Current carbon tax role in the choice of ecologically more acceptable transport mode

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Abstract

The internalization of external cost in transport sector can be made with a political (legal) decision or market-based instruments as the carbon tax is. Although it has been introduced already through the fuel, vehicle or emission trading taxes, many countries introduce a new, special carbon tax according to European Commission policy and Paris Protocol on reducing CO_2 emissions and the principle "polluter pays". Accepting the external costs as influencing factors on transport performance and solutions, there is enough reason to consider ecologically more acceptable transport modes and routes whenever possible. Since, road transportation is the largest producer of CO_2 emissions in the transport sector, the main aim of this paper is to get the answer to the question: "Can carbon tax size stimulate a logistic decision maker to choose the ecologically more acceptable transport mode and therefore the ecologically more acceptable transport routes?" Accordingly, to the mentioned research problem, the authors give the comparative analysis of the CO_2 emissions in three variants of transport modes on the route between a port and its hinterland. Using indicative calculation the results show that current carbon tax is not competitive with road transportation prices. These carbon values are not enough incentive to shift freight from road to rail and cannot change the transport route. Therefore, in valuing of a carbon tax should consider the objectives of common transport policy and align it with the tax structure of the signatory state, in function of ecologically more acceptable transport solutions.

*Keywords:*external cost, carbon tax, ecological transport mode, calculation, inland transport to and from port

1. Introduction

External costs of road transport participate with 94% of total external costs in traffic (UIC, 2012). They are the result of environmental impacts of road transport as well as congestion and accidents which are almost absent in the other transport modes. The White Paper on Transport (2011) set a reduction of at least 60% of greenhouse gas emissions by 2050 with respect to 1990 and 20 % by 2030 below their 2008 level (EC, 2011). It is necessary to shift the transport off the road as more as possible.

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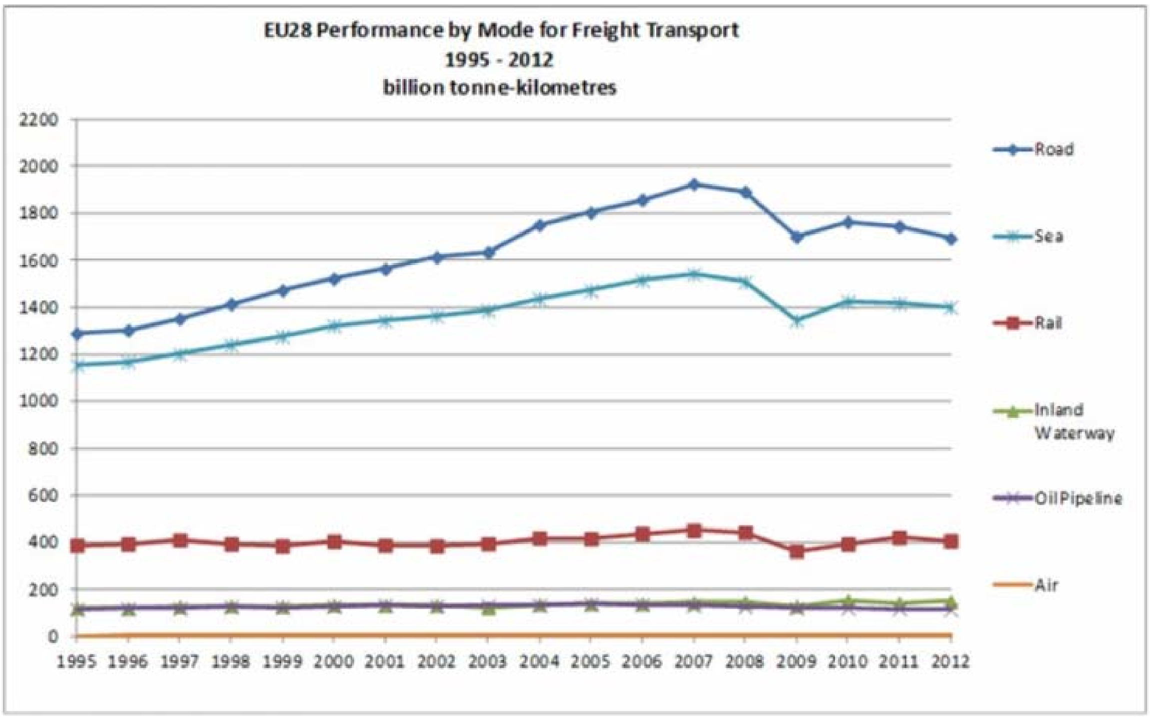
The European Commission ordered a transfer of 30% of goods transported by road to rail and other more acceptable transport modes by 2030 and 50% by 2050. A functional TEN-T network by 2030 and a high-quality TEN-T network with high, adequate capacity by 2050 is a necessary part of this plan. There is also a need for good connections of sea ports and rail freight network (Pastori, 2015).

