UDC 330

GREEN LOGISTICS – CLIMATE FRIENDLY TRANSPORTATION ASSESSMENT

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Abstract:
Paper presents measures for reducing CO_2 in logistic operations, especially transportation. Fundamental measures (transport fuels, improving vehicle efficiency, vehicle technology, transport efficiency, traffic infrastructure management, integration of transport systems, safety and security, economic aspects of change, broader environmental impacts, equity and accessibility, information and awareness, infrastructure, pricing and taxation and regulation) have been recognized and discussed. Data obtained using questionnaires on substantial number of experts has been used and statistically processed indicating research in transportation fuels, vehicle technology, infrastructure and pricing and taxation for road, waterborne, rail air and road freight transport.

Key words: *Green logistics, Measures reducing CO_2, Logistic environmental impact.*

ЗЕЛЕНАЯ ЛОГИСТИКА – ОЦЕНКА ЭКОЛОГИЧЕСКИ ЧИСТОЙ ТРАНСПОРТИРОВКИ

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Аннотация: *В статье представлены меры по сокращению CO_2 в логистических операциях, в первую очередь в транспортных. Кардинальные меры (топливо транспорта, повышение эффективности транспортных средств, эффективность транспорта, технологии, эффективность перевозок, управление транспортной инфраструктурой, интеграции транспортных систем, безопасность, экономические аспекты перемен, более широкие экологические последствия, обеспечения равенства и доступности услуг, информации и знаний, инфраструктуры, ценообразования и налогообложения и регулирования) были признаны и обсуждены. Данные, полученные методом анкетирования у значительного числа экспертов, рассматривающие транспортировку топлива, транспортные средства, технологии, инфраструктуры и ценообразование, налогообложение в области автомобильного, водного, железнодорожного воздушного и автомобильного грузового транспорта были использованы и статистически обработаны.*

Ключевые слова: *зеленая логистика, меры по снижению CO_2, логистическое воздействие на окружающую среду.*

Introduction

Logistics has been essential to economic development for long time, only in last 50 years it has been extensively used to describe transportation, storage and handling of goods from source to final user with minimal costs. As description states, the primary focus has been economical in order to maximize profit. Basic procedures and models have been created entirely using direct costs in the supply chain and omitting social and environmental costs. Only in recent decade, due to the societal and community concerns, companies are slowly bearing in mind that this costs, especially environmental costs, should be taken into account, especially because of greenhouse gas emission. In logistics, transportation has been primary cause of the environmental pollution, although all other components of logistics have sizeable environmental impact.

Transport intensity measure, especially for road transportation, as shown by Cascade Policy Institute (CPI, 2009), strictly correlates with the GDP of a country and even can be used as an wealth of a nation indicator. Methods aiming at greenhouse gas emission diminution have the challenge of changing this correlation encouraging a less transport intensive lifestyle with no damage to economic development.

Environmental impacts

Kahn Ribeiro and Kobayashi (2007) have estimated that 8% of CO_2 emissions worldwide are from freight transport, but in 2009 OECD "Transport and energy and $C0_2$ "(2) Tanaka has stated that 25% of all CO_2 emissions could be attributed to transport. Cars and trucks represent about 75% of all this emissions, but aviation and maritime transport emissions are growing radically. Although, there is considerable effort in diminution of CO_2 emissions from transportation, growth in transportation encourages transportation energy use, and it is anticipated that it could double by 2050. Additional prediction is that warehousing and goods handling are attributable to 2% to 4% of CO_2 emissions. Taking into account previously written, logistics is, after energetics, second biggest CO2 polluter.

The logistic sector is a very complex system and small changes within one area can have a remarkable consequence overall system, a phenomenon distinctly visible when it comes to research of congestion. Even single transport measure thus cannot be evaluated apart from all relations. When a measure for CO2 reduction is considered, there are always lateral consequences that influence the outcome of this measure. These influences can be operating in the same direction as the original impact and accordingly increasing it (known as multiplier effects) or working in the opposite trend and decreasing the original effect (known as rebound effects). For example, "induced traffic", an infrastructure measure to increase road capacity and to reduce congestion, could induce more traffic, as on improved road conditions there is increasing traffic trend is induced, as people tend to drive more on new and uncongested roads. This is in line with Braess paradox (Braess 1968), that demonstrate that construction of new additional motorway to shorten distances and travel times would increase travel time and congestion for all vehicles.

Measures for reducing GHG

Desk research has defined specific structured methodology, including high level measures for reducing greenhouse gas emission from logistic services. During the research primary objective was to be in line with EU target for carbon reduction (i.e. carbon emissions reductions by 20% by 2020), and it is structured around 15 different measures for GHG reduction used in REACT SRA (REACT 2011): transport fuels, improving vehicle efficiency, vehicle technology, transport efficiency, traffic infrastructure management, integration of transport systems, safety and security, economic aspects of change, broader environmental impacts, equity and accessibility , information and awareness, infrastructure, pricing and taxation , regulation.

