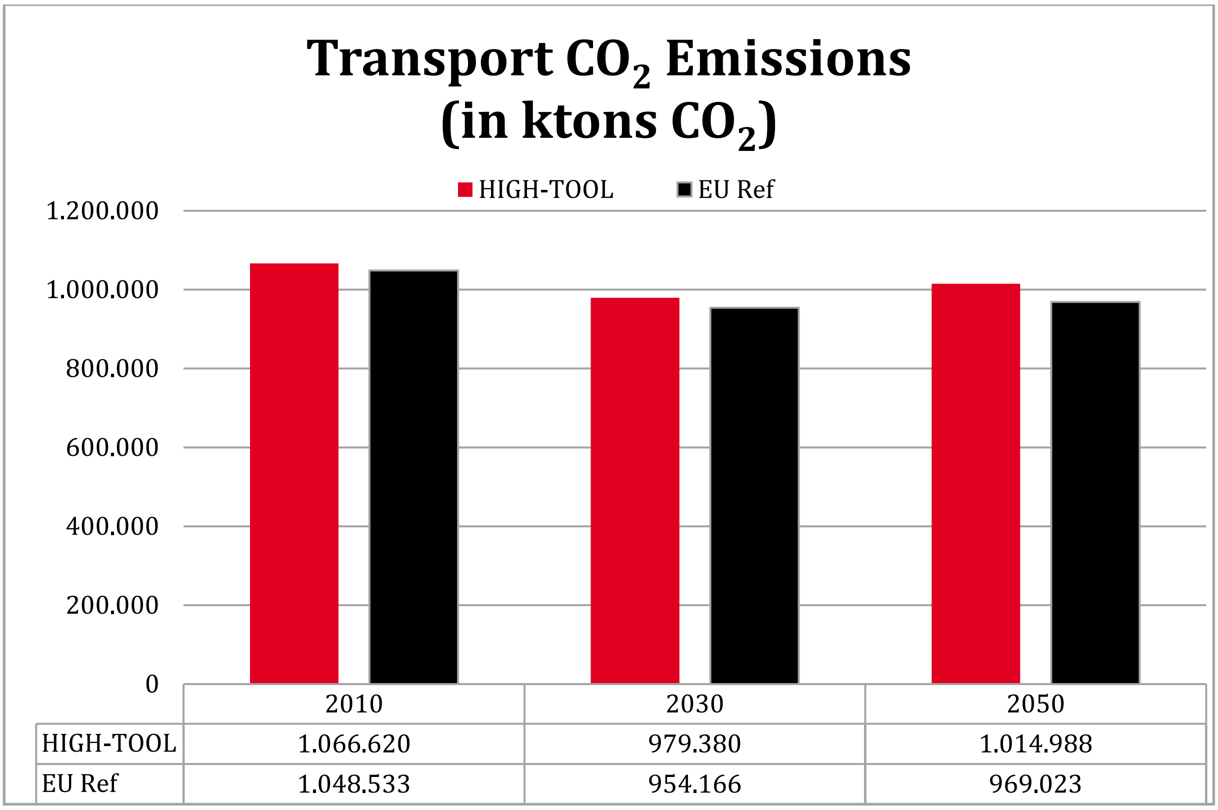
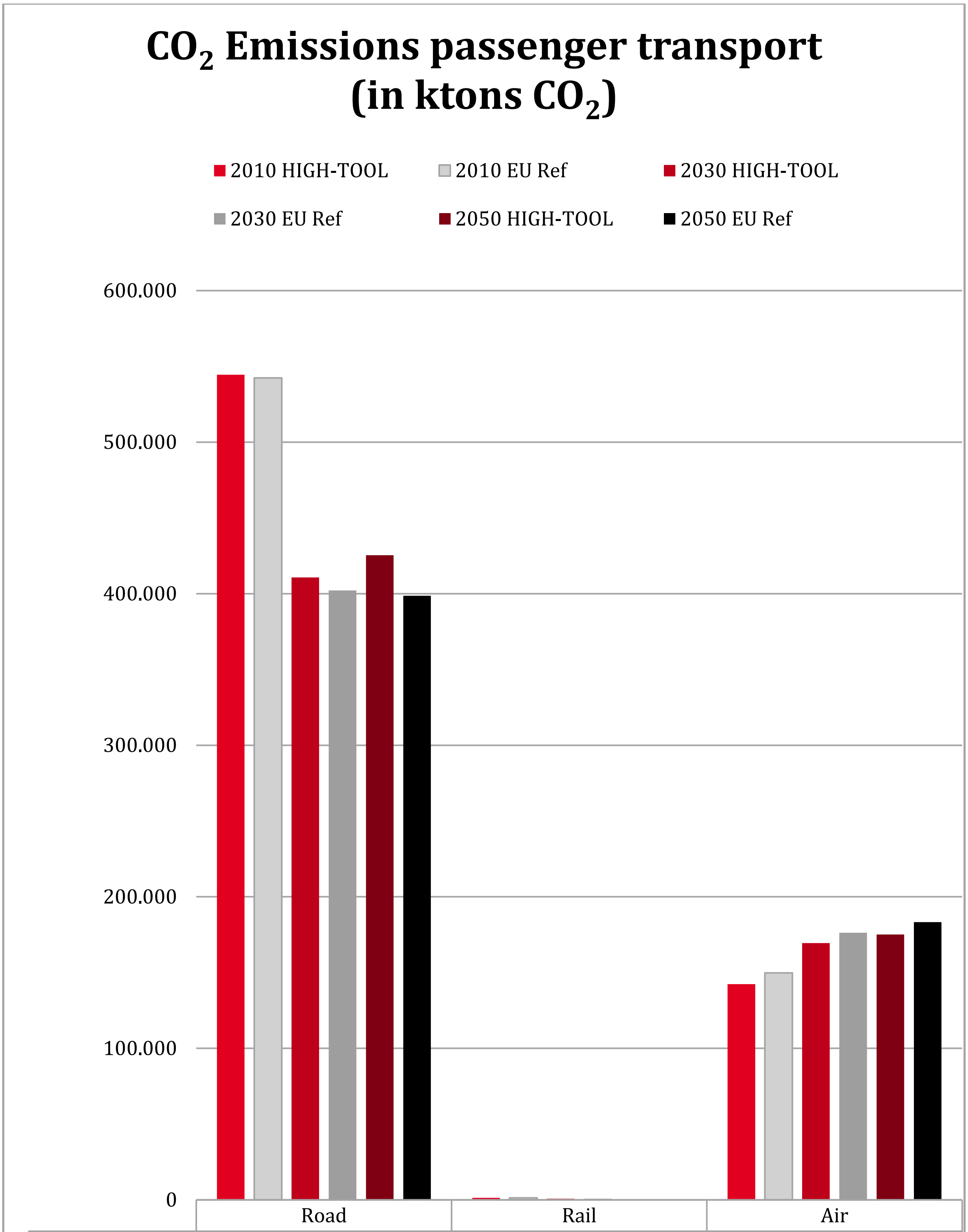


