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Policy developments for the reduction of climate change impacts by the transportation sector

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ABSTRACT

The transportation sector is one of the most significant sources of anthropogenic greenhouse gas emissions. In order to mitigate climate change, it is important to apply effective and immediate policies to reduce the transportation sector's emissions. This study aims to: (1) define the dimensions of the transportation sector, such as its environmental, economic, social, and political elements, and (2) investigate how they relate to climate change, in order to assess potential mitigation scenarios and policies that could reduce the sector's contribution to climate change. First, sector-related variables were specified using expert opinions and a literature survey. Relationships between the variables and the associated intensity values were then identified using document coding, as well as by gathering expert opinions through a workshop. A fuzzy cognitive map analysis was then conducted to investigate the relationships between the variables and the resulting impacts by the transportation sector on climate change. A scenario analysis was also conducted in order to identify the most effective policies in reducing the impacts of transportation on climate change, at both the local and global levels. For the scenario analysis at the global level, projections by the International Energy Agency were analyzed through the model. The local policy suggestions developed by Turkish authorities were also evaluated using scenario analysis.

1. Introduction

Predictions in the Fifth Assessment Report (AR5) developed by the Intergovernmental Panel on Climate Change (IPCC) generally estimate that a 2.0 °C increase in global average temperature is inevitable. The Copenhagen Accord anticipates that average global temperature change should be constrained to under 2.0 °C, which would necessitate reductions of 40 %–70% of total emissions by 2050, compared to 2010 emissions (IPCC, 2014). The projected warming in the twenty-first century is likely to be between two and ten times as large as the observed warming during the twentieth century (Pittock, 2009).

Statistics given by IPCC (2014) reveal that most of the policies have failed to reduce the growth rate of emissions. The highest decadal anthropogenic greenhouse gas (GHG) increase of human history was actualized in the period between 2000 and 2010 with 1.0 gigatonne CO_2-equivalent (CO_2e) average annual GHG emissions. If GHG emissions continue at current rates, the result would be greater warming and damage to the climate system. The largest source of emissions is from fossil fuel combustion and industrial processes, with an approximate share of 78% (IPCC, 2014). At the Paris climate conference (COP21), 195 countries announced their INDC (Intended Nationally Determined Contributions) values, showing their intended amount of CO_2 emission values in the context of their mitigation capabilities and circumstances. The main objective of COP21 was to set out a worldwide action plan to put the world on track to evade perilous environmental change, by constraining the global temperature increase to well beneath 2 °C. It is evident that delivering the likely outputs of possible action plans is vital. Unfortunately, since the agreement is to start in 2020, the countries have not yet provided action plans including policy options, which would help to build trust and accountability. This study aims to help countries in their efforts to develop effective action plans for this purpose.

Xenias and Whitmarsh (2013) reported that the highest increase in

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GHG emissions has been realized by the transportation sector in recent decades. With 14% of total emissions, ascertaining the current situation of the transportation sector and making scenario analyses by drawing from emission projections is extremely important (IPCC, 2014). Since 1997, transportation has become part of the political agenda of the 38 developed countries who signed the Kyoto protocol. Of these, there are some countries of which the transport-related CO_2 emissions currently appear to be trending downward, since the adoption of the Kyoto Protocol, as in the cases of Germany, France, and Japan (Hayashi et al., 2015). The projections of the International Energy Agency (IEA) reveal that world's primary energy demand is expected to increase by 40% between 2007 and 2030 (IEA, 2013). When emission reductions are compared with the expected increase in energy demands, it can be seen that there is much progress to be made.

The management of GHG emissions in the transportation sector can now be considered as one of the key issues on the national as well as the global level. Various studies on the environmental impacts of energy use (e.g. Sreekanth, 2016; Lu et al., 2016; Taylor et al., 2014) underline the rapid growth of pollutant emissions and reveal that national policy makers are in urgent need of appropriate modeling methodologies that can guide the analysis of the implications of different policies on reducing GHG emissions.

The aim of this study was four-fold; the first objective was to reveal an extensive range of variables that shape the structure of the transportation sector. In the first stage, a survey was conducted to reveal the variables related to GHG emissions in the transportation sector, resulting in a preliminary list of variables. This preliminary list was then sent to five internationally recognized transportation academics working on sustainable transportation, in order to reach a final revised list based on their opinions and suggestions.

The second objective was to analyze, with the participation of ten transportation experts during a workshop, the interrelations between the variables as well as the intensity of these relations (with information on magnitude and direction).