Transport fuels as a source of the GHG emissions, have been primary research target, and have been extensively reported as in (Brinkschulte, Deksnis et al. 2001, European Conference of Ministers of Transport 2007, International Energy, IEA et al. 2009, Figueroa, Lah et al. 2014),(European Conference of Ministers of Transport 2007, Black 2010). Main research focus is to substitute conventional fuels with synthetic fuels, LNG/LPG/Gas, fuel cells/hydrogen, biofuels, electricity, solar and wind power and even nuclear power for maritime transport.

Improving vehicle efficiency is based on technological innovations for advancement of fuel efficiency, because improved combustion technologies and optimized fuel systems can reduce fuel economy ((Liimatainen and Pöllänen 2013), (International Energy Agency 2001)

Vehicle technology can be subdivided into advanced internal combustion engines, new combustion systems, design of lightweight materials and aerodynamic / hydrodynamic forms, vehicle emission reduction systems, vehicle energy recovery and vehicle energy management systems. Vehicle technology is also interesting because hybrid-electric and plug-in hybrid-electric vehicles can considerably enhance fuel economy, replacing conventional fuels. This field of research aims to make batteries more affordable while enhancing battery range, life and performance. (Galus, Waraich et al. 2012, Georges, Noembrini et al. 2012, Calnan, Deane et al. 2013){Millo, 2014 #417}

Transport efficiency is significant GHG measure, as today about 30% trucks driving in European highways are empty. Adding to this LTL transport and fact that trucks are not always optimized for weight and volume, transport efficiency is gaining more insights as a important factor for reducing costs and GHG emissions. (Cowie, Ison et al. 2010, Demir, Bektaş et al. 2014). Therefore, better traffic management has the potential to provide substantial CO2 diminutions.

Congestions and gridlock are main problems in traffic infrastructure management, particularly in the cities. INRIX (2015) states that persons in Europe and the US are currently spend on average 111 hours annually in gridlock, and that it would increase about 50% in next 35 years. Smart cities projects are one of the main results of this problem.(Hesse 2008, Barcelona (Catalunya). Ajuntament 2010, Gil Castiñeira, Costa Montenegro et al. 2011, Bigazzi and Figliozzi 2012, Gibbs, Krueger et al. 2013, Grzybwska, Barceló et al. 2013) Today in Europe 50% of the cities with more than 100000 inhabitants that have implemented this initiative.

Integration of transport systems includes door to door applications and transport mode change. Door to door applications as logistics is perfecting, are on the rise, and also include intermodal transportation (Lättilä, Henttu et al. 2013, Sanchez Rodrigues, Beresford et al. 2014). Transport modal change due to greenhouse gas emission has also given more attention to short sea shipping and railway transportation.

Safety and security measure of the GHG emissions reductions are connected with vehicle systems that aim to improve road safety and driver convenience, and safety and security of air and waterborne transport. (Great Britain. Department of the Environment Transport and the Regions. 1999).

Economic aspects of change are significant, because many modification measures in the transport sector are relatively low cost compared to the energy, residential and commercial buildings sectors. . Nevertheless the capital costs of numerous transport sector technological innovations are expected to be elevated and this is an obstacle to commercialisation because upfront costs have a disproportional influence on results concerning energy-efficiency. (Hackmann 2012)

Broader environmental impacts measure is mainly connected with aviation and maritime transport modes, as they are creating additional emissions, for example emissions from aircraft at high altitudes, or sulphur emissions from waterborne transport, to name a few.(Committee for Environmental Conservation. Transport Sub-committee. 1973)

As transport system has to ensure that it is accessible for all people, especially those with reduced mobility, the disabled, the elderly, lower income residents, and those living in underprivileged areas, equity and accessibility is a significant measure, especially when there is a prediction of noteworthy change in logistics and transportation systems.{Blinge, 2014 #375}

Transportation equity and accessibility is a civil and human rights importance. Access to affordable and reliable transportation widens prospects to underprivileged persons, and is essential for those with reduced mobility, the disabled, the elderly, unemployed, poor and those living in disadvantaged areas. European policy documents such as the Mid-term Review of the 2001 Transport White Paper and the European Commission's Action Plan on Urban Mobility (Commission. 2006, Transport. 2009) put an increased emphasis on the quality of access that people and businesses have to the urban mobility system as well as on the protection of passenger rights across all modes of travel. (Stantchev and Merat 2010)

Information and awareness measure is responsible of supporting users in making informed decisions about instruments available for the reduction of CO2 emissions in the transport sector. Few of the policy instruments considered are travel planning, personalised travel planning, general/other awareness campaigns, public transport information, information for vehicle operators, encouraging fuel efficient driving through driver training, and CO2 labelling.
(Gablentz and Chisholm 2000, Ehmke 2012, Nousios, Overbeek et al. 2012)

