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POTENTIALS OF MODAL SHIFT FOR GHG EMISSION REDUCTION ON THE CORRIDOR IV
I. THE INNOVATIVE TRANSPORT ALTERNATIVES

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Abstract: *The paper presents the first part of analyses of possibilities for reduction of the greenhouse gas emission on Corridor IV by use of intermodal alternatives to present freight transport routes. The analyses is based on results of the EU funded project "Greening Intermodal Freight Transport in South-East Europe", which was motivated by the fact that the dominant polluter in the SEE is road freight transport. The main idea for reduction of the greenhouse gases emission on the Corridor IV was shift of part of freight transport from roads to present railway and maritime transport alternatives.*

In this first part of the analysis are presented methodologies for estimation of the effects of proposed measures, as well as the routes selected for study and the proposed innovative transport schemes that have potential to reduce the greenhouse gases emission of freight transport. The selection of the routes and transport schemes was driven by the needs to represent all transport modes present in the region, as well as to represent the dominant features of the Corridor IV, such as presence of seaports along eastern and western borders of the area connected by the corridor.

INTRODUCTION

The greenhouse gases (GHG) is a common name for gases that cause “the greenhouse effect”, the process of heating of the atmosphere due to absorption of thermal radiation emitted by Earth (not Sun, as it is sometimes misinterpreted). The greenhouse effect causes exchange of the heat between the Earth and its atmosphere, and, with present concentrations of GHG gases, it makes the heating of the atmosphere by Earth five times bigger than by Sun [1]. However, due to the increased industrial and transport activity, human emission of GHG gases increased 40% [2] since the start of Industrial Revolution, which caused increase of temperature of the atmosphere and climate changes that may threat to endanger the life on Earth. The key direct GHG emitted by human activities are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and F-gases (HFCs, PFCs, SF_6). Since the CO_2 is the primary GHG emitted through human activities, the emission of any GHG is expressed by the mass of CO_2 that would cause the same heat absorption, and the unit is called “kilogram-of-CO_2-equivalent”, denoted as $kgCO_{2e}$.

The transport sector is the second largest GHG emitting sector in European Union (EU), right after the energy industries. According to the European Environmental Agency [3], the contribution of the transport sector to the total GHG emissions in EU in 2011 was 20.30% , while the contribution of the energy industries which was 31.00%, constituting together a half of the total GHG emissions in the atmosphere, as presented in the Figure 1. Furthermore, the transport sector is the only major sector in the EU where greenhouse gas emissions are still rising. However, there are substantial differences between the GHG emissions of different transport modes, since the 94% of total transport emission in EU may be attributed to the road transport, which transports around 84% of passenger transport volume and 47% of the freight transport [3]. The main reason is that energy efficiency of fossil fuel engines rapidly increases with engine power, so that comparatively weak engines of road vehicles consume much more fossil fuel and, consequently, produce much more GHG than much stronger engines of railway vehicles and ships. The situation is even worse in economically less-well performing (former expression: poor) parts of EU, especially in South East Europe (SEE), where the quality of road vehicle engines and rail freight services is lower.

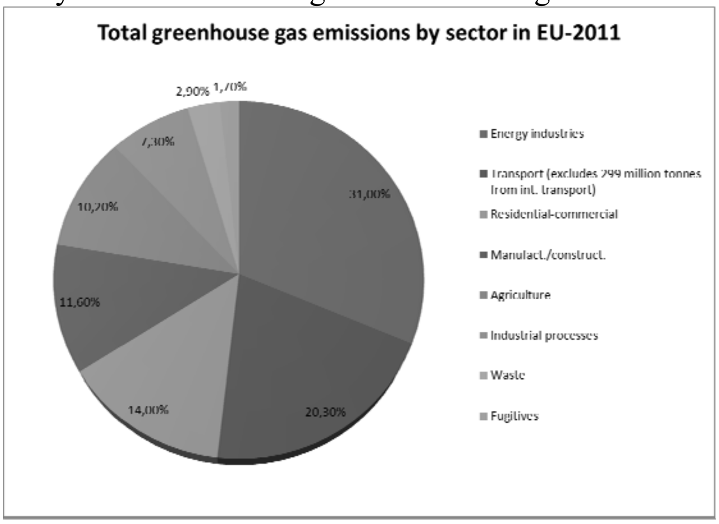

Figure 1 : Total GHG emissions by sector in EU-2011 (EEA, 2011)