The fuzzy cognitive map (FCM) structure can be used for the evaluation of sector responses resulting from positive or negative changes on a specific component, due to external interventions (policy instruments such as tax, emission limits, carbon pricing, or governmental campaigns in research and development (R&D) incentives, among others). Using the FCM structure, a scenario analysis was carried out in order to assess the impacts of different policy variables on the reduction of GHG emissions.

Although there exist numerous studies that focus on a specific transportation mode (e.g. Liu and Wang, 2017; Han et al., 2017; Tiwari et al., 2016), they do not cover the transportation sector as a whole, but rather focus on a specific sub-transportation mode or class (public transportation, freight or passenger transportation, air transport, road transport, among others). This type of modeling fails to reveal the interactions and the effects resulting from the change (either positive or negative) in other components (modes) of the transportation sector. To overcome this shortcoming, this study investigated the transportation sector as a whole, with a detailed variable description.

In fact, there are studies in literature that considers the transportation sector as a whole such as system dynamics approaches. Shepherd (2014) investigates the utilization of system dynamics approach for the strategic policy analysis of transportation systems and reviewed studies on this research area. The research states that there are studies which analyze transportation planning problems with system dynamic models that offer a whole system approach. These studies analyze the long-term effects of short term policies (see Shepherd, 2014 for details). However, those studies do not take into account uncertainties.

Since the proposed model has an uncertain structure in terms of the vagueness of expert opinions and the fuzzy meanings of the documents analyzed, it allows for the evaluation of "concepts" that cannot be assessed numerically. For example, it would not be possible to include the impact of "behavioral change" into a model without a fuzzy type of evaluation.

The final and the most important aim was to integrate qualitative assessment and rigorous modeling in a way that they complement each other in evaluating the impacts of different strategies on reducing emissions.

Hereby, this study defined the transportation sector in all its aspects, in order to analyze mitigation scenarios and develop policies to reduce the impact of the transportation sector on climate change.

The analysis of transportation sustainability necessitates the investigation of a complex system, with many interrelations among the variables. The policies intended to achieve sustainability may have unintended side-effects and may actually jeopardize the accomplishment of other objectives. Therefore, it is necessary to analyze the issue with a system-wide approach. Transportation systems are closely related to economic, environmental, and social dimensions. Policy makers with the challenge of creating a sustainable transportation sector should take a broad three-pronged approach: physical policies related to physical infrastructure, soft policies aiming to change behavior by informing the actors on the consequences of their choices, and knowledge policies that emphasize the critical role of investment in R&D for a sustainable model.

Planning for a sustainable transportation sector is a complicated task. There is a lack of data, an insufficiency of databases and statistics to guide government, industry and individuals, as well as a lack of the ability to analyze the implications of different policies (such as pricing, taxation, R&D, among others) for demography, energy, socio-economics, emissions and other transport–related variables. For these reasons, research and tools developed to date fall short of developing an agreed-upon strategy to reduce the impact of the transportation sector on climate change (Shiftan et al., 2003). This study overcomes the aforementioned drawbacks by proposing the use of an FCM and scenario analysis that provides a comprehensive basis of quantifying the variables and for the analysis of the effects of a particular policy on reducing the impacts of transportation on climate change from a wider perspective. This is done while taking into account the interrelations between demographic, energy, socio-economic, transportation and emission variables. This paper therefore has important contributions both from the point of view of policy, but also in terms of methodology.

The structure of this paper is as follows: the next section presents a literature survey on the assessment of policies on sustainable transport, FCM, and the use of scenario analysis in transportation planning. The third section highlights the basic steps of the methodology. The fourth section presents the results of the scenario analysis performed and specifies basic policies that should be adopted in order to reduce the GHG emissions of the transportation sector. Finally, conclusions and further suggestions are made.

2. Literature overview

2.1. Assessing policies for sustainable transport

In this study, the main focus of the literature survey is to investigate the research conducted in order to identify the implications of different transportation policies on climate change. The articles evaluated in this study provided the initial list of variables that were chosen to be input in the proposed model. Subsequently, this initial list was revised and enlarged based on expert suggestions. The experts chosen in this study were selected based on their specific areas of expertise. The experts were selected so as to ensure that transportation sector and climate interactions were analyzed from different perspectives (urban planning and economics, economic policy, transportation economics, civil engineering, distribution, and logistics). Therefore, although they are all transportation experts, each concentrates on a different sub-topic, which helped to have a rich and homogeneously-distributed set of parameters and thus a resulting model that was able to represent their interactions.