HIGH-TOOL – Een nieuw Europees modelsysteem

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Samenvatting

Deze bijdrage geeft een kort overzicht van het nieuw ontwikkelde Europese modelsysteem HIGH-TOOL. We willen met deze bijdrage HIGH-TOOL ook binnen Nederland en België verder onder de aandacht brengen. Het paper is eerder gepresenteerd in Szimba et al (2017).

HIGH-TOOL is een modelsysteem dat ontwikkeld is met als doel effecten van transportmaatregelen op Europees en nationaal niveau op een snelle wijze te berekenen. Daartoe wordt niet alleen gekeken naar de maatregelen zelf en de effecten op verkeer en vervoer, maar ook naar de ontwikkeling van de bevolking en de economie en externe effecten zoals emissies en veiligheid.

HIGH-TOOL kan gebruikt worden om een eerste indruk te krijgen van de effecten van één of meerdere maatregelen. Op basis van de eerste indruk kan een ordening in effectiviteit van maatregelen aangebracht worden Zodat maatregelen geselecteerd kunnen worden om in meer detail te analyseren.

HIGH-TOOL is een open-source model. Dat betekent dat iedereen gebruik kan en mag maken van het model. Er zijn in principe geen beperkingen aan het gebruik. Dit maakt het systeem ook geschikt voor gebruik op universiteiten en hogescholen om een verkeer en vervoermodel te doorgronden en na te gaan wat er nog meer bij komt kijken dan alleen het berekenen van veranderingen in vervoersvolumes.

Een groot voordeel van HIGH-TOOL ten opzichte van vergelijkbare Europese transport-modellen is dat het modelsysteem zeer gebruikersvriendelijk is. Geïnteresseerde gebruikers van het model kunnen snel aan de slag met het invoeren van scenario's en het analyseren van uitkomsten omdat het model op een makkelijke en snelle manier bediend kan worden.

Het modelsysteem is succesvol toegepast in enkele case studies waarvan dit paper er één beschrijft. De case study toont aan dat HIGH-TOOL op een ruimtelijk geaggregeerd niveau in Europa een goede aanvulling is op het bestaande modelinstrumentarium: een snel werkend systeem dat met minimale inspanningen een maximaal resultaat geeft bij het doorrekenen van transport maatregelen.

1. Introduction and policy context

Decisions on transport policy measures proposed by the European Union (EU) as addressed by the White Paper on Transport (European Commission, 2011a) have long-term and important impacts on economy, environment and society. Transport policy measures can lock up capital for decades and cause manifold external effects – thus, policy measures may have a tremendous scope, especially if proposed at the European level. Various authors, such as Sieber et al. (2013) and Nilsson et al. (2008), emphasize the increasing importance of impact assessment tools as decision support instruments for policy makers.

Thus, in order to allow European policy-makers the identification of the most advantageous transport policies and the evaluation of transport policies, a strategic assessment tool has been developed to compute economic, environmental and social impacts of transport policies. The strategic assessment tool needs to be responsive to EU transport policies – for instance addressed by the European Commission's White Paper on Transport –, while the tool's output indicators reflect policy documents such as the EU's Impact Assessment Guidelines (European Commission, 2009).

This paper presents the strategic transport policy assessment tool "HIGH-TOOL" (high-level strategic transport model), which has been developed for the European Commission in order to support EU policy analysts to identify the most beneficial policy options and to support the strategic assessment of policy measures. The EU requirements for the assessment tool, which provided a key framework for the model development, are addressed in more detail by Szimba et al. (2017) and Vanherle et al. (2014).

The paper is structured as follows: Chapter 2 provides an overview of general tool features and the structure of the model. Chapter 3 explains the methodology behind the individual modelling entities. Chapter 4 addresses the scope of policies the model can be applied for, while chapter 5 presents a case study. The paper closes with chapter 6, the conclusions.