There are many tools to realize the set goals, for instance, stimulating the production and use of non-fossil fuels, development of technological innovations to reduce emissions in industry, transport and households, adoption of spatial plans for energy-efficient construction, ecological waste management and nature conservation, and decisions and regulations to monitor sustainable development policy. Internalization of the external costs is one of them. It is a procedure for estimation and valuation of the side effects of transport in order to cover the external costs by ones who did them. It can be done directly (commands, control measures) or indirectly with so-called market-based instruments (taxes, charges, emission trading, tolls, and insurance conditions) making sure to be fair and those revenues do not exceed related infrastructure costs (Maibach et al., 2007). The carbon tax was currently introduced in some countries, and some others plan to do it. It has already existed in most countries as energy taxes (fuel, vehicle or kilometres driven taxes) rather than pollution taxes (Croatian Bureau of Statistics, 2016). Introducing a new, special carbon tax takes effects on the households, industry and entire economy leading to an increase in the cost of living (SlabeErker, 2002), and the benefits are still analyzed. The existing tax structure has to be considered before new tax enters into force (Maibach et al., 2007).

2. Trends in freight transport modal share to and from the ports

Data on the structure of goods traffic within Eu-28 indicate that the freight transport is performed predominantly by trucks (Graph1). The rail freight transport in 28 countries of EU in 2012 was about 400 billion tkm, 4.5 times less than truck transport.



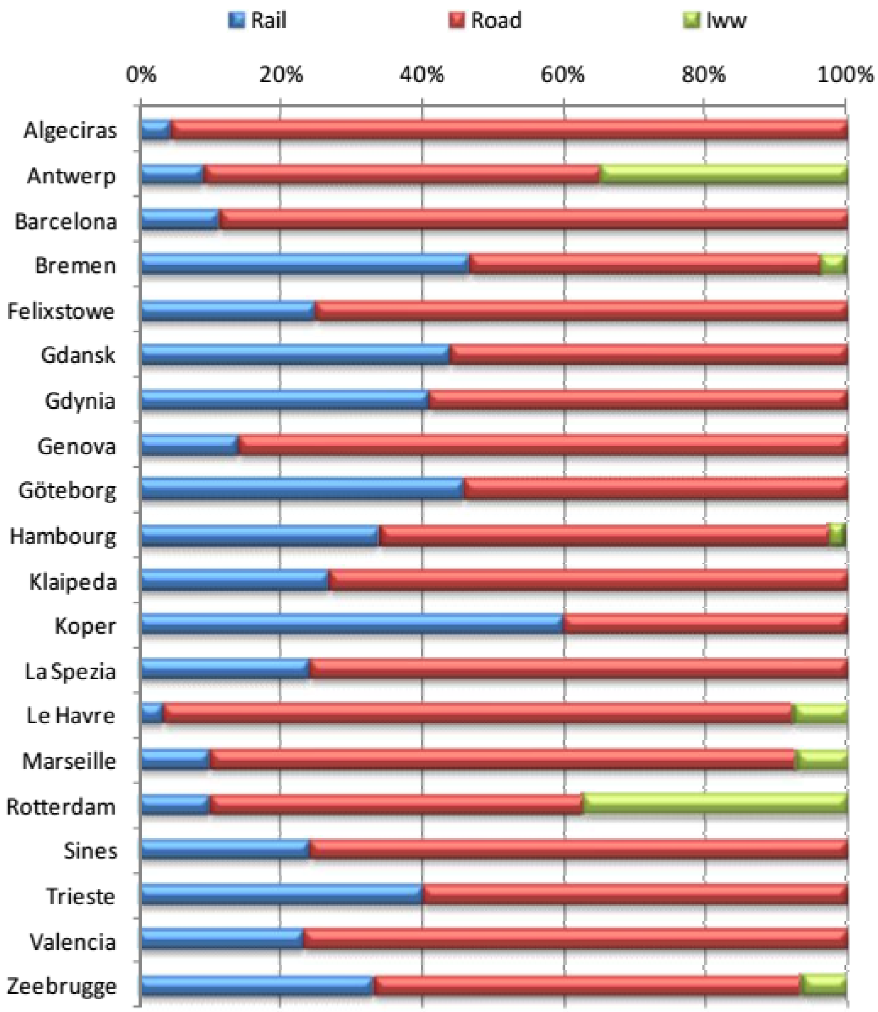
Graph 1: Intra-EU 28 performance by mode-freight transport (billion tonne-km)
Source: EC, 2014

The analysis of the structure of inland transport mode share from and to some of the world's leading container ports also points to the dominance of road (truck) transport.Indeed, in some of the most important ports in the world (Singapore, Hong Kong, most of the Chinese ports) until recently there were no railways at all (Steenken et al., 2005).Container transport to and from those ports still shows the same ratio.