One of many efforts to reduce the effects of the greenhouse gases (GHG) emission is the project "Greening Intermodal Freight Transport in South-East Europe" (acronym "GIFT"), which is carried out within the framework of SEE Transnational Cooperation Programme [4]. The main idea behind the project is to find, to study and to promote the already existing rail and ship alternatives for freight transport, which would partially reduce the GHG emission. A part of the effort was analysis of potential effects of modal shift to GHG emission on the Pan-European corridors. In this two-part paper, we present the results of analysis of potential effects of modal shift to GHG emission on Corridor IV, as one of key parts of SEE transport network. In the first part of the paper will be described the methodologies for estimation of the effects of proposed measures, and the proposition of innovative transport alternatives.

METHODOLOGY

There may be two approaches to estimation of the effects of GHG emission and the measures for reduction of the emission: the first is to estimate the costs of damage due to the GHG emission and the second is to estimate the costs of abatement of the effects of the GHG emission. The methodology for monetary valuation of GHG impacts in the project GIFT is based on the estimated abatement costs to achieve the emissions targets. The methodology is already presented in details [5], and here will be presented only the elements that are necessary to follow the further discussion.

When carrying out monetary valuation, it is important to distinguish between the emissions from those sectors that are included within the EU Emissions Trading System (EU ETS) – the "traded sector emissions") – and those that are not included in the EU ETS (the "non-traded sector emissions"). The traded sector covers emissions from power and heat generation, energy-intensive industry and, since 2012, aviation. Emissions arising from electricity consumption in transport belong to the traded sector emissions. The non-traded sector covers all other GHG emissions, so the emissions from other types of transport fuel, including petrol, diesel and gas oil, are in the non-traded sector. Inclusion in the traded sector caps relevant emissions and creates a market for them. In this way, they are controlled through the requirement for the relevant sectors to purchase EU allowances (EUAs) to cover relevant emissions. Since the purchase price is used in transport appraisal, the cost of the relevant EUAs will be included in the cost benefit analysis. Therefore, the costs of the emission in the traded and in the non-traded sectors are not the same, so the emissions in the traded and the non-traded should be valuated separately whenever possible. One of the objectives of the European Climate and Energy Package is to make the costs of the emission in the traded and in the non-traded sectors the same until 2030. The proposals of the GIFT project lead to slight increase of GHG emission in the traded sector by increased engagement of electric power for transport. The increase of GHG in the traded sector is compensated by large reduction in emission of the non-traded sector.

The GIFT project considers the innovative, environment–friendly ways to transport goods between transport nodes, where a part of transport corridor network between the transport nodes is called „route". Different transport modes may be available for freight transport along a route, and set of transport modes used for transport along a route is called "transport scheme". "Do-nothing" transport scheme consists of transport modes that are used for transport on the route in the present moment. Freight transport of goods along a route consists of several links, where "link" is defined as a part of the route that uses a single transport mean for transport of the goods. A "transport alternative" represents a combination of links for freight transport along a route in a certain transport scheme. The innovativeness of the GIFT proposal is development of transport alternatives that use transport modes that are available, but not used, or that are seldom used. The basic idea behind the introduction of the new alternatives is that each alternative has different GHG emission, and the proposed alternatives have smaller GHG emission than the present ones.

