

Multidisciplinary
SCIENTIFIC JOURNAL OF
MARITIME RESEARCH



University of Rijeka
Faculty of Maritime
Studies Rijeka

Multidisciplinarni
znanstveni časopis
POMORSTVO

Green logistics – measures for reducing CO₂

Alfonz Antoni¹, Mile Perić², Dragan Čišić³

¹ BKF University of applied sciences, Hungary

² Autoklub Rijeka, Croatia

³ University of Rijeka, Faculty of Maritime Studies Rijeka, Studentska 2, 51000 Rijeka, Croatia

ABSTRACT

Paper presents measures for reducing CO₂ 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. Using data mining techniques, authors have isolated information from a data set and converted it into an comprehensible structure for additional utilisation. Correlation analysis, multilevel hierarchy and principal factor analysis have been used. Finally, Bayesian classifier method is used to define Bayesian network in order to show interconnections between chosen factors.

ARTICLE INFO

Original Scientific Paper

Received 20 May 2015

Accepted 15 June 2015

Key words:

Green logistics

Measures reducing CO₂

Logistic environmental impact

1. 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 [12], 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.

2. Environmental impacts

Kahn Ribeiro and Kobayashi [33] have estimated that 8% of CO₂ emissions worldwide are from freight transport, but in 2009 OECD "Transport and energy and CO₂" [2] Tanaka has stated that 25% of all CO₂ 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 CO₂ 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 CO₂ 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 [6], that demonstrate that construction of new additional motorway to shorten distances and travel times would increase travel time and congestion for all vehicles.

3. 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 [44]: 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 [3, 4]. 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 [30, 37].

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. [5, 20, 21]

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 both weight and volume, transport efficiency is gaining more insights as a important factor for reducing costs and GHG emissions. [11, 15]. 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) [32] 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. [1, 2, 22, 25, 28] Today in Europe 50% of the cities with more than 100,000 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 [36, 42]. Transport modal change due to greenhouse gas emmision 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. [24]

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. [26]

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. [10]

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.

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 [9, 14] 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. [43]

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. [19, 38]

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. [27, 41]

Pricing and taxation measures involve motorway pricing, fuel taxation, congestion charging and purchase subsidies of low emission vehicles. This measures are tightly connected with regulation measures. Carbon pricing and taxation offer a 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. [7, 39, 34]

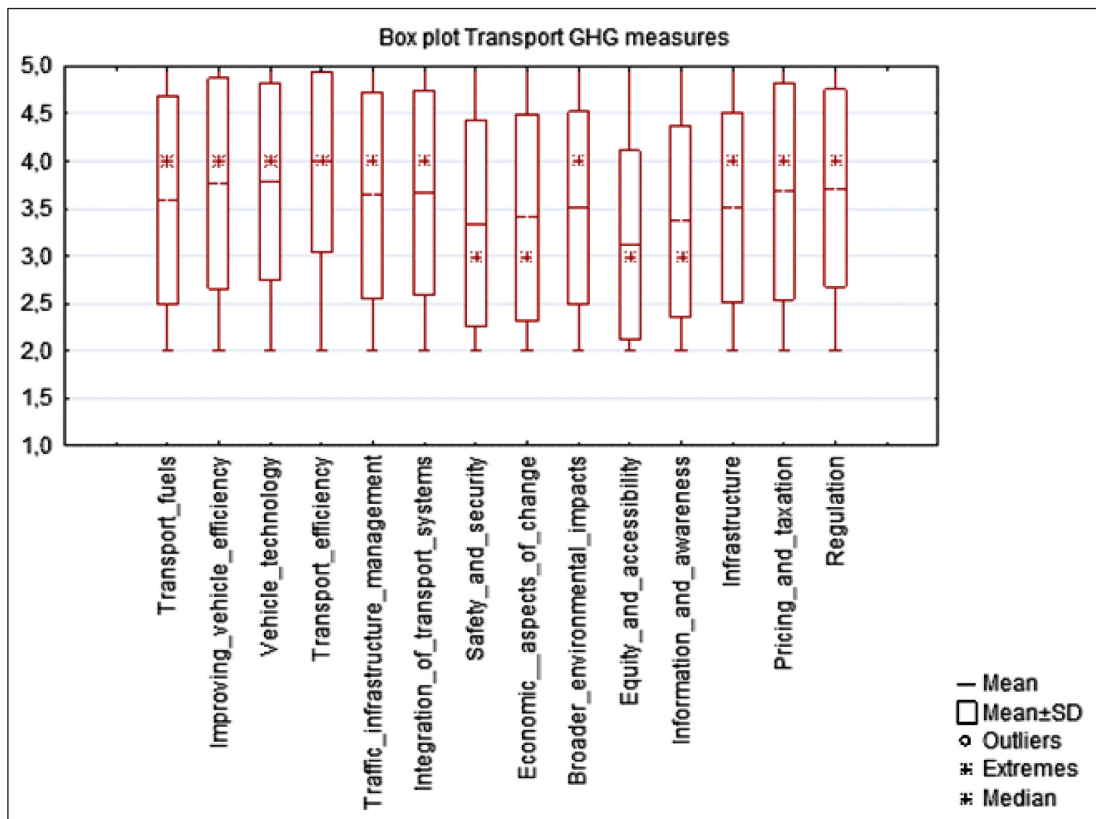
In last decade, regulation has been recognised as an exceedingly effective policy instrument in reducing harmful emissions. This measure is consisting of European regulation on emission performance, integration of transport into emission trading schemes, global transport industry GHG regulation and financial 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. [8, 35, 40]

