REKK

PROMOTING SUSTAINABLE ENERGY USE IN THE TRANSPORT SECTOR OF THE DANUBE REGION

TOWARDS A UNIFORM POLICY ASSESSMENT METHODOLOGY

MINISTRY OF
FOREIGN AFFAIRS AND TRADE
OF HUNGARY

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1. INTRODUCTION

Transportation is one of the major sources of greenhouse gas emission, accounting for 24 percent of carbon-dioxide emission globally, while also responsible for toxic pollutants causing harm to human health and the ecosystem, such as nitrogen oxides, sulphur oxides, carbon monoxide and particulate matter. Recognising this, the transport sector has got more attention recently in the EU climate policy which previously focused mainly on power generation and cooling & heating. Due to the nature of the sector, the importance of regional cooperation is particularly high in designing and executing policy interventions. Both passenger mobility and freight transportation have a significant international dimension, making the isolated national policies ineffective and insufficient.

Our study focuses on policies promoting sustainable energy use in the international freight transportation in the Danube Region and Poland. The region is especially affected by the environmental effects of the transportation, since a major transit route passes over the countries of the region from Turkey and Greece in the direction of Germany and Western Europe. Currently, diesel-fuelled road transportation is absolutely dominant in this route, being the principal responsible for the environmental damages.

Policies targeting the reduction of negative environmental and health impacts of freight transportation include several types of measures. Promoting sustainable energy use is just one path among many, however, it is much more ambitious and promising then conventional means like regulating the emissions of diesel vehicles, as it opens the way towards an entirely carbon-free transport sector. We analyse two different approach for that purpose:

- Incentivising the use of alternative fuels within road transportation, where LNG seems to be the most promising option for heavy duty vehicles currently (Századvég, 2017), but for longer term, liquified biogas or bio-synthetic gas (LBG) can bring a breakthrough in emission-reduction.
- Diverting the road transportation into less carbon-intensive transport modes, such as rail, where diesel is already largely replaced by electricity, which is increasingly being generated from renewable resources with close to zero emission.

Nevertheless, the potential measures are similar for the two approaches, as both try to enhance the relative competitiveness of the alternative of the diesel-fuelled trucks. The main policy categories are infrastructure investments (LNG station, railway), financial incentives (subsidies, fees and taxes), regulatory constraints (emission standards, quotas) and removal of non-physical bottlenecks (such as regulatory barriers).

As can be seen from the above, a wide variety of measures can contribute to achieve a more sustainable transportation sector, the effectiveness of which are difficult to compare. Our study aims to lay the groundwork for a uniform methodological framework, which can take the various welfare and external effects of the potential policies into account, and therefore it is suitable for assessment and comparison. Such methodologies have long been used in the energy sector for evaluation of infrastructure investments and different kind of regulatory measures. REKK has also developed its assessment methodology and applies it regularly.

The core of the REKK's methodology is the cost-benefit analysis (CBA) which relies on market modelling.[1] This approach ensures that the calculation of monetized benefits is based on market outcomes (quantities, utilisation rates, etc.) that are consistent with the analysed market situation (demand, infrastructures, costs, etc.), and not on ad hoc assumptions. Model-based CBA tools are also common in the transportation sector, however, there is need for a uniform methodological framework to assess policy measures promoting sustainable energy use in the sector. This document summarizes the findings of our research which can be a basis for developing a suitable model-based CBA methodology for that purpose.

The study has been conceived for the EU Strategy for the Danube Region (EUSDR), specifically for the Priority Area PA 2 of Sustainable Energy, but it is also connected to the Priority Area 1A and 1B of Waterways and Rail-Road-Air Mobility, as well as Priority Area PA 5 of Environmental Risks. The research built on the findings of two recently published and closely related study, both of which prepared in EUSDR context: TRT's 'Transport Study for the Danube Macro-Region' prepared for European Investment Bank and Századvég Economic Research Institute's study on 'Assessment of the alternative road fuels infrastructure and the development pathway to interoperability' commissioned by Ministry of Foreign Affairs and Trade, Hungary.

The study has been structured as follows. Chapter 2 presents the status of sustainable energy in the transport sector of the Danube Region. Section 2.1 gives an overview of the transport sector in the region, Section 2.2 describes the emission levels, trends and goals in the Danube Region countries, while Section 2.3 presents the potential policy measures to promote sustainable energy use in the transport sector.

Chapter 3 expounds the methodological issues of policy assessment in the transport sector. Section 3.1 provides an overview of the policy assessment methodologies, and

[1] REKK's European Electricity Market Model (EEMM) and European Gas Market Model (EGMM) are used for example for the assessment of candidate Projects of Energy Community Interest (PECI) and candidate Projects for Mutual Interest (PMI).

Section 3.2 reviews the related modelling tools.
Chapter 4 presents illustrative assessments for the external effects of two discussed policy approach (spread of LNG-fuelled trucks, modal shift from road to train). Chapter 5 summarizes the findings of the study and delineates the next steps toward a uniform policy assessment methodology.

2. SUSTAINABLE ENERGY IN THE TRANSPORT SECTOR OF THE DANUBE REGION

2.1. Overview of the transport sector in the Danube Region

In this chapter we illustrate a selection of basic datasets regarding economic performance, socioeconomic characteristics and some descriptive statistics that are relevant while approaching the transport sector and represent how heterogenous the countries of the Danube Region are. The illustrated data aim to present a colourful picture of some relevant characteristics instead of a comprehensive description of detailed statistics. In our selection we were following to some extent the approach of two studies we relied on during our work (TRT, 2017 and Századvég, 2017). This chapter is divided into four parts, starting with basic statistics to present some of the most influential demand pressure trends on transport. The second part is about vehicle fleets and transport networks to describe the sectoral assets and infrastructure in the region, the third part describes modal split data, finally the fourth part closes the chapter with a snapshot on renewable energy usage in transport.

The Danube Region is defined by the trail of the river from the Black Forest in Southern Germany to the Black Sea in Romania. The region includes countries en-route of the river and neighbouring ones like the Czech Republic, Poland, Slovenia, Bosnia and Herzegovina and Montenegro[2].

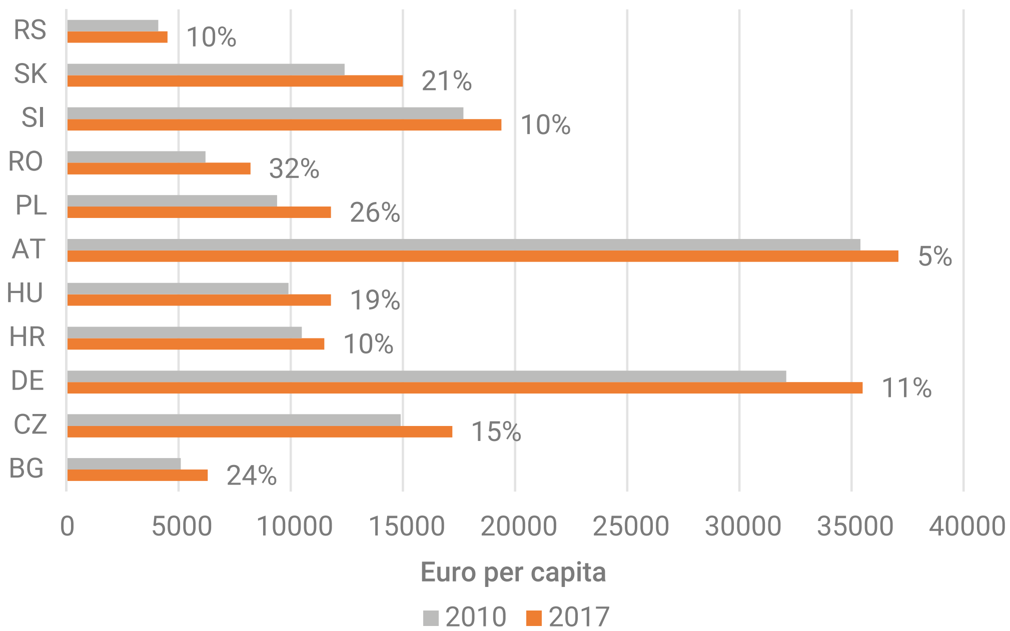
2.1.1. Socioeconomic characteristics

Welfare strongly determines demand for trade and transport. Project investments and policy interventions targeting the development of transport sector must deal with high level of inequalities in the region as the economic gap between the region's countries is very wide, there are sevenfold differences in terms of GDP per capita. The most developed countries show quite stable and slower growth in the last seven years, Germany is

[2] It is important to note that only two provinces of Germany belong to the Danube Region, but if we present German data it covers the entire country. In most of the cases we compared data from 2010 to the latest available to illustrate mid-term trends. Some figures do not cover all the 13 countries of the region because of limited data availability, as we were striving to present comparable data from the same sources for each statistic.

about to work out its lag behind Austria. Apart from the two far outstanding countries, which are differing from the others in most of the forthcoming illustrated statistics, the differences in the region are still very significant and seem durable as some of the least developed countries present quite slow growth. Romania, Bulgaria and Poland perform the best in catching up with the more developed part of the region as their income per resident grew with a quarter in the observed period.

Figure 1: Change of GDP per capita in the Danube Region

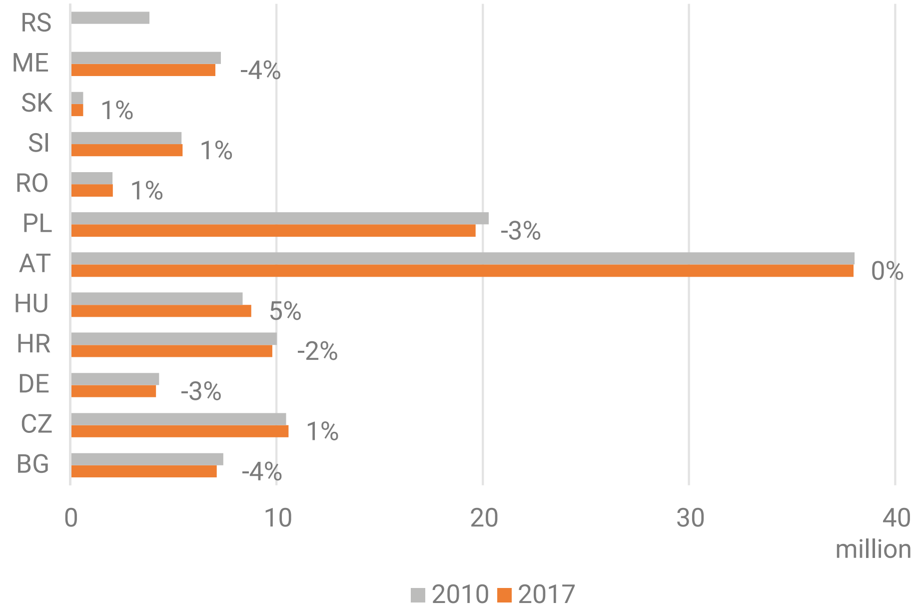


Source: Eurostat

Changes in population is also important determinant of market demand. The region consists of smaller countries, mostly having less than 10 million inhabitants[3]. Population of Bulgaria, Croatia, Hungary, Romania and Serbia decreased since 2010, Poland's is stagnating. Looking back to the first figure we can see that the economically less developed countries are dealing with negative demographic trends, which is a significant barrier to economic convergence.

[3] Germany is missing from the next figure because only two regions of the country (Baden-Württemberg and Bavaria) belongs to the Danube Region and it extremely stands out from the field with its overall 82,5 million inhabitants.

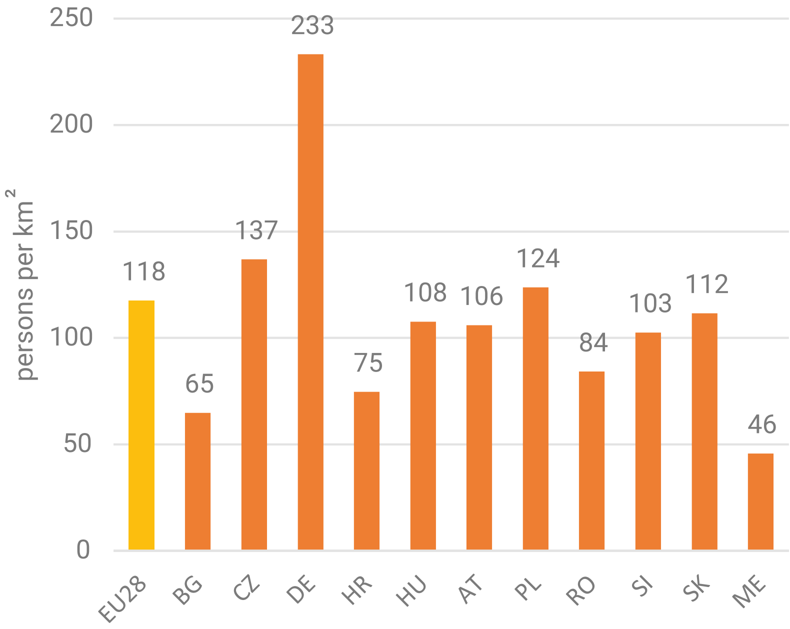
Figure 2: Change of population in the Danube Region



Source: Eurostat

Population density data is moving in line with the change of the population. Apart from Germany, which is an extremely densely populated country in the region, the other countries' values show a lot more homogeneous picture than in case of other statistics. Most of the countries are less densely populated than the EU28 average, this can have multi-directional effects on transport as population density affects infrastructural and investment needs, but can have external effects too, for example less populated areas set fewer obstacles to road constructions.

Figure 3: Population density, 2016



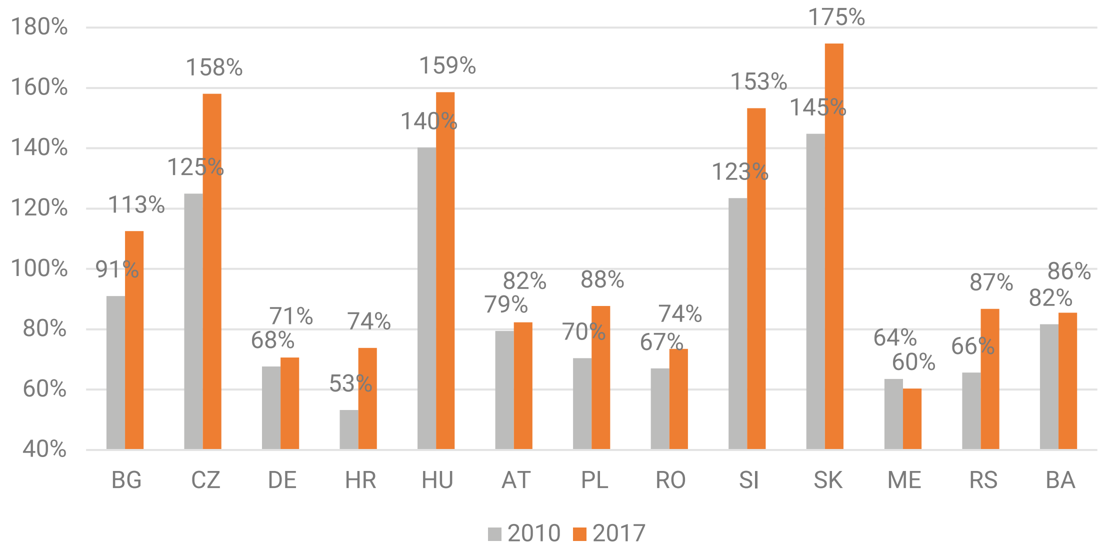
Source: Eurostat

The differences in GDP levels and demographic trends shows that the gap between the western and the eastern-southern countries of the region is remarkable and will be significant in the future.

The last statistic in this subchapter presents the intensity of international trade which possibly has a very strong effect on the volume of the transport sector as more intensive international trade creates higher demand for transportation services.

Small and commercially open Central-European countries like Czech Republic, Hungary, Slovenia and Slovakia are the most intensive foreign traders in the region compared to the size of their economies. These countries are particularly important transit countries due to their beneficial locations. Relative openness grew in every other country too excepting Montenegro. Croatia and Serbia almost doubled their relative volume of foreign trade, Poland also grew significantly from a relatively moderate level. The two most developed economies, Germany and Austria delivered moderate growth since 2010.

Figure 4: Volume of international trade (imports+exports) compared to GDP



Source: Eurostat

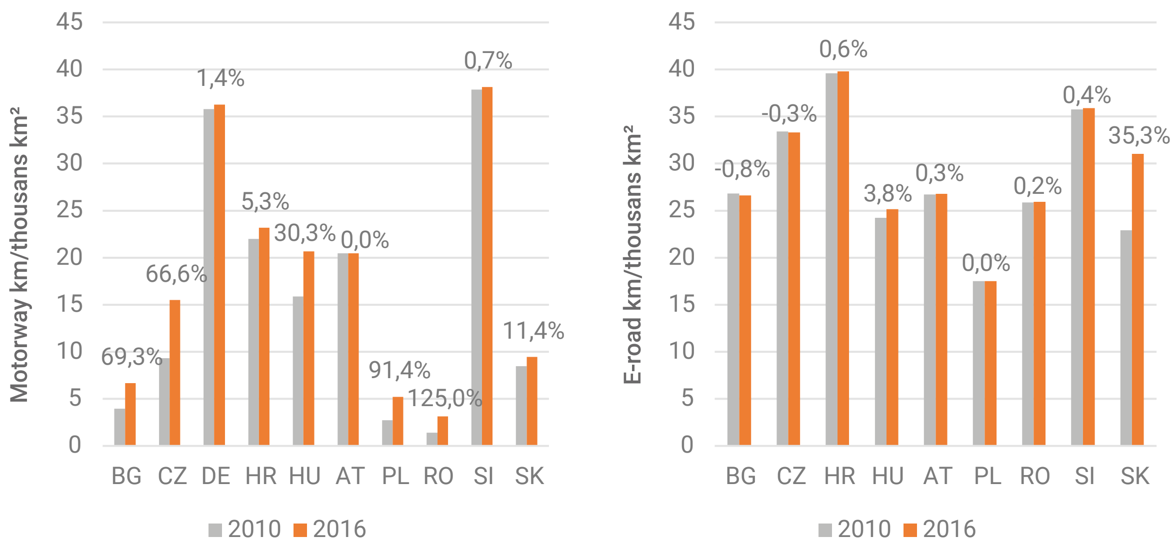
We can conclude that less developed countries generate bigger transport volume compared to their economies, this practically means that these countries function as transit countries carrying out transportation but are not a source of actual supply or demand.