Transport infrastructures are exposed to a shifting climate, especially as this involves sea level changes, precipitation, temperature, wind and storm frequency. Engineering standards and infrastructure managing traditions may need to be modified to account immense environmental alterations. (Harris, Naim et al. 2011, Rattanachot, Wang et al. 2015)

Pricing and taxation measures involve motorway pricing, fuel taxation, congestion charging and purchase subsidies of low emission vehicles. These measures are tightly connected with regulation measures. Carbon pricing and taxation offer theoretically cost-effective methods of reducing greenhouse gas emissions, as they help to address the problem of originators of greenhouse gases not tackling the social costs. (Proost, Delhaye et al. 2009, Kim, Schmöcker et al. 2013, Changzheng, Greene et al. 2014)

In last decade, regulation has been recognised as an exceedingly effective policy instrument in reducing harmful emissions. This measure is consisting of European regulation on emission performance, integration of transport into emission trading schemes, global transport industry GHG regulation and financial sector regulation to foster sustainable transport. Regulatory framework for reducing CO2 emissions from transportation should be technology neutral, allowing elasticity for producers to comply with the targets and preventing undesired market alterations. (Kodjak 2011, Chen, Zhang et al. 2013, Rajagopal, Plevin et al. 2015)

Results

Results discussed here are part of the results of the survey conducted during work on EU FP7 REACT project. Raw data from (Čišić 2011) have been used and additionally explored. The Open Consultation survey in total has 161 completed questionnaires. Using the calculations in [45], we can conclude that the sample size for 95% confidence interval is inside the error of 8% for the population size up to 500.000. This means that there is 95% of confidence that calculated survey question mean value could vary from -8% to +8% of the real mean value of full population size. Persons involved in answering the questionnaire have been nearly from all of Europe. As for research areas for reducing GHG, there is no major measure that has considerable significant priority.

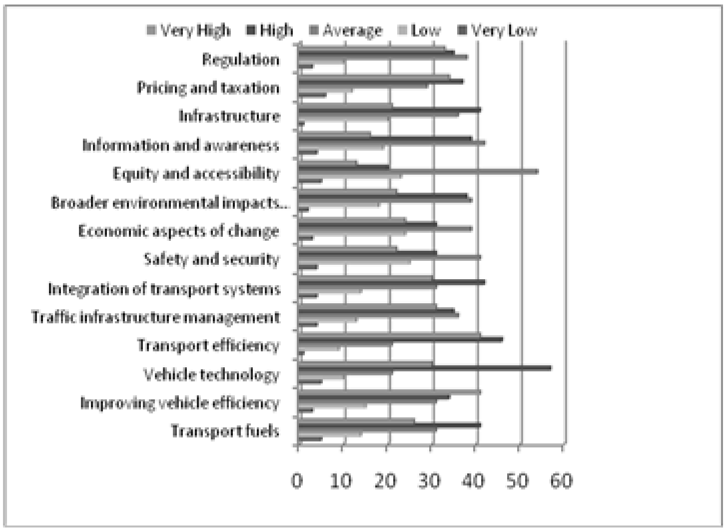

Figure 1 – Research area for reducing GHG priorities

Data from Figure 1 indicate that there is a small but significant difference between the perception of the different measures. Table 1 shows perception order of measures sorted by mean from largest to smallest.

Table1 – Significance of measures for reducing GHG

Measure	Mean	St.dev.
Transport_efficiency	3,991525	0,956273
Vehicle_technology	3,788618	1,034266
Improving_vehicle_efficiency	3,766129	1,112449
Regulation	3,714286	1,042673
Pricing_and_taxation	3,686441	1,145031
Integration_of_transport_systems	3,661157	1,076675
Traffic_infrastructure_management	3,638655	1,087144
Transport_fuels	3,589744	1,091928
Infrastructure	3,512605	0,998860
Broader_environmental_impacts	3,504202	1,015757
Economic__aspects_of_change	3,404959	1,092234
Information_and_awareness	3,366667	1,011973
Safety_and_security	3,341463	1,092668
Equity_and_accessibility	3,113043	0,997938

Although, as seen in the graph, there is a significant difference in priorities for different research areas, when the categorical text data is changed to numbers from 1 (for very low) to 5 (for very high), averages of the research area priorities are very close (ranging from 3.1 to 3.9) with standard deviation around 1. Equity and accessibility is the worst rated research area with average of 3,113 and std.dev of 0,997, and transport efficiency is prime research area with average of 3,9 and std.dev. of 0,995. It is interesting that statistical analysis shows big differences between priorities of participants from different sectors (administration, industry, NGO, research, and university)

It is attention-grabbing fact that experts define that transport efficiency, vehicle technology and improvement of vehicle efficiency have principal significance. Transport fuels are significantly at 8th place in expert significance, although for common person transport fuel alteration is basic idea in green transportation. The reason is that experts can conclude that in short time better results in reducing GHG can be obtained improving transport efficiency, vehicle technology and improving overall vehicle efficiency.