4. Results

Results discussed here are part of the results of the survey conducted during work on EU FP7 REACT project. Raw data from Čišić [13] have been used and additionally explored. Results from the questionnaire show 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.

Data from Picture 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. 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.



Picture 1 Results from expert questionnaires about significance of measures for reducing GHG

Table 1 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

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

Correlations from table 2 shows 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.

A universal problem is how to combine measures into meaningful structures, that is, to create taxonomies. Authors have used cluster analysis as an exploratory data analysis tool aiming at organising diverse measures into

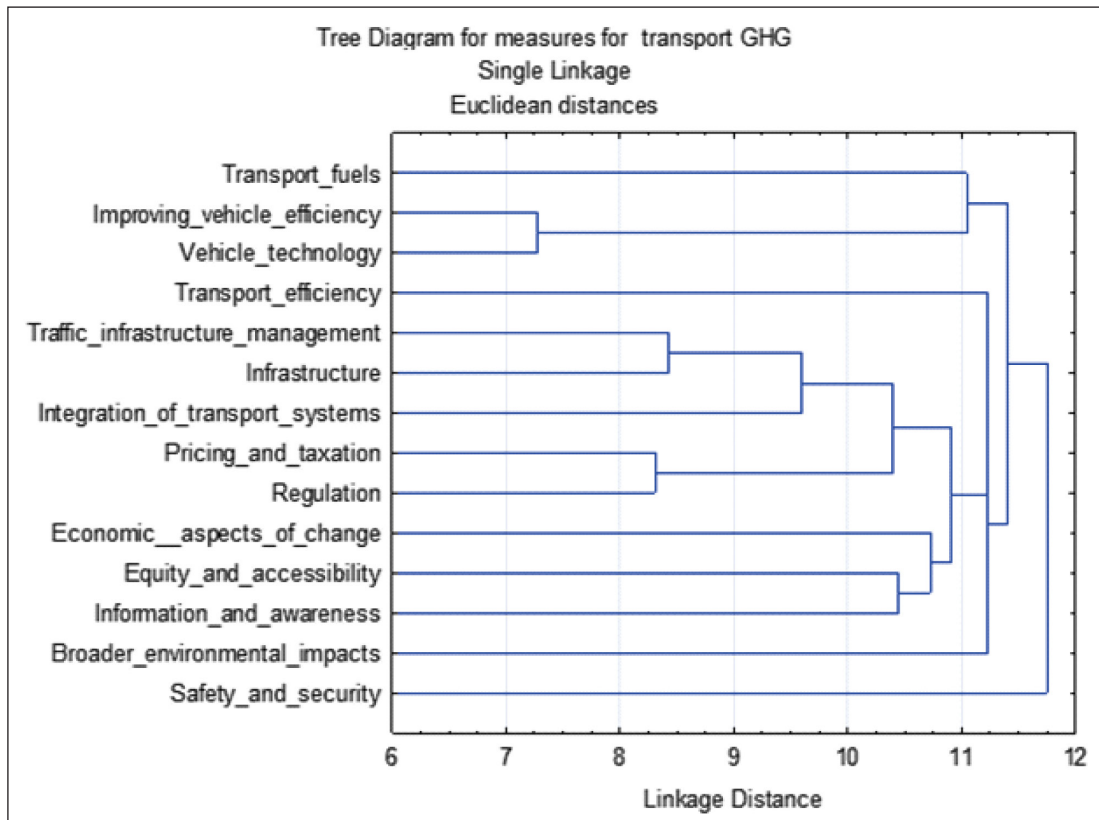
groups in such way that if two measures belong to the same group the degree of association between them is maximal and minimal otherwise. Cluster analysis is used to discover structures in data without explaining why they exist. Results from this procedure are shown in Picture 2. Vehicle technology and improving vehicle efficiency measures are highly associated, followed by the infrastructure and traffic infrastructure management as second group and regulation and pricing and taxation measures as third group. Although this is self explanatory for the expert, this fact shows quality of the data obtained from questionnaire, as cluster analysis method has closely associated measures just from filled marks marks from 1 to 5, given by transportation experts in study.