2.1.2. Transport network and assets in the sector

Physical network like roads and railways and the size of vehicle fleet can be a barrier to the development of the transport sector if it is not extensive enough or is not in a sufficient condition. Firstly, we present the density of motorways and E-roads of the region's countries as these roads are the main fields of road freight transport. E-road numbers can cover motorways too, the difference why it is interesting to illustrate both data is that motorways are mostly utilized within borders, while E-roads build up a cross-border road network, so E-road density is a good indicator for international connectedness.

Germany is considered to have one of the highest penetration of motorways (the German motorway network is almost 13 thousand kms long) but as we can see on the next figure Slovenian values are even higher. Romania, Poland, Bulgaria and Slovakia have quite small motorway networks in absolute values and in terms of penetration, however they are connected to the neighboring countries by growing networks of E-roads. The network of E-roads is quite stable in the region since 2010, only Slovakia got significantly more connected to its neighbors. Motorway networks expanded dramatically in Romania, Poland, Bulgaria and the Czech Republic, but almost every country presented some growth.

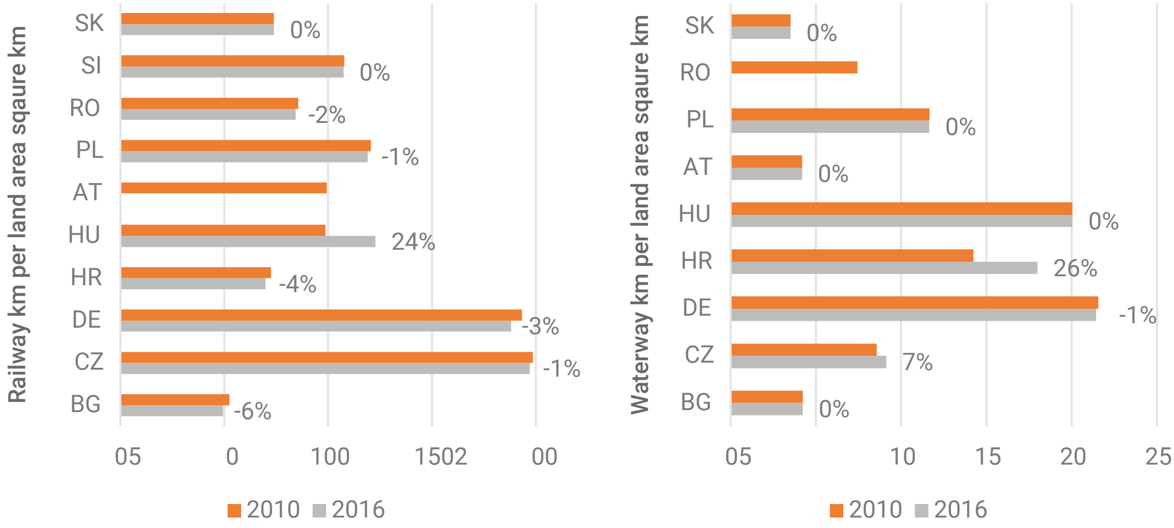
Figure 5: Change of road network density



Source: Eurostat

Unlike road constructions and network growth, the change in railway and waterway networks are not that straightforward. Railway density decreased or stagnated in every country in the region excepting Hungary since 2010, so it was quite common in most of the countries that some network infrastructure had to be withdrawn from operation. In case of waterways the density was stagnating, Croatia was the only country where there was a significant expansion of waterway network. In the latter two sectors the size of the existing infrastructure can be considered mature as its further physical expansion is not expectable based on the recent years.

Figure 6: Change of railway and waterway network density

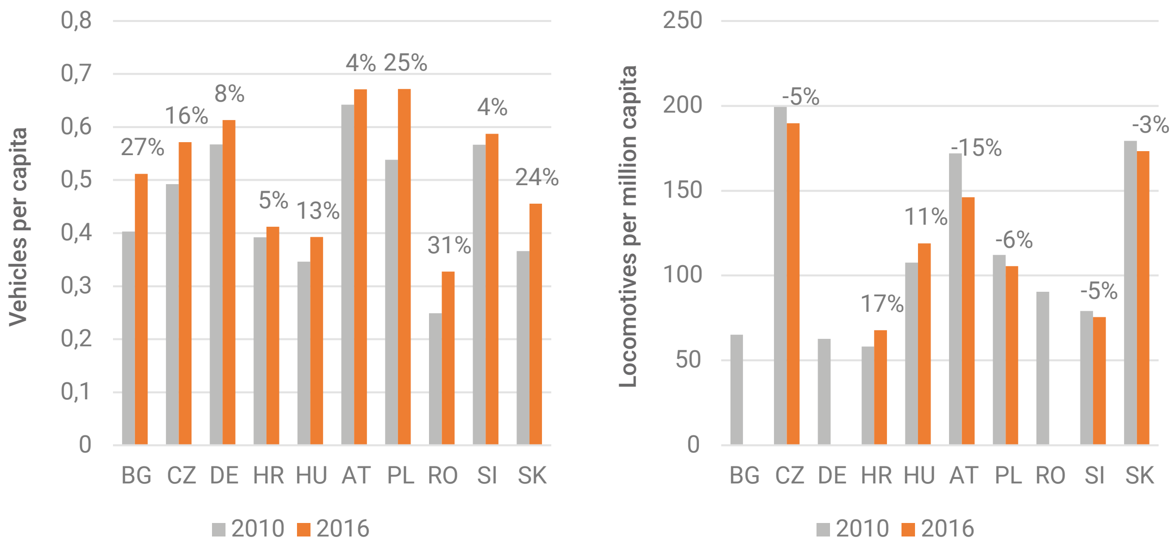


Source: Eurostat, Austrian railway data is from 2007 instead of 2010

Moving to further descriptive statistics we can see that vehicle fleet proportionate to the number of residents is not vary that much in the region, there are two times more vehicles per capita in Austria than in Romania. This data is not moving strictly with GDP per capita distribution as for example Bulgaria is in the middle of this range.

Changes of locomotive fleet show a more mixed picture in the cases where data was available to present the state in 2010 and 2016. On one hand the variation is quite big as for example there were almost four times more locomotives proportionate to the number of residents in the Czech Republic than in Germany in 2010. On the other hand, where data is available for both years only two of the countries presented growing locomotive fleet in contrast with the other five where the fleet decreased in a more or less significant extent.

Figure 7: Change of motorization rates



Source: Eurostat

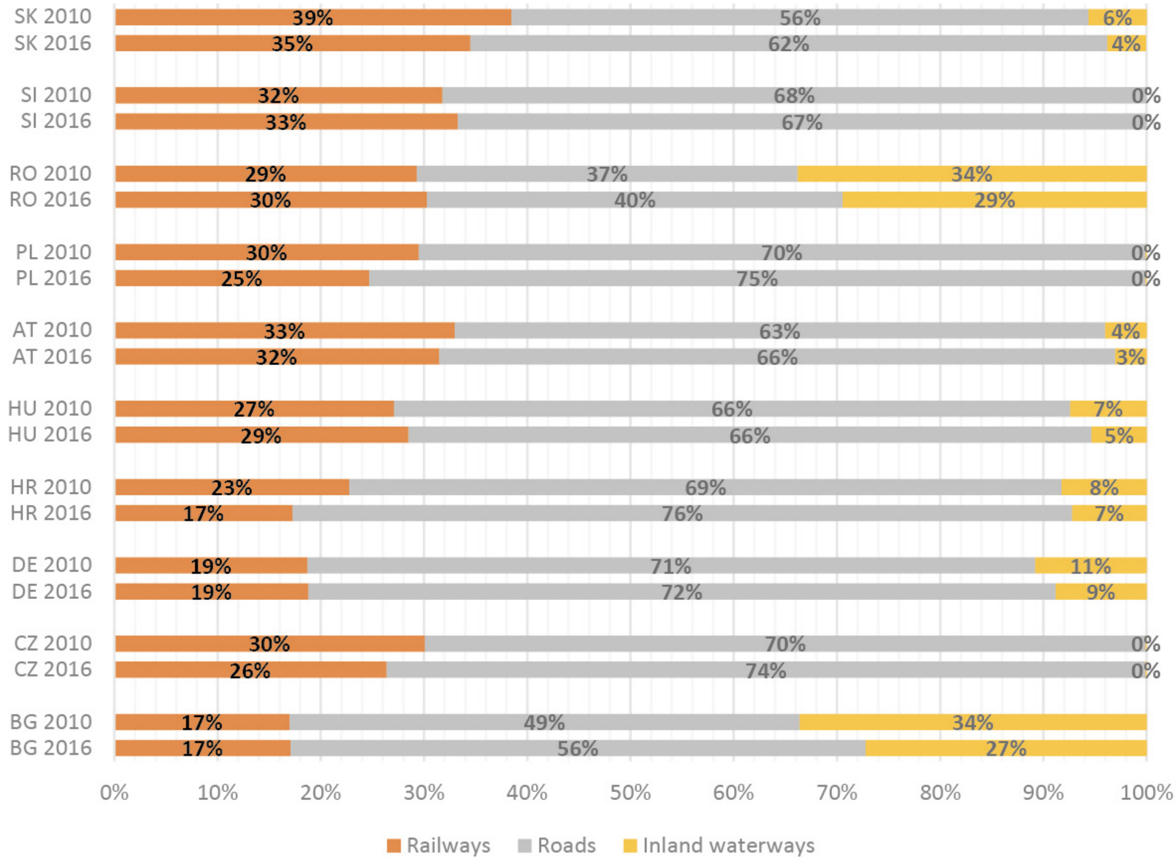
2.1.3. Transport modes

As we can see on the next figure the density of a certain transport mode network is not necessarily in line with its utilization. For example, Poland and the Czech Republic is in the midfield in waterway density in the region, but the significance of waterway transport is in fact close to zero in both countries, not like Bulgarian and Romanian waterways, which are amongst the least dense networks in the region but are highly utilized as this mode is just as or even more significant than railways. The case of Czech Republic is interesting as the country has the biggest proportional locomotive fleet and the densest railway network, but the significance of rails in transportation is not very high.

Compared to 2010, road transportation further increased its share in all DR countries but Hungary, where it remained unchanged. Share of rail transportation decreased in most of the countries, only Slovenia, Romania and Hungary could achieve some development in this regard, while share of inland waterways decreased in every country.

As the TRT (2017) study says the volume of transported good shipped on the Danube is quite volatile in the recent years in contrast with maritime freight demand which presented an annual 3% growth between 2010 and 2015.

Figure 8: Modal split of freight transport, tkm, 2010-2016



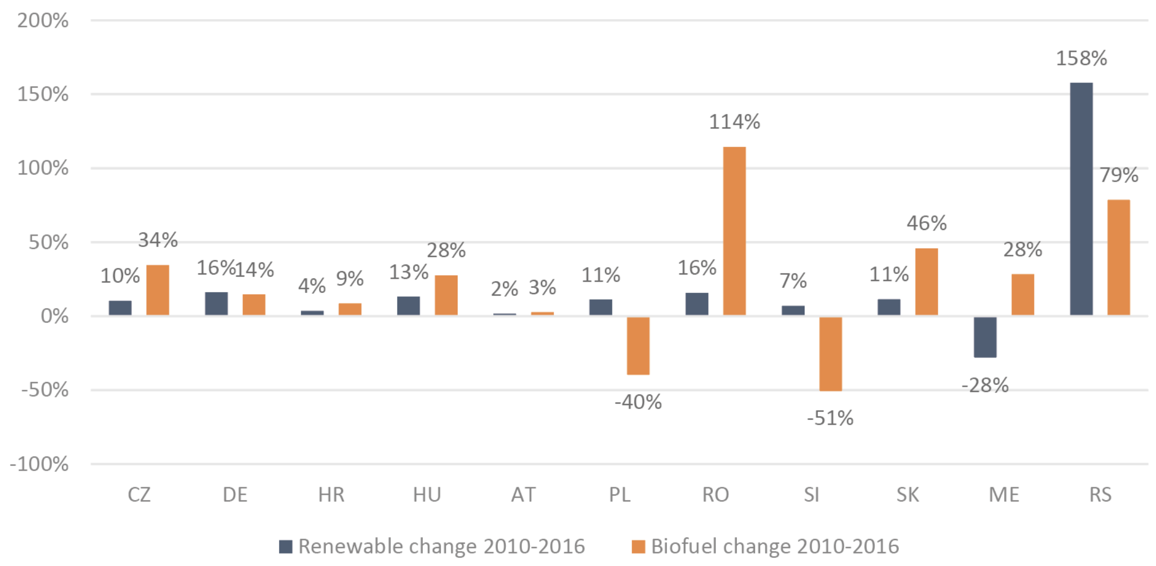
Source: Eurostat

According to the TRT (2017) study volumes transported on land are overwhelmingly domestic and freight transportation is mostly unbalanced for the benefit of road transport. In general, transport volumes are concentrated and attracted to western countries of the region. In the same time, it is expected that eastern countries will grow faster while their demand volumes are projected to be still lower compared to the western countries.

2.1.4. The role of renewables

The following figures show statistics related to renewables in transportation in 2010 and 2016. The first one presents the change in the usage of renewable electricity and biomass in transportation, the second one shows the overall share of renewables in the sector. Today biofuels accounts for the overwhelming majority of renewable energy sources in transport sector. Austria is an interesting exception as they use just as much renewable fuel-based electricity as Germany in absolute levels, but their biofuel usage barely exceeds the levels of the other less developed countries. It is important to note that while RES based electricity usage grew in every country excepting Montenegro, the usage of biofuels shows a little bit more mixed picture as it decreased significantly in Poland and Slovenia since 2010. Bulgaria is intentionally missing from the figure as biofuel usage increased six-fold since 2010 which is a very extreme change compared to the other countries.

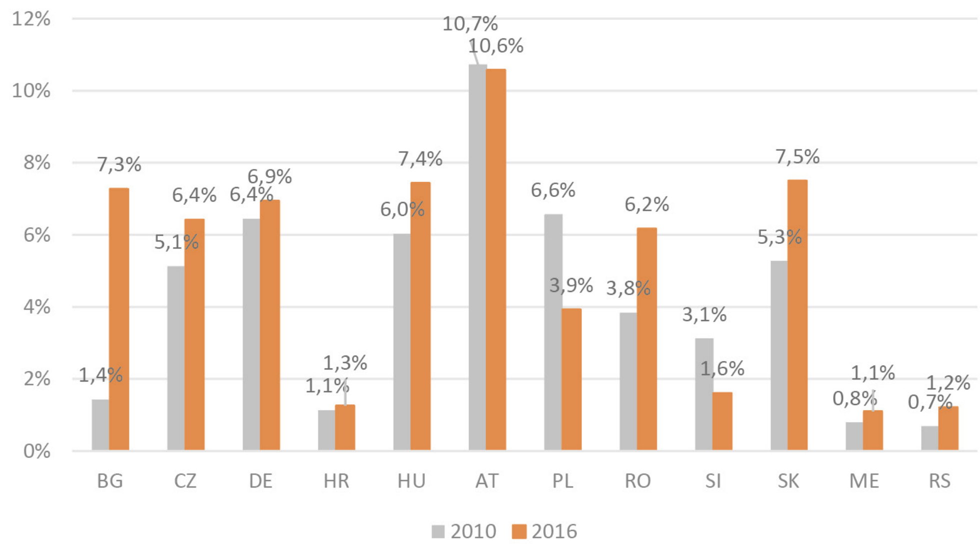
Figure 9: Change in renewable electricity and biofuel usage in transport



Source: Eurostat

The share of renewable energy usage in overall energy usage of transport sector shows smaller differences amongst the countries than the previous data. Austria stands out from the other countries again, other countries like Bulgaria, Czech Republic, Germany, Hungary, Romania and Slovakia increased their renewable consumption to a quite similar level to 2016 (6-8%). The case of Poland and Slovenia is interesting again as the ratio of their renewable energy consumption in transport almost halved between 2010 and 2016. The other countries present positive trends but the level of renewable usage is very much lagging behind.

Figure 10: Share of energy from renewable sources in transport



Source: Eurostat

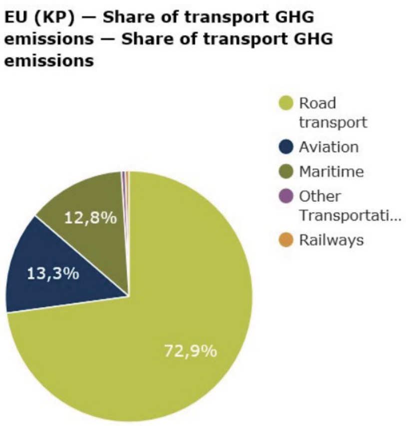
2.2. Transport related emission levels and goals in the Danube Region countries

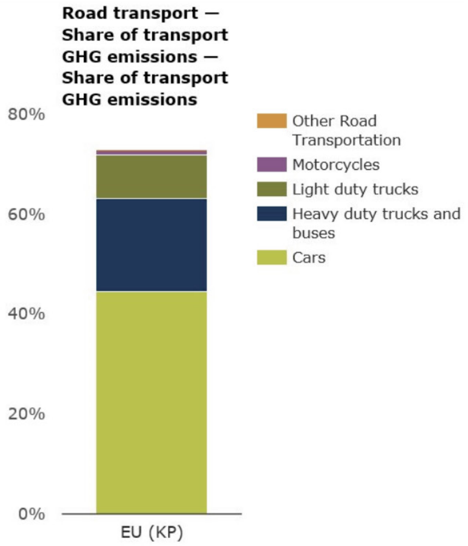
2.2.1. Role of the transport sector in greenhouse gas and air pollutant emissions

Transportation is one of the major sources of greenhouse gas emissions, accounting for 24 percent of carbon-dioxide emissions globally, and 21.7 percent in the EU (IEA (2017) and Eurostat GHG data). Other transport-related pollutants, released in higher concentrations in densely populated areas, cause health problems and environmental damage locally and at greater distances, e.g. in the form of acid rain or acid deposition.

Carbon-dioxide is the dominant GHG resulting from the combustion of petroleum products in vehicles. Minor amounts of methane (CH4) and nitrous-oxides (N2O) are also released from internal combustion engines, and small amounts of hydrofluorocarbon (HFC) emissions stem from the use of mobile air conditioners. In 2015, 1048 million t_{CO2eq} GHG came from transportation (including aviation) and 135 t_{CO2eq} from international maritime transport.