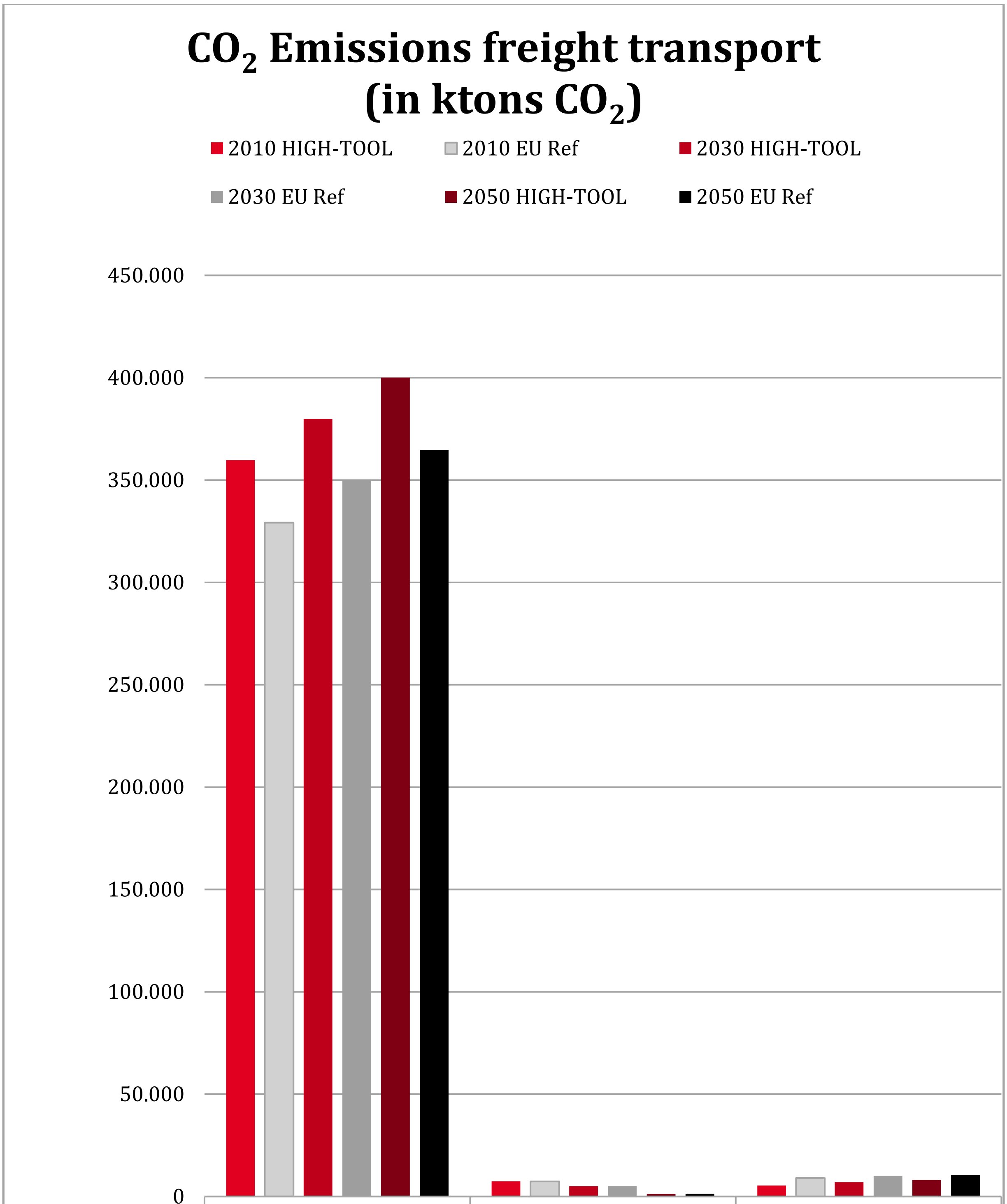

Figure 28: Development of transport $CO_2$ emissions, HIGH-TOOL vs. EU Reference Scenario (EU28)

The distribution of $CO_2$ emissions by modes of transport for passenger (Figure 29) and freight (Figure 30) reveals an overall consistent picture. For inland waterway navigation the $CO_2$ emissions forecasted by HIGH-TOOL are lower than those of the EU Reference Scenario 2013, since the demand generated by the HIGH-TOOL model is lower than the demand by the EU Reference Scenario. This pattern is due to different data definitions, as explained in section 6.2.4 .




