Urszula MOTOWIDLAK

THE POTENTIAL FOR ROAD TRANSPORT COMPANIES TO IMPLEMENT ADAPTATION MEASURES CONCERNING CLIMATE CHANGE

Urszula **Motowidlak**, Associate Prof. (ORCID 0000-0002-2777-9451) – *University of Lodz*

Correspondence address:
Faculty of Economics and Sociology, University of Lodz
Rewolucji 1905 Street 37, 90-214, Łódź, Poland
e-mail: urszula.motowidlak@uni.lodz.pl

ABSTRACT: Since transport is of great importance for sustainable socio-economic development, it is necessary to implement adaptive measures aimed at increasing the resistance of enterprises in the Transport-Forwarding-Logistics (TFL) sector to the negative effects of climate phenomena. The involvement of many entities and institutions at the national, regional, and local levels is necessary to implement effective adaptative and preventive measures. An important role in the implementation of these activities was assigned to transport companies, which are the subject of the article. Based on a survey conducted among a purposefully selected group of enterprises from the TFL sector, an assessment of the awareness of the climate change effects and the need to undertake adaptative activities was made.

KEY WORDS: road transport, CO_2 emission, climate change, adaptation to climate change

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Introduction

Climate change poses a moderate threat to the current sustainable development of transport and a serious threat to the implementation of future development strategies, mainly due to the increased risk of insecurity and the lowering of transport performance standards. The process of identifying the effects of climate change on transport is a multifaceted and very complex process. The consequences of these changes may occur in the form of direct or indirect effects, and they may be measurable or non-measurable. Climate change will result in increased ocean levels, river floods, a change in the distribution of rainfall and its intensity, and extreme climatic events, among others (Rattanachot et al., 2015, p. 162). All these effects interact with each other, creating a chain of processes that is difficult to break, and causing numerous problems in the functioning of transport, especially road transport.

Governments and international communities have focused on the effects of climate change. The study of the climate change impact on transport systems indicates the risk of negative economic, social, and environmental effects (Climate impacts in Europe, 2014). One of the key challenges of the European Union's (EU) transport policy in the coming years will be to ensure the sustainable development of transport and the efficient use of environmental resources in the conditions of climate change. Reducing the sensitivity of transport to climate change will be undertaken simultaneously with the implemented activities that limit greenhouse gas (GHG) emissions (Roadmap to a Single European Transport Area, 2011). The implementation of adaptive activities is a process that requires the involvement of many entities, and entrepreneurs should play an important role in implementing them. The aim of the article is to assess both the awareness of the effects of climate change and the need for transport companies to undertake adaptive activities. The assessment was made on the basis of the results of a survey carried out among a purposefully selected group of Transport-Forwarding-Logistics (TFL) enterprises in Poland.

The effects of climate change in transport as a research area

On the basis of an analysis carried out by the European Topic Center on Climate Change Adaptation (ETC/CCA) at the European Environment Agency (EEA), one can say that one of the sectors of the European economy that is highly sensitive to climate change is transport (EIONET, 2018). The assessment of the potential consequences of climate change in transport is a relatively new but rapidly growing area of research. In Schmidt and Fleig's assessment of the integration of climate policy objectives with the objectives of individual sectoral policies, in the 171 countries covered by the study, a systematic increase in the importance of climate change issues in transport development strategies was identified (Schmidt, Fleig, 2018, p. 179).

The results of the research presented by the EEA confirmed that climate change has an enormous impact on transport (EEA, 2014). The vast majority of transport infrastructure elements and means of transport are exposed to the direct impact of climatic factors. Analyzing the potential effects of climate change on transport, it can be predicted that some will positively affect its effectiveness, e.g., reducing the ice cover of the seas and rivers. However, most of the consequences of climate change will have a negative impact on transport efficiency (Moretti, Loprencipe, 2018, p. 3). The sensitivity and impact of climate change can be analyzed in relation to each type of transport. Road transport, due to its spatial character, is particularly sensitive to changing climatic phenomena (table 1). It is anticipated more intense precipitation events will result in the deterioration of road safety due to the increased frequency of accidents. Precipitation may also increase transport bottlenecks, especially during rush hour. In addition, climate change may cause disturbances in the functioning of road infrastructure. The increased frequency of high temperatures as well as temperatures close to 0°C in the absence of snow cover causes faster degradation of the surface condition.