According to recommendations of shifting freight off the roads, there are trends of changes in favour of rail, inland waterway (IWW) and maritime transportation. New railway trucks were built and distribution network was improved in China (Eco Logistics, 2015).

Since 2005 the share of container rail transport in the port of Hamburg (Germany) grew from 18% (Steenken et al., 2015) to 35% in 2013 (Pastori, 2015). Port of Fremantle (Perth, Australia)has increased the rail transport of containers from 2% in 2002 to 14% in 2014 and reduced the 72,000 truck trips per year (Fremantle Ports, 2013).

Similar trends can be noted also in other ports especially in those which have not the possibility of inland waterway transportation. Rail port shuttles are increasingly introduced connecting port and intermodal terminals into hinterland which can be hundreds of kilometers far away (Probert, 2015). The modal share in selected ports in 2013 is shown inGraph2.



Graph 2**:** Modal share in selected ports (Container throughput)
Source: Pastori E, 2015

Despite trends, the share of rail mode container transport in ports does not exceed 50% anywhere except in the port of Koper. The growth of freight transport limits the efforts in shifting the transport mode despite building the new railway and other traffic infrastructure.

The growth of freight transport limits the efforts of shifting the transport to eco-friendly mode despite building the new railway and other traffic infrastructure (Pastori, 2015; Port of Hamburg, 2017). Anyway, the European Commission is strongly committed to the implementation of the planned policy of sustainable transport (EC, 2011).

3. Analysis of external costs structure by different criteria

External costs represent a monetary expression of externalities, negative consequences of transport influences on nature and society (Rodrigue JP, 2017). The share of external costs by externalities and by various transport modes are shown in Table 1.

Table 1: The share of external costs by externalities and by various transport modes in 2012

EXTERNAL COSTS			
BY EXTERNALITY		BY TRANSPORT MODES	
Climate change	35 %	**Cars**	62%
Congestion	22 %	**HDV**[2]	14%
Accidents	22 %	**LDV**[3]	9%
Air Pollution	8 %	**Motorcycles**	5%
Up and downstream processes	7 %	**Buses**	4%
Noise	3 %	**Air**	4%
Other[1]	3 %	**Rail passenger**	1%
Total	100%	**Total**	100%

[1]waste, water, soil, urban effects, biodiversity, landscape;[2]HDV (Heavy-Duty Vehicle);[3]LDV (Light-Duty Vehicle)
Source: UIC, 2012, modified by authors

Congestion and accidents are important items of external costs participating more than 20% each. They significantly influence the EU GDP congestion 1% (Schlewing A, 2012) and accidents 2% (EC, 2013). They are, almost exclusively, products of road transportation (Thune-Larsen et al., 2014). The share of external costs by various transport modes is accordingly to the expected domination (94%) of external costs produced by road transport.The real values of external cost of freight transport (excluding congestion) by modes are shown in Table 2.

Table 2: Values of external cost of freight transport in 2012

Modes of Freight Transport	**Values of external cost (€/1000 tkm)**
Road (Total)	50.6
HDV*	34
Rail (Total)	7.9
Inland waterways	11.2

*HDV – Heavy-Duty Vehicle
Source: UIC, 2012, modified

The data shown in the previous table point to the conclusion of the need for shifting the freight off the road and making the external cost as less as possible. Comparing the values with those in the rail freight transport it can be confirmed the justification of this intention (Table 3).

Table 3: Comparison of external cost values of road and rail freight transport in 2014 per item (€/1000 tkm)

Type of cost	**Truck cost** (€/1000 tkm)	**Rail cost** (€/1000 tkm)
Pavement Damage	4.3-5.7	0.3-0.4
Traffic Congestion	2.5-5.3	0-0.2
Accident Risk	5.0-13.4	0.7-1.5
Emissions: PM and NO_x	3.5-4.7	0.8-1.4
Emissions: CO_2	0.11-5.4	0.04-1.4
Total	**15.4-34.5**	**1.84-4.9**

Source: Austin, 2015, modified

The size of external costs is large in itself representing a burning issue for modern economy and society. But it should be remembered that the costs of climate change are not usually included in the displayed results and need to be added in the amount of 35% of the expressed values.

4. Possibilities and effects of external cost internalization with carbon tax: an example of indicative calculation in the port

4.1 Carbon tax as mode of external costs internalization

The carbon tax is a mode of internalization of external costs (SlabeErker, 2009). Carbon dioxide is the best representative of emissions, not considering its toxicity (there are more toxic gasses or particles in emissions), but its dominant share in emissions as a product of fuel combustion and role in climate change. The road traffic shares with 72% of a total traffic CO_2 emission (EC, 2016). By introducing a special carbon tax in traffic it could be expected to decrease of CO_2 emission shifting the road freight transport into other transport modes.