| | Road | Rail | Air |
|---|---|---|---|
| 2010 HIGH-TOOL | 544.505 | 1.325 | 142.357 |
| 2010 EU Ref | 542.433 | 1.329 | 149.762 |
| 2030 HIGH-TOOL | 410.737 | 748 | 169.443 |
| 2030 EU Ref | 402.138 | 749 | 176.320 |
| 2050 HIGH-TOOL | 425.391 | 171 | 175.159 |
| 2050 EU Ref | 398.605 | 171 | 183.263 |

Figure 29: Development of passenger transport $CO_2$ emissions, HIGH-TOOL vs. EU Reference Scenario




| | Road | Rail | IWW |
|---|---|---|---|
| 2010 HIGH-TOOL | 359.775 | 7.435 | 5.391 |
| 2010 EU Ref | 329.170 | 7.392 | 9.015 |
| 2030 HIGH-TOOL | 379.922 | 5.055 | 6.979 |
| 2030 EU Ref | 350.032 | 5.156 | 10.068 |
| 2050 HIGH-TOOL | 400.076 | 1.334 | 8.115 |
| 2050 EU Ref | 364.722 | 1.387 | 10.597 |

Figure 30: Development of freight transport $CO_2$ emissions, HIGH-TOOL vs. EU Reference Scenario

## 6.3 Testing and Validation

The HIGH-TOOL model was subject to an extensive validation and testing approach. Robustness tests were carried out to ensure that the model works correctly in the presence of invalid inputs or stressful environmental conditions. Furthermore, the modules' reactions on changes in input variables were tested by sensitivity checks.

Finally, the HIGH-TOOL model was tested by following case studies, which are documented in the second project report on model validation (Kiel et al., 2016):

- Case 1: Post 2020 introduction of $CO_2$ standards for cars and vans
- Case 2: Evaluation of corridor improvement for rail passenger transport via the hypernet
- Case 3: Introduction of speed limits for light commercial vehicles
- Case 4: Untapped potential of maritime ports related to liberalisation policies
- Case 5: Cost sensitivity of the HIGH-TOOL model for passenger road mode
- Case 6: Modules' stability in a given time-step
- Case 7: Increase of public and private transport infrastructure investments
- Case 8: Competition between high-speed rail and air.

The obtained results demonstrate that the HIGH-TOOL model is capable of assessing a wide variety of different types of policies at a strategic level. The integrated model – i.e. the composition of the interlinked modules – is well-functioning, and the impact chains are correctly covered (e.g. the modification of impedances in the hypernet for passenger transport results in passenger demand changes, which subsequently affect environmental, economic and safety-related indicators). Also the well-functioning and the usefulness of the hypernet model for passenger transport – which represents an add-on to the original scope of the HIGH-TOOL model – has been demonstrated.

The model shows clearly a converging behaviour, and produces stable results at all levels of analysis: at an aggregated level, in different time steps and across different geographical units. For the calculation of the baseline scenario a few iterative calculations (over the previous results) are recommended. Iterative calculations in a policy scenario simulation could produce marginal changes to the results, at the expense of much more computation time. However, an iterative calculation process for policy scenarios to refine the results is not required, since the model produces stable results.

The model outputs are largely in line with expectations. However, as it is usually the case with interpretation of results of any model, features such as modelling methodology, the spatial scope or the underlying assumptions need to be considered when interpreting the results of the HIGH-TOOL model. Furthermore, the case study analyses provided some insights in possible extensions of HIGH-TOOL in the future. Being an open source instrument which does not require any commercial software products to be run, the HIGH-TOOL model provides the basis for an efficient further development in the future.

# 7 Model Application

A detailed description of model application and user interface features are provided by the HIGH-TOOL reports on model documentation (Larrea, 2016) and the User Interface (Biosca, Larrea and Ulied, 2016).

## 7.1 Design Principles of the User Interface

The design principles adopted for the User Interface are based on the criteria outlined by Tognazini (2013). They include:

- Anticipation
- Visible Navigation
- Efficiency
- Consistency
- Explorable Interfaces
- Learnability
- Readability, and
- Intuitiveness.

All design criteria together empower users to work efficiently with the HIGH-TOOL model while enjoying all features.

## 7.2 Options for Transport Policy Analysis

The HIGH-TOOL model offers three options to define policies to be assessed:

- Using a *single* pre-defined Transport Policy Measure
- Using *combinations* of pre-defined Transport Policy Measures
- Using a *customised policy package* of policy variables.

### 7.2.1 Applying pre-defined Transport Policy Measures

The HIGH-TOOL model offers 30 pre-defined Transport Policy Measures (TPM), which can either be selected individually or in combinations. The scope of pre-defined Transport Policy Measures is shown by Table 1.

Table 1: Transport Policy Measures addressed in HIGH-TOOL

| Category | Single Pre-Defined Transport Policy Measures |
|---|---|
| **Efficiency standards and flanking measures** | Improving local public transport |
| | Deployment of efficient vehicles |
| | Replacement of inefficient LDVs and buses |
| | HDV limitation for urban areas |
| | LDV speed limit |
| | Diffusion of $H_2$ fuel cell cars |
| | Diffusion of electro cars |
| | Replacement of inefficient cars |
| **Pricing** | $CO_2$ feebates for road transport |
| | $CO_2$ certificate system for road transport |
| | Circulation tax for cars |
| | Internalisation of external costs |
| | HDV infrastructure change |
| | Urban road charging |
| **Research and innovation** | Intelligent road vehicles |
| | Dynamic traffic management for road |
| | Intelligent traffic information system for road |
| | Road vehicle safety technology protecting other transport users |
| | Safety systems for road vehicle users |
| **Internal market** | Acceleration of TEN-T implementation |
| | River information system |
| | European Rail Traffic Management System |
| | Harmonised handling of dangerous goods |
| | Harmonisation of rail safety |
| | Harmonised social rules for truck drivers |
| | Opening the internal IWW market |
| | Enhance service quality at ports |
| | Maritime traffic management system |
| | Freight corridor management |
| | Single rail vehicle authorisation and certification |

Policies can be defined in terms of extent of policy implementation, temporal dimension (2015 to 2050) and geographical distribution (countries and regions in Europe).