Figure 11: Share of transport modes in European greenhouse gas emissions

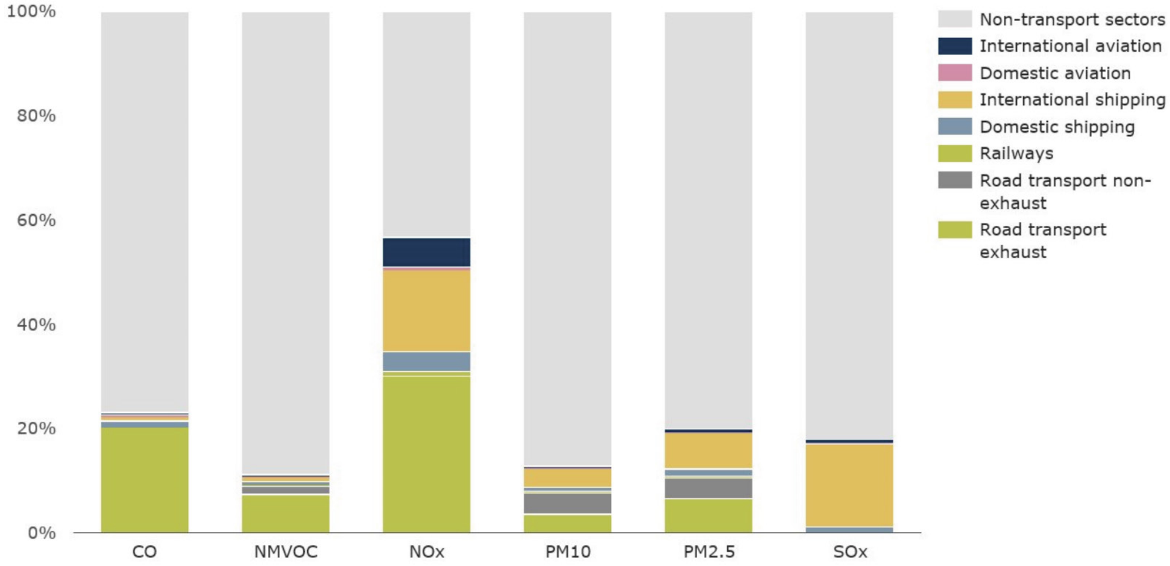




Source: EEA (n.d.)a

As regards toxic pollutants causing harm to human health and the ecosystem, primary and secondary pollutants can be differentiated. Primary pollutants, such as nitrogen oxides (NO_x), sulphur oxides (SO_x) carbon monoxide (CO), particulate matter (PM10 and PM2.5) and non-methane volatile organic compounds (NMVOC) are emitted from vehicles directly into the air, either as exhaust emissions (NO_x, SO_x, CO, PM, NMVOC) or as non-exhaust emissions, caused by the abrasion and corrosion of vehicle components and road surfaces (PM) or the evaporation of harmful substances escaping from the fuelling system (NMVOC). Primary pollutants also contribute to the formation of secondary pollutants, such as ground-level ozone (O_3) and secondary PM, which, besides causing health problems, also contribute to climate change. The next figure shows the relative share of transport related emissions in overall pollution, based on statistics from the EU.

Figure 12: Contribution of transport sector to total emissions of selected air pollutants in the EU (2015)



Source: EEA (n.d.) b

The transport sector is the largest emitter of nitrogen-oxides, contributing to more than half of NO_x emissions in the EU (and also globally), mainly due to road-transportation and navigation (IEA, 2016). The sector is responsible also for a significant share of carbon-monoxide emissions and particulate matter formation (PM10 and PM2.5), partially due to abrasion, as mentioned above[4]. International shipping release nearly 20% of sulphur oxides, because of its extensive reliance on heavy fuel oil, although recent EU regulation (Directive 2016/802/EU) related to the sulphur content of marine fuels is expected to alleviate this problem.

Other negative impacts of transport include traffic jams, noise pollution and heat traps in urban areas, caused by local heat formation due to extensive parking zones that occupy a substantial share of public space in cities, displacing green areas.

2.2.2. Transport-related emission reduction policies in the EU

The EU set a 60% reduction goal in carbon emissions by 2050 compared to 1990 in its White Paper on Transport (European Commission, 2011), providing a framework for required policy development in the sector.

[4] PM10 and PM2.5 are small particulate matters of less than 10 or 2.5 microns in diameter, that can penetrate into the respiratory system.

The European Strategy for Low-Emission Mobility (European Commission, 2016a) identifies three priority areas in reaching the target including the increasing the efficiency of the transport system, acceleration of the deployment of low-emission energy and moving towards zero-emission vehicles.

The main policies introduced in the EU aiming at reducing carbon and air pollution emissions from transportation include the Renewable Energy Directive (RED 2009/28/EC) setting a targeted share of renewable energy use within the final energy consumption of transportation, the Fuel Quality Directive (1998/70) including common standards for petrol and diesel fuels used in vehicles as well as requirements related to biofuels, the Regulations related to GHG emission performance standards for new passenger cars (443/2009) and for new light commercial vehicles (510/2011). The continuously improving EURO emission standards (at present EURO VI) define acceptable limits of exhaust emissions of NO_x, hydrocarbons, CO and PM for new vehicles sold in the EU, regulated by several EU directives amending 70/220/EEC. Standards are in place for light-duty, heavy-duty and non-road mobile machinery as well. Countries of the Energy Community have also adopted the RED and are in the process of adopting regulations related to fuel quality.

The EU set a 10% renewable energy target in the transport sector by 2020, an obligation for all member states laid down in the Renewable Energy Directive (RES Directive, 2009/28/EC). The expansion of the use of renewable fuels, however, does not automatically lead to the reduction of emissions. Firstly, in case the demand for transportation grows, both GHG and air pollutant emission levels might increase, despite a growing share of green vehicles. The legislation that aims to ensure that the emissions of sectors not included in the EU ETS (Emission Trading System) are also kept under control in the EU member states is the Effort Sharing Decision/Regulation (Decision No 406/2009/EC (ESD) and Regulation (EU) 2018/842 (ESR)), including transportation in addition to the buildings, agriculture and waste sectors. However, it does not specify any special target for the transport sector. Secondly, biofuels blended into fossil fuels to meet renewable targets are also burnt in internal combustion engines, producing particulates, carbon monoxide and nitrous oxides similarly to fossil fuels. There are also concerns about the land use and land use change related to the production of biofuels that have led to the revision of the RES directive in 2015 (ILUC Directive (2015/1513/EU))[5].

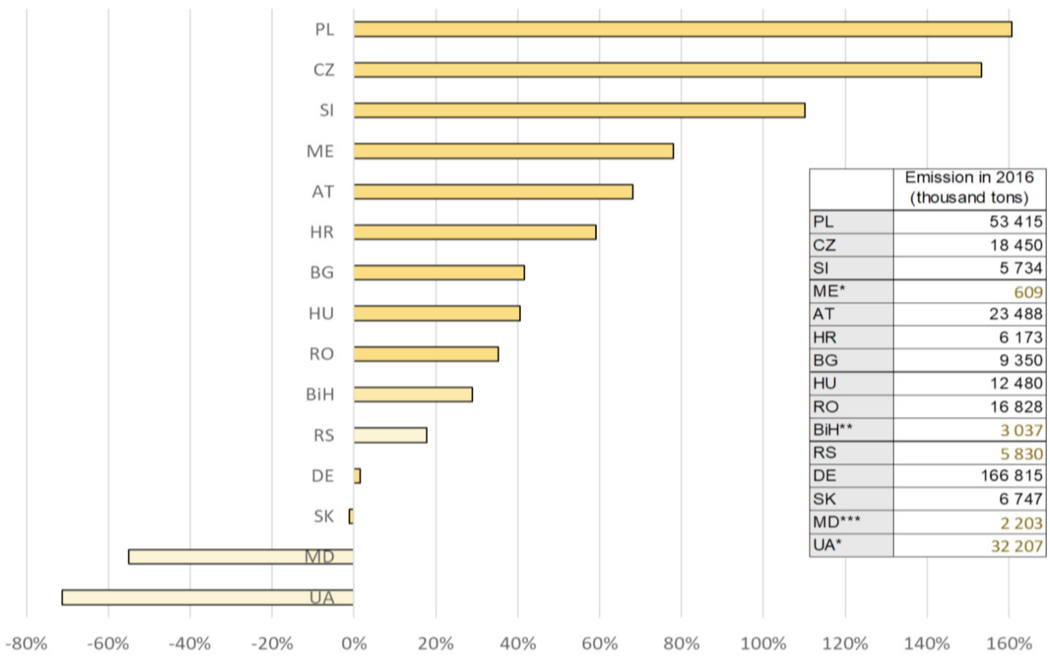
[5] The ILUC Directive (2015/1513/EU) amending the RES directive and the fuel quality directive (FQD, 2009/30/EC) set a 7% limit on conventional biofuels within the 10% renewable target, while promoting the use of advanced biofuels and renewable electricity by providing the opportunity to count their multiple values to against the renewable target.

As a result of renewable energy obligations, all diesel fuel sold in the EU contains biodiesel by now (mostly B7 including 7% biocomponent), while 85% of petrol sold in 2016 included bioethanol, 75% of which was type E5, with up to 5% ethanol content (EEA, 2017).

2.2.3. Trends in greenhouse gas emissions in the Danube Region

As the next chart shows, transport-related GHG emissions have increased in most of the DR countries since 1990. Their level more than doubled in Poland, the Czech Republic and Slovenia, and increased substantially (more than 50%) in Montenegro, Austria and Croatia. Only Germany and Slovakia managed to keep the change at the minimum, while emissions dropped in Moldova and Ukraine in the first years of the period, because their transportation sectors went through a dramatic structural change after the collapse of the Soviet Union.

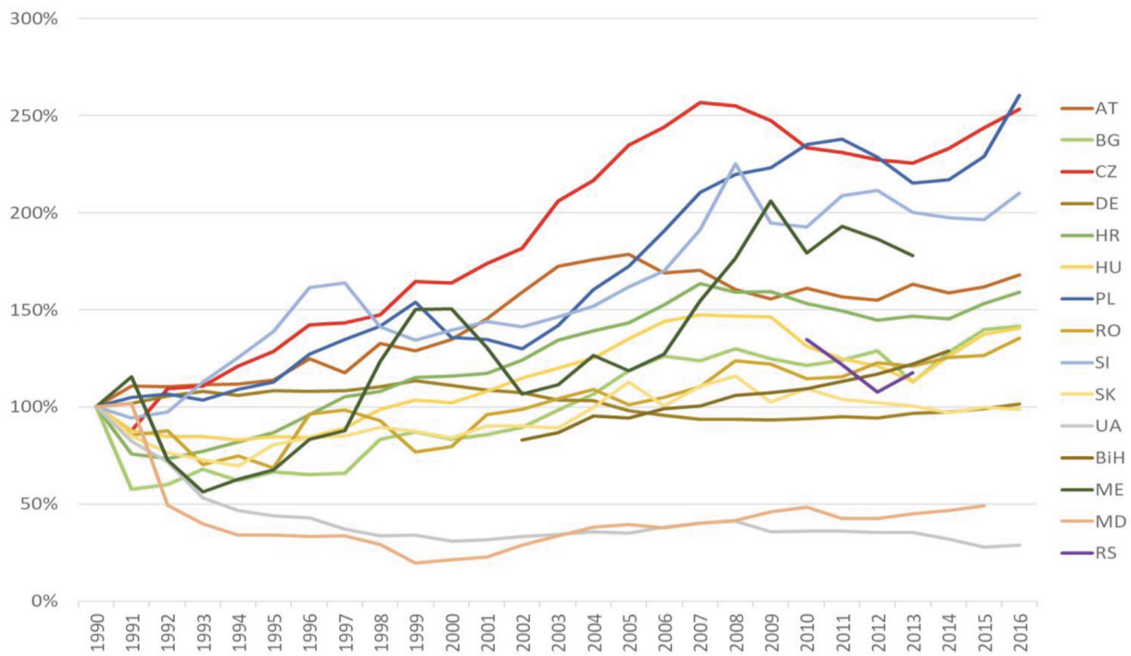
Figure 13: Change in GHG emissions from transportation compared to 1990*



Source of data: Eurostat and UNFCCC. *1990 emissions are compared to data from 2016 for EU member states, ***2015 for MD, **2014 for BiH, and *2013 for ME and RS.

The changes in the 25-26 years period show quite different trends across countries, as shown in the next figure. In Austria, for example, emissions increased up to 2005, but since then they have remained relatively stable. In Germany, emissions peaked in 1989, and dropped below the 1990 level in 2005, exceeding it again by 1.5% only in 2016. Transition economies all experienced a continuous growth in their transport emissions, except for a transitional drawback in the years of high fuel prices after the economic crisis. Only Slovakia experienced a different trend, as emissions dropped substantially in the years of transition following 1990, reaching the same level only in 2005, and falling again since 2013. The demand for transport and the level of carbon emissions have also been increasing in the non-EU countries, except for Ukraine.

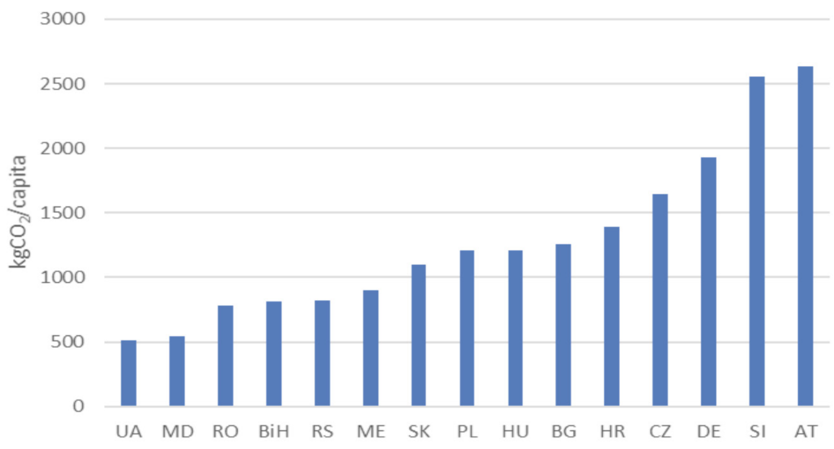
Figure 14: Change in transport emissions compared to 1990 (1990=100%)



Source of data: Eurostat and UNFCCC

The current level of development of the transport sector, as well as the composition of vehicle fleet by age is likely to have an impact on how emissions evolve over time and may explain why Germany and Austria managed to decrease emissions at around 2005, earlier than the years of economic crisis. To look at differences in development, apart from the overall emission trends it is also worth to look at the per capita emissions in the DR countries. The amounts are shown in the next figure.

Figure 15: Per capita emissions in the transport sector in 2015

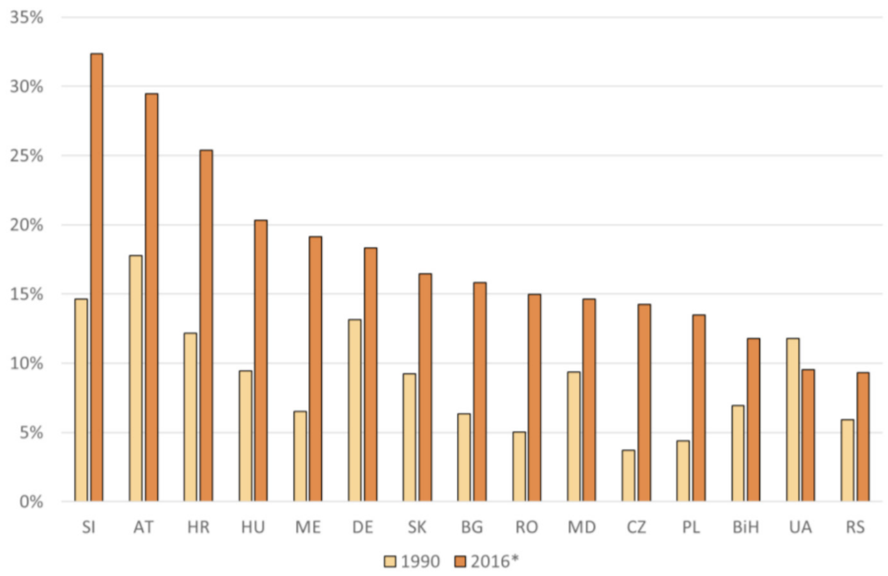


Source:/IEA (2017) CO2 emissions from fuel combustion, Highlights

The chart reveals that the transport sector of non-EU Danube Region countries and Romania emit relatively the smallest amount of carbon-dioxide, if per capita levels are compared, and the countries with highest GDP/capita have the highest per capita emissions. Poland, in spite of the substantial increase in its transport emissions, is among the countries with intermediate per capita emissions.

The share of transport within total GHG emissions increased in all DR countries, except for Ukraine. In 8 countries the share of transport doubled, mainly due to increased transport activities. In Moldova, the decreased demand for transportation did not affect the share of transportation emissions in a similar way to Ukraine, because energy production has also dropped dramatically after the collapse of the Soviet Union (Ministry of Environment of Moldova, 2015). In recent years the number of vehicles grew, but due to the low purchasing power of the population, mainly used vehicles are put into operation having weaker environmental effectiveness.