2. General Model Features and Structure

2.1 Model type

The HIGH-TOOL model represents 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.

2.2 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[1] for all EU Member States (EU28), Norway and Switzerland, NUTS-0 for EU neighboring 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.

2.3 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 vehicle fleet is distinguished by 60 vehicle types and 17 fuel types.

2.4 Baseline

The HIGH-TOOL baseline or business-as-usual scenario 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.

2.5 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 Database is realized as a PostgreSQL database with PostGIS extension.

2.6 Model structure

The HIGH-TOOL model consists of three main elements: Core modules that represent the modelling framework; the Database that facilitates the exchange of data; and the User Interface for application of the model and providing access to the assessment results. The core modules are as follows: Demography (DEM), Economy & Resources (ECR), Passenger Demand (PAD), Freight Demand (FRD), Vehicle Stock (VES), Environment (ENV), and Safety (SAF). Figure 1 displays the detailed structure of the model, also depicting the structure within the core modules. The model structure is explained in detail by Mandel et al. (2016).

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[1] NUTS: Nomenclature of Units for Territorial Statistics

3. Model Methodology

These modules interact sequentially with each other. The methodologies of these core modules are briefly summarized in the following paragraphs. While the contents of this chapter are largely based on the Final Report of the HIGH-TOOL project (Szimba, 2016), a detailed description of the methodology is presented by van Grol et al. (2016).

3.1 Demography Module

The Demography module (DEM) estimates the regional population and labor force in the 28 EU Member States and in Norway and Switzerland. UN projections (United Nations, 2014) are used for other countries worldwide and are adapted to the geographic zoning system used in HIGH-TOOL.

The population and labor force are calculated at country level for the EU 28, Norway and Switzerland based on the EU Reference Scenario 2013's assumptions on fertility rates, life expectancies at birth and net migration (European Commission, 2013), which embraces the Europop assumptions on demographic trends (European Commission, 2011b). 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. Labor force is estimated from the labor force percentage defined in the EU Reference Scenario and underlying assumptions.

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.

The Economy sub-module estimates total output, capital stock and labor 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 labor 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 (Wood et al., 2015) for CO_2, NOx, SOx, 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 labor 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.

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 generalized 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 generalized 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 methodology underlying the Vehicle Stock module is aligned with TRACCS (Papadimitrio et al., 2013) and TREMOVE (De Ceuster et al., 2007).

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-kilometers and vehicle-kilometers.

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 (De Jong et al., 2007). For the cost functions, the concept of generalized 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 motorization levels.

A hypernet model linked to the core PAD module was developed for road and rail, which contains virtual network links between neighboring NUTS-2 regions. The impedances of these virtual links have been aggregated from ETISplus impedance matrices. The model 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.

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 ton-kilometers and vehicle-kilometers. 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 (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 transported volumes 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 transshipment 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 generalized cost per available mode connecting an Origin and Destination of a leg through a multinomial logit function according to TRANSTOOLS (Burgess et al., 2008; NEA, 2007).

Subsequently based on total generalized costs for route chains connecting the trade relation's Origin and Destination, demand is distributed across the route chains connecting Origin and Destination through transshipment regions in the Route choice component by applying a multinomial logit.

The conversion step calculates ton-kilometer and vehicle-kilometer 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 ETIS+.

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

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

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-kilometer or number of 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 computed 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 transport modes, the focus is on fatalities. For all modes the social costs are calculated. The general approach of adjusting risk trends based on changes in accident causal factors is based on the European Road Safety Action Program (ERSAP) (Delhaye et al., 2010).

3.8 Module Interaction

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.

4. 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 the pre-defined Transport Policy Measures is shown by Table 1.

Table 1: Transport Policy Measures covered by 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 H2 fuel cell cars
	Diffusion of electro cars
	Replacement of inefficient cars
Pricing	CO2 feebates for road transport
	CO2 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 specified in terms of intensity, temporal effectiveness (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 analyzed 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.