Also combinations of pre-defined TPMs can be applied. All combinations of TPMs have been analysed in terms of interdependencies. While the majority of the policies have revealed to be additive, the user is informed by the system on the existence of interdependencies, if interdependent policy combinations are chosen.

### 7.2.2 Applying Customised Policy Packages

A customised policy package can be defined using any combination of policy levers. The policy levers are organised per module. The number of levers are shown in Table 2.

Table 2: Number of policy levers per module for the Customised Policy package interface

| Module | Number of individual levers |
|---|---|
| Economy and Resources | 3 |
| Vehicle Stock | 430 |
| Passenger Demand | 100 |
| Freight Demand | 79 |
| Environment | 127 |
| Safety | 60 |

### 7.2.3 Expert Mode

After defining a transport policy measure in one of the three available procedures (Single TPM, Combined TPM package, Customised Policy package), the user may enter the Expert Mode to edit input tables and/or the Hyper-Network to control the impedances used in the model. The Expert Mode is an optional feature for advanced editing of the database values before running the model.

## 7.3 Reporting of Assessment Results

### 7.3.1 Policy Assessment Report

For each model run, the assessment results are presented in a report in MS EXCEL format, and are downloadable from the server through the User Interface. This Policy Assessment Report is generated automatically by the Interface and is designed as an interactive Excel report. Tables, graphs or single values can be imported to a presentation tool (MS PowerPoint) or a text editor (MS Word, OpenOffice) using copy and paste functions.

The Policy Assessment Report comprises the following elements:

- **Contextual Information** including the scenario name and abstract.
- **Model inputs** comprising a list of all inputs entered using the TPM editors. For each policy lever active, it shows policy intensity for the 2010–2050 period, a map of the changes in policy intensity across the EU territory (if any), and the specific policy intensities 2010–2050 for each country/region with customised changes (if any).
- **Results for each thematic area** (Demography, Economy and Resources, Passenger Demand, Freight Demand, Vehicle Stock, Environment, Safety) are presented in tables and graphs, each on a separate page. Results are presented in absolute values and compared with the baseline scenario.

The following sequence of figures illustrates the configuration of the assessment report (Figure 31 to Figure 34).


Figure 31: Main menu of the Policy Assessment Report in MS Excel

HIGH TOOL

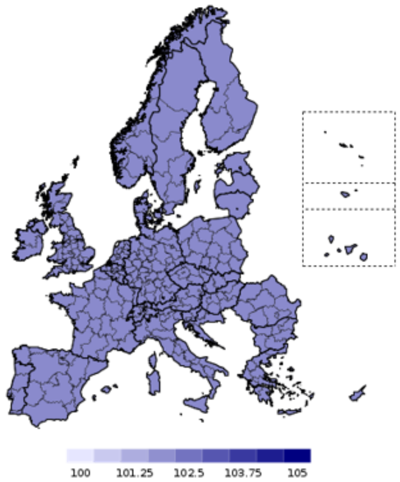
*Go to main page*

## MODEL INPUTS

**Load factor for rail in count (100 = baseline)**

| Year | EU28 Value |
|---|---|
| 2010 | 100 |
| 2015 | 102 |
| 2020 | 102 |
| 2025 | 102 |
| 2030 | 102 |
| 2035 | 102 |
| 2040 | 102 |
| 2045 | 102 |
| 2050 | 102 |

**EU28 + NO + CH at NUTS2 Level**




**Custom region values**

Figure 32: Model inputs to the Policy Assessment Report

HIGH TOOL

*Go to main page*

## DEMOGRAPHY TABLES

European population by gender (in million) SCENARIO

| Year | Male | Female | Total | % Male | % Female |
|---|---|---|---|---|---|
| 2010 | 266 | 253 | 519 | 51,3% | 48,7% |
| 2015 | 258 | 269 | 527 | 49,0% | 51,0% |
| 2020 | 262 | 272 | 534 | 49,1% | 50,9% |
| 2025 | 265 | 275 | 540 | 49,1% | 50,9% |
| 2030 | 267 | 276 | 543 | 49,2% | 50,8% |
| 2035 | 268 | 278 | 546 | 49,1% | 50,9% |
| 2040 | 269 | 278 | 547 | 49,2% | 50,8% |
| 2045 | 269 | 278 | 547 | 49,2% | 50,8% |
| 2050 | 269 | 277 | 546 | 49,3% | 50,7% |

European population by gender (in million) BASELINE

| Year | Male | Female | Total | % Male | % Female |
|---|---|---|---|---|---|
| 2010 | 266 | 253 | 519 | 51,3% | 48,7% |
| 2015 | 258 | 269 | 527 | 49,0% | 51,0% |
| 2020 | 262 | 272 | 534 | 49,1% | 50,9% |
| 2025 | 265 | 275 | 540 | 49,1% | 50,9% |
| 2030 | 267 | 276 | 543 | 49,2% | 50,8% |
| 2035 | 268 | 278 | 546 | 49,1% | 50,9% |
| 2040 | 269 | 278 | 547 | 49,2% | 50,8% |
| 2045 | 269 | 278 | 547 | 49,2% | 50,8% |
| 2050 | 269 | 277 | 546 | 49,3% | 50,7% |