Table 1. Impact of climate change on road transport

Climate factors/their impact	Effect	Signs of the negative impact of climatic factors on road transport infrastructure and services
Temperature		
High temperatures	Overheating	Destruction of road infrastructure; Reduction in the reliability of electronic components of infrastructure and mean vehicles; The instability of slopes in mountainous regions.
Sudden changes in temperature	Material tension	Signalling problems; Hillside fires;
Change of freezing and thawing cycles	Soil erosion, fog	Rapid degradation of the surface condition; The necessity to conduct earthworks.
Precipitation		
Heavy rain	Landslides, floods	Decrease in traffic safety in road transport; Delays in transport services; An increase in the number of inspections of tunnels, bridges, etc.

Drought	Drying	Decrease in traffic safety in transport (dust); Faster tread wear of motor vehicle wheels; Increased abrasion of mechanical components of infra-structure and mean vehicles.
Snow and ice	Heavy snowfalls, avalanches	Decrease in traffic safety in road transport; Delays in transport services;.
Wind		
Storms on land	High wind force, fallen trees	Decrease in traffic safety in transport; Delays in transport services.
Atmospheric discharges	Surges	Disruptions in the operation of traffic control systems in road transport; Disturbances and a decrease in road safety.

Source: Motowidlak, 2016, p. 98-99.

Depending on the scenario of climate change, the GDP forecast for 2100 may be at least 190 billion EUR annually, which is 1.8% of the current EU GDP. The biggest losses will be borne by the southern and south-central EU regions, which will account for 70% of the EU's financial losses due to climate change. Global warming will affect Northern Europe the least; their share in these losses will amount to about 1%. On the other hand, North-Central Europe, including Poland, will bear 24% of the total financial losses caused by climate change. Analysis conducted by an international team of experts, as part of the WEATHER and EWENT projects, shows that due to extreme weather events, the total costs borne by European transport could increase from 3.5 to 15.0 billion EUR per year to 2070 compared to the 2010 costs, i.e., the base year. In road transport, the annual increase in these costs between 2040 and 2070 could amount to EUR 6 billion, mainly due to higher infrastructure costs (EEA, 2017). Therefore, the consequences of climate change are determined by new areas of research which make it possible to assess the degree of sensitivity, vulnerability, and adaptability of transport.

CO_2 emissions in transport

Observational and model studies of temperature change show that the CO_2 emissions associated with human activities have caused atmospheric warming of at least 0,3°C over the last 15 years (IPCC, 2014). At the same time, scientists warn that by the end of the 21st century, the CO_2 and CH_4 emissions accumulated in the atmosphere could largely be responsible for producing global warming 2-4°C above the pre-1850-1900 levels. In a special report prepared by the Intergovernmental Panel on Climate Change concerning the effects of an average increase in surface temperatures, scientists confirm that exceeding the threshold by more than 1.5°C increases the risks associated with long-term, irreversible changes (IPCC, 2018). Stopping global warming at 1.5°C, according to the Paris Agreement, will require rapid changes, including in the area of transport. Despite this, most of the effects of climate change will still be felt for many centuries, even if GHG emissions are reduced.

The main anthropogenic source of GHG emissions on a global scale is the burning of fossil fuels, on which EU transport is 96% dependent (EU energy and figures, 2018). Measurements of global concentrations of GHG in the atmosphere show a significant increase. In comparison with the data from 1995, their growth in no sector of the EU economy was as high as in the case of transport.

Calculations were made for a linear development trend model using statistical data on GHG emissions, expressed in million tonnes of CO_2 equivalent, in individual sectors of the EU economy in the years 1995-2015:

$$Y_t = \alpha_0 + \alpha_1 T_t + \varepsilon_t, \tag{1}$$

where:
Y_t – total GHG in million tonnes of CO_2 equivalent,
T_t – time variable which accepts the following values: 1, 2, …, 16,
α_0, α_1 – structural parameters of the model,
ε_t – random variable.

The results presented in table 2 show that in industry, households, agriculture, services, and other sectors, there was a systematic decrease in GHG emissions, as the a_1 scores for these sectors are negative.