Shifting from exclusively truck transport to intermodal truck-rail transport on route from Changping (Dongguan) Station to Port of Yantian (Shenzhen) the CO_2 emissions have decreased to less than one-tenth of their previous level (Eco Logistics, 2015).
The price of CO_2 varies mostly from 10 to 40 €/t, rarely above them, varying after a type of fuel used, daily upper and lower rates, a lot of discounts and combinations with other taxes. As a rule, lower tax, fewer variants. The prices of CO2 emissions in different countries in 2016 are shown in Table 4.

Table 4: Prices of CO_2emissions in different countries in 2016 (€/tCO_2)

Country	Prices of CO_2 emissions (€/tCO_2)	Country	Prices of CO_2 emissions (€/tCO_2)
Sweden	123.50	Ireland	20.73
Switzerland	81.08	Slovenia	17.91
Finland	61.27 (upper)	Alberta	14.14
Finland	56.56 (lower)	Korea	14.14
Norway	49.02 (upper)	Iceland	9.43
Norway	2.83 (lower)	Portugal	6.60
Denmark	24.51	Latvia	3.77
France	23.56	Estonia	2.83
UK	22.62 (var.)[1]	Japan	2.83
Br. Columbia	21.68	Poland	<1

[1]var. – a lot of variants
Source: World Bank, 2016, modified

In Alberta, Canada, which introduced the tax, the price of CO2is 15$ per ton, and in the USA which did not, 37 $ per ton in 2015 (Than, 2015; Szabo, 2015).

Given to the total tax burden, introducing carbon tax some countries decreased energy taxes, and some others did not. However, all these countries reduced income taxes and stimulated employment in this way (SlabeErker, 2002).

According to TU Delft (2012), the eco-value of CO_2 is 135€/t, and Moore and Diaz (2015) at Stanford University have proven a real price of 220 $/t considering cumulative effects of emissions. The economic CO_2 price is calculated towards the costs that need to invest in technology to reduce emissions from actual levels to the agreed levels.
Industrial growth raises actual levels of CO_2 and the gap towards agreed levels becomes greater and greater. Thus the price of CO_2 increases (TU Delft, 2012). Although some researchers think that 'the answer to climate tragedies is a carbon tax' (Schmidt, 2016), some others express doubt on its effectsespecially in terms of discount rates (Harrington, 2017). There are also other modes of taxes introduced in some countries, as emission trading schemes (ETS), i.e. cap-and-trade, but it is not considered here. Summarizing all taxes impacts, OECD (Organization for Economic Cooperation and Development) published in 2016 the so-called 'effective carbon price' in the average value of 14 € per ton of CO_2 for 41 countries. It concludes that it is so low as to be ineffectual and should be minimum of 30 €/tCO_2 (Evans S, 2016).

4.2 Purpose and method of indicative carbon tax calculation

Considering the road traffic as one of the target points of the European Commission Transport Policy the paper tries to find out if carbon tax can help shifting freight off the road at this moment.

For this purpose, an indicative calculation of carbon tax size was performed in an imaginary port for transport of 1,000 TEU weighing 14 tons each by various transport modes. They should be transported into hinterland intermodal terminal situated 25 km away from the port in three of possible variants:

- variant A): transport from port to hinterland by trucks
- variant B): transport from port to hinterland by rail
- variant C): transport from port to another port (closer to the final destination in hinterland) by feeder

It will be calculated emission of CO2 of each variant and compared.

According to the recommended tax price of 30 €/tCO2, the cost will be calculated for each truck, rail, and feeder. The cost will be estimated as competitive or uncompetitive compared with the transport price. Finally, the same will be done calculating ‘eco-cost' of 135 €/tCO2. It should answer if carbon tax size stimulates a logistic decision maker to choose the ecologically more acceptable transport mode and therefore transport routes.

4.3 Calculation and results

Although it can be different in reality, for research in this example calculation will count one TEU per a truck, 50 TEU per a train, 1000 TEU per a feeder, and all TEUs full loaded. A lower number of transported TEU is compensated by excluding empty TEUs. As it is unknown if the vehicles come to the port full of empty, it is assumed that they are loaded 75% in both directions. So, the interest of transport logistics would be satisfied, but a load of engine and fuel consumption will be 75% of maximum.