European population by gender (in million) DIFFERENCE

| Year | Male | Female | Total |
|---|---|---|---|
| 2010 | 0 | 0 | 0 |
| 2015 | 0 | 0 | 0 |
| 2020 | 0 | 0 | 0 |
| 2025 | 0 | 0 | 0 |
| 2030 | 0 | 0 | 0 |
| 2035 | 0 | 0 | 0 |
| 2040 | 0 | 0 | 0 |
| 2045 | 0 | 0 | 0 |
| 2050 | 0 | 0 | 0 |

European population by age cohort (in millions) SCENARIO

| Year | 0-19 | 20-39 | 40-59 | =>60 | % (0-19) | % (20-39) | % (40-59) | % (=>60) |
|---|---|---|---|---|---|---|---|---|
| 2010 | 110,8 | 141,1 | 146,3 | 119,7 | 21,4% | 27,2% | 28,2% | 23,1% |
| 2015 | 109,9 | 136,9 | 149,2 | 130,1 | 20,9% | 26,0% | 28,4% | 24,7% |
| 2020 | 110,6 | 132,1 | 149,3 | 141,0 | 20,7% | 24,8% | 28,0% | 26,5% |
| 2025 | 110,8 | 127,3 | 147,3 | 153,0 | 20,6% | 23,6% | 27,4% | 28,4% |
| 2030 | 109,2 | 124,3 | 144,0 | 164,8 | 20,1% | 22,9% | 26,6% | 30,4% |
| 2035 | 106,8 | 123,5 | 140,5 | 174,0 | 19,6% | 22,7% | 25,8% | 31,9% |
| 2040 | 105,4 | 124,1 | 136,0 | 180,8 | 19,3% | 22,7% | 24,9% | 33,1% |
| 2045 | 105,1 | 124,1 | 131,4 | 186,0 | 19,2% | 22,7% | 24,0% | 34,0% |
| 2050 | 105,4 | 122,1 | 128,4 | 189,6 | 19,3% | 22,4% | 23,5% | 34,8% |

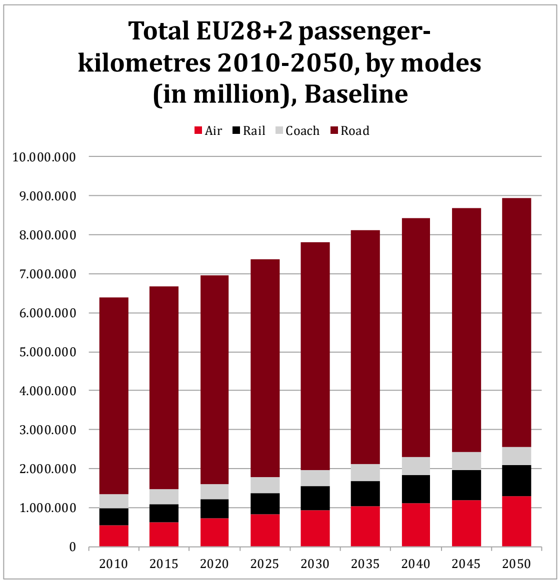
European population by age cohort (in millions) BASELINE

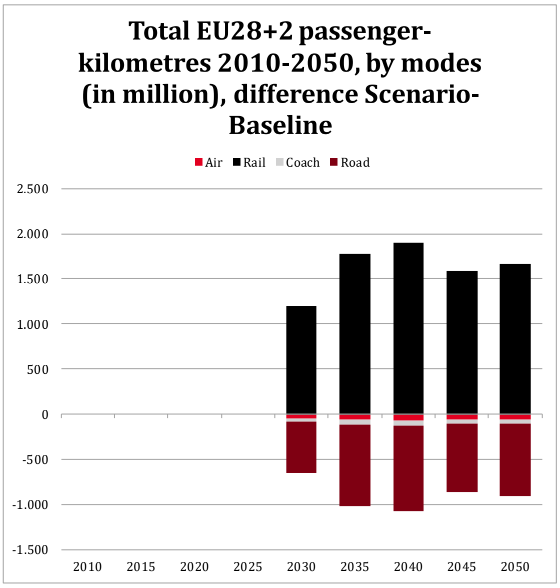
| Year | 0-19 | 20-39 | 40-59 | =>60 | % (0-19) | % (20-39) | % (40-59) | % (=>60) |
|---|---|---|---|---|---|---|---|---|
| 2010 | 110,8 | 141,1 | 146,3 | 119,7 | 21,4% | 27,2% | 28,2% | 23,1% |
| 2015 | 109,9 | 136,9 | 149,2 | 130,1 | 20,9% | 26,0% | 28,4% | 24,7% |
| 2020 | 110,6 | 132,1 | 149,3 | 141,0 | 20,7% | 24,8% | 28,0% | 26,5% |
| 2025 | 110,8 | 127,3 | 147,3 | 153,0 | 20,6% | 23,6% | 27,4% | 28,4% |
| 2030 | 109,2 | 124,3 | 144,0 | 164,8 | 20,1% | 22,9% | 26,6% | 30,4% |
| 2035 | 106,8 | 123,5 | 140,5 | 174,0 | 19,6% | 22,7% | 25,8% | 31,9% |
| 2040 | 105,4 | 124,1 | 136,0 | 180,8 | 19,3% | 22,7% | 24,9% | 33,1% |
| 2045 | 105,1 | 124,1 | 131,4 | 186,0 | 19,2% | 22,7% | 24,0% | 34,0% |
| 2050 | 105,4 | 122,1 | 128,4 | 189,6 | 19,3% | 22,4% | 23,5% | 34,8% |

