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A selected review on the negative externalities of the freight transportation: Modeling and pricing

Emrah Demir [a,*], Yuan Huang [b], Sebastiaan Scholts [a], Tom Van Woensel [a]

[a] School of Industrial Engineering, Operations, Planning, Accounting and Control, Eindhoven University of Technology, Eindhoven, The Netherlands
[b] School of Management and Centre for Operational Research, Management Science and Information Systems, University of Southampton, Southampton, United Kingdom

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ABSTRACT

The planning of freight transportation activities creates benefits as well as costs. Among those costs, some of them, namely externalities, fall on other people/society that have no direct relevance to the operations of transportation. Such externalities are accrued expenses which should be addressed by actual pricing policies to enable an efficient and sustainable freight transportation system. This paper reviews externalities in quantitative terms, and then provides pricing studies of these costs per unit of freight transported along with the most recent estimations. The associated negative externalities are structured by transportation mode (road, rail, maritime, and air).

1. Introduction

Transportation deals with carrying goods and/or passengers using one or multiple modes of transport. A conventional focus on planning the associated activities, in particular for the former namely freight transportation, is to reduce expenses and, consequently, increase profitability by considering internal transportation costs, e.g., fuel costs, drivers' wages (see, e.g., Greene and Wegener, 1997; Forkenbrock, 1999, 2001). With an ever growing concern about the environment by governments, markets, and other private entities worldwide, organizations have started to realize the importance of the environmental and social impacts (e.g., air pollution, noise, and congestion) associated with transportation on other parties or the society as a whole. Such impact is termed as 'externalities', where 'other parties' are entities that did not choose to incur the impact. In 2008, the total external costs of transport in EU-27 (EU's 27 states plus Norway and Switzerland) amount to more than 5–6% of the total GDP (Van Essen et al., 2011). Kinnock (1995) provides a rough estimation of the external costs of transportation: proportional figures of 0.4%, 0.2%, 1.5% and 2% are applied to the total costs of air pollution, noise, accidents and congestion, respectively.

While it is acknowledged that passenger transportation plays a no-less significant role than freight transportation in externalities (Van Essen et al., 2011), the choice of transportation modes varies significantly in individual circumstances (e.g., travel distance, travel purpose, time and location constraints, local transportation infrastructure). The purpose of the paper is to promote awareness and understanding of transportation external costs from the perspective of business rather than individuals (e.g., passengers) as the latter to a greater extent involves the context and subjective decisions. Thus, the rest of the study mainly focuses on freight transportation. Where papers describing general transportation are included, the referred external

* Corresponding author.
E-mail addresses: e.demir@tue.nl (E. Demir), yuan.huang@soton.ac.uk (Y. Huang), sebastiaan.scholts@gmail.com (S. Scholts), t.v.woensel@tue.nl (T. Van Woensel).

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costs are considered of direct relevance to freight transportation. Estimating the external costs of freight transportation can be used for several purposes: to guide for the design of more economically efficient pricing systems; to facilitate the allocation of research and development funds for mitigating the largest external costs; to support cost-benefit analysis of optimal investment in transportation modes and infrastructure[1]; and to aid historical or comparative analyses.

Externalities incur benefits as well as costs, termed as positive externalities and negative externalities. This paper addresses the latter. The most prominent negative externalities of relevance to transportation contain emissions (air pollution and greenhouse gases (GHGs)), noise, water pollution, congestion and accidents (see, e.g., Levinson et al., 1998; Spellerberg, 1998; Santos et al., 2010). Moreover, Land use (or infrastructure) is an increasing source of concern, due to the negative effects (e.g., visual intrusion) on the environment (Blum, 1998). Air pollution includes particulate matter (i.e., small particles of dust, soot, and organic matter suspended in the atmosphere), carbon monoxide (i.e., colorless, odorless, poisonous gas produced when carbon-containing fuel is not burned completely), ozone which is formed when emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) chemically react in the presence of sunlight, and hazardous air pollutants, also referred to as air toxics (i.e., chemicals emitted into the atmosphere that cause or are suspected to cause cancer or other severe health effects). The emissions of GHGs is probably the most well-known and studied externality of transportation due to its global effects. Transportation related noise can cause health problems, which is mostly considered to be nuisance for those that have to deal with it. Water pollution is resulting from spills, leakages and accidental or deliberate disposal of cargo material or other materials used in the transportation process. Congestion costs mainly arise due to the fact that the travel time of other transportation users increases. Accident costs refer to the emergency services attending the accidents, delay of traffic, and the costs to the victim's family in pain and suffering. Examples of land use effects include the visual intrusion of transportation on the landscape, and the destruction of habitats and species loss due to transport infrastructure.