Figure 16: Share of transport in total GHG emissions in 1990 and 2016*



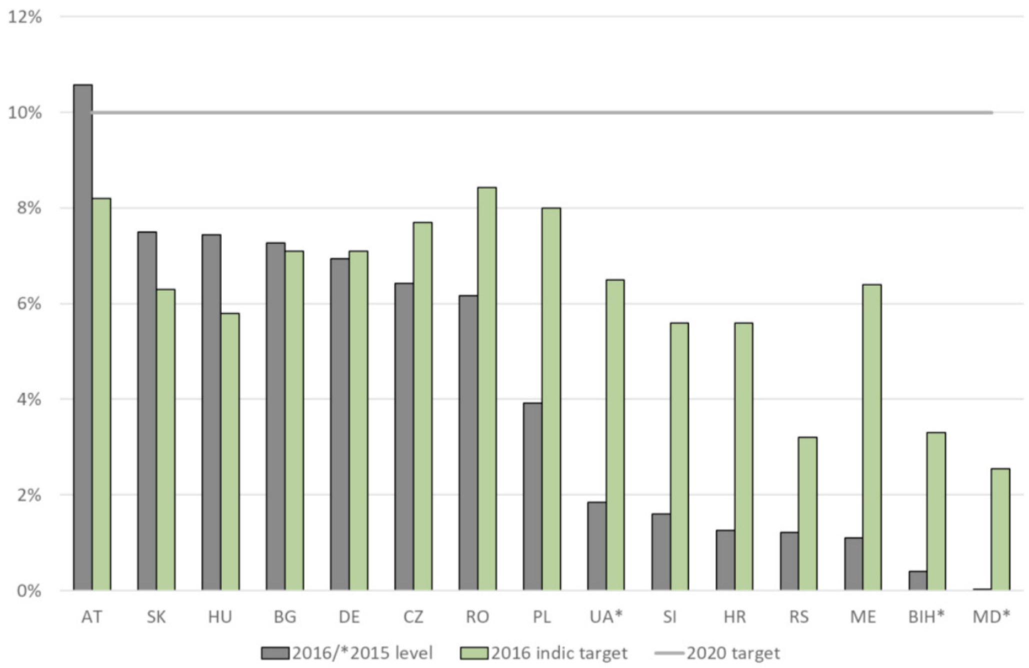
Source of data: Eurostat and UNFCCC. *Most recent data for RS are from 2014, and for ME, MD and RS from 2013.

2.2.4. Progress towards renewable targets

The renewable target set in the EU was also adopted by countries within the Energy Community, which have elaborated their National Renewable Energy Action Plans (NREAPs) indicating a similar 10% target of renewable energy use compared to final transport energy consumption. The next figure shows the progress of DR countries towards reaching their objectives.

The comparison of the current renewable energy deployment rate and the indicative targets for 2015/2016 laid down in the National Renewable Energy Action Plans of the respective countries reveals that only four EU member states seem to be on track to reach their 2020 targets, including Austria that have already exceeded its goal. Poland and Croatia, as well as the parties to the Energy Community have managed to reach only less than half of what they planned for 2016.

Figure 17: Share of renewable energy use in transportation compared to indicative targets for 2016



Source of data: Eurostat SHARES database for EU member states, ME and RS, RES Progress Reports to Energy Community for BiH, MD and UA (latest data available for 2015)

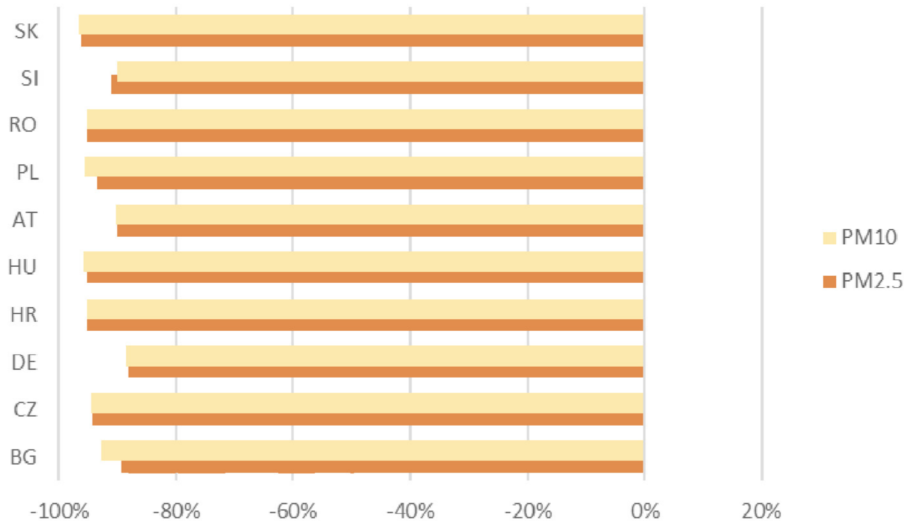
The latest Renewable Energy Progress Report of the Energy Community (EnC) claims that the reasons for being below the aggregated NREAP trajectories in 2015 were the high mitigation costs and the regulatory uncertainty stemming from the discussions related to the effects on land use of crop cultivation for biofuels (Energy Community, 2017). The report also states that EnC members failed to adopt and implement sustainability criteria for biofuels, and are in lack of existing certification bodies, meaning that they cannot count the biofuel produced in their countries towards their RES-T targets.

2.2.5. Trends in the emission of air pollutants from transportation in the Danube Region

The next figures show the progress in limiting pollutant emissions from transportation in Danube Region countries belonging to the EU. As can be seen in the following figures, a substantial share of harmful emissions has been avoided in the last decades (EEA,

2016). Data availability for non-EU members is rather limited, therefore we highlight some trends for those countries for which information could be found.
According to the next graph, particulate matter emissions from transportation decreased by more than 90% in DR countries belonging to the EU in the period of 2000-2016.

Figure 18: Change in PM10 and PM2.5 emissions in DR countries belonging to the EU, 2000-2016



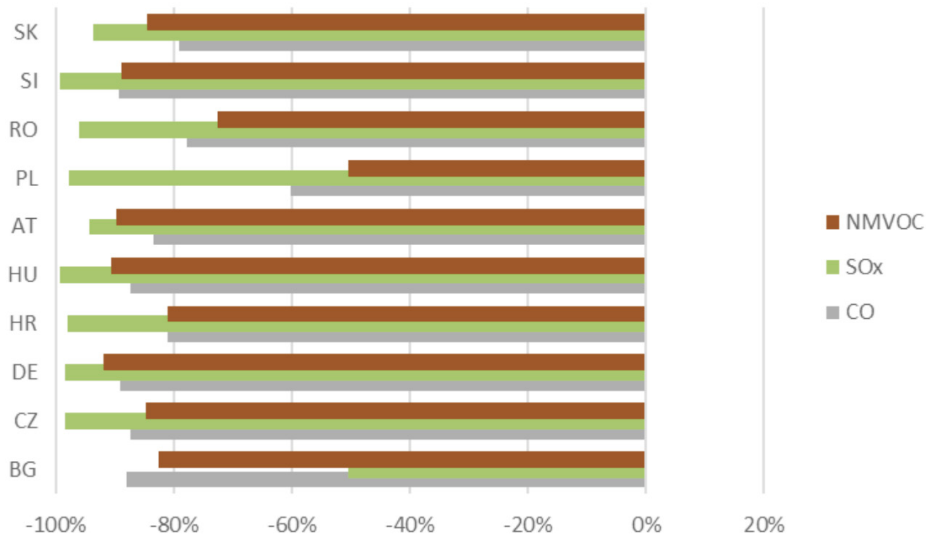
Source of data: Eurostat

Officially reported emission data for the Long-Range Transboundary Air Pollution Convention (CLRTAP) at CEIP (n.d.)[6] show that non-member DR countries did not manage to achieve similar results. Transport related PM2.5 emissions in Serbia increased from 2.01 to 2.54 ktons between 2000 and 2016, while PM10 released from transport grew from 2.39 to 3.38 ktons. In Moldova, PM2.5 and PM10 emissions were 0.1 and 0.17 ktons in 2000, respectively, both values rising to 0.45 ktons in 2015. In Montenegro, PM2.5 and PM10 emissions were at the same level of around 0.3 ktons in 2000 and in 2011. No information could be found on the evolution of emissions in Bosnia and Herzegovina.
The next figure shows the change in the amount of released non-methane volatile organic compounds, sulphur-oxides and carbon-monoxide in DR countries belonging to the EU. SO_x emissions declined by more than 90% in all countries but Bulgaria, most

[6] CLRTAP is a convention aiming at limiting the emission of acidifying pollutants. All DR countries ratified the convention.

probably due to the importance of marine transportation in the country. NMVOC and CO emissions also fell substantially in all countries, although to a smaller extent in Poland, where diesel oil consumption reached 3.5 times its 1990 level in 2016 (OECD, 2015).

Figure 19: Change in NMVOC, SO_x and CO emissions in DR countries belonging to the EU, 1990 - 2016



Source of data: Eurostat and EEA

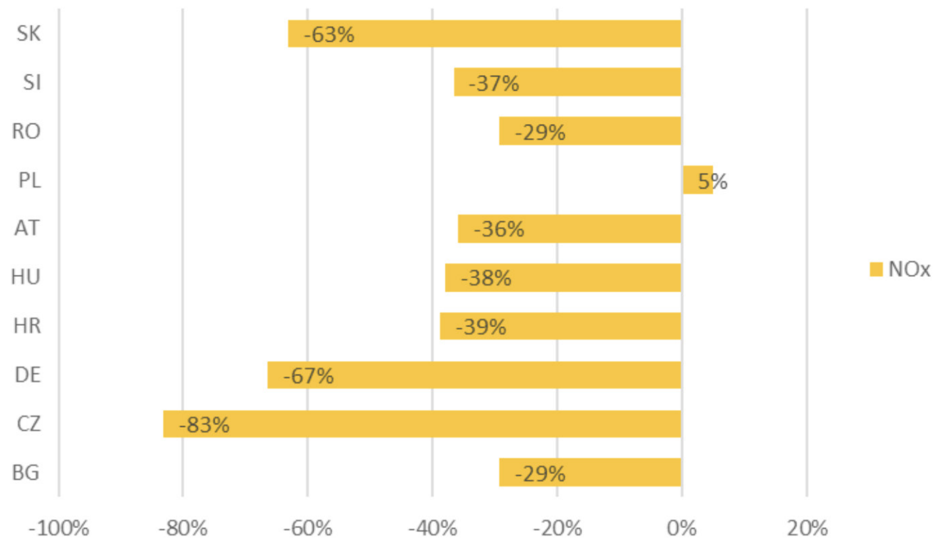
NMVOC emissions decreased in Serbia by 62% between 1990 and 2016, by 68.5 % in Ukraine from 2002 to 2016, dropped by 27.4% in Moldova from 1990 to 2015 and also fell by almost 65% in Montenegro in the period of 1990 to 2011.

CO released from transportation was 75% less in 2016 than in 1990 in Serbia, 56% smaller in 2016 than in 2002 in Ukraine, dropped by 30% between 1990 and 2015 in Moldova, and was only one fifth of its 1990 level in Montenegro in 2011.

SO_x emission data are only available for SO_2 in non-EU DR countries, showing a 54% decrease in Serbia from 1990 to 2016, 77% fall in Ukraine by 2016 compared to 2002, being basically eliminated in Moldova, but raising in Montenegro between 1990 and 2011 by 87.5%. However, this latter increase happened compared to a rather small initial amount (from 0.08 to 0.05 ktons), probably due to the increase in demand for road transportation.

NO$_x$ emissions include nitric oxide (NO) and nitrogen dioxide (NO$_2$). Their share in the exhaust emissions of diesel vehicles is higher than in petrol vehicles. The next figure reveals that nitrogen oxides emitted from transportation have decreased to a less extent by 2016 compared to other pollutants in EU member DR countries, and even slightly increased in Poland.

Figure 20: Change in NO$_x$ emissions in DR countries belonging to the EU, 1990 - 2016



Source of data: Eurostat and EEA

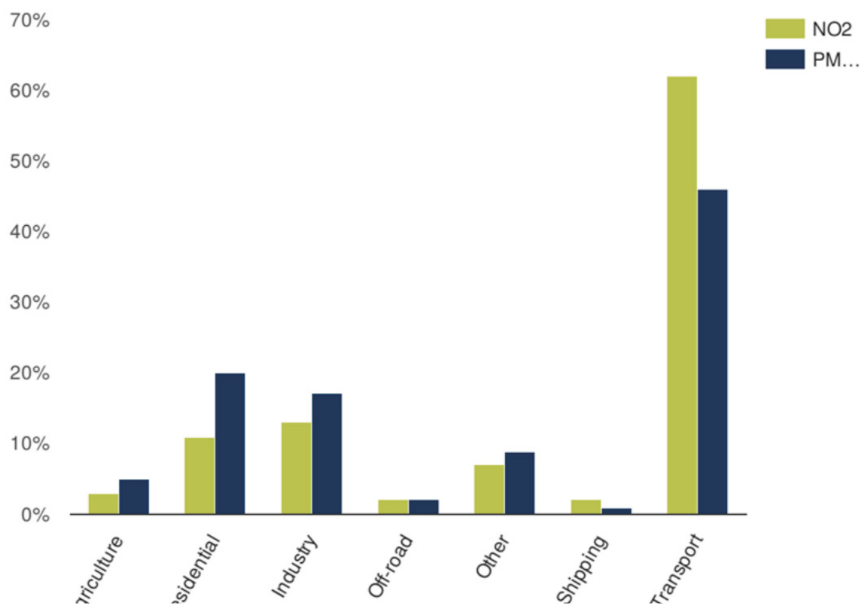
From among the non-EU member DR countries, Montenegro increased its transport NO$_2$ emissions from 3.75 ktons 1990 to in 5.11 ktons 2011 (36% increase). The other countries managed to achieve reductions: in Serbia NO$_2$ emissions decreased by 26.6% between 1990 and 2016, in Ukraine the level of emissions was 17.4% lower in 2016 than in 1990, and in Moldova, vehicles released 22.5% less NO$_2$ than in 1990. NO$_x$ emission data were not available for BiH.

Although these trends suggest substantial improvements in tackling transport-related pollution, problems remain. Exposure to air pollutants is much higher in densely populated areas, especially large cities, where the level of harmful substances reaches critical levels.

According to the 2017 Air Quality Report of the EEA, based on an analysis of data from 2500 monitoring stations across Europe, high concentrations of PM2.5, NO_2 and O_3 can be associated with 428 000, 78 000 and 14 400 premature deaths, respectively, in 41 European countries. The list of studied countries also includes BiH, ME and Serbia[7].

In order to keep pollution below a certain threshold and avoid serious damages to the health of people, the EU set maximum pollutant concentrations (air quality standards), that cannot be exceeded in a given time period(2008/50/EC Directive on Ambient Air Quality and Cleaner Air for Europe and 2004/107/EC Directive on heavy metals and polycyclic aromatic hydrocarbons in ambient air). Although the maximum values set by the EU legislation are higher in case of some pollutants (PM and O_3) than the concentration levels recommended by the World Health Organization (WHO) determined on the basis of scientific evidence, they are often exceeded in large European cities. Exceedances of the thresholds in EU member states must be reported, and authorities are obliged to develop and implement air quality management plans to reduce pollutant concentrations. According to the Briefing of the European Environmental Agency summarizing country reports on air quality standards in 2014, 2015 and 2016, the most commonly exceeded air quality thresholds were PM10 and NO_2 emissions in the three consecutive years in the EU, and most incidences and corrective measures reported were related to the transport sector. The next chart shows the distribution of all reported exceedances by sectors.

Figure 21: Sectors addressed by reported corrective measures for exceeding PM10 and NO2 standards in the EU, in 2014 - 2016



Source: EEA, 2018

According to the graph, 46% of the total number of the reported measures related to exceeding the PM10 limit, and over 60% of those related to exceeding the NO_2 threshold targeted the road transport sector.

2.3. Policy measures to promote sustainable energy use in freight transportation

Promoting the use of alternative fuels basically mean the facilitation of the use of renewable and low emissions fuels such as electricity and LNG. Regarding road transportation, electricity is presently an option only in short-distance, light weight transportation mainly in urban areas. It is used however to a great extent for rail transportation, therefore by diverting the shipments from road to rail, there is an opportunity to rely more on renewable electricity. Although local air pollution can be alleviated substantially in this way, electricity-based transportation contributes to less pollution only in countries with higher shares of renewable electricity and cleaner sources of energy. Carbon emission intensity (CI) of electricity highly determines the positive effects of using electric vehicles. CI depends on the generation mix of a particular country. E.g. in the EU it decreased from 431 gCO2/kWh to 275,9 gCO2/kWh between 1990 and 2014, while in Poland, its value was 670,6 in 2014 (EEA). Using carbon intensity data for EU member states, Moro and Lonza (2017) estimated that on average, using passenger EVs in the EU saved around 50-60% of the GHG emissions compared to similar internal combustion vehicles in 2013.

As electricity use in heavy road transportation is not yet a viable option, natural gas technology might serve as a bridging technology to low-carbon transportation. CNG (compressed natural gas) is already used to drive urban light vehicles, as well as public transportation vehicles, however LNG can be a better alternative for longer distances, due to its higher energy density. Using LNG makes it possible to take 2.4 times longer distances with the same volume of fuel. Heavy duty vehicles running on LNG emit 20% less GHG and almost 100% less SO_x and PM compared to diesel trucks. (Osorio et al., 2015)

The following section presents the most common measures aiming to support the spread of sustainable energy in freight transportation by enhancing its relative competitiveness: infrastructure investments, financial incentives, regulatory constraints, removal of non-physical bottlenecks.

2.3.1. Infrastructure investments

Use of LNG in freight transportation is mainly supported in the EU by promoting the establishment of fuelling infrastructure. The alternative fuels infrastructure directive (2014/94/EU) prescribes the installation of an appropriate number of refuelling stations by 2025 along roads and at ports, enabling the TEN-T Core Network to serve HDVs with LNG. Hydrogen fuelling stations also have to be installed by the same date, although experts doubt that the deployment of hydrogen vehicles will improve at the same pace. On the other hand, the installed gas stations should facilitate the blending of biogas (biomethane) with natural gas, contributing to the reduction of the carbon intensity of the fuel. (Osorio et al., 2015)

In addition to the provisions of the alternative fuel infrastructure directive, additional measures contribute to the further expansion of fuelling facilities. The LNG Blue Corridors project (including 3 existent and 3 proposed routes) is a specific project of the EU, aiming at building 14 new LNG stations and 100 LNG HDVs to operate along the corridors (Századvéd, 2017 p.86.). Moreover, the Mediterranean Sea will become and Emission Control Area, favouring the use of LNG as a fuel for HDVs.

Századvég (2017) claims that the national strategies related to alternative transport infrastructure improvements are not really ambitious as regards the instalment of LNG fuelling stations, while Hungary plans to install 147 of them by 2030 according to its low penetration scenario, Austria plans to build only 5 by 2025 and the Czech Republic targeted to have 14 LNG filling stations by 2030 (Századvég (2017), p. 80).