The calculation of the power of each vehicle was as follows in Table 5:

Table 5:Calculation of power necessary for transportation of 1000 TEU by different transport modes

Vehicle	Average power (kW)	No. of vehicles	Total transport power (kW) (both directions)
Truck	372.85 kW (Tunnell, 2009)	1000	745,700
Rail (diesel)	2982.80 kW (Ilyayeva, 2001)	20	119,312
Rail (electric, -35%)	1,938.82 kW (Thomas, 2012)	20	77,552.80
1000 TEU feeder (medium)	8,000 kW (Norden, 2014)	1	16,000*

*conditional both directions

Total transport power for the job is extremely predominant in truck transport mode showing e.g. almost ten times higher values than in electric train mode. There is an uncertainty where the feeder comes from and if it comes full of empty. It is assumed the routine feeder transport by connection established already between two ports. If not so, the two directions cannot be included into calculation although the feeder power is the lowest per hour even with a sum of both directions. It will be discussed later.
According to the data published by CEC (Commission for Environmental Cooperation, 2009), CO2 emission of diesel engine loaded by 75% is 71 g CO2/MJ. The average speed of rail and truck on the route between port and hinterland is estimated at 50 km/h. It is assumed for the hinterland terminal to be located 25 km long way from the port, and rail or truck needs an hour to cross that distance in both directions. The same time needs a feeder to enter and leave the port. The calculation of CO_2 emission in the set task done by different transport modes is shown in Table 6.

Table 6: Calculation of CO_2 emission in transportation of 1000 TEU by different transport modes

Vehicle	CO_2 emission calculation	Total CO_2 (kg)	%	%
Truck	745,700 x 3.6* x 0.071	190,600.92	84.64	88.85
Rail (diesel)	119,312 x 3.6 x 0.071	30,496.15	13.54	
Rail (electric)	77,552.80 x 3.6 x 0.071	19,822.50		9.24
Feeder	16,000 x 3.6 x 0.071	4,089.60 kg/h*	1.82	1.90

*1 kWh = 3.6 MJ
**time to enter and leave the port

In accordance with the data in Table 5, one can be noted again a ten times higher emission of CO_2 by truck transportation in relation to the transportation by electric rail on this route. There is an uncertainty where the feeder comes from and if it is full of empty. It is assumed the routine feeder transport by connection established already between two ports. If not so, the two directions cannot be included into calculation although the feeder power is the lowest per hour even with a sum of both directions. It will be discussed later.

Despite the complexity of pricing, there are data on indicative truck transport prices. Such prices for a different region of the world are shown in Table 7. The prices were included into account for the route in the set task. These are long distance prices so they can be understood as minimal.

Table 7: Transport price per a truck for the 50 km route in the research (according to minimal transport prices per a truck in different regions)

Minimal transport price per a truck (long distance)	Transport price per a truck for the 50 km route (€)
Europe (Golinska and Hajdul, 2012) 0.63 €/km	**31.50**
Australia (Manders and Carolan, 2013) 0.036-0.071 €/tkm	**25.20-49.70**
South Africa (Geissner and Moller, 2011) 0.25 €/km	12.50
USA (Corner et al., 2012) 0.51 €/km	**25.50**

The transport prices in South Africa are cheaper by 50% but this country does not belong to the group of the most developed countries in the world. So, the minimal truck transport price of 0.5 € can be taken as relevant. The results are compared with carbon tax calculated for the same route including separately the real cost and eco-cost of CO2.

Carbon tax per a truck (real cost) = 0.19 x ***30 € = 5.7 €/50 km (not competitive)***(1)
Carbon tax per a truck (eco-cost) = 0.19 x ***135 € = 25.65 €/50 km (competitive)***(2)

The results show that carbon tax calculated with the real cost of CO_2 participates with about only 20% of total transport price on the same route being not competitive in decision made procedure. Calculation with the eco-cost of CO_2 the carbon tax reaches the full transport price.

Including the values of all external cost impacts in road freight transport (€/tkm) from Table 3 as well as the value of CO_2 cost separately, a total external cost and CO_2 cost share on the task route is calculated and shown in Table 8.

Table 8: Total external costs and CO_2 external cost share (mean) of truck transport for the route (according to Table 3 price data)

External cost	Distance (km)	Weight (t),75%	tkm	Price (€/tkm, Tab.3)	Total (€)	Mean	%
Total	50	10.5	525	0.0154-0.0345	**8.09-18.11**	**13.10**	
CO_2	50	10.5	525	0.00276 (mean)		**1.45**	**11.07**

The mean value of total external costs is about 50% lower than carbon tax calculated with eco-cost of CO2 for the same task. The mean value of the CO2 share in total external costs is about 75% lower than carbon tax calculated with the real cost of CO2. There is a real paradox between the eco-cost carbon tax which double surpasses total external costs and the CO2 cost share which makes 11.07% of total external costs in the same task.

4.4 CO2 costs and carbon tax targets

A type of fuel and power necessary for transportation of certain amount of goods are the best and enough indicator of the size of emissions. The results in variant A confirmed extreme domination of road transport in CO_2 emissions (84-89%). It is 6-10 times more than in rail (variant B) and 47 times more than in feeder transportation at the same time (variant C). Although the maritime transport shows lowest emissions it should be careful here and note that the result of emission is expressed per hour. If it needs a long journey the emissions will be significantly higher than in variant A and B but out of living area, and it still remains the need for transportation from another port to the final destination with further emissions, maybe over another hinterland terminal too.