It is also significant that many measures are correlated between them, as shown in table 2.

Table 2 – Correlations between measures. Marked (*) correlations are significant at p< 0,05

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Transport fuels	1	1,00	0,50*	0,43*	0,22*	0,17	0,18	0,31*	0,05	0,31*	0,18	0,13	0,12	0,32*	0,17
Improving vehicle efficiency	2	0,50*	1,00	0,76*	0,30*	0,09	0,08	0,33*	0,09	0,33*	0,20	0,14	0,13	0,15	0,05
Vehicle technology	3	0,43*	0,76*	1,00	0,26*	0,15	0,16	0,31*	0,18	0,30*	0,23*	0,19	0,23*	0,20*	0,14
Transport efficiency	4	0,22*	0,30*	0,26*	1,00	0,36*	0,35*	0,15	0,27*	0,34*	0,29*	0,31*	0,06	0,24*	0,09
Traffic infrastructure management	5	0,17	0,09	0,15	0,36*	1,00	0,57*	0,36*	0,29*	0,15	0,32*	0,24*	0,64*	0,44*	0,49
Integration of transport systems	6	0,18	0,08	0,16	0,35*	0,57*	1,00	0,21*	0,39*	0,30*	0,55*	0,32*	0,38*	0,34*	0,16
Safety and security	7	0,31*	0,33*	0,31*	0,15	0,36*	0,21*	1,00	0,31*	0,15	0,29*	0,20	0,33*	0,11	0,20
Economic aspects of change	8	0,05	0,09	0,18	0,27*	0,29*	0,39*	0,31*	1,00	0,32*	0,45*	0,43*	0,28*	0,35*	0,30
Broader environmental impacts	9	0,31*	0,33*	0,30*	0,34*	0,15	0,30*	0,15	0,32*	1,00	0,45*	0,31*	0,12	0,18	0,07
Equity and accessibility	10	0,18	0,20	0,23*	0,29*	0,32*	0,55*	0,29*	0,45*	0,45*	1,00	0,47*	0,31*	0,30*	0,25
Information and awareness	11	0,13	0,14	0,19	0,31*	0,24*	0,32*	0,20	0,43*	0,31*	0,47*	1,00	0,38*	0,37*	0,30
Infrastructure	12	0,12	0,13	0,23*	0,06	0,64*	0,38*	0,33*	0,28*	0,12	0,31*	0,38*	1,00	0,41*	0,47
Pricing and taxation	13	0,32*	0,15	0,20*	0,24*	0,44*	0,34*	0,11	0,35*	0,18	0,30*	0,37*	0,41*	1,00	0,71
Regulation	14	0,17	0,05	0,14	0,09	0,49*	0,16	0,20	0,30*	0,07	0,25*	0,30*	0,47*	0,71*	1,00

Correlations from table 2 show that there is meaningful interaction between different measures, and that they are closely coupled together. When similar situation occurs, there is possibility, and hope, that number of measures could be reduced. Authors have used principal factor analysis in order to diminish measures and to detect structure in the relationships between variables that is to classify measure. Unfortunately, results have shown that although measures are highly correlated, it is not possible to lower number number of variables, as all eigenvalues extensively involve all measures. Consequently, this means that measures for reducing GHG have been meticulously chosen, and that they represent distinctive collection of descriptive measures.

Although participants have been asked for general opinion about priorities and research mode, results show significant differences for different transportation modes (road, road freight, air, maritime and rail). For the purpose of this paper we will show results on each topic for different transportation mode.