Shifts in freight transport to lower emission modes can be enhanced by providing support for the establishment of infrastructure. For example, the Connecting Europe Facility (CEF) Regulation (1316/2013) allocated EUR 22.4 billion for improving the European transport sector infrastructure (European Commission, 2018b). Formerly, the Marco Polo programmes served as a support program to enhance modal shift and traffic avoidance projects, providing financial support to projects enabling the shift of transfer haulage from road to alternative modes. However, the programme was ceased in 2013, as the European Court of Auditors found it inefficient, claiming that subsidies were provided to projects which would have been implemented even without receiving a grant, and to projects of limited sustainability, while lack of reliable data made it difficult to assess the resulting environmental benefits. The European Commission decided to replace the “top-down supply push” approach with the CEF programme, targeting the development of the infrastructure. (Apostolides, 2013)

The Interreg Danube Transnational Programme identified EU SDR targets and actions, including the target of increasing the cargo transport on the river by 20% by 2020. The actions include investing in waterway infrastructure to develop interconnections and develop ports in the river into multimodal logistics centres (DTP, n.d.). There are 3 intermodal terminals (multimodal facilities) operating in Hungary with a connection to inland waterways (ports of Baja, Budapest and Győr (Gönyű) connecting road, railways and inland waterways.

Modern infrastructure development is highly interlinked with the need to improve information systems. One example for this is the adoption of the RIS system (River Information Services) enabling real-time information exchange between the vessels and ports at the riverside, as well as among the vessels. The EU Strategy for the Danube Region proposes the inclusion of non-member DR countries in the system (DTP, n.d.).

2.3.2. Financial incentives

Examples for applying financial incentives to encourage modal shift include tolls and vignettes in roads. In the EU, Directive 2011/76/EU provides a regulatory framework for charging distance-related tolls and time-based user charges (vignettes) for heavy-duty vehicles (HDVs weighting more than 3.5 tonnes). This market-based instrument enables member states to internalise some of the external costs caused by transportation vehicles, while at the same time decreasing the demand for road transportation through the resulting price increase.

The directive also prescribes charging varying fees according to the environmental performance of vehicles, promoting the replacement of old and inefficient transport fleets. Therefore, HDVs with alternative fuels can get discounts. The other, even more effective way to promote LNG-trucks is to is supporting the purchase of vehicles in the form of direct contribution or tax allowance, as a main barrier is the high investment cost.

2.3.3. Regulatory constraints

In the field of road transportation, the EU and its neighbouring countries move towards open markets, albeit liberalising mutual road market access remains an issue. EU Member States maintain bilateral road transport agreements with neighbouring non-member countries, which set quotas, meaning that the number of haulages into or across the other country is limited. This measure can be considered as a regulatory instrument to reduce transportation activities, although the same transportation activity can be carried out by domestic hauliers, favouring national transport companies over competitors from other countries. The cost advantage of eastern countries within the EU already brought the companies of these countries in a better competitive position, reducing the domestic market opportunities of freight companies of the member states with higher wage levels. Increasing the road market access of third countries would further increase cost competition in the haulage market. For this reason, market integration requires that third countries adopt equal levels of relevant safety and environmental standards.

Regulatory instruments include emissions standards set for newly registered vehicles. Heavy-duty emission standards have been in place in the EU since 1988. EURO I standards were introduced in 1992, followed by more stringent and extended updates specified in EURO II-VI standards. EURO VI was introduced by Regulation No 595/2009, with an implementation date of 2013 January (Transportpolicy.net, 2018). In May 2018 the European Commission proposed the introduction of CO_2 emission standards for heavy-duty vehicles, aiming to reach a 15% reduction in CO_2 emissions from new lorries by 2025, and a 30% decrease by 2030 compared to 2030 (COM/2018/284). The overall EU targets are translated into manufacturer-specific standards specified in gCO2/km (European Commission 2018).

As complying emission standards raise the costs of manufacturers and therefore shippers too, it also incentives the use of less carbon-intensive modes of transportation, thus contributes to an uptake of both LNG driven vehicles and rail transportation.

2.3.4. Removal of non-physical bottlenecks

Improving market conditions for less polluting modes of transport can be severely hindered by the presence of non-physical bottlenecks. Rail transport encounters numerous problems due to low reliability of services in some countries, lack of cross-border coordination, poor traffic management and varying technical conditions. As safety standards differ from country to country, safety authorisation has to be required from all the states crossed by a given haulage route (EC, n.d.). The 4th Railway Package of the EU addresses these questions introducing structural and technical reforms to break down existing barriers. (European Commission, 2016b)

Communication on transport cooperation of the EU and its neighbouring countries COM(2011) 415 proposes a closer integration between the transport markets of the EU and its neighbouring countries, encouraging them to apply similar safety, security and environmental standards to those valid in the EU, facilitating the integration of transport systems (COM(2011) 415 final). The communication on the Danube Region also emphasize the importance of good connections among countries involved and points to the bad quality, insufficient capacity and poor maintenance of transport infrastructures existing in these states, while highlighting the potential for sustainable inland navigation on the Danube and its tributaries. The NAIADES programme aims at creating the conditions for inland navigation transport to become a quality mode of transport, setting out a programme for policy action for the period of 2014-2020. Besides improving the environmental performance of vehicles and the quality and availability of necessary infrastructure, goals also include the development of information services. (COM(2010) 715)

3. METHODOLOGICAL ISSUES OF POLICY ASSESSMENT IN THE TRANSPORT SECTOR

The following chapter includes two main sections. Firstly, we give a short summary of the main theoretical concepts of the extended project evaluation in transport sector. The section presents the most commonly used approaches such as the social cost-benefit analysis (SCBA) and the multi-criteria assessment (MCA).

In the second section we focus on the modelling of the transportation sector. We give a brief overview about the existing transportation models and try to categorize them based on their application fields, and the modelling technics they use. The main aim of this section however is to formulate suggestions about a potential transportation policy analysis framework with the spatial scope of the Danube region, based on the experiences of the currently existing transportation models.

3.1. Overview of the policy assessment methodologies in the transport sector

The purpose of using evaluation framework in transport sector can be diverse also in timeframe and in focus of assessment. The two main group of methods are different in the number and nature of general criterions. The first group of methodologies convert all impacts to a monetary basis. The most common method of this approach is the cost-benefit analysis (CBA).

The second group of methods highlight the importance of factors which are difficult to express in monetary terms. These methods, such as the multi-criteria assessment (MCA) combine the qualitative and quantitative technics (Beria et. al, 2016, De Bruckner et. al. 2011, Jones et al, 2014).

3.1.1. CBA and its extensions

There are several methodological articles and handbooks about how to prepare a CBA in the transport sector (EC, 2014, Siciliano, 2015). The common approach of the concept of CBA is the monetisation and the inter-temporal discounting. The CBA monetizes not only market goods and services but also goods traded at an imperfect market or non-traded goods. The result of the CBA is the surplus which can be divided into three main categories: consumers', producers' and government's surplus (Beria et al., 2016).
The economic Cost-Benefit Analysis systematically compares the benefits and costs arising over the life span of an investment project for all relevant groups of stakeholders within a geographic area. It is widely applied at the societal and company level to enumerate collective and investor effects. Whereas in the private sector evaluation of investment and financial analysis of a company's costs and benefits takes place against maximization of the company's net benefit, the economic CBA takes a broader, long-term perspective. It also captures externalities of broader groups of stakeholders, such as environmental and reliability impacts, providing the wide scope for maximizing welfare of a society.
There are several ways to calculate the net economic benefit of infrastructure investments, the most common being Net Present Value (NPV) and the Internal Rate of Return (IRR) which calculates the payback period or uses the benefit/cost ratio (Bristow & Nellthorp, 2000). In the NPV calculations, costs and benefits are aggregated to single numerical values, however infrastructure projects create significant redistribution of wealth amongst stakeholders and between countries as well. In order to reflect these distributional effects, the costs and benefits of the individual scenarios are assessed in economic terms for all of the effected stakeholders.
The social cost-benefit analysis (SCBA) also uses the monetary terms of the net present value (NPV) criterion, however it based on the concept of societal optimum or social welfare. The welfare increases, if as a result of a new project the winners' increases in utility can compensate the losers' decreases and the overall societal utility level exceeds the level before project execution.
The European Commission published a guideline in 2014 (EC, 2014) about the way of

applying the CBA method in EU co-founded investment projects. The study highlights the main conceptual elements of a CBA as follows:

- Long term perspective: 10 to 30 years of timeframe depending on the way of intervention;
- Opportunity costs: the cost of best alternative forgone is included in the assessment;
- Comparability of monetized indicators: the project overall performance is measured by indicators, namely the Economic Net Present Value (ENPV), and the Economic Rate of Return (ERR).
- Microeconomic approach: indirect (i.e. on secondary markets) and wider effects (i.e. on public funds, employment, regional growth, etc.) should be excluded.
- Incremental approach: CBA compares a scenario “with” and a baseline scenario “without” the project. The economic performance indicators calculated on the basis of the incremental cash-flow.

Although CBA is a common approach for project assessment, there are some critical points of its concept. The most debatable structural element of the CBA is the complete and correct way of monetization of all impacts including the non-market goods and services. (Jones at al., 2013, The long-term perspective indicates methodological debates about, how to define a “fair” long-term social discount rate. The higher rates favour shorter-time benefits and smaller investments. The inclusion of equity is also a problematic part of the CBA based approach, as equity is not included in CBA. Last but not least, the evaluation of residual value at the end of the CBA also can be problematic element of the concept, because the time horizon of the analysis is generally shorter than the technical life of the assets.

Despite the critical points, CBA is the most commonly used for project valuation and recommended by various international organizations as a central element for assessing new infrastructure project proposals. Since not all possible costs and benefits can be quantified and/or monetized, some other impacts are only assessed qualitatively. If these elements are judged to be an important factor in the assessment of the new network elements, they could be included in a multi-criteria assessment method.

3.1.2. Multi-criteria analysis (MCA)

Multi-criteria analysis (MCA) gives a relative freedom compared to CBA to combine the economic and non-economic evaluation factors of a planned project. The concept of MCA does not require to convert all indicators to monetary terms. The alternatives are evaluated on a predefined set of criteria which reflect the goals of the decision-maker and ranked with weights.

MCA takes the personal ranking of the decision maker as an input and weights it together with other stakeholders' ones. (Beria et al., 2016). To include the qualitative or non-monetised impacts in the appraisal, it is necessary for the stakeholders involved to discuss and prioritise the various impacts. The MCA is a good tool to articulate the different preferences of stakeholder groups. The stakeholder-driven approach of institutional framework, including the analysis the state interventions can guarantee the social optimum in case of well-designed implementation path (e.g., based on government incentives or a social marketing campaign) for alternatives based on divergent stakeholder priorities (De Bruckner et al., 2011).

3.1.3. Structural parts of a transport evaluation framework

Despite the variety of areas of use of assessment and applied methodologies, there are some common structural elements in the evaluation frameworks.

- Structuring phase (objectives, criteria, causality / hierarchy);
- weighting;
- assessment of alternatives (evaluation with the same parameters and weights);
- exploration phase.

The following table summarizes the main activities of the above steps of the assessment process.

Structuring phase	Weighting	Assessment of alternatives	Exploration

• Definition of valuation objectives and goals (ex ante or ex post) assessment of project or policy measures
• Choice of analytical framework: CBA or MCA or combination
• Collection of relevant indicators
• Research framework: Usage of models in assessment
	• Time-related weights (discount rate in monetized terms) residual value
	• Equal or different weights for measuring the externalities (combination of expert opinions)
	• Single criterion (monetary terms) vs. multiple criteria
		• Strategic option analysis
		• Evaluation of alternatives with the same parameters and weights
		  • "With" and without the project"
		  • "do minimum" vs. proposed project
			• Sensitivity analysis
			• Qualitative risk assessment
			• Probabilistic risk analysis

3.1.4. Assessed environmental benefit categories

Evaluation methodologies usually use a two-step approach. The first step maps the effects of the given policy measures on modal splits, routes, transported amount of goods and/or number of vehicles. The second step – presented in detail below – would use the outputs from the first-step model to monetize the external costs of the outcome. The first model can be run with and without the observed policy measure, and the external costs of the two cases then can be compared.

Several studies try to capture the external cost effect of a certain investment or policy intervention in the transport sector. In the following table we select four studies of the sources we examined during our work and present how researchers distinguish the potential cost categories.

Table 1: Assessed environmental benefit categories in the literature

Study	Ricardo-AEA (2014)	Tsamboulas D.-Mikroudis G. (2000)	Transport Research Knowledge Centre (2009)	EEA TERM Report (2015)
Dimensions of evaluation	Accidents	Accidents-hazards	–	–
	Air pollution	Air	Air pollution	Air pollution
	Noise	Noise	Noise and related vibration	Noise
	Climate change	–	Climate change	Greenhouse gas emissions
	Congestion	Traffic, residential areas, land use, city planning, cultural heritage, public appearance	Land take	Habitat fragmentation and biodiversity
	–	Landscape, soil, waters, ecosystem, natural resources	Resource use Water impacts	–

There is no absolute overlap regarding the assessed benefit categories, however, some similarities can be discovered. All the presented studies mention air pollution and noise as dimensions of evaluation, while most of them also consider the effects on climate change. The approach of spatial factors is different in the presented studies, some emphasizes changes in traffic, others point out social viewpoints like habitat fragmentation and cultural heritage. Biological aspects of resources and pollution also appears but with different emphasis. Two of the studies focus on traffic accidents and other related risks.

3.2. Modelling tools for transport policy assessment

3.2.1. Theoretical framework of transportation models

De Jong at al. (2004) gives a general overview about the existing freight transportation models. His paper is very relevant as it,

1) gives a general overview about existing transportation models;
2) categorizes the models based on several different frameworks;
3) presents a theoretical overview and a schematic model about the creation of a freight transportation model.

According to de Jong et al. (2004), freight transport models are generally originated from passenger transportation modelling. On the other hand, the creation of freight models is more challenging than passenger transportation because the availability of data is significantly more limited, there are more players on the market and there is a large variety of transported goods. On top of these differences however they argue, that freight transportation model logic is very similar to passenger transportation logic. This is the reason why many of the currently existing freight transportation models include a passenger transportation module as well. In this brief analysis however, we focus our attention toward the transportation of goods not people.

The most important determinant of a freight transportation model is its spatial coverage. de Jong et al. (2004) identifies three main types of models based on their spatial scope. There are models which cover a simple region or city, country level models and international models. As the Danube Region consist of several countries we will only consider those models which are international. This does not mean however that in these models it is not possible that basic spatial units are regions or sub-regions.

Four-step modelling structure

The more interesting aspect is related to the modelling procedure itself. de Jong et al. (2004) suggest that freight transportation models generally follow a four-step operating structure. Even this statement is dating back to 2004, the four-step modelling structure is still the dominant classification of transportation models, so we will use it as a starting framework for our own analysis. In this section we will present the four-step modelling framework based on the work of Jong et al (2004). The four steps are the following:

1) Production and attraction: Determines the quantities, that are to be transported from and to every trade zone, within the model.
2) Distribution: Determines the flows between the origin and destination places.
3) Modal split: Determines that on what modes the projected flows will occur.
4) Assignment: Flows are assigned to exact networks, lines.

Almost all the freight transportation model operates through the presented four steps. The only difference between them is the used modelling technic, within the different categories, and what are the geographical scale. For this reason, we will highlight the main model types in all four categories.

For production and attraction modelling four different categories can be defined:

1) Trend and time-series models
2) System dynamics models
3) Zonal trip rate models
4) Input-output related models

The authors highlights, that all four types operate with aggregated data. De Jong et al. (2013) updated their work in 2013, with the recent developments in freight transportation modelling. One of the most important update is that in the last couple of years several models were created that not operate with aggregate data, in production and attraction but rather consider more market participants and disaggregated data and actions.

Perhaps the simplest method is trend and time series modelling. This technic build on the collection of aggregated time-series data and extrapolate these values into the future. It is possible to make this extrapolation through raw growth rates but more complex time-series regression-based methods are also applicable.

System dynamic models operate with different sub-systems which model several segments of the economy, such as macro-economic growth, transportation, land use etc. The different sub-models are interlinked with each other, an output data of one acts as an input for another model. The different systems however are calibrated through exogenous parameters which are the results from other models or values from the relevant literature. Zonal trip rate models try to classify transportation and production based on

cross sectional data and create zone types from regions with similar characteristic. This model type is only applicable for high level analysis because of drastic aggregations.
The most complex methods are the so-called input-output models. This method requires a large amount of data for all relations. This method creates a detailed input-output matrix, which determines the amount of goods traded between the different sectors and regions of the modelled space. The future forecasts are based on these relation matrices.
The other important factor on top of production and attraction which determines trade flows is the cost of transportation. Related to distribution there are two main types of models.

1) Gravity models
2) Input-Output models

In gravity models generalized transportation costs are determined based on travel kilometres, transportation related fees etc. and these costs are considered in modelling when the destination of goods are determined. In input-output models however these relations are incorporated within the values of the input-output matrices, so no additional modelling for transportation costs are needed.
One of the most interesting question in transportation modelling, that what determines the selection of modes in transportation. For this reason, there are huge variety of methods from quite distant economic fields to model this selection. The main categories are the following:

1) Elasticity-based models
2) Aggregate modal split models
3) Neoclassical economic models
4) Econometric direct demand models
5) Disaggregate modal split models
6) Micro-simulation approach
7) Multi-modal network models

The simplest technic is to model modal split using elasticity parameters. These parameters show the substitution willingness of the system between different modes, if one key parameter (for example transportation price with the mode) changes. This method is not data intensive, but only applicable in general evaluations. The aggregate modal split models are very similar in logic but incorporate more variables that affect modal choice. This method tries to determine the share of the different transportation mods for the different regions with regression methods. Econometric direct demand models also use regression methods, but instead of the share of the different mods they try to estimate the absolute amount of transported goods for different vehicle types.

It is visible that related to modal split not only models with aggregated data exits but also models with disaggregated actors, such as neoclassical economic model, disaggregated modal split models or micro-simulation models. The neoclassical models use the theory of the firm as a starting point and derive individual demands based on pure microeconomic theory. Disaggregated modal split frameworks operating similarly to the aggregated ones by estimating modal choice based on regression analysis. However, in disaggregated models the estimation is conducted on firm level, based on mostly survey data. Finally, micro-simulation models operating with quite different methodology as they are agent-based models, where the actors are assigned with different parameters and mode selection is determined through simulation. In their updated evaluation, de Jong et al. (2013) stated that between 2000s and 2010s the number of those models increased which operates with disaggregated data, as modelling of the modal choice gained a huge attention, and estimation methods become more complex in the field.