In order to create model from research data including taxonomies, authors have used Bayesian networks as a graphical model that predetermines probabilistic relationships between variables (measures in our case). When used in combination with previously described statistical methods, graphical model has a number of advantages for data analysis. Bayesian networks are capable of getting results from data where single data is missing and they learn causal relationships, and therefore can be used to extend interpretation about a problem domain and to predict the outcomes of intermediation. Furthermore Bayesian statistical methods in combination with Bayesian networks offer an efficient and righteous method for avoiding the over fitting of data.

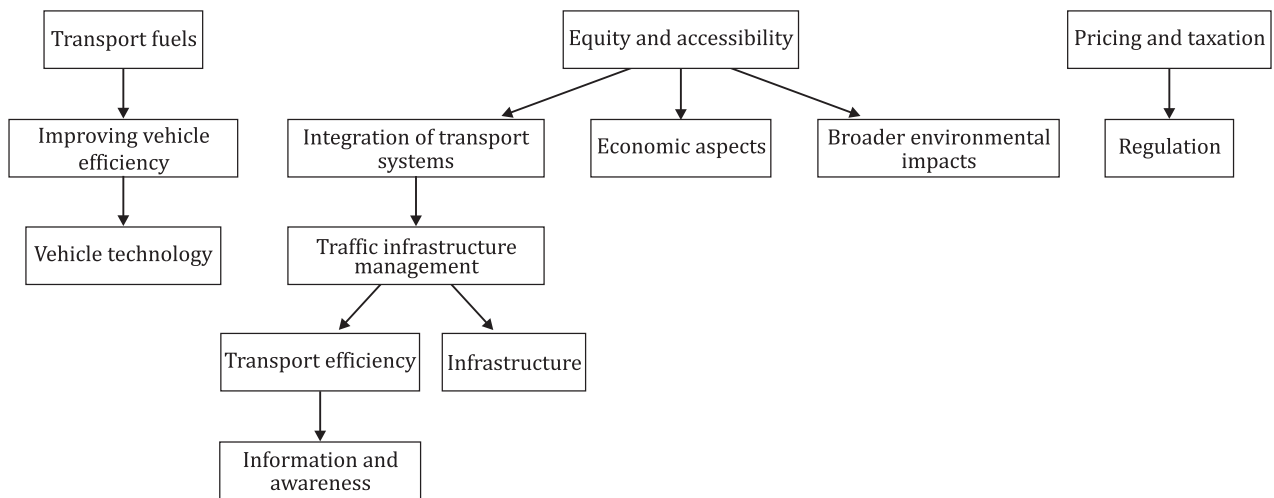
Outcomes from Bayesian inference have created Bayesian network defining relationships between measures for reducing GHG (Picture 3) There are four separate trees in the network starting from transport fuels, equity and accessibility, pricing and taxation and safety and security. All other measures are in subsequent branches following starting measures. This result, combined with previously described statistical methods gives us comprehensive graphical model, grouping measures in structures and specifying taxonomy from the researched data.

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



Picture 2 Clustering tree diagram



Picture 3 Bayesian network of measures for reducing GHG

5. 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, this measures have been analysed. Research has shown significant correlation between them. Hierarchical clustering has been used to group data over a range of scales by generating a cluster tree. This data

have then been used to create Bayesian network defining relationships between measures for reducing GHG. There are three different trees, as measures separate in three different sets; technological, regulatory and socio-economic, and one single measure: safety and security, that no branches. Technological is consisting of transport fuels, vehicle efficiency and vehicle technology. Second set, regulatory, is consisting of pricing and taxation and regulation. Third group is the biggest and is consisting

on all other measures – transport efficiency, traffic infrastructure management, integration of transport systems, economic aspects of change, broader environmental impacts, equity and accessibility, information and awareness, infrastructure.