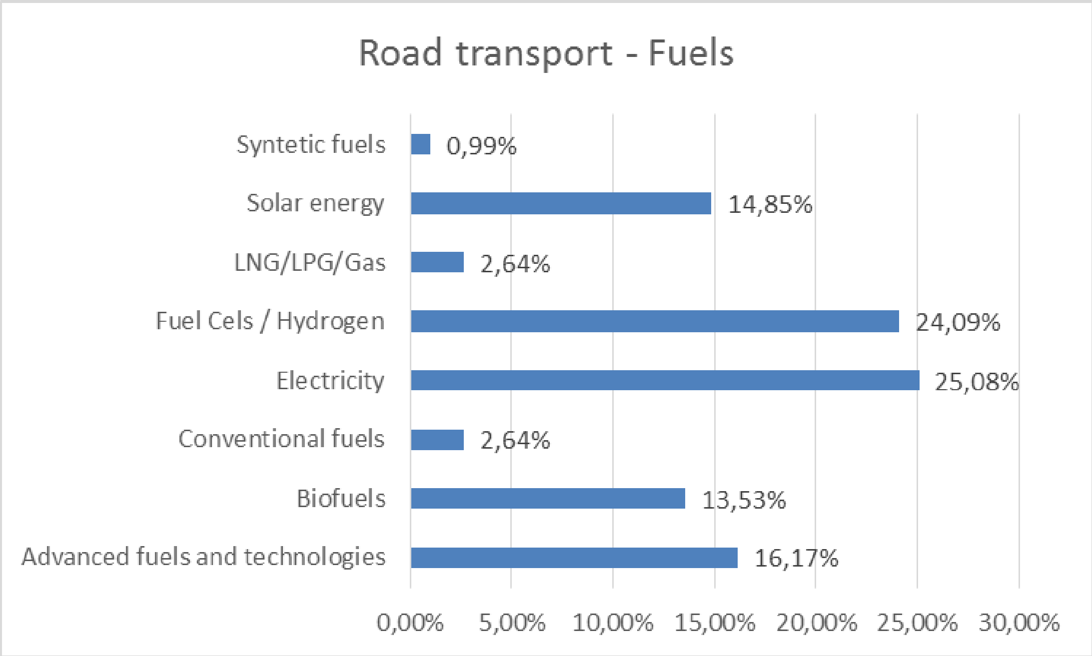

Figure 2 – Results for road transport – needs in fuels research segment

As seen in Figure 2, experts have identified two main roads in research in fuels for road transport – eg. electricity and fuel cells, followed by advanced fuels and technologies and solar energy. It is interesting that conventional fuels, LNG/LPG/Gas and synthetic fuels research should, by the experts opinion, been nearly ignored. As for vehicle technology (Figure 3.) that could be used in road transport the results show that research should be directed towards power generation and distribution and vehicle energy management systems, followed by vehicle emission reduction and vehicle energy recovery. Research in new combustion systems, advanced internal combustion engines and design of lightweight materials and aerodynamic forms would not, by the expert opinion, generate sufficient results that would improve road vehicle technology.