Considering the problem and research objectives in thispaper the real value of a carbon tax that would have produced an effect of shifting the freight off the road on the route of 25 km between the port and hinterland surpasses the value of total external costs on the same route. The difference between economic (eco-cost) and real (political) price of a CO_2 ton is so large that the current carbon tax would not have produces the effects even if the trucks transported more than one TEU, in only one direction or the TEU were empty (lower engine load). The fuel price most affects the price of transport (Berwick & Farooq, 2003). Even if there is a discount of 50% on fuel price the effective carbon tax is not competitive with transport price in practice. With the carbon tax share of only 20% of a minimal transport price, the road transportation in and from the port is worth it. As in every tax system, there are tax reliefs and real incomeof carbon taxes are even less (Fletcher, 2016). The input transport rates are minimal only for transportation on long distances (usually over 1,000 km). In shorter distances the prices go up over 1 and 2, rarely over 3 €/km (Della, 2017) and the difference between a current carbon tax and transport price becomes greater and greater.

It is difficult and thankless to compare the prices especially those in the transport sector. Pricing is a very complicated procedure depending on many variables which have to be taken into account (Berwick & Farooq, 2003). They depend on fuel prices, distance, quantity and kind of goods, kind and size of vehicle, quality of roads, tolls, price policy in transport sector, insurance, handling, waiting and deadlines. Although it is evident in the research that current carbon tax is not competitive, in practice it is difficult to mark exactly the level when it would have been able to become it. The value of 135 €/tCO_2 is certainly high enough price to do it. It deletes complete income of truck on examined route and seems to be exaggerated. The effect of shifting the freight from road to rail transportation can also be done with half the price of eco-cost. However, the eco-cost calculates primarily the impacts of CO_2 on climate change. It is interesting that the value of CO_2 eco-cost covers total external costs calculated in this example (13.10 €) with the input values taken from Table 3. It means that the value of CO_2 taken from it to calculate the share of CO_2 emission cost (11.07 %) in total external cost is significantly underestimated even adding the impact on the climate by 35% more.According to the results, the value of CO_2 emissions in road freight transport might be at least equal (at the level of 65-70 €/tCO_2) and probably higher than the sum of values of all other road transport impacts. Thus, by introducing the carbon tax at the level of 135 €/tCO_2 can mean the complete internalization of external costs in road traffic including the impact on climate change. There is no ambition here to consider the impact of such tax on households, macro economy and development knowing the complexity of introducing a new tax, but it is clear that carbon tax in its present form cannot shift the freight off the road. However, regardless of the transport sector, there are duties determined by the European Commission and the Paris Protocol (Eur-lex, 2016) on the Control of CO_2 emissions and global warming. Since the industrial growth makes this control more and more difficult in order to fulfill the requirements it will be necessary to introduce a tax on carbon in economic form or apply some other economic measure.

5. Conclusions

In terms of the CO_2 emissions, transport policy of the EU, as well as the rest of modern world, is clear: it is necessary to reduce the emissions and control global warming. External costs get the meaning different than before; they become a factor of competitiveness in the transport sector. Internalization of external costs is an operative tool to realize desired objectives bringing new relationships among stakeholders in transport. Introducing the carbon tax should reduce the CO_2 emission shifting the transport from the road to other ecologically more acceptable transport mode including the change of transport routes. A new tax always influences the whole state's tax structure, macro economy and the quality of life. Maximal care in this procedure can result in the values of tax by which it cannot be realized its purpose. The indicative calculation in presented example shows mostly underestimated the external cost of CO_2 emission impact. In this way, a new carbon tax probably does not significantly influence the current tax system but also cannot control CO_2 emissions, shift the freight off the road and choose the eco-friendly routes. According to the results increasing the average tax value by 2 times at least could probably lead to being competitive. The full internalization of external costs including the impact of climate change can be achieved by eco-values of CO_2.

References

International Union of Railways (UIC) (2012) Greening Transport-Reduce External Cost, CER: Paris, Available at: www.cer.be/sites/default/files/publication/2312_ExSum-215x255WEB.pdf (Accessed 10 June 2017)

European Commission (EC)(2011) Transport white paper - roadmap to a single European transport area – towards a competitive and resource efficient transport system, COM (2011) 144 final, Brussels, March 28, Available at:https://ec.europa.eu/transport/themes/strategies/2011_white_paper_en (Accessed 05 June 2017)

Pastori, E.(2011)"Modal share of freight transport to and from EU ports",*European Parliament – Policy Department B: Structural and Cohesion Policies*, DOI:10.2861/21159

Maibach, M., Schreyer, C., Sutter, D., Van Essen, H.P., Boon, B.H., Smokers, R., Schroten, A., Doll, C., Pawlowska, B., Bak, M.(2007)*Handbook on estimation of external cost in the transport sector, Internalization Measures and Policies for All external Cost of Transport* (IMPACT), CE Delft, The Netherlands.