Furthermore, customized policy package can be defined using any combination of policy levers. The policy levers are organized 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

Finally, using the Expert Mode the user can edit input tables and/or the hypernet 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.

5. Case Study

5.1 Case Study Description

The case study examines the application of the hypernet facility of the HIGH-TOOL model. The assumption is made that rail passenger travel times will further decrease by 10% along the "Magistrale" corridor Paris–Strasbourg–Karlsruhe–Munich–Vienna–Bratislava (see Figure 1 in the hypernet interface of the HIGH-TOOL model). The travel time decrease is assumed to be on top of the time savings due to TEN-T/CEF policies already in the baseline scenario. Thus, the investment assumptions do not refer to concrete rail infrastructure projects, but are hypothetical. The infrastructure improvements are assumed to become effective in the year 2030 (see Kiel et al. 2016).

5.2 Model Results

The model predicts an increase in rail passenger demand while the demand of competing modes (road – i.e. private passenger cars –, coach and air) is expected to decrease (see Figure 2). The results do not only reveal a mode shift effect, but also that the increase in rail passenger-kilometers exceeds the loss of passenger-kilometers by competing mode. Thus, the improvement of rail level-of-service is expected to generate induced traffic: the model outputs show an increase in average length of passenger rail trips.

The percentage changes in relation to the total passenger transport demand are limited, which is explained by the limited geographical scope of the measures, as well as by the pattern that the infrastructure improvements relate to inter-zonal passenger transport flows at the level of NUTS-2, which represent only a small share of the overall market.

Regarding impacts on demand by mode of transport for 2050 at NUTS-0 level, the strongest impacts in absolute terms are expected for Germany and France, followed by Austria. These countries are the key beneficiaries of the assumed infrastructure investments. Due to the network effects, which are covered by the hypernet approach, also the demand structures of other countries, which are not directly concerned by the investments – such as the Netherlands, the Czech Republic, Hungary or Switzerland – reveal slight impacts in favor of rail.
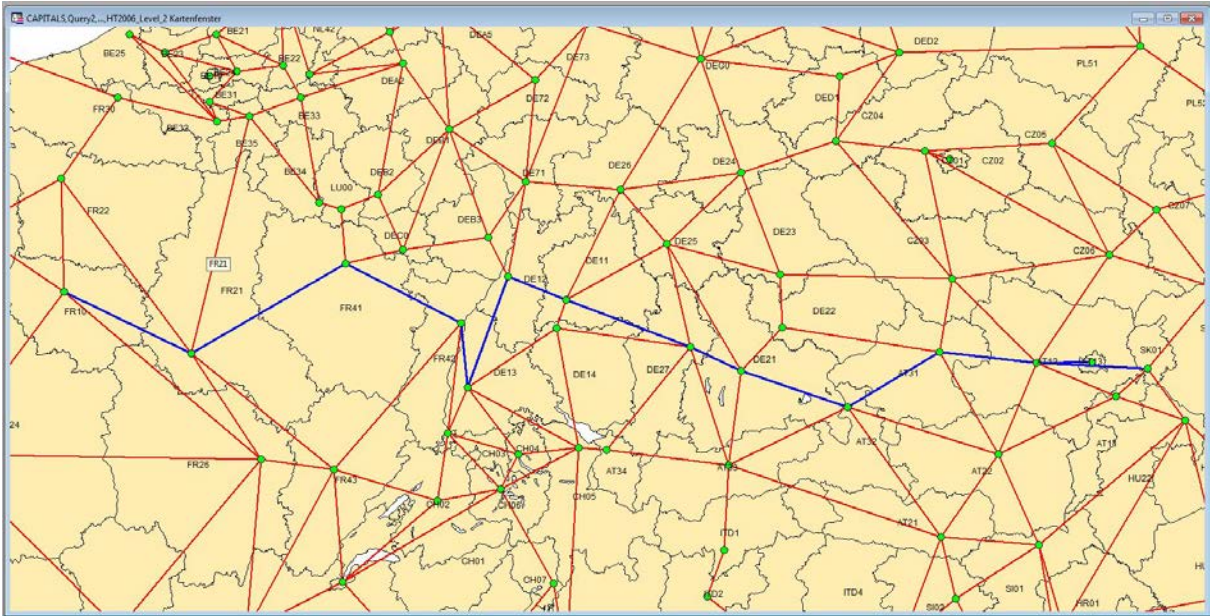
Figure 1: Case study 2 – Map showing the hypernet rail links of the Magistrale corridor (blue), other hypernet rail links (red) and NUTS-2 zone centroids (green)