To the best of our knowledge, the definitions of externalities in freight transportation have been limited to the above-mentioned ones (i.e., emissions, noise, congestion, accidents, water pollution and land use) in the literature. However, there are other important externalities that require further attentions in academia as well as practice, such as the effects due to the production of vehicles and transport infrastructure (i.e., energy production, vehicle production, maintenance and disposal, infrastructure construction). In this paper, we have not covered the later group since the aim of the paper is to review the most widely discussed externalities in the literature and there is yet sufficient scientific evidence in the latter group. The maturity in this matter is still needed to fill the academic void left over by the researchers. A few initiatives (see, e.g., Maibach et al., 2008; Korzhenevych et al., 2014) have already emerged to provide a full assessment of externalities, but this was not enough to make a comparison like in other well discussed externalities.

Among prior studies investigating externalities of transportation (see, e.g., Miller and Moffet, 1993; Mauch and Rothengatter, 1995; IBI Group, 1995; Spellerberg, 1998; Ranaiefar and Regan, 2011), a predominate stream encloses initiatives to reduce emissions (e.g., carbon dioxide) from transportation by, for example, minimizing 'empty kilometers' (see, e.g., Demir et al., 2014b) or using 'greener' transportation modes (e.g., trains/barges compared with cars or trucks) (see, e.g., Forkenbrock, 2001; Black et al., 2003; Lawson, 2007; Zimmer and Schmied, 2008). While a few studies have paid attention to other externalities, the focus is limited on road transportation (see, e.g., Forkenbrock, 1999; Lindberg, 2002). This is not surprising as road is the dominant mode of inland transportation. However, transportation services involve various transportation modes – road, rail, maritime, air and pipeline, where externalities that arise are dramatically different (Maibach et al., 2008). Despite the increasing attention to transportation related externalities in the literature, actions to mitigate the externalities in practice do not seem as promising as expected due to the lack of alignment between the economic concern and environmental impact. Should the external costs of freight transportation be effectively internalized and paid, decisions and activities can be shifted from economic-led to the balance between economic and environmental concerns.

In the last decade, the body of knowledge on the reduction of externalities from freight transportation has grown notably, where most of the studies are case or context specific. This paper aims to provide a state-of-the-art review of the models and the pricing studies for externalities incurred by transportation and logistics covering different transportation modes. The scientific contribution of this study is threefold: (i) to review negative externalities that have been addressed in the freight transportation literature; (ii) to present and compare a proper mathematical modelling of each externalities, where possible; and (iii) to review the scientific literature on the internalization of the externalities. The remainder of this paper is organized as follows. Section 2 presents a review methodology for the literature study. Section 3 discusses the externalities of freight transportation followed by the modelling of externalities in Section 4. Section 5 investigates the pricing of the negative externalities. Conclusions and future research directions are stated in Section 6.

2. Review methodology

This review focuses on the freight transportation literature that addresses the negative externalities. The negative externalities are studied mainly based on the work of Maibach et al. (2008) and Brons and Christidis (2012) who examine

[1] In order to have a full assessment (Rodrigue et al., 2013) of transportation modes, a life-cycle of the transportation asset and infrastructure should be considered. However, it is not easy to consider the life-cycle of every input to the transportation system. These include: pre-production, construction, utilization, refurbishing, destruction, and disposal. Ignoring the life-cycle of all inputs may lead less reliable results.