Croatian Bureau of Statistics(2016) Environmental Taxes and Charges 2014,First Release, Vol. LIII, No. 6.1.6., the Croatian Bureau of Statistics: Zagreb, Available at: http://www.dzs.hr/Hrv_Eng/publication/2016/06-01-06_01_2016.htm (Accessed 10 June 2017)

Slabe-Erker, R.(2002)"Poreznaugljikkaomjerasmanjenjaemisijeugljičnogdioksida", *Financijskateorijaipraksa*, **26**(3), 631-655. (in Croatian)

European Commission (EC) (2014)"EU Transport in Figures – Statistical Pocketbook 2014",Luxembourg,*Publications Office of the European Union*, p. 35, DOI:10.2832/63317

Steenken, D., Voß, S., Stahlbock, R.(2005) "Container terminal operation and operations research - a classification and literature review", In: Günther, H.O., Kim, K.H. (eds.) *Container Terminals and Automated Transport Systems*, Logistics Control Issues and Quantitative Decision Support, Springer: Berlin-Heidelberg-New York, p.7. DOI: 10.1007/s00291-003-0157-z

Eco Logistics(2015) Reduction of CO2 Emissions by Improving Distribution Networks, Available at: www.kyoceradocumentsolutions.com/ecology/process/ecologistics.html (Accessed 3 July 2017)

Fremantle Ports(2013) North Quay Rail Terminal Extension, Australian Government, Department of Transport, Western Australia, Available at: www.fremantleports.com.au/SiteCollectionDocuments/NQ%20Rail%20Terminal%20Extension%20newsletter%20Oct2013.pdf (Accessed 3 July 2017)

Probert, O.(2015) Rail port shuttles growing trend in Europe, The Metro tunnel Project, Rail Express, July 24th, Available at: www.railexpress.com.au/rail-port-shuttles-growing-trend-in-europe/ (Accessed 10 June 2017)

Port of Hamburg(2017) Rail access to all Hamburg terminals,Hafen Hamburg Marketing e.V., Hamburg, Germany, Available at: www.hafen-hamburg.de/en/efficient-and-environmentally-friendly-freight-transport (Accessed 10 June 2017)

Rodrigue, J.P.(2017) The Environmental Impacts of Transportation, Dept. of Global Studies & Geography, Hofstra University, New York, USA, Available at: https://people.hofstra.edu/geotrans/eng/ch8en/conc8en/ch8c1en.html (Accessed 10 June 2017)

Schlewing, A.(2012) EC Vision and Policy for Urban Freight Transport - Supply concepts for conurbation from a European perspective, European Commission & DG MOVE, *29th International Supply Chain Conference,* Berlin, Germany, Available at: DLK12_E2-1_Praesentation_Schlewing.pdf (Accessed 15 June 2017)

European Commission (EC)(2013) Towards a Strategy on Serious Road Traffic Injuries – Frequently asked questions, Available at: http://europa.eu/rapid/press-release_MEMO-13-232_en.htm (Accessed 15 June 2017)

Thune-Larsen, H., Veisten, K., Rødseth, K.L., Klæboe, R.(2014) Marginal external costs of road transport. Institute of Transport Economics, Norwegian Centre for Transport Research, Oslo, Norway, Available at: www.toi.no/getfile.php/Publikasjoner/T%C3%98I%20rapporter/2014/1307-2014/1307-2014-sum.pdf (Accessed 5 July 2017)

Austin, D.(2015)Pricing Freight Transport to Account for External Costs, Congressional Budget Office, Working Paper 2015-03, Washington, USA, Available at: http://www.cbo.gov/sites/default/files/114th-congress-2015-2016/workingpaper/50049-Freight_Transport_Working_Paper-2.pdf (Accessed 5 July 2017)

SlabeErker, R., Koman, K., Majcen, B.(2009)"Economic Instruments for Reducing CO2 Emissions and their Consequences",*International Public Administration Review*,Faculty of Administration, University of Ljubljana, **7**(1), 7-25.

European Commission (EC)(2016) Legislative initiative on Fair and Efficient road pricing (review of the Eurovignette Directive), Inception Impact Assessment, Available at: http://ec.europa.eu/smart regulation/roadmaps/docs/2016_move_004_eurovignette_en.pdf (Accessed 15 July 2017)

World Bank(2016) State and Trends of Carbon Pricing, Available at: https://www.carbontax.org/where-carbon-is-taxed/ (Accessed 15 July 2017)

Than, K.(2015) Estimated social cost of climate change not accurate, Stanford scientists say, Stanford News, January 12th, Stanford University, Stanford, California, USA, Available at: http://news.stanford.edu/2015/01/12/emissions-social-costs-011215/ (Accessed 15 July 2017)