References

- [1] Barcelona (Catalunya). Ajuntament (2010). eGovernment en Barcelona: Barcelona, smart city, digital city. Barcelona, Ajuntament de Barcelona.
- [2] Bigazzi, A. Y. and M. A. Figliozzi (2012). "Congestion and emissions mitigation: A comparison of capacity, demand, and vehicle based strategies." *Transportation Research, Part D (Transport and Environment)* 17(7): 538–547.
- [3] Black, W. R. (2010). *Sustainable transportation: problems and solutions*. New York, Guilford Press.
- [4] Brinkschulte, H., E. Deksnis, A. S. Bransden, IEA and OECD (2001). *Saving oil and reducing CO₂ emissions in transport, options & strategies*. Paris Cedex, IEA.
- [5] Calnan, P., J. P. Deane and B. P. Ó Gallachóir (2013). "Modeling the impact of EVs on electricity generation, costs and CO₂ emissions. Assessing the impact of different charging regimes and future generation profiles for Ireland in 2025." *Energy Policy* 61: 230–237.
- [6] Braess (1968) Über ein Paradoxon aus der Verkehrsplanung, available from <http://homepage.ruhr-unibochum.de/dietrich.braess/paradox.pdf>
- [7] Changzheng, L., D. L. Greene and D. S. Bunch (2014). "Vehicle Manufacturer Technology Adoption and Pricing Strategies under Fuel Economy/Emissions Standards and Feebates." *Energy Journal* 35(3): 71–89.
- [8] Chen, L., B. Zhang, H. Hou and A. Taudes (2013). "Carbon trading system for road freight transport: the impact of government regulation." *Advances in Transportation Studies*: 49–60.
- [9] Commission., E. (2006). *Keep Europe moving – Sustainable mobility for our continent Mid-term review of the European Commission's 2001 Transport White Paper Communication from the commission to the council and the european parliament brussels*.
- [10] Committee for Environmental Conservation. Transport Subcommittee (1973). *Transport and the environment [Transport Sub-Committee of the] Committee for Environmental Conservation*. London, CoEnCo.
- [11] Cowie, J., S. Ison, T. Rye and G. Riddington (2010). *The economics of transport: a theoretical and applied perspective*. London; New York, Routledge.
- [12] CPI (Cascade Policy Institute 2009): *Driving the Economy: Automotive Travel, Economic Growth, and the Risks of Global Warming Regulations*, available from <http://www.cascadepolicy.org/pdf/VMT%20102109.pdf>
- [13] Čišić, D., Perić-Hadžić, A., Tijan, E., Ogrizović, D. (2011). *Methods of Defining and Evaluating Future Research Priorities in Climate Friendly Transport: Preliminary Results from the REACT Open Consultation*. International Conference on Climate Friendly Transport "Shaping Climate Friendly Transport in Europe: Key Findings & Future Directions". Ed: Z. Radmilović, D. Čišić, Belgrade, University of Belgrade – Faculty of Transport and Traffic Engineering 2011: 346–349.
- [14] DG Energy and Transport. Transport. E. C. D. G. f. M. a. (2009). *Action Plan on Urban Mobility communication from the commission to the european parliament, the council, the european economic and social committee and the committee of the regions in Brussels, Commission of the European Communities*.
- [15] Demir, E., T. Bektaş and G. Laporte (2014). "Invited Review: A review of recent research on green road freight transportation." *European Journal of Operational Research* 237: 775–793.
- [16] Ehmke, J. F. (2012). *Integration of Information and Optimization Models for Routing in City Logistics*. International Series in Operations Research & Management Science, Boston, Springer: v. digital (XIV, p. 197).
- [17] European Conference of Ministers of Transport (2007). *Cutting Transport CO₂ Emissions What Progress?* Paris, OECD Publishing: p. 264.
- [18] Figueroa, M., O. Lah, L. M. Fulton, A. McKinnon and G. Tiwari (2014). "Energy for Transport." *Annual Review of Environment & Resources* 39(1): 295–325.
- [19] Gablentz, O. v. d. and L. Chisholm (2000). *Europe 2020: Adapting to a Changing World*. Baden-Baden, Nomos.
- [20] Galus, M. D., R. A. Waraich, F. Noembrini, K. Steurs, G. Georges, K. Boulouchos, K. W. Axhausen and G. Andersson (2012). "Integrating Power Systems, Transport Systems and Vehicle Technology for Electric Mobility Impact Assessment and Efficient Control." *IEEE Transactions on Smart Grid* 3(2): 934–949.
- [21] Georges, G., F. Noembrini and K. Boulouchos (2012). "Technology Assessment of Plugin Hybrid Electric Vehicles with Respect to Energy Demand and CO₂ Emissions." *Procedia – Social and Behavioral Sciences* 48: 2415–2421.
- [22] Gibbs, D., R. Krueger and G. MacLeod (2013). *Planning smart city-regions in an age of market-driven urbanism*.
- [23] Gil Castiñeira, F., E. Costa Montenegro, F. J. González Castaño, C. López Bravo, T. Ojala and R. Bose (2011). *Experiences inside the Ubiquitous Oulu Smart City*.
- [24] Great Britain. Department of the Environment Transport and the Regions (1999). *Consultation document on transport safety*. London, The Dept.
- [25] Grzybwska, H., J. Barceló and Universitat Politècnica de Catalunya. Departament d'Estadística i Investigació Operativa (2013). *Combination of vehicle routing models and dynamic traffic simulation for city logistics applications*. [Barcelona], Universitat Politècnica de Catalunya: 1 recurs electrònic (p. 320).
- [26] Hackmann, B. (2012). "Analysis of the governance architecture to regulate GHG emissions from international shipping." *International Environmental Agreements: Politics, Law & Economics* 12(1): 85–103.
- [27] Harris, I., M. Naim, A. Palmer, A. Potter and C. Mumford (2011). "Assessing the impact of cost optimization based on infrastructure modelling on CO₂ emissions." *International Journal of Production Economics* 131: 313–321.
- [28] Hesse, M. (2008). *The city as a terminal: the urban context of logistics and freight transport*. Hampshire; Burlington, Ashgate.
- [29] International Energy, A., IEA and OECD (2009). *Transport, Energy And CO₂: Moving Toward Sustainability*. Paris, IEA.
- [30] International Energy Agency (2001). *Saving Oil and Reducing CO₂ Emissions in Transport Options and Strategies*. Paris, OECD Publishing: 200 p.