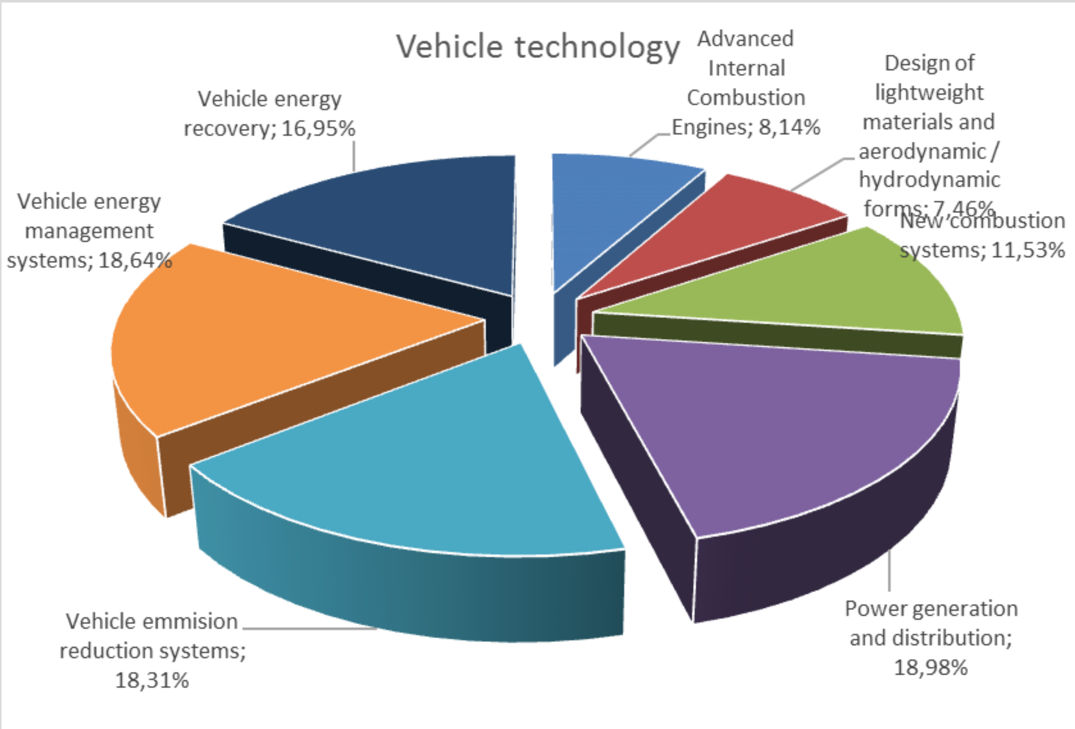

Figure 3 – Results for road transport –needs for research in vehicle technology

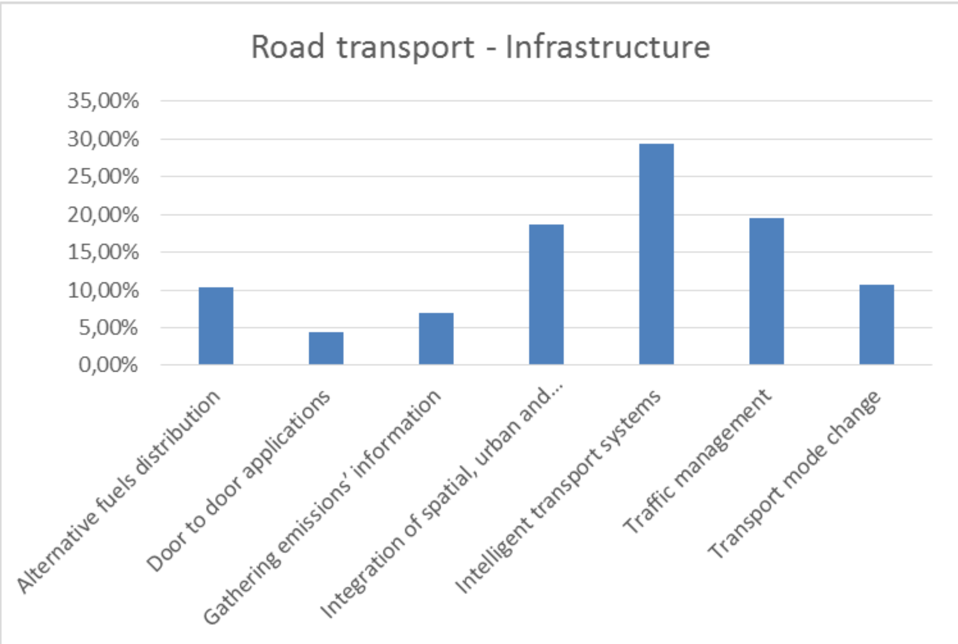

Figure 4 – Results for road transport – research in infrastructure

Infrastructure will generate additional improvement in reducing environmental impact (Figure 4). For road transport ITS (Intelligent transport systems) are first choice for reducing GHG. Traffic management and Integration of spatial, urban and transportation planning and economic policies show that the management systems can in significant levels improve road transport environmental friendliness.

Regulations, pricing and taxation should have economic effect on transportation GHG reduction. Pricing and taxation on non-environmentally friendly vehicles, should reduce the demand and use of polluting vehicles. For road transport (Figure 5.) there nearly all measures have roughly same impact, although congestion charging is leading, followed by fuel taxation , European regulation on emission performance and Financial sector regulation to foster sustainable transport. It is interesting that motorway pricing has been indicated as lowest measure in group.

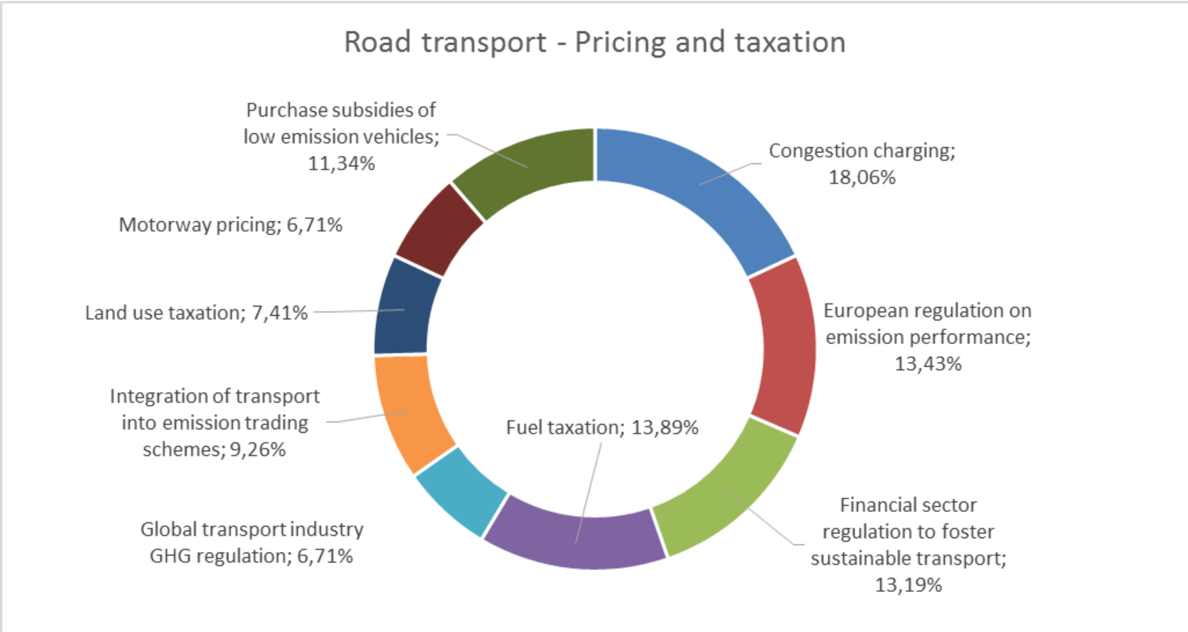

Figure 5 – Road transportation-pricing and taxation measures

Although participants have been asked for general opinion about priorities and research mode, results show significant differences for different transportation modes (road, road freight, air, maritime and rail).For the purpose of this paper we will show results on each topic for different transportation mode.