Table 2. Parameter evaluations and statistical characteristics for the trend model

Specification	a_0	$t(a_0)$	a_1	$t(a_1)$	Se	R^2
Industry	1191.59	69.94	-11.84	5.91	30.17	0.744
Household	850.04	101.45	10.57	10.72	14.83	0.909
Services	544.46	39.91	-7.14	4.47	24.16	0.622
Transport	91.98	103.34	-1.30	12.59	1.56	0.929
Agriculture	192.56	34.50	-1.29	1.99	9.87	0.247
Other sectors	2366.85	137.16	-4.50	2.23	30.55	0.290
Total	5237.59	136.25	-15.60	3.46	68.10	0.501

Source: author's work.

These ratings, except for the service sector, are statistically significant. Only for the transport sector was there a systematic increase in GHG emissions, of 10.57 million tonnes of CO_2 equivalent per year. For this sector, the highest value of determination coefficient $R^2 = 0.909$ was also obtained.

The subject of the analysis was also the volume of GHG emissions (in millions of tonnes of CO_2 equivalent) by particular branches of transport in the EU between 1995 and 2015, based on which calculations were made using the linear development trend model. The calculation results for this model are presented in table 3.

Table 3. Transport – parameter evaluations and statistical characteristics for the trend model

Specification	a_0	$t(a_0)$	a_1	$t(a_1)$	Se	R^2
Road transport	786.59	129.11	11.50	14.96	10.38	0.955
Railway transport	10.79	84.20	-0.22	12.20	0.22	0.930
Air transport	99.00	37.21	4.71	14.01	4.51	0.946
Shipping	18.53	29.59	0.21	2.72	1.08	0.402
Total	1030.31	164.28	21.45	27.14	10.68	0.984

Source: author's work.

The results presented in table 3 show that there was a systematic increase in the examined period for road transport, air transport, total navigation, as well as for total GHG emissions. This is evidenced by the positive assessment of a_1 parameter α_1. These ratings are statistically significant. There are also high values (except for shipping) of R^2 coefficients of determination, which range from 0.946 (for air transport) to 0.955 (for road transport) and up to 0.984 for total GHG emissions. The greatest impact on the growth of GHG emissions, in general, was due to road transport (11.50 million tonnes of CO_2 equivalent) and air transport (4.71 million tonnes of CO_2 equivalent). Only rail transport recorded systematically decreasing GHG emissions – by 0.22 million tons of CO_2 equivalent per year. The a_0 and a_1 ratings are statistically significant in this case. A high degree of concordance between the theoretical results and the empirical data was also obtained. This is evidenced by the high value of the determination coefficient, which is 0.930. This is also confirmed by the low value of the standard residual deviation, which in this case is 0.22 million tons of CO_2 equivalent.

The analysis of the statistical data collected in the Eurostat database (EU transport in figures, 2017) on the volume of GHG emissions in individual sectors in the EU between 1995 and 2015 confirms the growing importance of transport policy in the context of mitigating and adapting to climate change. Special attention should be given to road transport.

Adapting road transport to climate change

Planning adaptation activities in road transport

Adapting to climate change means increasing the resilience of the economy and society to the negative effects of current and predicted climatic events (White paper, 2009). Increased protection is determined by having an effective and efficient response to emerging extreme weather phenomena. The increased road transport capacity to deal with the inevitable effects of climate change makes it necessary to take adaptation measures. The essence of these activities is to use opportunities and reduce economic and social risks resulting from the increase in the frequency of extreme snowfall, heavy rain, as well as wind, heat, and the temperature fluctuating around 0°C.

The process of adapting transport to the effects of climate change on the territory of the EU is already taking place. However, in most EU Member States, it requires a coherent approach and improved coordination at different levels of planning and management. One of the main principles of adapting sectors that are vulnerable to climate change is the win-win rule. It should be understood as the basis for choosing activities that, while pursuing one specific goal, contribute simultaneously to achieving other important social, environmental, and economic goals (Ministry of the Environment, 2018). The actions undertaken in road transport for adapting to climate change require a strategic approach that guarantees cohesion in individual transport subsystems and sectors of the economy. Good examples of such activities are investing in the development of low-emission transport, for example, by introducing new propulsion and alternative fuel technologies and promoting energy efficiency. Increasing road transport capacity to adapt to climate change also means modernizing transport infrastructure or building blue-green infrastructure. The implementation of these adaptive measures has many positive consequences other than just reducing the effects of climate-related hazards. It favors, among others, improving the competitiveness of transport and the economy as well as the quality of life of society.