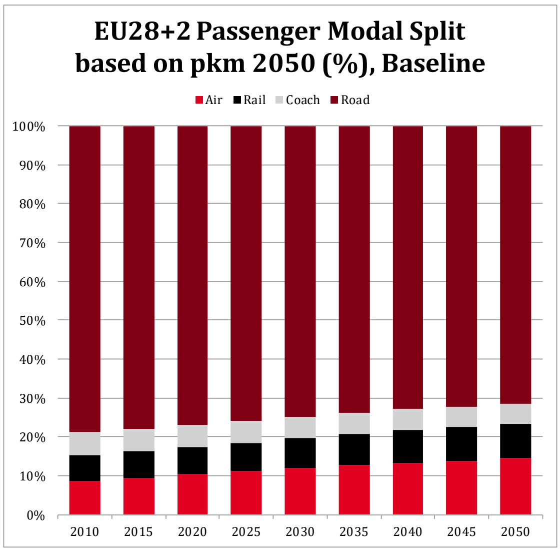
Figure 33: Full results displayed in tables per theme

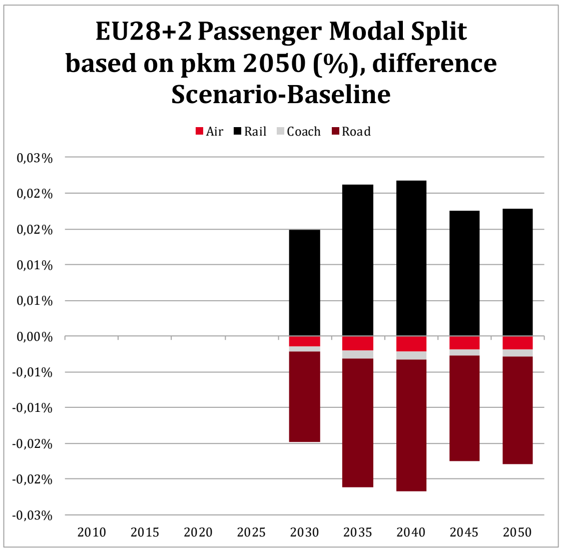
*Go to main page*

## PASSENGER DEMAND GRAPHS



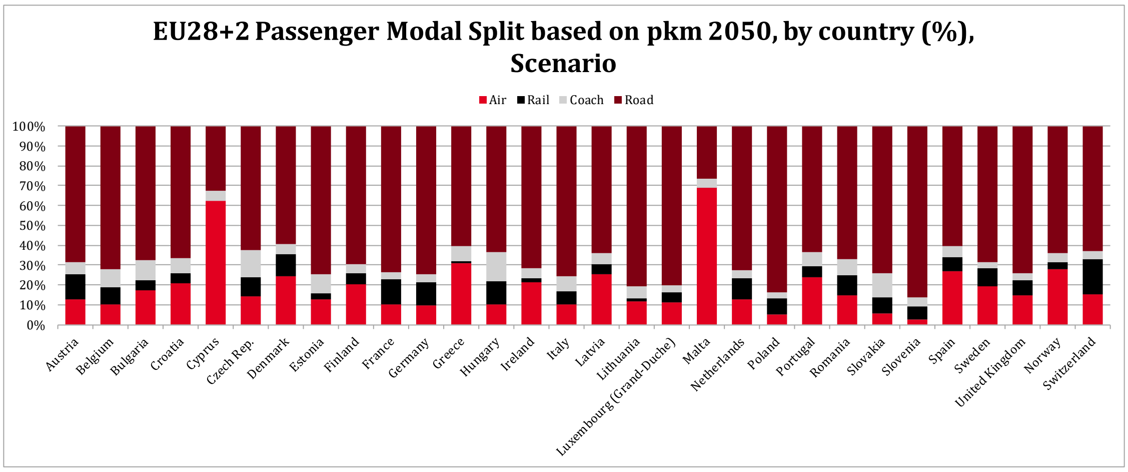



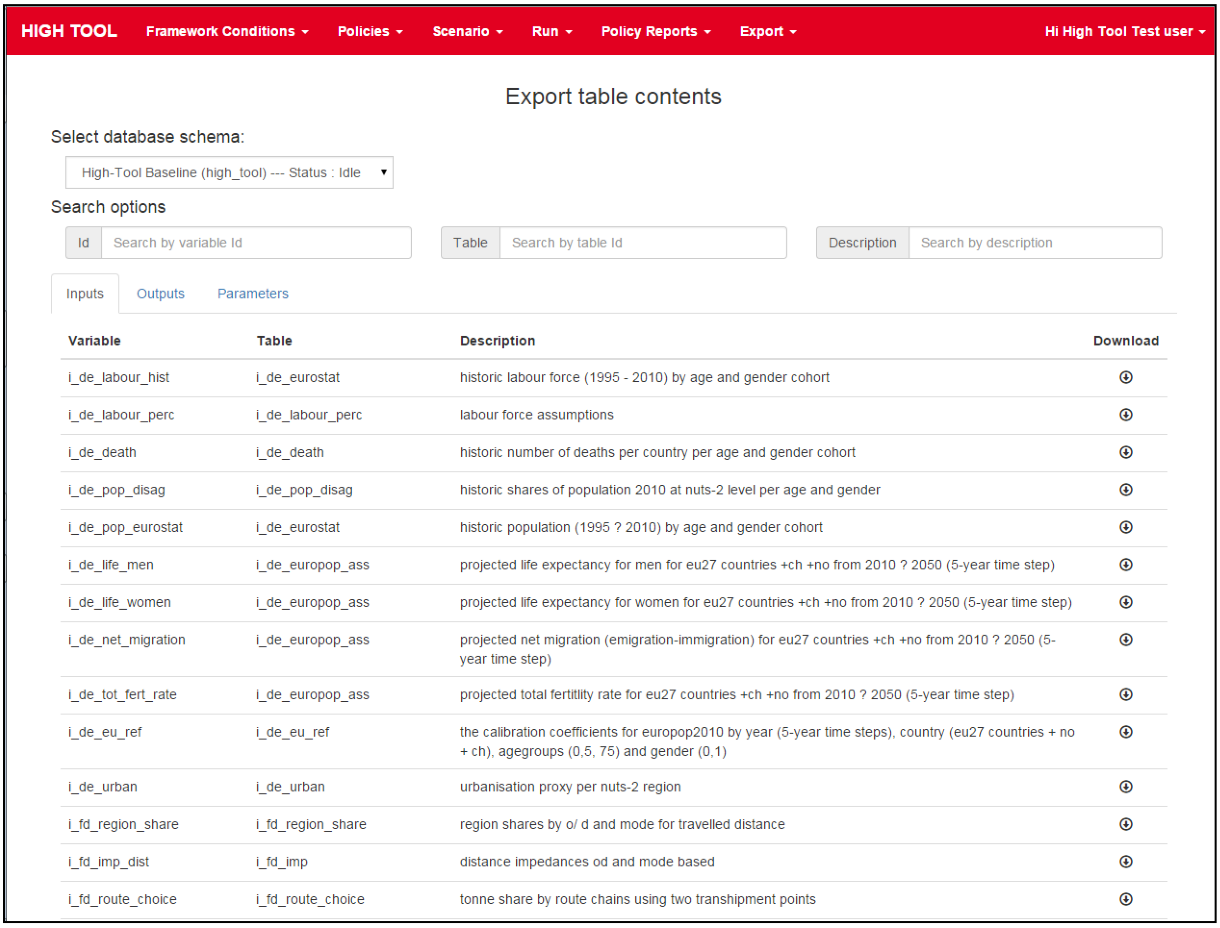

Figure 34: Full results displayed in graphs per theme

## 7.3.2 Export of Results

The User Interface also allows raw data from tables in the Data Stock to be exported in CSV format.

After selecting the database corresponding to an existing model run, the User Interface shows all variables for a specific run. Variables can be filtered by restricting the search to specific strings in the variable name, the table name to which the variable belongs, or parts of the description of such variable.

Figure 35 illustrates the control panel for the export of raw data.




| Variable | Table | Description | Download |
|---|---|---|---|
| i_de_labour_hist | i_de_eurostat | historic labour force (1995 - 2010) by age and gender cohort | |
| i_de_labour_perc | i_de_labour_perc | labour force assumptions | |
| i_de_death | i_de_death | historic number of deaths per country per age and gender cohort | |
| i_de_pop_disag | i_de_pop_disag | historic shares of population 2010 at nuts-2 level per age and gender | |
| i_de_pop_eurostat | i_de_eurostat | historic population (1995 ? 2010) by age and gender cohort | |
| i_de_life_men | i_de_europop_ass | projected life expectancy for men for eu27 countries +ch +no from 2010 ? 2050 (5-year time step) | |
| i_de_life_women | i_de_europop_ass | projected life expectancy for women for eu27 countries +ch +no from 2010 ? 2050 (5-year time step) | |
| i_de_net_migration | i_de_europop_ass | projected net migration (emigration-immigration) for eu27 countries +ch +no from 2010 ? 2050 (5-year time step) | |
| i_de_tot_fert_rate | i_de_europop_ass | projected total fertitlity rate for eu27 countries +ch +no from 2010 ? 2050 (5-year time step) | |