The most complex models of mode selection are multi-modal network models. In this framework modal split and the exact route on which the good will be delivered are modelled at least partly simultaneously. The number of these type of models are relatively few currently, but multi-model network modelling is gaining momentum (Huber, 2017). This type of models are very data and computation time intensive, as a huge amount of route-mode combinations have to be considered.

Finally, based on assignment models can be categorized in two types. This is the final step of the four-step modelling procedure, when the exact routes are determined where the goods will be transported. The two methods are:

1) Models with separate assignment stage
2) Multi-modal network

In the former type of assignment, after the optimization is completed for the former three steps, so the origin, the mode and the destination are decided, a separate assignment module select the exact transportation routes. As we highlighted earlier in multi-modal networks mode-selection and assignment is not easily separable, but in some cases, it is possible to make this distinction.

In Table 1 we summarize all the presented categories in the four-step freight transportation modelling framework, and the different types of modelling technics identified by de Jong et al. (2004).

Table 2: Summary of the four-step transportation modelling framework

Production and attraction	Trend and time series models
	System dynamics models
	Zonal trip rate models
Distribution	Input-Output models
	Gravity models
Modal split	Elasticity based models
	Aggregate modal split models
	Neoclassical economic models
	Econometric direct demand models
	Disaggregate modal split models
	Micro-simulation models
Assignment	Multi-modal networks
	Models with separate assignment stage

Source: de Jong (2004) et al.

Modelling spatial and socio-economic impacts of transportation

A different type of categorization was introduced by Tavasszy et al. (2004). They state that the four-step transportation model is generally applicable to ceteris paribus analysis related to the transportation network. On the other hand, there are models that are not solely focusing on outcomes related to transportation but other socioeconomical factors as well. So, they supplemented the four-step models with additional model types that focus on the spatial and socioeconomic impacts of transportation.

The additional types of model frameworks are the following. The categorization and their description are completely based on Tavasszy et al. (2004).

1) National and regional growth approach
2) Production function approach
3) Accessibility approach
4) Regional input-output approach
5) Trade integration approach

National and regional growth models based on the neoclassical macroeconomic models, which relates growth to capital stock. In these models, transportation infrastructure act as a special type of capital stock. In this sense, investment in transportation infrastructure in regions with lower GDP level can enhance convergence as the source of differences in wealth lies in the uneven distribution of capital, in this case transportation infrastructure. It is visible that in these models, macro-economic performance and transportation sector are the two fields that are closely interlinked.

Production function approach is also closely linked to neoclassical economic theory. In the traditional production function output generated from land, labour and capital. This framework is extended with transportation infrastructure as an additional factor. This model framework can include a wide variety of fields (eg. labour market).

The accessibility approach is based on the idea that regions with access to better infrastructure have higher potential to become economically more developed. For this reason, in this modelling framework accessibility links are determined based on transportation characteristics which are directly linked to other socioeconomic field such as labour market or population.

The input-output approach follows the same modelling logic that was presented in the four-step modelling framework by de Jong et al. (2004). The only difference in this case is whether other socioeconomic factors are considered in the analysis or not.

Finally, in the trade integration approach, production and consumption of goods is modelled for all regions. It is possible however for regions to trade with each other. The magnitude of traded goods is calculated based on the market prices of the goods on the different markets and transportation possibilities. So, these models are equilibrium models where equilibrium is heavily affected by transportation possibilities, for example available infrastructure.

3.2.2. Summary of the existing freight transportation models

After introducing the theoretical framework, we briefly summarize the current European international freight transport models. We have made three different types of categories. The first category consists some models that are trying to provide a detailed representation of good's flow. The second category account for the solely impact assessment models, while in the third category we introduce models in which transportation is heavily interlinked with socioeconomic factors through the model outcomes. We made this categorization because we think that modelling methods are quite different depending on which goal the given model tries to achieve. On top of the models discussed in more detail, several other international fright models exist however the detailed presentation of all existing models was not our goal in this study. For more information about other national and international level freight models see de Jong et al. (2004), de Jong et al. (2013) and Tavasszy et al. (2004).

Flow representation models

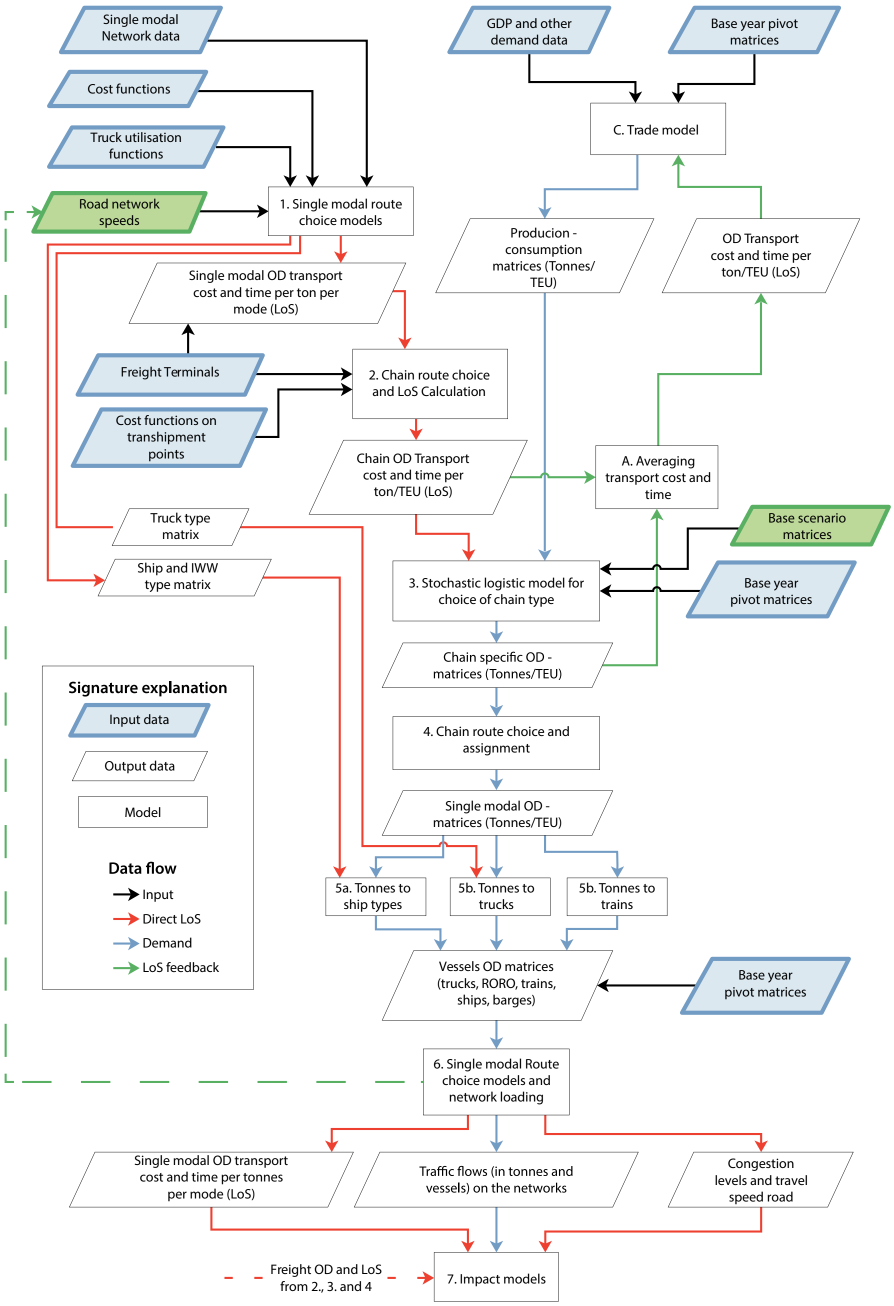
The European Commission coordinates the development of a complex freight and passenger transportation model called TRANSTOOLS. The model has three consecutive versions. TRANSTOOLS was finalized in 2008 (Burgess et al. 2008), however for the Ten-Connect study, the European Commission have requested to improve the model, which resulted in the completion of TRANSTOOLS2 in 2009 (Petersen et al. 2009). In the 2010s the development of the TRANSTOOLS3 model has started. According to the project webpage and project reports, TRANSTOOLS3 model development is in its final phase (Transportmodel.eu, 2018). The model itself is already created and filled with data, but the developers are still validating the model results, to make the framework more robust. As the final report of the model structure has been already delivered, we decided to present a short summary about the Transtool3 modelling framework.

The general goal of TRANSTOOLS models are to represent the freight and passenger transportation within and in close relation to European Union countries. So, the model tries to identify and generalize supply and demand factors that affect transportation flows, so its final output are general trade patterns. The aim of the Transtool3 project are formulated as follows (Transportmodel.eu, 2018).

- Analyses of EU-wide transport policies.
- Analyses of TEN-projects.
- Detailed EU-wide sector analyses including freight, passenger transport and specific modes.
- Links to interregional and national project appraisals and use within the member states.

The operation framework of TRANSTOOLS3 freight model is described in detail in the final report of the freight model framework (de Jong et al., 2016). A summary about the model operation is presented in below. The freight transportation model consists of three important sub-models; however, the complete structure of the model system is shown in Figure 22.

Figure 22: The operation framework of TRANSTOOLS3



Source: de Jong et al. (2016)

The four-step modelling framework is applicable related to Transtool3, as production, distribution, modal split and assignment are all relevant part of the modelling and can be assigned to the main sub-models:

- Trade model: Accounts for production and distribution
- Chain level of service model: Accounts for modal split
- Logistic model: Accounts for modal split and assignment

The trade model is based on historical origin-destination data, between different NUTS3 zones. Supply and demand of the different regions are determined based on GDP data. Trade relations are modelled with a set of gravity models, so the main determinant of distribution is the distance between the regions and their corresponding GDP. The trade model calculates the relations with random effect panel econometric models. In the specifications some additional factors were defined that can influence the destination of trade such as EU membership, common or similar language, or Euro as currency. The effects of these variables are also determined with panel regressions. De de Jong et al. (2016) are also investigate several other estimation methods for the trade model such as fixed effect model, Heckman-selection model, but as they were generally interested in the effect of GDP a random effect model seemed the most suitable estimated method, because of the restrictions imposed in fixed effect type regressions. So, the trade model gives an estimation about the sensitivity of trade patterns with respect to the above-mentioned variables.

The chain service model and the logistic models (also referred as transport chain choice model) are closely interlinked as they both account for the modal selection. The difference is that while chain level of service model determines the optimal mode choices, and defines paths based on different combination of transportation modes, the logistic model assigns these choices of modes to exact routes. The role of chain service model is to define freight transportation chains and based on general and country specific unit cost calculates determine the cost of using a specific transportation chain on a case by case basis. It is visible form this fact that TRANSTOOLS3 is not a unimodal model, so during a travel it is possible that the transportation mode of the good changes. These type of transportation models are very rare. According to the analysis of Huber (2017) out of 125 investigated transport frameworks only 17 operates directly with chain service modelling[8]. When the cost is determined the route, selection is made by the logistic module which calculate the probability of selecting a chain and the corresponding route based on parameters estimated from logistic regressions.

[8] Not only international models were considered.

In order to use TRANSTOOLS for policy analysis it is needed to define additional scenarios on top of the base case scenario. Policy analysis can be done by comparing the results of the base and alternative case scenarios. The exact effects are measured by the impact models within TRANSTOOLS, which are the environmental model and the transport impact model. These models consider externalities such as CO_2 emission and accidents.
A similar type of model is the SCENES, which is the extension of the STREAMS model with Eastern Europeans countries. For this reason, in the is literature review we will only describe SCENES as it is really similar to STREAMS. SCENES is a very detailed multiregional input-output model (ME&P et al., 2002). The model is classical four-stage transportation model described by de Jong et al. (2004). The regions of the model are based on NUTS2 regions.
The freight model consists of three different sub-models: The regional economic module, which creates trade matrixes in monetary terms between the regions, the interface module which converts these monetary linkages into origin destination matrixes, and a transportation module which is responsible for the modal split and route assignment (ME&P et al., 2002). The regional economic model determines freight demand for each region for each product based on inter-industry technical coefficient, domestic production, public consumption and investment, private consumption and export-import values from third countries. The regional economic model operates with 23 categories of goods which are aggregated into 13 wider categories for the transportation model (ME&P et al., 2002).
The transportation module generates transportation costs, which will determine the modal split and the exact route assignment. SCENES is very detailed in transportation flow modelling as well as ten main modes and nine additional intra-zonal travel modes are possible to select for travel. Modal split is determined by multinomial nested logit models. (ME&P et al., 2002).
It is visible from the description that SCENES is similar to Transtool in many senses. The aim of SCENES model is to give an as detailed representation of the transportation flows as possible. It is possible to model policy changes with SCENES similarly to TRANSTOOLS, by changing the input parameters of the model and comparing the base case scenario result, with the new scenario with the changed parameters. But the model is generally centered around the representation of transportation flows and not directly around policy impact assessment. Of course, there are several differences

identifiable between SCENES and TRANSTOOLS. To give some example SCENES only operate with NUTS2 regions, it does not model chain service but operates with more modes, than TRANSTOOLS, and there are differences in the econometric estimation of the two models as well.

Impact assessment models

ASTRA is a system dynamics model, which means that models representing the different parts of the economy are continuously interacting and giving feedbacks to each other. These different sub-models however are not endogenously interlinked. The outputs of one sub-model serve as an input for another sub-model, but on top of that there is no direct connection between the different parts of a system dynamic model. These means that to find a solution, the model uses complex iteration procedures and often uses exogenous values from the literature or other more complex models (such as STREAMS) as inputs and as model validation. These simplifications allow a dynamic interaction between the sub-models of ASTRA but keeps the model system relatively simple. (IWW et al., 2000)

The ASTRA model consists of four different modules which are (IWW et al., 2000):

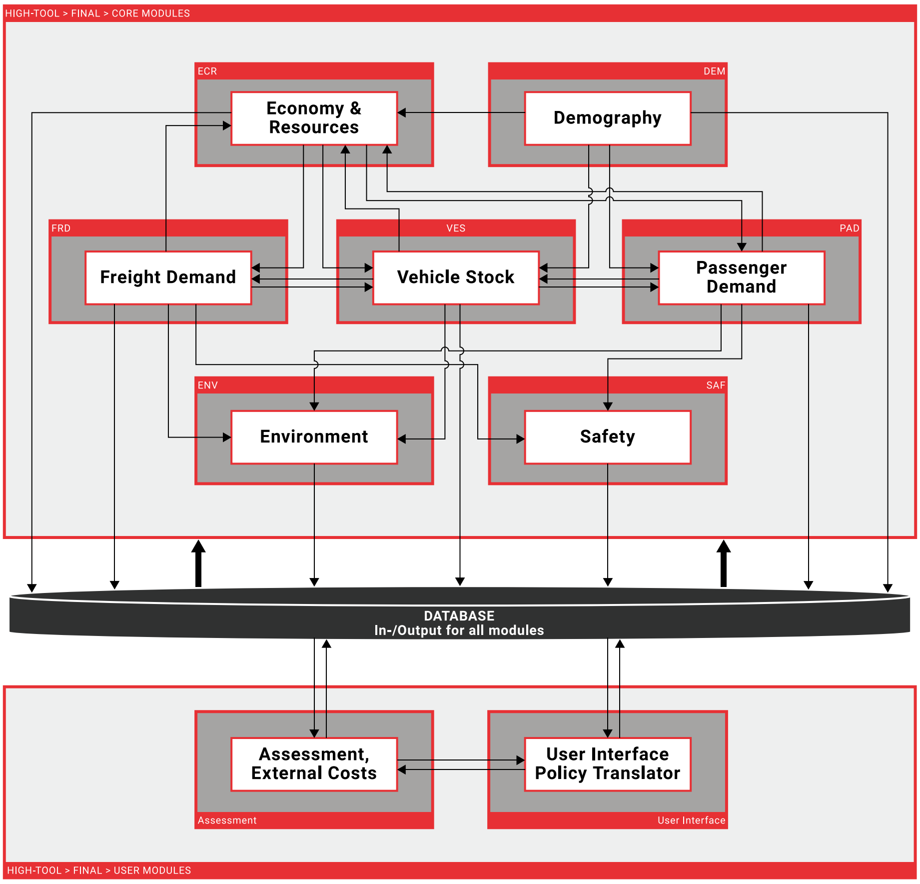
1) Macroeconomic sub-model
2) Regional Economics and Land-use sub-model
3) Transportation sub-model
4) Environment sub-model

The final report about the ASTRA model (IWW et al., 2000) highlights that the model can be generally used for impact assessment, by calculating the effect of a policy change on all sub-systems of the model. In this sense ASTRA's model outcome is little bit different than TRANSTOOLS' as ASTRA model does not operate with detailed regional or travel route representation, so it is not possible to estimate detailed transportation flows with the model. ASTRA in this sense operates as a high-level cost-benefit analysis model, as it does not model the relations of interest in high detail but makes rough assessment about a large scale of sectors. This conclusion is strengthened by the fact that ASTRA operates based on large macro regions which consist of more countries with similar model characteristics (Region I: Germany, Austria; Region II: France, Belgium, Luxemburg, the Netherlands; Region III: Italy, Spain, Greece, Portugal; Region IV: Great Britain, Ireland, Sweden, Denmark, Finland; Region V: Rest of the world) which does not enable

detailed modelling (IWW et al., 2000). Freight transportation demand for example is determined in ASTRA on this macro regional level.
ASTRA model was extended to ASTRA-EC model in 2014 (Fermi et al. 2014). The general framework of ASTRA remained the same, but the model became more detailed. The model was extended to include 29 countries[9], additional influencing factors were implemented such as the effect of oil-price or renewable policies, and macro regional level analysis for freight transportation was replaced with country level analysis (Astra-model.eu, 2018). The main modules of ASTRA-EC are similar to the original ASTRA but within a module the sub-module system become significantly wider, and accounts for wide variety of socioeconomic fields. ASTRA EC model is able to monetise externalities in the transportation sector as it accounts for CO_2, NO_x, VOC, $PM_{2.5}$ emissions and accidents according to their seriousness.
The development of ASTRA is currently underway according to the project's web page. Current development tries to integrate ASTRA with the TRUST network model (Astra-model.eu, 2018).
A similar type of framework is the so-called HIGH-TOOL model (Szimba et al., 2016). The model is a high-level policy analysis tool related to passenger and freight transportation. The framework includes a large number of countries; however, the EU member states have a detailed NUTS2 representation while other countries are included only at NUTS0 level. The aim of the model is to assess the economic, environmental and sociological aspect of different transportation policies. Figure 23 summarize the general operation framework of HIGH-TOOL.