Total EU28+2 passenger-kilometres 2010–2050, by modes (in million), difference Scenario-Baseline

Legend: ■ Road ■ Coach ▪ Rail ■ Air

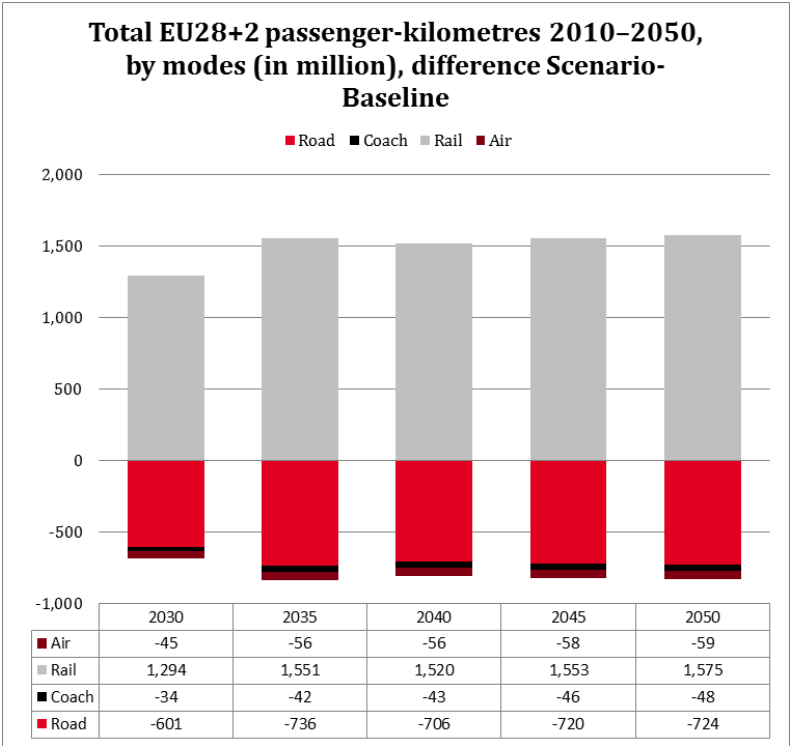|	2030	2035	2040	2045	2050
■ Air	-45	-56	-56	-58	-59
▪ Rail	1,294	1,551	1,520	1,553	1,575
■ Coach	-34	-42	-43	-46	-48
■ Road	-601	-736	-706	-720	-724

Figure 2: Case study – Impact on passenger demand by mode of transport

The modal shift from road and air to rail leads to a decrease in fuel consumption, CO_2 emissions and the emission of air pollutants (see Table 3). Furthermore, the modal shift results in a slight reduction in the number of road accidents (see Table 4). Finally, the HIGH-TOOL model predicts moderate economic impacts: the decrease in rail passenger travel times results in savings in generalized costs and, thus, increases economic competitiveness (second order effect).