| i_de_eu_ref | i_de_eu_ref | the calibration coefficients for europop2010 by year (5-year time steps), country (eu27 countries + no + ch), agegroups (0,5, 75) and gender (0,1) | |
| i_de_urban | i_de_urban | urbanisation proxy per nuts-2 region | |
| i_fd_region_share | i_fd_region_share | region shares by o/ d and mode for travelled distance | |
| i_fd_imp_dist | i_fd_imp | distance impedances od and mode based | |
| i_fd_route_choice | i_fd_route_choice | tonne share by route chains using two transhipment points | |

Figure 35: Control panel for export of raw data

# 8 Impact, Dissemination and Exploitation of Results

## 8.1 Impact

The key target of the FP7 Transport Work Programme is to “develop integrated, safer, ‘greener’ and ‘smarter’ pan-European transport systems for the benefit of all citizens and society and climate policy, respecting the environment and natural resources; and securing and further developing the competitiveness attained by the European industries in the global market” (EC, 2011d). In order to develop policy measures which address “strategic research and innovation priorities [...], which [...] will focus around the following socioeconomic challenges: 1) eco-innovation through decarbonisation and efficient use of natural resources; 2) safe and seamless mobility; and 3) competitiveness through innovation” (EC, 2011d), the EC requires specific tools to adequately assess whether or not certain policy options are suitable. HIGH-TOOL allows transport policy-makers to quantify the impacts of transport policy measures so that a wide range of policy options can be efficiently analysed and pre-assessed.

The output variables of the HIGH-TOOL model consider a large number of impact variables in the realm of environmental, economic, social or transport safety-related indicators. Therefore, HIGH-TOOL allows the EC decision-makers to reveal policy options “for the benefit of all citizens and society and climate policy, respecting the environment and natural resources” (EC, 2011d).