[9] European Union countries without Croatia and with the inclusion of Norway and Switzerland.

Figure 23: The structure of HIGH-TOOL model



Source: Szimba et al. (2016)

The model consists of seven different operation modules. The demography module estimates regional population and labour force, the economy and resources module estimates the most important macroeconomic indicators such as GDP or capital stock. Three modules (the freight demand, the vehicle and the passenger demand) are responsible for the representation of the transportation sector. The environment and safety models generate indicators which help in the assessment of external cost, which is the main goal of the HIGH-TOOL model. The environmental module mainly considers CO_2, CO, VOC, NO_X and SO_2 emissions, while the safety module the number of fatalities and injuries.

The passenger transportation model follows the classical four-step transportation model framework described by de Jong et al. (2004). As HIGH-TOOL is a high-level policy analysis tool the framework the four-step framework is altered. The freight transportation module consists of four sub-modules:

1) Trade-conversion
2) Route choice
3) Modal split
4) Conversion

The optimization process includes 61 different road and 12 different non-road vehicles. The first three sub-modules are the equivalent of the generation, distribution and modal split parts of the four-step modelling framework. On the other hand, however as HIGH-TOOL is not interested in exact detailed flows, there is no assignment phase of the modelling. This is replaced with a Conversion sub-module which calculates transportation indicators such as tonne-kilometres or vehicle-kilometres.

It is visible that ASTRA and HIGH-TOOL models are very different in many senses from TRANSTOOLS. Although all the models are generally focusing on transportation modelling, ASTRA and HIGH-TOOL considers a wider range of factors such as land use, environmental impacts or safety. With ASTRA and HIGH-TOOL it is not possible to model exact transportation flows, but aggregation allows the model framework to cover sector which would make a model like TRANSTOOLS very complicated.

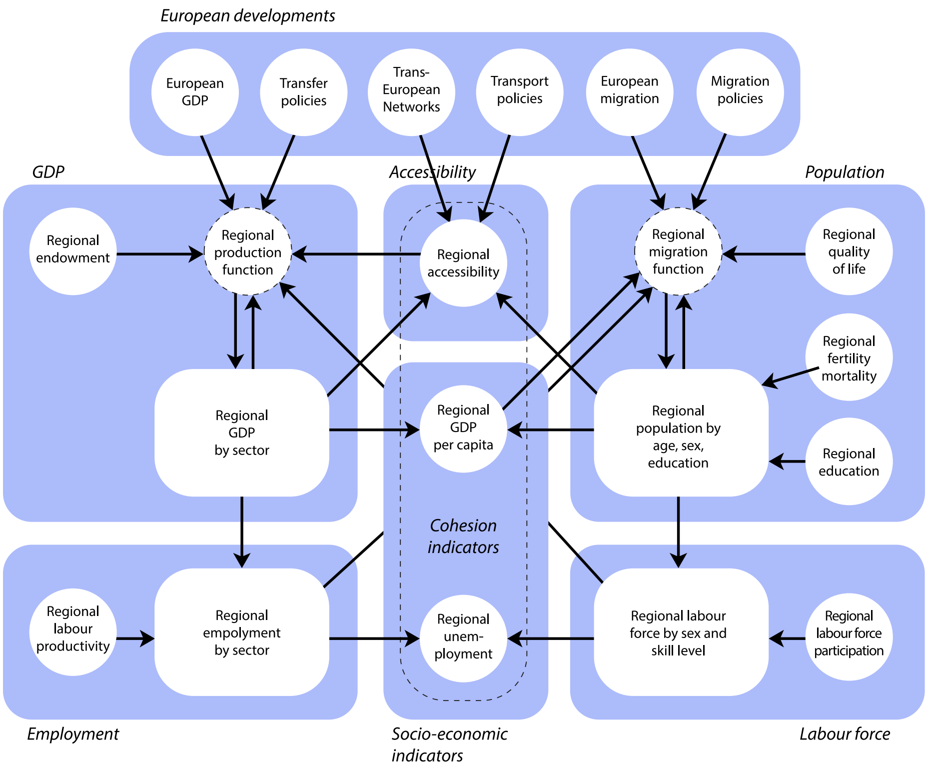
As both HIGH-TOOL and ASTRA models are high level policy analysis tools, they evaluate world states through performance indicators, which are the outcomes of the modelling. This means that there is not a single monetized welfare value is calculated, but the effect of the policy is measured through several different indexes. Both models have large number of pre-defined policy options to evaluate such as the implementation of CO_2 certificate system for road transport or the accelerated implementation of TEN-T projects.

Multidimensional models

In ASTRA other dimensions such as environmental impact was considered in the modelling, but these fields are directly related to freight transportations. There are other models, however where transportation relates to other fields indirectly, and the estimation framework tries to capture this indirect link. One such model is the so called SASI model. Based on the categorization of Tavasszy et al. (2004) the model follows the accessibility transportation modelling approach. The original SASI model was developed by ME&P (2001) but updated by Tavasszy et al. (2004). In this report we will analyse the updated SASI model. The main aim of the SASI model to analyses the transport accessibility level of the different regions, by passenger and freight transportation. The model has a much wider scope as two other main outputs are present. In addition to regional accessibility important outcome factors are regional level GDP/capita, and unemployment levels as well (Tavasszy et al., 2004). With these set of outcome variables SASI model creates a linkage between transportation economics and socioeconomic factors in a bidirectional sense.

The model consists of six sub-models which are: European development, Regional Accessibility, Regional GDP, Regional Employment, Regional Population and Regional Labor force and Socio-Economic indicators calculation (Tavasszy et al., 2004). The detailed operation of model is presented in Figure 24.

Figure 24: The operation framework of SASI model



source: Tavasszy et al. (2004)

The interactions between the sub-models occurs through lagged variables and time-series modelling (Tavasszy et. al, 2004). This means that no iteration occurs, so the model is not endogenous in one time-period (defined as one year) only dynamically. For example, that GDP as output in a given year does not affect the same year results but serves as an input for the next year modelling. Regional accessibility is modelled through travel time and travel related costs.

Another model which on top of freight transportation modelling accounts for additional socio-economic factors is the CGEurope. The model was originally developed by Bröcker (1998) but was updated similarly to SASI by Tavasszy et al. (2004). CGEurope is step-forward in this multi-dimensional analysis as in this model, transportation is modelled but the main outcome variable is the welfare of the households and firms in the region. The model is based on microeconomic principles as it is a general equilibrium system with monopolistic competition. In CGEurope transportation is more like a main component of welfare, but not the exact aim of the modelling. In this sense CGEurope follows a trade-integration approach based on Tavasszy et al. (2004). The most recent model which applies trade integration approach is the so called RHOMOLO model, which is a more detailed general equilibrium model (Lecca et al. 2018).

3.2.3.Conclusions from existing transportation models and suggestions for future modelling

In this section we summarize the important findings relating to the existing transportation models and drew some conclusions relating the planned evaluation framework of the Danube Region freight transportation analysis.

Related to the existing transportation models it is important to highlight an important finding which is a fundamental element for future modelling. All the models that we have presented are consist of several sub-models. This structure is independent from the fact whether we consider a very detailed input-output model or a more general tool which is used for impact assessment. In our view, the complex systems capture the most important aspect in which transportation modelling is different from other energy market modelling. Transportation models are very complex by nature as they include several factors that are difficult to incorporate in a single model. That is why every researcher modelled these diverse effects with different sub-models and that is why a creation of a new transportation model is a very challenging task.

In the previous section we categorized the existing transportation models into three groups based on their purpose. An important finding is that data intensive estimation technics were generally present in those case when the model estimates the exact transportation flows. It is possible to make policy evaluations with this type of models, however we showed that the detailed representation of flows is not necessary for higher level policy analysis.

De Jong et al. (2004) made a similar conclusion when he stated that an optimal policy evaluation set for a country's transportation sector should consist of two main models. First, they need a fast policy analysis model to evaluate important policy changes, or broadly calculate the welfare effect of a completion of new road or railway. On top of that a detailed forecasting model is also needed to complete in depth transportation analysis. We think that this statement can be generalized for international transportation models as well.

In the framework presented by de Jong et al. (2004), the model for in depth analysis are the ones that tries to determine the exact transportation flows such as TRANSTOOLS. We think it is not necessary to develop a model with detailed transportation flow representation for two reasons. First, it would need high effort from the developers to outperform the existing transportation models. Second, these models are very data intensive, so it is not enough to develop a model, but it is also necessary to develop a corresponding dataset that can serve as an input for the modelling. These models take several years and a lot of financial resources to develop. In our view, for detailed transportation analysis, it would be a wiser solution to use or upgrade existing models for the Danube Region countries, but for high level policy analysis these models are unnecessarily detailed.

The other situation when we identified the role of modelling as a very important tool was the cases when not transportation sector itself, but other sections of the economy were presented simultaneously in multidimensional models such as in SASI. We think it can be beneficial to include several socioeconomic outcomes into a model framework, but we also think these are not necessary components of transportation policy evaluation, it serves more like an extra, a future extension of the protentional evaluation framework.

Relating to pure impact assessment the optimal tool is not as trivial to decide. There are several cases when cost-benefit analysis is a result of indicator calculations and transformations, but the ASTRA or the HIGH-TOOL model are good examples when impact assessment is carried out through modelling. With the categorization of de Jong et al. (2004) we think a model like the above mentioned to can generally serve as a high-level policy analysis model for the Danube Region.

Although these high-level policy analysis models are simpler than those models which tries to capture the exact transportation flows on the network, these models steel require abundant resources to develop. We suggest that instead of developing a completely new freight transportation model a currently existing policy analysis tool such as ASTRA-EC or HIGH-TOOLS should be extended further to model the transportation sector in the Danube Region.

According to our view there are several important factors that need to be upgraded so they can become applicable model for the Danube Region. First and foremost, both ASTRA-EC and HIGH-TOOLS model generally covers the EU member states countries in great spatial detail. It would be important to widen the scope of these models and include the relevant data for those countries, which are not part of the European Union but located in the Danube Region. Additionally, in those models generally travel related accidents and CO_2 and pollutant emissions are being considered as externalities. On the other hand, as external cost guide of the European Union (Ricardo-AEA, 2014) highlights, there are many other sources of externalities that emerge related to transportation such as noise pollution or the additional effects of congestion. We think that the inclusion of these factors would be important step to give a good estimation about the transportation policies affecting the Danube Region.

To conclude in this section, we presented the most important existing transportation models in Europe and formulated some suggestions relating to a future transportation model for the Danube Region. We categorized the existing transportation models into three groups. Although all presented models, tools were created in order to assess policies, we identified models which operate with very detailed transportation representation, models with the aim of high-level policy assessment and models which integrates transportation sector with a greater extent into a socioeconomic environment. We concluded that for the Danube Region on the long run the implementation of high-level policy analysis tool would be the most beneficiary. We think the creation of a new transportation model is not necessary, but it can be a possible future goal to extend an existing high-level policy analysis model for the Danube Region countries. On the other hand, significant further work is needed to implement such model.

4.ILLUSTRATIVE ASSESSMENTS FOR THE DANUBE REGION

We present an illustrative assessment for the external benefits of the two displayed policy approaches. LNG scenario assumes the uptake of LNG trucks, while 'From road to rail' scenario speculates a considerable modal shift towards rail transportation. The assessment addresses only the last step of a policy evaluation: the quantification and monetisation of the welfare effects of a given change on the market (such as fuel or modal shift), regardless of the concrete policy action that achieved the change. The calculation is carried out to demonstrate the main steps and challenges of such estimation, as well as to illustrate the main environmental related benefit categories and the differences between them in case of road (diesel and LNG) and rail transportation. In case of LNG scenario, an NPV calculation is also presented to compare the estimated external benefits with the estimated investment costs related to filling infrastructure. As the assessment serves primary demonstrative purposes, the results must be treated with caution.

We emphasize that we consider the analysed scenarios as complementaries and not substitutes, since they can be achieved parallelly, targeting different segments of road transportation (with different ability to switch to rail).

4.1. Short description of the assessed scenarios

The two assessed scenarios are probably the most-discussed ones in connection with "greening the transport sector" in the last couple of years.

The first scenario is the switch from conventional trucks to LNG-trucks. This is monetized for three different penetration sub-scenarios, from 2020 to 2045. The values are compared in case of EURO VI diesel trucks and EURO VI LNG trucks, assuming LNG trucks would not replace existing diesel trucks, but rather LNG fuelled trucks would come online instead of new diesel trucks in the future. Benefit changes are estimated for emission related categories, no noise, accident and congestion related welfare gains are considered.

The second scenario estimates the effect of a modal shift from road to rail. It is assumed that for every truck that is taken off from the roads (assuming these are EURO V diesel trucks on average) its transported freight volume would be put to rail. In this scenario the electrification rate of the analysed rail route is taken into account for all five countries separately. Benefits are estimated for emission, noise, congestion and accident related effects.

We analysed the scenarios on one specific route, the part of the Orient/East-Med TEN-T Corridor that is located in the Danube Region: from Kulata (Bulgaria-Greece border) to Děčín (Czech Republic-Germany border). Thus, five countries are included in the calculation: Bulgaria, Romania, Hungary, Slovakia and the Czech Republic. We note, that a partial alternative of this transit route goes through Serbia instead of Romania, however, as Serbia is not EU-member, the TEN-T corridors steer clear of the country, and therefore data availability is constrained.

4.2. Applied methodology

In this assessment the environment related avoided external costs are estimated along five plus one categories:

- Congestion
- Accidents
- Air pollution (local emission)
- Noise
- Climate Change (local emission)
- Well to tank air pollution and climate change (WTT)

Congestion related costs are not closely environment related, as usually are calculated as the value of "wasted time". However, congestion itself implies further damage to environment (through higher emission and noise), that is not always included completely in the related categories. Also, it is typical to include this category in external cost calculations (see Chapter 3), thus, we also included congestion costs in our calculation.

In case of climate change and air pollution the costs are calculated for two categories: emission connected to operation (local emission) is calculated separately from the "indirect" or non-local emission, that is the total emission related to the production of energy/fuel being used by the vehicles.

The main inputs for our calculation are the following:

- Length of the route in all five countries separately (for railway and roads, in km)
- Number of shipments (by truck) per year along the corridor by country[10]
- Electrification rate of the analysed railway sections
- Average payload weight of one vehicle (truck and train, in tons)

[10] Estimated based on the numbers in iC consulenten et al. (2014)

- Unit costs of external damage for all above mentioned categories (in €ct/vehicle-km)
- Investment costs of building up the LNG infrastructure[11]

Unit costs are primary taken from the study of Ricardo-AEA et al. (2014), where in most cases marginal unit costs of the above presented categories are monetized for road and rail transportation separately. Where data is available country specific values are used, otherwise EU average values are taken into account. In most of the cases marginal unit cost values are included, the only exception is accident cost for freight rail transport, where only average unit cost values are available[12].

For the LNG scenario, based on Somogyi et al. (2016), the (local) air pollution (PM, VOC, NO_x) and (local) climate change (CO_2, CH_4) related emissions of LNG (EURO VI) and diesel (EURO VI) trucks are compared. From this calculation, as a best estimate, the marginal costs of LNG trucks are calculated from the marginal costs of diesel trucks (in Ricardo AEA et al., 2014) proportionately to their emissions. For total well-to-tank emissions the values from the International LNG procurement scenario (from Somogyi et al., 2016) are applied.

To arrive to the total avoided external costs, unit costs are simply multiplied by the given kilometres and the number of shipments for all vehicle types. Then, according to the given policy scenario, external benefit differences between reference and policy cases are calculated (e.g. external benefit for LNG scenario is the difference between the total external costs of transporting all goods with diesel trucks and the total external costs of transporting one part with LNG trucks and the remaining part with diesel trucks).

For the LNG scenario a net present value (NPV) calculation is carried out. Penetration of LNG trucks is defined for three scenarios (low, medium, high), considering 5%, 20% and 40% switching rate by 2030[13], with a linear uptake from 0 in 2020, continuing until 2045. Investment is considered in the first year (2020), later on no other costs are considered. As a typical approach, 4% social discount rate is considered. Future changes in total shipment volumes are estimated from GDP forecasts.

The number of LNG stations are calculated in two ways. A minimum number of necessary station is determined based on the "DAFI" Directive ("Deployment of alternative fuels infrastructure") (EC, 2013), which states that an LNG station is needed in at least every 400 km of the corridor. Taking into account the station that are already existing or currently under development, four new stations have to be built along the road (one in Bulgaria, two in Romania, and one in Slovakia or Czech Republic). However, a 20-40%

[11] Estimation from Alexander Gabl (2017) and Századvég (2017)

[12] For Bulgaria, Hungary, Slovakia and the Czech Republic the analysed route is fully electrified, for Romania the rate of electrification is 75% (iC consulenten et al., 2014)

[13] We set the penetration rates considering the values used in Somogyi et al. (2016), but modified the medium value from 30% to 20%.

penetration of LNG trucks obviously requires a much higher station density. Average vehicle-km/station values for 2030 from Somogyi el al. (2016) are used to estimate the number of stations, which led to need of 19 new station along the way in the 20% penetration rate scenario.