The result showing priorities for transport fuels for waterborne transport is shown in Figure 6. Results show that the primary priority in maritime transportation is LNG/LPG/ gas as a fuel for waterborne transport. Second rated are advanced fuels and technologies, and third conventional fuels. It is interesting that even nuclear energy as main transport propulsion system is indicated, although with very small priority.

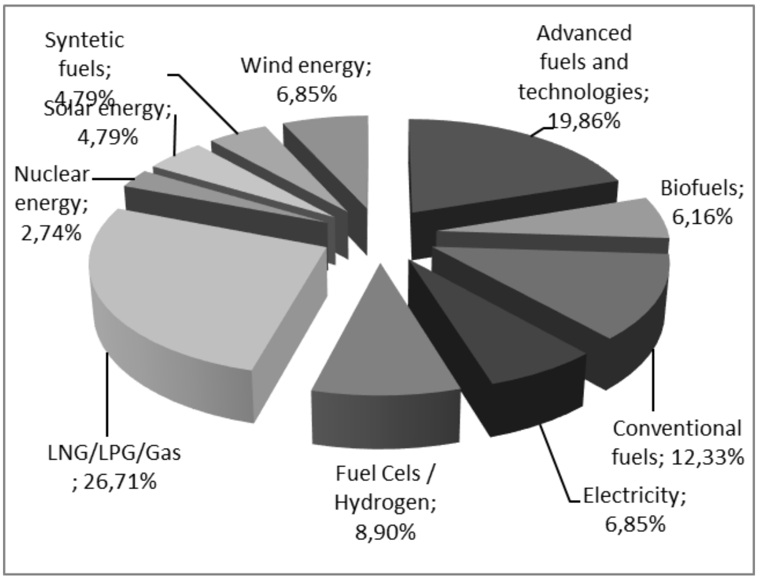

Figure 6 – Priorities in propulsion system for maritime transport

Results showing priorities for vehicle technology for Air transportation are shown in Figure 7.

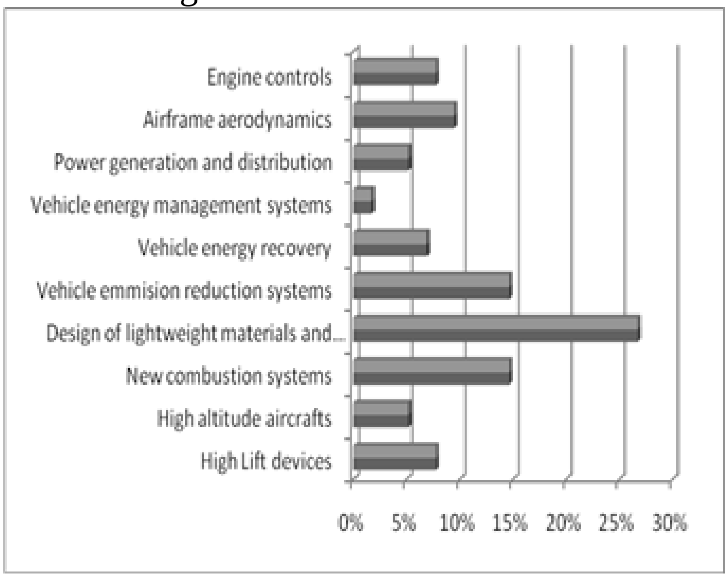

Figure 7 – Priorities in vehicle technology for air transportation

As apparent from the graph, primary vehicle technology for air transportation is design of lightweight materials and aerodynamic forms, which have collected nearly 30% of answers as most important technologies. New combustion systems and vehicle reduction systems are sharing the second and third place, although vehicle reduction systems have obtained more second places. Main propulsion systems for air transport are bio fuels (21%), advanced fuels and technologies (18%) and synthetic fuels (17%).

Research trends in infrastructure have also been a part of the research. Results showing the priorities for infrastructure for road freight transport are shown in Figure 8.