"Market share of an alternative" represents the ratio between the amount of goods transported on a certain route using that alternative and the total amount of the goods transported on that route. The market share of an alternative depends on its costs, duration and transport policies that are created to facilitate some outcomes. "Scenario" comprises a certain evolution of market shares between various alternatives of a selected transport scheme withing a selected timeframe. Scenarios are used to study the effects of new transport policies. The „as-is" scenario is the baseline scenario, which estimates the effects that would arise with present transport policies. "Probability of a scenario" shows relative (in comparison to other possible scenarios) chance that the scenario will actualize. In order to calculate the expected effect of the proposed actions it is necessary to obtain estimations of time evolution of market share of each of the alternatives for transport along the studied route in a certain period.

Let $G_0^{(i)}$ denotes the equivalent emission of GHG gases per unit mass of the transported load (measured in kilogram-equivalent-of-CO_2-per-ton) in the "do-nothing" transport scheme over the *i*-th route, and $G_{jm}^{(i)}$ denotes the equivalent emission of GHG gases per unit mass of the load over the *m*-th alternative of the *j*-th innovative ("to-be") transport scheme. The estimated absolute (denoted as $\Delta_{jk}^{(i)}$) and relative (denoted as $\delta_{jk}^{(i)}$) reduction of GHG emission in year *t* of the *k*-th scenario of development of the *j*-th transport scheme on the *i*-th route can be then calculated as:

(1) $\Delta_{jk}^{(i)}(t) = G_0^{(i)}(t) - \sum_{m=1}^{M_j^{(i)}} q_{jkm}^{(i)}(t) \cdot G_{jm}^{(i)}$ and $\delta_{jk}^{(i)}(t) = \frac{\Delta_{jk}^{(i)}(t)}{G_0^{(i)}(t)}$

The expected (denoted by line above the letter) absolute and relative reduction of GHG emission in year t of the j-th transport scheme on the i-th route could be then calculated as:

(2) $\overline{\Delta_j^{(i)}}(t) = \sum_{k=0}^{K_j^{(i)}} p_{jk}^{(i)} \cdot \Delta_j^{(i)}(t)$ and $\overline{\delta_j^{(i)}}(t) = \frac{\overline{\Delta_j^{(i)}}(t)}{G_0^{(i)}}$.

The monetary value of reductions of GHG emission per unit mass of the transported load in the period 2014-2030 is calculated according to the formula:

(3) $V_j^{(i)}(t) = c(t) \cdot \Delta_j^{(i)}(t)$

where $c(t)$ represents the estimation of marginal GHG abatement cost for the year and $V_j^{(i)}(t)$ stands for the estimated monetary value of reductions of the GHG emission using the j-th scheme on the i-th route, during the considered year.

There are different ways of assessing cost-effectiveness of an action. The most straightforward way of assessing whether an action is good value-for-money is to consider the "Net Present Value" (NPV), which is the sum of all monetized costs and benefits, discounted to the base year chosen. When the NPV has positive value, the analyzed action brings benefits to the society. In the GIFT project, the base year was $t_0 = 2014$, and the yearly discount rate was adopted to be $d = 3,5\%$ [5]. Let $C_0^{(i)}$ denotes the cost of transport per unit mass of the transported load (measured in EUR-per-ton) in the "do-nothing" transport scheme over the i-th route, and $C_{jm}^{(i)}$ denotes the cost of transport per unit mass of the load in the m-th alternative of the j-th "to-be" transport scheme. The NPV of the effects of k-th scenario in year t of development of the j-th transport scheme of the i-th route can be then calculated as:

(4) $NPV_{jk}^{(i)}(t) = (1-d)^{t-t_0} \cdot \left[c(t) \cdot \Delta_{jk}^{(i)}(t) + \left(C_0^{(i)} - C_{jk}^{(i)} \right) \right]$

The expected NPV in year t of the j-th transport scheme of the i-th route can be then calculated as:

(5) $\overline{NPV_j^{(i)}(t)} = \sum_{k=0}^{K_j^{(i)}} p_{jk}^{(i)} \cdot NPV_{jk}^{(i)}(t)$

SELECTED ROUTES AND SCHEMES

The Corridor IV connects Central Europe with Aegean and Black Sea ports, running between Dresden / Nuremberg in Germany and Thessaloniki (Greece) / Constanţa (Romania) / Istanbul (Turkey), following the route presented in the Figure 2. The corridor is completely on EU territory, bypassing the countries of former Yugoslavia and Pan-European Corridor X.