Understanding the nature of the negative effects of climate change on road transport, and indirectly on the functioning of other sectors of the economy, has prompted some EU countries to identify the necessary adaptive measures in the design, construction, and operation of transport infrastructure. One example is France, where a review of standards and guidelines for the design, maintenance, and operation of road infrastructure was completed in 2015. As a result, several hundred technical standards were changed, including over 800 for roads. The ultimate goal of this review is to adapt road infrastructure, especially with long service periods (sometimes 100 years and more), to future climatic conditions and to support greater resilience to the effects of extreme weather events. At the same time, long-term savings in operating costs and the maintenance of transport infrastructure are expected (Ministry of Ecology, 2015). The information available on the European Adaptation Platform Climate-ADAPT, which resulted from a review of 61 adaptive activities, provides further examples of transport adaptation, including road transport, to climate change (Climate change, 2018). Aparicio emphasizes that most of these activities are local and focused on short-term implementations with immediate effectiveness (figure 1a). They mainly concern the modernization of transport infrastructure, i.e., "Engineering resilience" (Aparicio, 2017, p. 3531-3532).

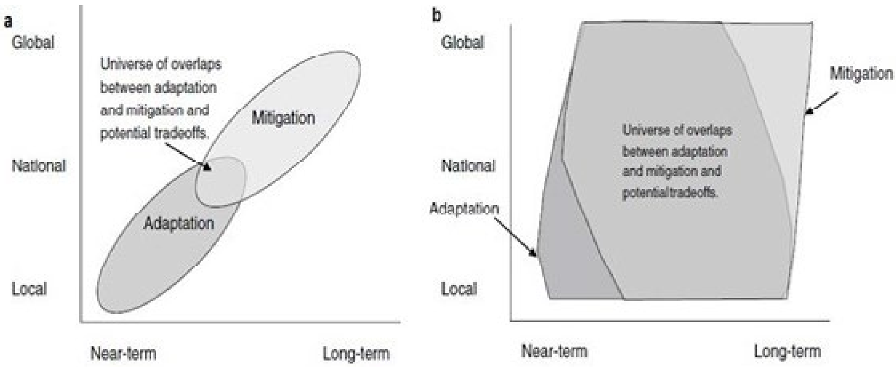

Figure 1. Overlap of Adaptation and Mitigation and the Universe of Potential Tradeoffs
Source: Aparicio, 2017, p. 3531.

Meanwhile, from a long-term perspective, it is important to increase the robustness of the transport system (figure 1b). This will be favoured by ensuring a common approach and consistency between climate change mitigation strategies and plans for adapting to these changes, among others, thanks to modal changes, the development of low-carbon transport, the dissemination of information and communication technologies (ITCs), and a change in public awareness. The effectiveness of these activities will depend to a large extent on the decisions of managers of shipping and transport companies

The importance of adaptive activities to climate change in the assessment of TFL representatives

The development of road transport in the conditions of climate change requires that effective adaptive and preventive measures be undertaken (Ministry of the Environment, 2013). The construction standards that have been developed, as well as ways of managing communication routes, may prove insufficient in the context of challenges related to adapting to climate change. Effective adaptation is not possible without an adequate level of awareness of the hazards and the need to undertake adaptive activities by transport companies. The results of the study, in which assessments of adapting to climate change in road transport were key issues, revealed the significance of these aspects.

Methods

The analysis of the literature on the subject and the activities resulting from the climate policy made it possible to identify essential adaptive measures to climate change in road transport, which are presented in table 4. The significance of these activities was assessed based on a questionnaire survey carried out online. The time range of the study covered the period from January to February 2019. The survey was completed by 78 owners of companies operating in Poland that belong to the TFL sector. Over 3/4 of them are small companies, employing up to 9 people. They ship mainly to the countries of Southern Europe, Great Britain, and Scandinavia. This was a pilot study, and due to the size of the research sample, the results should not be extrapolated to the entire truck transport services sector in Poland. Despite this, the research made it possible to estimate the importance of individual adaptive measures in road transport. The results of this evaluation will be used to refine the directions for further research.