Szabo, M.(2015) Keep Alberta's carbon levy programme but raise CO_2 price to $50, leaked report recommends, Carbon Pulse, September 28th, Available at: http://carbon-pulse.com/9455/ (Accessed 15 July 2017)

TU Delft(2012) The Model of the Eco-costs / Value Ratio (EVR). Eco-costs of emissions (Virtual Pollution Prevention Costs, VPPC), Delft University of Technology, Nederlands, Available at: http://www.ecocostsvalue.com/EVR/model/theory/2-emissions.html (Accessed 15 July 2017)

Moore, F.C., Diaz, D.B. (2015)"Temperature impacts on economic growth warrant stringent mitigation policy",*Nature Climate Change,***5**(2), 127–131. DOI: 10.1038/nclimate2481

Schmidt, G.(2016)The Answer to Climate Tragedies is a Carbon Tax, Carbon Tax Center (CTC), Available at: https://www.carbontax.org/the-answer-to-climate-tragedies-is-a-carbon-tax/(Accessed 15 July 2017)

Harrington, K.(2017): What Is Wrong with a Carbon Tax, Scientific American, February 24th, Available at: https://blogs.scientificamerican.com/guest-blog/what-is-wrong-with-a-carbon-tax/(Accessed 15 July 2017)

Evans, S.(2016) Mapped: The countries with the highest carbon price, Carbon Brief, Global Emissions, Available at: www.carbonbrief.org/mapped-countries-with-highest-carbon-price (Accessed 15 July 2017)

Tunnell, M. (2009) Estimating truck-related fuel consumption and emission in Maine: A comparative analysis for a 6-axle 100,000 pound vehicle configuration, ATRI, Arlington, VA, USA, Available at: www.maine.gov/mdot/ofbs/docs/atrimainereport.pdf (Accessed 10 June 2017)

Ilyayeva, R.(2001) Power of a Train, The Physics of Factbook, An encyclopedia of scientific essays, Available at: http://hypertextbook.com/facts/2001/RadmilaIlyayeva.shtml (Accessed 10 June 2017)

Thomas, G.P.(2012) Are Electric Trains Eco-Friendly?,AZoCleantech, Editorial Feature, August 7th, Available at: http://www.azocleantech.com/article.aspx?ArticleID=262(Accessed 10 June 2017)

Norden Ship Design House(2014) 1000 TEU Container Vessel, Istanbul, Turkey, Available at: http://www.nordenshipdesign.com/yuklenen/pdf/container.pdf (Accessed 10 June 2017)

The Commission for Environmental Cooperation (CEC)(2009)ARB LCFS fuel life□cycle pathway documents. 4/9/2009, Available at: http://www.energy.ca.gov/ab118/documents/2009-04-09_meeting/2009-04-09_Carbon_Emission_Graphs.pdf (Accessed 10 June 2017)

Golinska, P., Hajdul, M.(2012)*Development of Intermodal Train Concept*. Sustainable Transport: New Trends and Business Practices, Springer Science & Business Media, Berlin.

Manders, S., Carolan, A.(2013)BITRE Freight rates update for TFES 2012-13, Sinclair Knight Merz: Melbourne, Available at: https://bitre.gov.au/publications/2013/files/SKM_final_report_for_BITRE_2013.pdf (Accessed 15 July 2017)

Geissner, H., Moller, K.(2011)*Case Studies in Logistics,*GablerVerlag/Springer Fachmedien GmbH: Wiesbaden.

Comer, B., Corbett, J.J., Hawker, J.S., Korfmacher, K., Lee, E.E., Prokop, C., Winebrake, J.J.(2010)"Marine Vessels as Substitutes for Heavy-Duty Trucks in Great Lakes Freight Transportation",*Journal of the Air & Waste Management Association*, 60(7), 884-890,DOI:10.3155/10473289.60.7.884

Berwick, M., Farooq, M.(2003) Truck Costing Model for Transportation Managers, Upper Great Plains Transportation Institute, North Dakota State University, Available at: https://ntl.bts.gov/lib/24000/24200/24223/24223.pdf (Accessed 15 July 2017)

Fletcher, R.(2016) Alberta carbon tax calculator: How much will you pay — or get back?,CBC News Interactives, CBC News, Dec 16th, Available at: http://www.cbc.ca/news/canada/calgary/multimedia/alberta-carbon-tax-calculator-1.3900339 (Accessed 5 July 2017)

Della(2017) Transportation prices, Transportation Prices Europe — Europe, Available at: http://www.della.eu/price/local/ (Accessed 15 July 2017)

Eur-lex(2016) Paris Agreement, Official Journal of the European Union, L 282/4, 2016, Available at:http://eurlex.europa.eu/legalcontent/EN/TXT/HTML/?uri=CELEX:22016A1019(01)&from=EN) (Accessed 15 July 2017)