To understand the effects of the actions aimed at the Corridor IV, the area of the study should be extended to include the important regional transport routes connected to the Corridor IV [5]. The studied network therefore included the important regional routes Thessaloniki–Athens and Thessaloniki–Istanbul, which extend and join the network in the endpoints of the Corridor IV. Besides, the study includes the important SEE economic centers Athens and Ploiesti, because the Corridor IV is their main transport route. A specific feature of the Corridor IV is that its southern (Thessaloniki) and eastern (Istanbul and Constanţa) ends are seaports, so the alternatives on the Corridor IV include sea transport links. For that reason, the routes that are selected for study of effects of innovative intermodal transport alternatives are "Athens–Sopron" and "Athens – Ploiesti". Athens (the capital of Greece) belongs to the most important ports in the SEE region, and is common node for both routes. Sopron is a Hungarian town close to the border with Austria, and it is the place where the Corridor IV leaves territory of the SEE countries. Therefore, the route "Athens – Sopron" represents a route that connects endpoints of the studied transport network. Ploiesti is the

Romanian center of oil production and refining, and a major transport hub of the SEE region. Therefore, the route "Athens – Ploiesti" is selected as a route that connects important industrial, trade and transport nodes of the studied transport network.

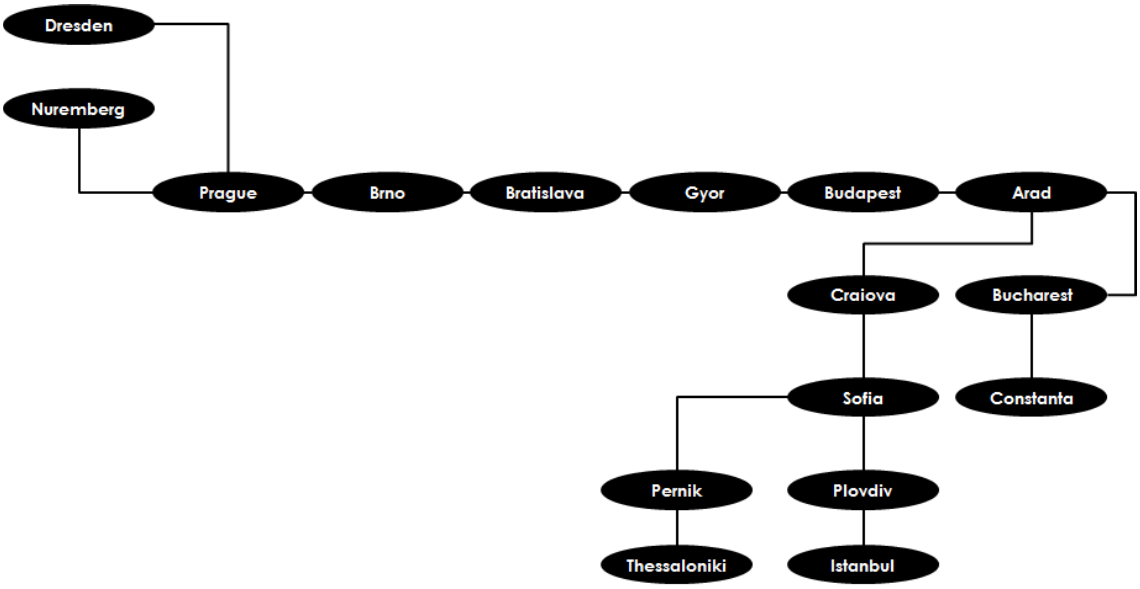

Figure 2: Structure of the routes of Corridor IV