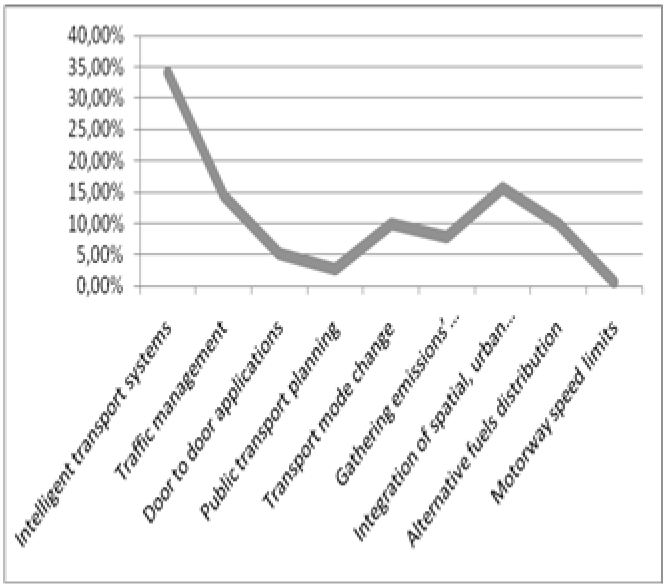

Figure 8 – Priorities in infrastructure for road freight transportation

Intelligent transportation systems are the main infrastructure technology that has to be indicated, followed by Integration of spatial, urban and transportation planning and economic policies and traffic management. It is significant that more than half of respondents have indicated that intelligent transport systems are the main priority in future research for road transportation environment improvement.

Last group of questions have been about environmental taxation and pricing that should contribute to the efficient distribution of environmental goods and services in transportation. Results showing priorities for pricing and taxation for rail and fixed track transport are shown in Figure 9.

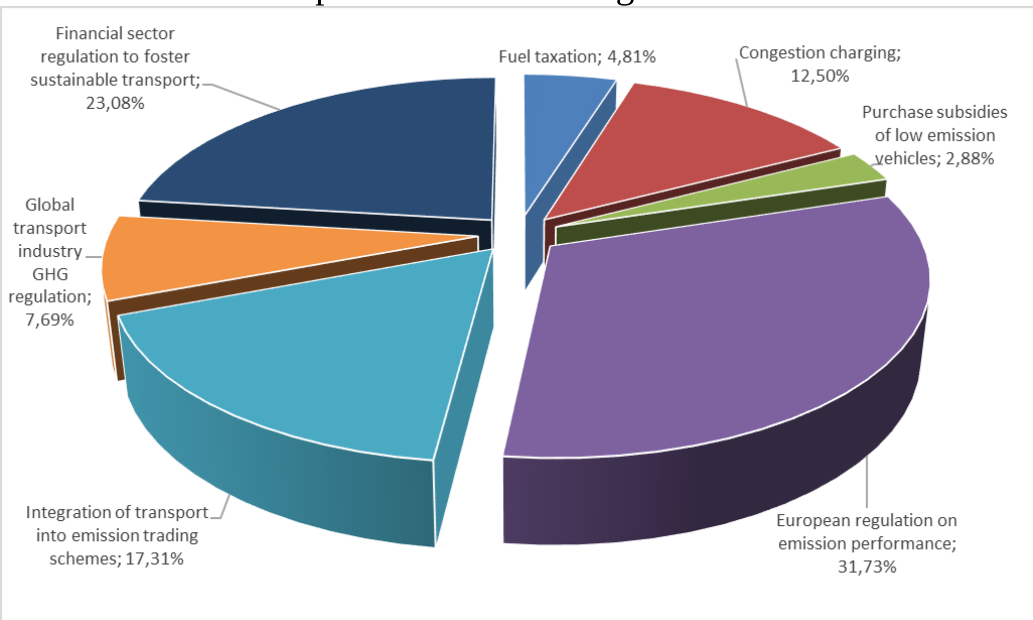

Figure 9 – Priorities in pricing and taxation for rail transportation

It is not a surprise that the main priority for pricing and taxation for rail and fixed track transportation is European regulation on emission performance, followed by financial sector regulation to foster sustainable transport. Interestingly, global transport industry GHG regulation, that is the most significant factor for maritime transportation has very low priority in rail and fixed track sector. Explanation for this is the global presence and performance of maritime transport in contrast with regional (European) presence of rail transport.

Conclusions

This paper presents analysis of main measures for diminishing CO2 in logistics. Essential set of measures has been identified, and then documented. Using results from REACT questionnaire, these measures have been analysed. Research has shown significant correlation between them. Although results have shown that although measures are highly correlated, it is not possible to lower number of variables, as all eigenvalues extensively involve all measures. Consequently, this means that measures for reducing GHG have been meticulously chosen, and that they represent distinctive collection of descriptive measures. Additionally results indicating research in transportation fuels, vehicle technology, infrastructure and pricing and taxation for road transport have been discussed, and the same results for waterborne, rail, air and road freight transportation have been presented.

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