Table 3: Case study – Impact on emissions and fuel consumption p.a. (in tons), EU28+2

Year	Fuel consumption	CO2	NOx	PM	SO2
2030	-7.434	-26.136	-56	-3	-1
2035	-10.634	-35.254	-62	-3	-1
2040	-10.991	-35.718	-58	-3	-1
2045	-11.107	-36.228	-60	-3	-1
2050	-10.866	-35.471	-62	-3	-1

Table 4: Case study – Impact on road accidents p.a. (number of injured persons), EU28+2

Year	Serious injuries	Slight injuries
2030	-5	-66
2035	-7	-78
2040	-8	-73
2045	-12	-66
2050	-10	-78

6. Conclusions

To develop the HIGH-TOOL model, originally independently functioning models – i.e. a passenger and freight demand model, demography model, vehicle stock model, as well as economic, environmental and safety assessment models – have been integrated on a common platform. Several methodological, technical and data-related challenges have been addressed to attain this model integration. A key enabler of the development work in HIGH-TOOL was the European reference database ETISplus, covering a large share of data sets relevant for the models which were integrated in HIGH-TOOL. In this respect, HIGH-TOOL can be regarded as a logical consequence of the European Union's strategy to provide not only publicly available data for transport policy and modelling – as accomplished by EU-funded projects such as ETIS-BASE and ETISplus –, but also to establish a publicly available open source tool for strategic policy assessment.

Also the existence of the EU Reference Scenario, which outlines long-term projections until 2050 and covers aspects such as transport demand, energy consumption and vehicle fleet, was a substantial support for the calibration of the HIGH-TOOL model. On the other side, it has been becoming a broadly accepted view that there will be large structural changes in the (near) future in many economic sectors and also within transport and mobility (see e.g., Chen et al, 2016). Also the currently instable political and geo-political situation in many world regions, wars and migration cause a high level of uncertainty in terms of future development of demographic, social, societal and socio-economic patterns which substantially influence transport demand. However, the official national and EU forecasts currently tend to suffer from a lack of adapted methodology to be able to anticipate for the future in which direct and indirect impacts of disruptive technologies will play a major role. Thus further research is needed to develop a generally accepted, trusted, transparent and repeatable approach that does not solely rely on historical developments, but which allows to deal with breaks in trends and derived developments.

The current version of the HIGH-TOOL model offers various possibilities for further developments: for instance, lowering the zoning system of the transport demand modelling from the spatial level of NUTS-2 to NUTS-3 will significantly reduce the share of intra-zonal transport demand and increase the accuracy of transport demand modelling. Also a closer link to a network-based model, which goes beyond the currently implemented hypernet approach for passenger transport, will enhance the tool's scope of application and improve the spatial representation of infrastructure-related policies.

Lowering the regional level of traffic cells and connecting the HIGH-TOOL model with a network-based model however, implies unfavourable impacts on model run time, which needs to be avoided as far as possible by smart data handling and processing method. Moreover, the increasing relevance of Sharing Economy concepts in transport (e.g., car/bike sharing; ride sharing) calls for a more sophisticated and explicit consideration of these schemes by transport demand and policy assessment tools.

Further mega trends in transport are electrification and autonomous driving. The electrification of the road transport sector indicates the requirement to connect more closely transport demand and energy modelling in order to obtain a better understanding of interdependencies between these sectors and to explore the potential of electrification of transport for decentral energy supply concepts (e.g., by using electric vehicles as mobile energy storage). Autonomous driving will result in tremendous impacts on the transport sector by enhancing access to mobility, improve safety, and the potential to alleviate congestion, reduce travel times and reduce environmental impacts, while it remains unclear in how far all potential benefits will actually be exploited, since vehicle mileage is expected to increase (Szimba and Orschiedt, 2017). Supported by further research on travel behaviour, traffic engineering and the scope of business models expected from autonomous driving, an extended version of the HIGH-TOOL model could be used to estimate the impacts of autonomous driving at European scale.

Finally, the consideration of future modes of transport such as drones or the Hyperloop concept may provide the basis for model enhancement.

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 indicated directions and beyond.

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