Both of the studies routes include road, railway and maritime transport modes as alternatives. The route Athens – Sopron represents a western route, which has Adriatic Sea as alternative, while the route Athens – Ploiesti represents an eastern route, which has Aegean Sea as alternative. The "do-nothing" schemes assume that the present freight transport is almost completely performed by the road, and the innovative transport schemes include road, railway and maritime transport modes. The transport schemes proposed by the GIFT project comprise the introduction of only railway transport mode ("+Rail" scheme), only maritime transport mode ("+Ship" scheme), as well as the introduction of the combination of the two transport modes ("+Rail+Ship" scheme).

Athens – Sopron route

Four alternatives, presented in the Figure 3, are studied for the route "Athens-Sopron". Their properties, calculated according to the presented methodology [7], are given in the Table 1. The alternatives "Rd" and "Ra" are unimodal, while the alternatives "ShRd" and "ShRa" use the Slovenian port of Koper as the intermodal hub.

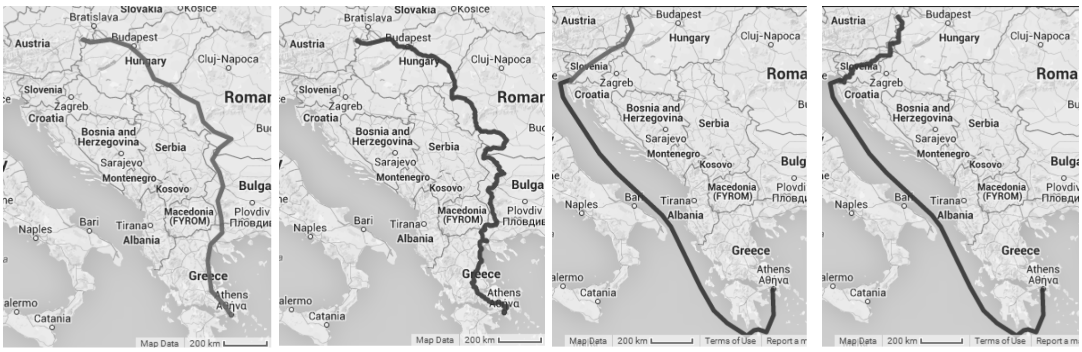

Figure 3: The paths of the transport alternatives of the "Athens – Sopron" route
From left to right: "Rd", "Ra", "ShRd", "ShRa"

The baseline ("do-nothing") transport scheme on the route "Athens-Sopron" considers only road transport using the "Rd" alternative.

Table 1: Properties of alternatives of the "Athens – Sopron" transport route

Code	Description	Length (km)	GHG emission (kgCO$_2$e/t)	
			Traded	Non-traded
Rd	Athens-Sopron (Road)	1950	0.00	134.9
Ra	Athens-Sopron (Rail)	2042	42.2	2.50
ShRd	Athens-Koper (Ship) Koper-Sopron (Road)	2109	0.00	55.9
ShRa	Athens-Koper(Ship) Koper-Sopron (Rail)	2185	8.5	16.5

Athens-Ploiesti route

For the route "Athens-Ploiesti" are studied four alternatives, presented in the Figure 4. Their properties, calculated according to the presented methodology [7], are given in the Table 2. The alternatives "Rd" and "Ra" are unimodal, while the alternatives "ShRd" and "ShRa" use the Greek port of Alexandropouli as the intermodal hub.