The logic of the questions and the rules of providing answers were related to the degree of acceptance. In order to measure the intensity of "agreement" with the statements, a five-point Likert scale was used. The answers were scored as follows: 5 – strongly agree; 4 – agree; 3 – undecided; 2 – disagree; 1 – strongly disagree. The variability of responses regarding individual items of the scale contained in the question was estimated based on percentages, and then measures of variation.

Table 4. A set of variables to assess the importance of adapting to climate change in road transport

Symbol	Description of activities
TA	The effects of climate change pose a threat to the development of competitive road transport and require adaptive activities
Adaptation activities:	
A1	Providing information about the costs and benefits of adaptive activities
A2	Promoting insurance regarding the effects of climate change
A3	Making available knowledge platforms on the subject of climate change
A4	Using innovative ITC solutions
A5	Joint business-science-administration projects
A6	Taking into account the risks of climate change in the company's financial plans
A7	Developing adaptive strategies in the enterprise
A8	Setting up early warning systems
A9	Strengthening the resilience of transport infrastructure
A10	Modal changes and improving transport efficiency
A11	Using new drive technologies and alternative fuels
A12	Developing social attitudes which are conducive to adapting to climate change

Source: author's work.

Results

The results of the survey, presented in table 5, indicate an overall high awareness among members of the TFL sector of the effects of climate change and the need to undertake adaptive activities. All activities were considered valid. The variables perceived by the respondents as being very important include strengthening the immunity of transport infrastructure (A9), setting up early warning systems (A8), and the use of innovative ITC solutions (A4). The significance of social awareness was also high (average 3.93 and a standard deviation of 1.01).

Table 5. Characteristics of response variability

Symbol	Measurement of consent intensity [%]					Measures		
	5	4	3	2	1	Average	Variance	Standard deviation
TA	37.2	43.5	9.3	7.1	2.9	4.05	1.01	1.01
A1	20.2	44.1	6.7	18.9	10.1	3.45	1.64	1.28
A2	18.6	32.0	17.2	21.8	10.4	3.27	1.63	1.28
A3	15.6	24.7	28.5	22.1	9.1	3.16	1.43	1.20
A4	48.5	36.8	7.9	3.9	2.9	4.24	0.92	0.96
A5	16.5	25.8	26.2	21.8	9.7	3.18	1.49	1.22
A6	15.2	20.5	32.8	22.1	9.4	3.10	1.40	1.18
A7	19.6	28.2	26.2	15.6	10.4	3.31	1.54	1.24
A8	69.2	22.7	5.8	2.1	0.2	4.59	0.51	0.71
A9	86.2	11.9	1.4	0.3	0.2	4.84	0.20	0.45
A10	30.8	34.2	14.2	17.4	3.4	3.72	1.37	1.18
A11	30.7	34.9	18.5	10.7	5.2	3.75	1.33	1.15
A12	33.1	39.1	17.9	7.2	2.7	3.93	1.01	1.01

Source: author's work.

The study also featured three variables that were considered important but less relevant in the area of adapting to climate change. These are A6 (taking into account the risks of climate change in the company's financial plans), A3 (making available knowledge platforms on climate change issues), and A5 (joint business-science-administration projects). The study also shows that A6, A3, and A5 were the least significant variables to small enterprises in the TSL sector. On the other hand, variable A12 (developing social attitudes which are conducive to adapting to climate change) had a higher degree of significance for medium-sized enterprises employing between 10 and 49 people.

Conclusions

Climate change impacts on the transport systems in three different sensitivity aspects: infrastructure, transport operations and transport demand. Therefore, the potential impacts of climate change on transport cannot be overlooked. Due to the large dispersion of the supply side of the domestic TFL services market, it is particularly important to take steps to increase adaptation potential. Small enterprises are usually underinvested and have problems obtaining external capital, so they are less able to adapt to climate change; this may reduce their competitiveness in the international transport market.

The results confirm:

- Climate change poses governance challenges at diverse scales and across the dimensions of risk and responsibility.
- The characteristics of the variability of the response indicate that the effects of climate change are perceived as a serious problem for the development of competitive road transport and the need to adapt.
- According to the questionnaires, the most important actions are based on the so-called "engineering resilience".
- The research indicates the possibility of increasing the adaptive potential of enterprises by including climate change issues in the company's strategy and financial planning, as well as developing cooperation with research and development centres, among others.

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