Due to lack of data several simplifications are applied:

- In the LNG scenario where data is available 40t (max gross weight) and EURO VI category diesel truck values are taken into account from Ricardo-AEA et al. (2014) data, representing an "average truck" to be put on roads, instead of which LNG trucks will be procured. For well-to-tank and local emission related climate change costs only EURO V values are available for diesel trucks, thus that data is used instead.
- In the From road to rail switch scenario it is assumed that putting freight to rail from road would lead to the withdrawal of the average trucks, thus EURO V diesel truck related external cost values are compared to rail related costs.
- No differentiation is made between road categories simple average is used for values of all categories[14].
- For noise, simple average of day and night cost values and simple average of dense and thin traffic type values are used.
- EU average values are used in case of rail congestion and rail accident costs, and for the unit costs of climate change in case of both road and rail, as only EU average is available in Ricardo-AEA et al. (2014)
- One average freight value is assumed for trucks and one for trains. For calculating the road-rail switch the rate of these two values are applied.
- As a prudent approach, in case of congestion values for trucks the lowest available values are taken into account ("free flow", instead of "near capacity" and "over capacity").
- The number of total yearly shipments is calculated based on the transported volumes on the OEM corridor reported by iC consulenten et al. (2014). Only internationally transported volumes are taken into account (crosses at least one border), and divided by the average payload of trucks (13t[15]). As data is only available for 2010, these shipment values are multiplied by the growth rate in international road transportation (Eurostat, 2018) in the respective country from 2010 to 2017.

In case of the NPV calculation the same year-on-year growth rate is assumed for the benefits as for the GDP[16], considering a linear connection between transportation volumes and GDP growth in each country. It is important to note that the assessment only

[14] The road categories are: urban, suburban, interurban, motorway. In case of climate change costs for roads, average was indicated for this category, therefore it was used instead of simple average of the values.

[15] According to NTM (n.d.) the load capacity of a 34-40t (max. gross weight) truck is 26t, and 50% capacity utilisation can be considered. iC consulenten et al. (2014) reports transported volumes and number of trucks in certain sections of the OEM corridor, which suggests the same 13t/truck value.

[16] Taken from the European Commission's EU Reference Scenario, 2016, PRIMES modelling (E3M-Lab et al., 2016)

includes the cost of policy implementation for the LNG scenario, and not for the From road to rail scenario. This could be an important further development of this illustrative estimation, to see how costs relate to benefits in case of the other scenario as well.

4.3. Results

4.3.1. Main results

The main results of the calculations are presented in the following tables:

Table 3: Results of the illustrative assessment, LNG scenario (medium, 20% switch, 2030)

LNG scenario	**External yearly benefits of the policy (avoided costs) €(2018) - values for 2030**					
Benefit categories	Bulgaria	Romania	Hungary	Slovakia	Czech Republic	**Sum**
Congestion	0	0	0	0	0	**0**
Accidents	0	0	0	0	0	**0**
Air pollution (local emis-sion)	196 509	412 484	653 872	244 520	382 493	**1 889 878**
Noise	0	0	0	0	0	**0**
Climate change (local emission)	165 693	245 852	443 511	153 414	295 375	**1 303 845**
Well-to-tank air pollution + climate change	483 007	714 688	1 290 746	446 180	860 480	**3 795 102**
Sum	**845 209**	**1 373 024**	**2 388 129**	**844 114**	**1 538 348**	**6 988 825**

Source: REKK calculation, primary based on Ricardo-AEA et al. (2014)

Table 4: Results of the illustrative assessment, From road to rail scenario (10% switch, 2030)

From road to rail	**External yearly benefits of the policy (avoided costs) €(2018)**					
Benefit categories	Bulgaria	Romania	Hungary	Slovakia	Czech Republic	**Sum**
Congestion	80 704	131 905	380 982	157 943	314 195	**1 065 729**
Accidents	71 687	643 798	804 716	465 029	164 344	**2 149 575**
Air pollution (local emission)	471 130	347 149	1 756 662	692 817	876 293	**4 144 050**
Noise	246 355	391 122	1 018 519	414 748	801 076	**2 871 820**
Climate change (local emission)	850 831	1 107 900	2 277 423	787 778	1 516 746	**6 540 679**
Well-to-tank air pollution + climate change	-264 506	-546 637	-423 848	-59 219	-447 086	**-1 741 297**
Sum	**1 456 202**	**2 075 236**	**5 814 454**	**2 459 096**	**3 225 568**	**15 030 556**

Source: REKK calculation, primary based on Ricardo-AEA et al. (2014)

As it is visible, not only the sum but the individual benefit (avoided cost) values of almost all considered categories are positive. The only exception is the well-to-tank total air pollution and climate change cost in case of road-rail switch. This means that the results of both scenarios confirm the positive welfare effects of the observed policy measures in almost all analysed environmental categories. However, in case of From road to rail scenario (strictly speaking of switching EURO V trucks to rail) there is a trade-off between local and WTT effects, meaning less emission, congestion, accidents and noise would go with somewhat more emission on the upstream level.

4.3.2. Sensitivity results

We also calculated three sensitivity scenarios reflecting on the potential progress in use of sustainable energy. Regarding LNG scenario, sensitivity scenario was carried out to see whether "locally produced biogas"-based LNG (liquified biogas, LBG) would increase benefits compared to internationally procured and transported LNG. To estimate the benefits of this sensitivity case the values of Local deponiagas scenario (from Somogyi et al., 2016) were used to calculate WTT values[17], while IEA/OECD (2013) values were applied for local green-house-gas emission related cost estimation. In the literature local air pollution related benefits are rarely mentioned and quantified in case of LBG, thus we assume the same values as in case of conventional LNG.

Table 5: Sensitivity results of the of the illustrative assessment, LNG scenario, Local biogas (LBG)

LNG scenario: Local biogas	**External yearly benefits of the policy (avoided costs) €(2018)**					
Benefit categories	Bulgaria	Romania	Hungary	Slovakia	Czech Republic	**Sum**
Congestion	0	0	0	0	0	**0**
Accidents	0	0	0	0	0	**0**
Air pollution (local emission)	196 509	412 484	653 872	244 520	382 493	**1 889 878**
Noise	0	0	0	0	0	**0**
Climate change (local emission)	850 831	1 262 449	2 277 423	787 778	1 516 746	**6 695 228**
Well-to-tank air pollution + climate change	570 102	844 597	1 524 597	527 173	1 015 932	**4 482 401**
Sum	**1 617 442**	**2 519 530**	**4 455 892**	**1 559 471**	**2 915 171**	**13 067 508**

Source: REKK calculation, primary based on Ricardo-AEA et al. (2014)

[17] These values are estimations for Hungary but were used for all analysed countries due to lack of other data.

Using local biogas to fuel LNG trucks would lead to a very significant, 87% benefit increase if we consider 2030 values compared to LNG usage from international natural gas sources, that mostly comes from climate change related external benefits.
As future developments are probable in case of rail electrification (in Romania) and greening electricity production throughout Europe in the coming years, two sensitivity analyses are carried out for the From road to rail scenario. The first assumes 100% electrification of rails (included in the analysed route) in Romania, the second calculates with a greener European electricity production mix than the one as of 2017 (used in base case), thus -50% CO_2 intensity and -50% air pollution values are considered. The results are indicated in the following tables.

Table 6: Sensitivity results of the illustrative assessment, From road to rail scenario, RO 100% electrification

From road to rail: RO 100% electrification	**External yearly benefits of the policy (avoided costs) €(2018)**					
Benefit categories	Bulgaria	Romania	Hungary	Slovakia	Czech Republic	**Sum**
Congestion	80 704	131 905	380 982	157 943	314 195	**1 065 729**
Accidents	71 687	643 798	804 716	465 029	164 344	**2 149 575**
Air pollution (local emission)	471 130	1 051 494	1 756 662	692 817	876 293	**4 848 396**
Noise	246 355	391 122	1 018 519	414 748	801 076	**2 871 820**
Climate change (local emission)	850 831	1 262 449	2 277 423	787 778	1 516 746	**6 695 228**
Well-to-tank air pollution + climate change	-264 506	-377 784	-423 848	-59 219	-447 086	**-1 572 444**
Sum	**1 456 202**	**3 102 984**	**5 814 454**	**2 459 096**	**3 225 568**	**16 058 304**

Source: REKK calculation, primary based on Ricardo-AEA et al. (2014)

Table 7: Sensitivity results of the illustrative assessment, From road to rail scenario, Increased RES

From road to rail: RO 100% electrification	External yearly benefits of the policy (avoided costs) €(2018)					
Benefit categories	Bulgaria	Romania	Hungary	Slovakia	Czech Republic	**Sum**
Congestion	80 704	131 905	380 982	157 943	314 195	**1 065 729**
Accidents	71 687	643 798	804 716	465 029	164 344	**2 149 575**
Air pollution (local emission)	471 130	347 149	1 756 662	692 817	876 293	**4 144 050**
Noise	246 355	391 122	1 018 519	414 748	801 076	**2 871 820**
Climate change (local emission)	850 831	1 107 900	2 277 423	787 778	1 516 746	**6 540 679**
Well-to-tank air pollution + climate change	52 265	-194 694	281 975	141 234	105 390	**386 169**
Sum	**1 772 973**	**2 427 179**	**6 520 277**	**2 659 549**	**3 778 044**	**17 158 022**

Source: REKK calculation, primary based on Ricardo-AEA et al. (2014)

In both cases benefits are increasing: the Romanian electrification case adds around 7% increase alone, however WTT related changes are still negative. Increasing whole Europe's RES share in the power sector (through which CO_2 intensity and air pollution values would go down by 50%) would bring a 14% benefit increase to the From road to rail switch policy scenario. The following table summarizes the results.

Table 8: Summary of the results of the illustrative assessment

	External yearly benefits of the policy (avoided costs) €(2018)				
Scenarios	LNG trucks (20% switching)		From road to rail (10% switching)		
Benefit categories	Main scenario	LBG from local biogas	Main scenario	RO 100% electrification	Increased RES
Congestion	0	0	1 065 729	1 065 729	1 065 729
Accidents	0	0	2 149 575	2 149 575	2 149 575
Air pollution (local emission)	1 889 878	1 889 878	4 144 050	4 848 396	4 144 050
Noise	0	0	2 871 820	2 871 820	2 871 820
Climate change (local emission)	1 303 845	6 695 228	6 540 679	6 695 228	6 540 679
Well-to-tank air pollution + climate change	3 795 102	4 482 401	-1 741 297	-1 572 444	386 169
Sum	**6 988 825**	**13 067 508**	**15 030 556**	**16 058 304**	**17 158 022**

Source: REKK calculation, primary based on Ricardo-AEA et al. (2014)

It is clearly visible, that both analysed directions – substituting diesel trucks with either trains or LNG trucks – lead to higher external benefits than the base case.

In case of LNG scenario, an NPV calculation is carried out to compare the benefits with the estimated infrastructure costs (see next section). In case of the From road to rail scenario, however, implementation costs are not easy to be included as the barriers are more complex and less infrastructure-related. As it is mentioned before, several non-physical constraints need to be solved in order to be able to implement the shift of freight transportation from trucks to trains. Non-standardized regulation in the different countries makes the international transportation difficult, while even in the EU several border-related problems occur such as language difficulties and lengthy customs clearance process. Labour shortage, lack of financial resources and tight factory capacities in the recuperating sector after the economic crises worsens the situation.

4.3.3. Net present value for LNG scenarios

In first step, discounted external benefits have been calculated for the assumed lifetime of the infrastructure (25 years), based on the above presented yearly benefits, a linear uptake of the penetration rate, GDP grow rates (as indicator for transport demand changes) and a social discount rate of 4%. In second step, investments costs have been estimated based on the necessary number of LNG filling stations and their unit costs. Discounted lifetime benefits are estimated to exceed EUR 127 million in the main case (internationally traded LNG, 20% switching rate), which is linear regarding the switching rate. In case of liquefied (locally produced) biogas, the benefits are almost doubled.

Table 9: Discounted external benefits, LNG scenarios, 2020-2045

LNG scenarios	Switching rate		
	5%	20%	40%
LNG trucks	31 872 708	127 490 834	254 981 667
LBG trucks	59 598 250	238 393 000	476 786 000

Source: REKK calculation, primary based on Ricardo-AEA et al. (2014)

Calculating the total NPV of the LNG scenario confirms that investing in LNG infrastructure has a great potential regarding social welfare gains. The minimum investments that make the corridor passable for LNG trucks cost only EUR 4 million, which is greatly outweighed by the benefits. However, if higher station density is assumed to be necessary for reaching higher penetration rates, the investment costs are still well below the

expected benefits. Somogyi et al. (2016) assumes higher utilisation rates for higher penetration rates, which means there is no need for a double number of stations to achieve a double switching rate. This implies proportionally higher NPV values for scenarios assuming higher penetration rates. As no additional investment costs are considered for using liquified biogas, the NPV values are approximately twice in this scenario.
However, it should be mentioned that LNG filling station investment might be supplemented with additional measures that help the penetration of LNG trucks, and the costs of these measures are not included in this illustrative calculation. This is even more relevant for the case of biogas where the production is constrained by several factors.

Table 10: Infrastructure costs and NPV values, LNG scenarios, 2020-2045

LNG scenarios	**Switching rate**		
	5%	20%	40%
Number of LNG filling stations	13	19	24
Infrastructure costs	13 000 000	19 000 000	24 000 000
NPV (LNG trucks)	18 872 708	108 490 834	230 981 667
NPV (LBG trucks)	46 598 250	219 393 000	452 786 000

Source: REKK calculation, primary based on Ricardo-AEA et al. (2014)

5. SUMMARY AND NEXT STEPS

The objective of the study was to contribute to the researches on promoting sustainable energy use in transport sector through laying the groundwork for a uniform policy assessment framework. The sector is one of the major sources of greenhouse gas emission, and unlike in electricity generation, the carbon-emission is continuously growing as a result of increasing demand.
Our study focused on the international freight transportation in the Danube Region, where

the detrimental effects are particularly high due to its transit role and the dominance of diesel-fuelled road transportation. Transport-related GHG emissions have increased substantially in most of the countries in the region, and it is expected to grow further as increasing economic welfare (GDP/capita) induce increasing emissions per capita from transportation. On the other hand, EU member countries of the region achieved massive results in reduction of transport related air pollutants, decreasing both particulate matter, non-methane volatile organic compounds, sulphur-oxides and carbon-monoxide, and to a less extent nitrogen oxides as well. The performance of the non-EU members of the region is more diverse as the emission of particulate matter increased in several countries.

We analysed two policy approaches for promoting sustainable energy use in transport sector, which are considered to be the most promising among the many potential options. The first is to incentivise the use of alternative fuels within road transportation. As high energy density of fuels is a key criterion for long-haul trucks, LNG seems to be the most suitable substitute for diesel in international freight transportation for short term, while using liquified biogas or bio-synthetic gas (LBG) can reduce the emission even more substantially on longer term. The other approach is to divert the road transportation into less carbon-intensive transport modes, such as rail, where diesel is already largely replaced by electricity, which is increasingly being generated from renewable resources with close to zero emission.

Today biofuels account for the overwhelming majority of renewable energy sources in transport sector. However, while RES based electricity usage has grown in almost every country in the Danube Region, the usage of biofuels shows a little bit more mixed picture as it decreased significantly in some countries. The comparison of the current renewable energy deployment rate and the indicative targets for 2015/2016 reveals that only four EU member states of the region seem to be on track to reach their 2020 sectoral targets. The situation is even worse form the modal-shift point of view, as the share of road transportation increased further in the last decade in the region, on the expanse of less-carbon intensive modes (rail, internal waterways).

The potential measures are similar for the two approaches, as both try to enhance the relative competitiveness of the alternatives of the diesel-fuelled trucks. The main policy categories are infrastructure investments (LNG station, railway), financial incentives (subsidies, fees and taxes), regulatory constraints (emission standards, quotas), and removal of non-physical bottlenecks (such as regulatory barriers). As the effectiveness and efficiency of the diverse policy options are difficult to compare, there is a need for a uniform methodological framework which can take the various welfare and external effects of the potential policies into account.

We presented the most important transportation policy assessment models in Europe and formulated some suggestions relating to a future transportation model for the Danube Region. We categorized the existing transportation models into three groups. Although all presented models, tools were created in order to assess policies, we identified models which operate with very detailed transportation representation, models with the aim of high-level policy assessment and models which integrates transportation sector with a greater extent into a socioeconomic environment. We concluded that the implementation of a high-level policy analysis tool would be the most beneficiary on the long run for the Danube Region. We think the creation of a new transportation model is not necessary, but it can be a future goal to extend an existing high-level policy analysis model for the Danube Region, and to make it more suitable to assess the potential of sustainable energy use in the sector. On the other hand, significant further work is needed to implement such a model.

For demonstrative purposes, an illustrative assessment was carried out for the above mentioned two policy approaches. The mechanism of a transport policy measure is highly complex, starting from the determinants of the passenger and freight demand, as well as supply-side factors (vehicle fleets and infrastructures) through the mode- and route-selection algorithms to the conversion of transportation volumes into benefits and costs of the society. Our illustrative calculation addresses only the last issue by giving a rough estimation for the external benefits of different "green" policies, and in case of the LNG scenario an estimate for the infrastructure development costs.

Our results showed that both analysed policy approaches lead to higher external benefits than the base case, and further progress in biogas production, electrification of railways and renewable electricity generation could substantially enhance the results. However, to arrive to a reliable assessment of different exact policies, a sophisticated, model-based CBA methodology has to be developed and applied.

Our conclusion is that an existing high-level policy assessment tool (such as ASTRA-EC and HIGH-TOOL) should be adapted for the Danube Region and for the specifics of the policies that promote sustainable energy use. We envisage four reasonable directions of development, which address the (1) geographic scope, (2) the relationship with energy markets, (3) the set of evaluable policy instruments, and (4) the assessed benefit categories. The following table presents the suggested developments of model-based assessment methods in the Danube Region.

Table 11: Suggested developments of existing high-level policy assessment models in transportation sector

Directions of development	Current state	Goal of the development
Geographic scope	Focus on EU member countries (country or NUTS2 level) Non-EU Danube Region countries are not included or only at high aggregation level.	Cover the whole territory of the Danube Region with the same level of detail (at least NUTS2 or equivalent in non-EU countries).
Relationship with energy markets	No direct relationship (input prices are exogenous).	Consider interactions of the transportation and the energy (electricity, gas) markets to have more reliable information on prices, accessibility issues and environmental effects (eg. carbon-intensity).
Evaluable policy instruments	Broad set of pre-defined instruments but too general options for infrastructures (spending).	Allow more detailed representation of infrastructure deployment (such as the installation of LNG filling stations) or infrastructure upgrade (electrification of railways) in the set of analyzable policies.
Assessed benefit categories	Modelled transportation volumes in non-monetary terms; effects on climate change, air pollution and accidents are monetized.	All internal (transportation) and external (environmental) effects should be monetized. Assessed external effects should be broaden to cover effects on noise and congestion.

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