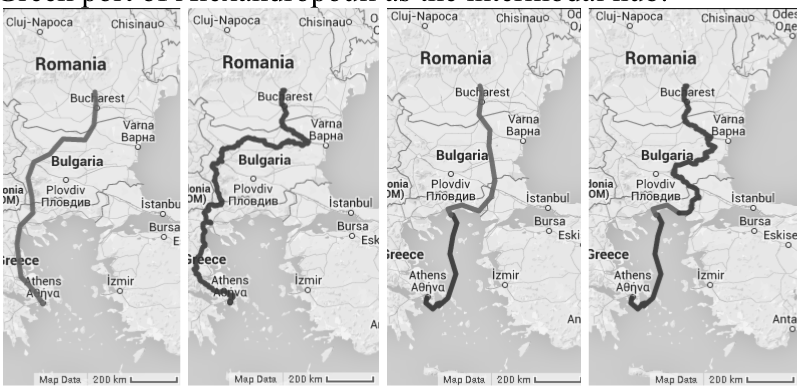

Figure 4: The paths of the transport alternatives of the "Athens – Ploiesti" route
From left to right: "Rd", "Ra", "ShRd", "ShRa"

The baseline ("do-nothing") transport scheme on the route "Athens-Ploiesti" considers only road transport using the "Rd" alternative, as it was the case with the "Athens–Sopron" route.

Table 2: Properties of alternatives of the "Athens – Ploiesti" transport route

Code	Description	Length (km)	GHG emission (kgCO$_2$e/t)	
			Traded	Non-traded
Rd	Athens-Ploiesti (Road)	1254	0.00	89.31
Ra	Athens-Ploiesti (Rail)	1576	28.26	8.84
ShRd	Athens-Alexandropouli (Ship) Alexandropouli -Ploiesti (Road)	1259	0.00	62.7
ShRa	Athens-Alexandropouli (Ship) Alexandropouli -Ploiesti (Rail)	1500	21.3	35.2

CONCLUSION

The paper represents the first part of two-part paper and it presents the basis for the results of the study that will be presented in the second part of the paper. The basis consists of the methodology for calculation of the proposed measures and the set of proposed alternatives that should reduce GHG emission of the freight transport in the CEE.

The methodology that is used to study transport alternatives requires as input the data on specific GHG emission (equivalent CO_2 emission per kilometer and per transported ton of goods) in the countries of the region, and has the estimation of the absolute and relative reduction of specific GHG emission, as well at the NPV of the reduction, as the output.

The set of proposed alternatives considers use of road, rail and sea freight transport for transport along the routes Athens-Sopron and Athens-Ploiesti. The proposed set of alternatives is representative since it covers the whole area of the Corridor IV, and includes all possible transport modes that exist in the region.

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ПОТЕНЦИАЛИ ПРИ СМЯНАТА НА ВИДОВЕТЕ ТРАНСПОРТ ПО КОРИДОР IV ЗА НАМАЛЯВАНЕ НА ГАЗОВИТЕ ЕМИСИИ I. ИНОВАТИВНИ ТРАНСПОРТНИ АЛТЕРНАТИВИ

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Ключови думи: *Опазване на околната среда, намаляване на газовите емисии, трафик замърсяване*

Резюме:*Статията представя първата част от анализа на възможностите за намаляване на емисиите на парникови газове при товарни транспортни маршрути по Коридор IV чрез използване на интермодални алтернативи. Анализите се основават на резултатите от финансиран от ЕС проект "Зелен интермодален товарен транспорт в Югоизточна Европа", което е мотивирано от факта, че доминиращият замърсителят в Югоизточна Европа е автомобилния товарен транспорт. Основната идея за намаляване на емисиите на парникови газове по Коридор IV е изместване на част от товарния транспорт от автомобилния към железопътни и морски транспортни алтернативи. Въпреки това, подобни алтернативи за смяна, водят до увеличаване загубите на време и производителността на товарния транспорт, което изисква внимателен анализ на разходите и ползите, преди изпълнението.*

В тази първа част от анализа са представени методики за оценка на въздействието на предложените мерки, както и избраните за изследване маршрути и предложените иновативни транспортни схеми, които имат потенциал за намаляване на емисиите на парникови газове на товарния транспорт. Изборът на маршрути и транспортни схеми се ръководи от нуждите да представлява всички видове транспорт, присъстващи в региона, както и да представлява доминиращите характеристики на Коридор IV, като например наличие на морските пристанища по източните и западните граници на района, свързан с коридора.