Decisions on transport policy measures proposed by the EU have long-term and important impacts on society, environment and economy. Transport policy measures can lock up capital for decades and cause manifold external effects. Therefore, policy measures may have a tremendous scope, especially if proposed at the European level. Since a wide range of different policy measures are within the scope of the EC, an instrument which is able to assess strategically certain policy options is highly beneficial. Thus, HIGH-TOOL will improve, facilitate, smoothen and speed-up the decision-making processes at the EC. Since a target of EC is to design transport policies for the benefit of all sectors of the society, the development of the HIGH-TOOL model will subsequently benefit the EU Community.

Although the HIGH-TOOL model is developed for the European Union, it may have additional positive impacts for other stakeholders: HIGH-TOOL provides a thoroughly documented open source software tool, which can be modified, adjusted and extended relatively easily. With the utmost degree of openness, HIGH-TOOL can foster the emergence of a community that continuously improves and extends the functionality of the HIGH-TOOL model. Thus it has the potential to enhance competitiveness of the market within the realm of transport policy assessment and transport consultancy.

To summarise, HIGH-TOOL clearly addressed the challenges of EU policies, targets of the FP7 and Horizon 2020 Transport Work Programmes. Furthermore, the HIGH-TOOL model will improve decision-making processes at the European level, facilitating the identification of transport policies for the benefit of all sectors of the community.

## 8.2 Dissemination

A wide dissemination approach was applied within the HIGH-TOOL project. Besides the creation of a consistent visual identity for the project and the continuous update of the project homepage, three project leaflets were created and distributed.

The first project presentation leaflet provides an overview on the project and its main objectives, having the main purpose of arising awareness of the project. The second leaflet contains the model structure ("blueprint") of the HIGH-TOOL model, as well as information on project status at that time and the way forward. The third project presentation leaflet covers some user aspects of the final version of the HIGH-TOOL model.

The HIGH-TOOL project was presented on four major transport research conferences, the European Transport Conference (ETC) in Frankfurt, Germany (September 2015); the 6th European Transport Research Conference (TRA) in Warsaw, Poland (April 2016); the14th World Conference on Transport Research (WCTR), Shanghai, China (July 2016); and the European Transport Conference (ETC) in Barcelona, Spain (October 2016).

Furthermore, the project was presented on the Workshop of the WCTRS Special Interest Group E1, Transport Systems Analysis & Economic Evaluation in Istanbul, Turkey (October 2015), on a Workshop of the German-Turkish Science Year Programme in Istanbul, Turkey (May 2015), to visiting delegations at KIT, as well as to national policy-makers and students.

Three User Workshops were conducted to learn user requirements, to present the model, to raise awareness on the project, and to facilitate personal interaction between the model developers and the future users of the tool.

Finally, HIGH-TOOL was presented to a wider audience through press releases.

## 8.3 Exploitation of Results

Exploitation activities can be differentiated by public, scientific and business exploitation. Public exploitation is not directly interested in commercial use and revenue making; the main focus lies on the benefit of the whole society. The motive of business exploitation is clearly commercially oriented, while the scientific exploitation addresses the benefit for education and research. For HIGH-TOOL all types – public, scientific and private exploitation activities – are relevant.

Exploitation options have been discussed among the HIGH-TOOL Consortium, as well as between the HIGH-TOOL Consortium and the European Commission. The key target is to ensure that the knowledge and the strategic assessment instrument developed within HIGH-TOOL continues to exist beyond the lifetime of the project.

Exploitation options of the HIGH-TOOL project can be distinguished by three directions: First, future adjustments of the HIGH-TOOL model for the European Commission to cover recent user requirements; second, application of the HIGH-TOOL model and/or the data for further studies and consultation tasks; third, use of the HIGH-TOOL model for teaching purposes and as a basis for further scientific work.

# 9 Conclusions

The HIGH-TOOL Project Consortium developed a strategic transport policy assessment tool to support the European Commission (DG MOVE). The tool was developed in three stages: prototype, pre-final, and final. In combination with the three User Workshops, this development approach ensured a close involvement of the future tool users during the whole development process, as well as the consideration of user requirements.

Integrating knowledge from several domains, such as demography, economy, transport demand, vehicle stock, environment and safety, the HIGH-TOOL model constitutes an integrated assessment model.

As elaborated by Szimba et al. (2016), a (transport) policy assessment tool is expected to meet various requirements, such as short run time, high level of detail of results, simple maintenance, coverage of a high number of policies, or intuitive and user-friendly application. Although some of these model requirements tend to be inherently conflicting, high level of attention was attached to develop a model which represents a well-balanced trade-off between these objectives: although a strategic assessment tool, the HIGH-TOOL model provides a considerable level of detail, for instance in terms of number of modelling zones (314), freight commodities (52) vehicles types (60) or fuel technologies (17). The model run time of a few hours allows conducting multiple model runs during a working day. Particular attention was attached to user-friendliness aspects: the User Interface of the HIGH-TOOL model provides a wide range of options to define both pre-defined and tailor-made policy scenarios. The expert mode allows the user all degrees of freedom to define policies and framework conditions. Future model maintenance is facilitated by detailed model and data documentations.

Albeit beyond the scope of HIGH-TOOL, the rail and road hypernet models developed for the passenger demand module have proven to be a useful add-on for the computation of impedances at the level of O/D relations. The hypernet approach allows a more realistic representation of transport infrastructure policies. Extending the linkages of the HIGH-TOOL model and network-based transport demand models represents one important direction to extent the functionalities of the HIGH-TOOL model.

The HIGH-TOOL model is an open source instrument, and does not require any commercial software products to be run. This pattern – which distinguishes the HIGH-TOOL model from other European transport policy assessment instruments – ensures thorough transparency of computations, allows the experienced user to modify calculation methodologies, and provides the basis for an efficient further development of the model. Thus the knowledge and the strategic assessment instrument developed within HIGH-TOOL is likely to exist beyond the lifetime of the project.

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