- [31] IEA (2009), *Transport Energy and CO₂: Moving towards Sustainability*, OECD Publishing, Paris. DOI: <http://dx.doi.org/10.1787/9789264073173-en>
- [32] INRIX (2014) available from <http://inrix.com/economic-environment-cost-congestion/>
- [33] Kahn Ribeiro, S and Kobayashi, S (2007). Transport and its infrastructure, in *Fourth Assessment Report: Climate change 2007 – mitigation of climate change*, Inter-governmental Panel on Climate Change, Geneva.
- [34] Kim, J., J.-D. Schmöcker, S. Fujii and R. B. Noland (2013). "Attitudes towards road pricing and environmental taxation among US and UK students." *Transportation Research Part A* 48: 50–62.
- [35] Kodjak, D. (2011). "Global evolution of heavy-duty vehicle fuel economy and GHG regulations." *Carbon Management* 2(3): 245–260.
- [36] Lättilä, L., V. Henttu and O.-P. Hilmola (2013). "Hinterland operations of sea ports do matter: Dry port usage effects on transportation costs and CO₂ emissions." *Transportation Research Part E* 55: 23–42.
- [37] Liimatainen, H. and M. Pöllänen (2013). "The impact of sectoral economic development on the energy efficiency and CO₂ emissions of road freight transport." *Transport Policy* 27: 150–157.
- [38] Nousios, P., H. Overbeek and A. Tsolakis (2012). *Globalisation and European integration : critical approaches to regional order and international relations*. Abingdon, Oxon; New York, Routledge.
- [39] Proost, S., E. Delhay, W. Nijs and D. V. Regemorter (2009). "Will a radical transport pricing reform jeopardize the ambitious EU climate change objectives?" *Energy Policy* 37: 3863–3871.
- [40] Rajagopal, D., R. Plevin, G. Hochman and D. Zilberman (2015). "Multi-objective regulations on transportation fuels: Comparing renewable fuel mandates and emission standards." *Energy Economics* 49: 359–369.
- [41] Rattanachot, W., Y. Wang, D. Chong and S. Suwansawas (2015). "Adaptation strategies of transport infrastructures to global climate change." *Transport Policy*.
- [42] Sanchez Rodrigues, V., A. Beresford, S. Pettit, S. Bhattacharya and I. Harris (2014). "Assessing the cost and CO₂e impacts of rerouting UK import containers." *Transportation Research Part A* 61: 53–67.
- [43] Stantchev, D. and N. Merat (2010). *Thematic Research Summary: Equity and Accessibility*, European Commission.
- [44] REACT (2011) FP7 Eu project results available from <http://www.react-transport.eu/>