Journal of Cleaner Production 164 (2017) 153–162

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

The influence of new carbon emission abatement goals on the truck-freight transportation sector in South Korea

Jaehun Sim*

Industrial & Management System Engineering, Dong-A University, Busan, South Korea

ARTICLE INFO

Article history:
Received 21 January 2017
Received in revised form
23 June 2017
Accepted 23 June 2017
Available online 24 June 2017

Handling Editor: Cecilia Maria Villas Bôas de Almeida

Keywords:
Carbon emission abatement plan
Monte Carlo simulation
Parametric sensitivity analysis
System dynamics approach
Transportation

ABSTRACT

As South Korea is one of the largest global carbon emission contributors, its government has committed to mitigating the environmental impact of carbon emissions by assigning specific goals for carbon emission abatement to each major industry sector. The South Korean government has recently put forward four national abatement plans for carbon emissions from the projected 2030 business-as-usual level. The government elected to follow the third of the four plans. However, it is possible that the government might adjust to future economic fluctuations by going forward with one of the other three plans. This study focuses on the four carbon emission abatement goals as they relate specifically to the truck transportation industry, which is a subsector of the larger transportation industry. Since it is expected that truck-freight volume will continue to grow, this study utilizes a system dynamics modeling tool to develop a carbon-emission-abatement plan model to measure the abatement amounts required for South Korea's truck-freight sector from the year 2015 to the year 2030, while investigating the effects of uncertainty in truck-freight volumes and technology developments on those abatement amounts. The results indicate that the truck sector needs to abate carbon emissions by 272.77 M kg CO_2 for Plan One, 356.27 M kg CO_2 for Plan Two, 476.88 M kg CO_2 for Plan Three, and 580.79 M kg CO_2 for Plan Four by the year 2030. In addition, this study formulates a simple mathematical model for determining the optimal transportation volumes of a combination of three trucks types and rail transport for the assigned carbon emission quota.

1. Introduction

As the direct and indirect influences of global warming on the global economy have emerged as some of the most important business issues in recent years, many multinational companies have realized the necessity of reducing carbon dioxide (CO_2) emissions to mitigate possible disruption risks in the production and transportation sectors of their supply chains that could be caused by natural disasters (Chen and Wang, 2016). In addition to these companies, both developed and developing nations take seriously the long-term effects of global warming on their national prosperity in terms of economy, environment, and society. As a result, many nations have formulated various environmental plans and regulations intended to decrease carbon emission (CE) production (Chen and Wang, 2016). Because South Korea (SK) is one of largest sources of CE production in the world (IEA, 2012), the South Korean government (SKG) has drafted various plans aimed at achieving a 30% greenhouse gas (GHG) emission abatement (233 M CO_2 equivalent tons) from the projected 2030 business-as-usual (BAU) level by the year 2020 (Sonnenschein and Mundaca, 2016).

In order to attain South Korea's GHG abatement goal, specific CE-abatement goals have been assigned to seven major sectors – 34.3% for transportation, 26.9% for building, 26.7% for energy, 25% for public, 18.5% for industry, 12.3% for waste management, and 5.2% for agricultural and fishery (ME, 2014). The transportation sector has been assigned the largest abatement goal since it produces the largest portion of total CEs (Dekker et al., 2012). Among the three major transportation modes within this sector – air, land, and sea – the land-transportation sector transports approximately 76% of the total transportation volume in SK (KOTI, 2015) and therefore has been assigned the majority share: 34.2 M CO_2 equivalent tons reduction by the year 2020.

The recent slow economic growth has led to a reconsideration of the nation's aggressive GHG emission abatement goals, resulting in four alternatives −14.7%, 19.2%, 25.7%, and 31.3% – from the

* 37 Nakdong-dearo 550 beon-gil, Saha-gu, Busan, 49315, South Korea.
E-mail address: jaehunsim88@gmail.com.

http://dx.doi.org/10.1016/j.jclepro.2017.06.207
0959-6526/

projected 2030 BAU level (MLIT, 2015). At the national level, the first plan (Plan One) aims at decreasing 125 M CO_2 equivalent tons by decreasing GHG emissions 14.7% from the projected 2030 BAU level, the second (Plan Two) aims at reducing 163 M CO_2 equivalent tons by decreasing GHG emissions 19.2%, the third (Plan Three) aims at decreasing 218 M CO_2 equivalent tons by decreasing GHG emissions 25.7%, and the last (Plan Four) aims at reducing 266 M CO_2 equivalent tons by decreasing GHG emissions 31.3% (MLIT, 2015). The need for action is clear: it is anticipated that 850.6 M CO_2 equivalent tons of carbon will be produced by the year 2030 if no change is made.

In June 2015, the SKG selected Plan Three as the nation's new CE-abatement goal. However, it is possible that there will be adjustments to the abatement goal in response to future economic fluctuations. To prepare for that case, this study aims to estimate for each of the suggested plans the recommended abatement amount of CEs for the truck-freight transportation sector, which contributes the largest portion to SK's industrial and economic development under its trade-oriented growth strategy. According to the specific carbon-reduction targets assigned to each industry by SKG, automobile material acquisition and automobile production belong to the manufacturing industry, while truck-freight transportation is considered as belonging to the transportation sector (Sim and Sim, 2017).

For these reasons, this study defines the truck-freight transportation sector as the system boundary, while employing a system dynamics approach to analyze the requisite CE-abatement goals in the four plans for the truck-freight transportation sector by the year 2030. This study also performs a sensitivity analysis to measure the influence of annual freight-transportation volume and CE-density values on the anticipated total CEs generated from the truck-freight transportation sector. In addition, this study calculates the optimal transportation volume of a combination of truck and rail modes under the parameters of the acceptable annual CEs in the transportation sector. Based on the results of this study, policy makers in the SK government will be able to estimate the required amounts of CEs at a given reduction target in the truck-freight transportation sector.

2. Literature review

Several research studies have been carried out to estimate the carbon emissions generated from the land-transportation sector, as well as to investigate the effects of various strategies on CE abatement in that sector. Other studies to determine CEs within the land-transportation sector have occurred in Asia (El-Fadel and Bou-Zeid, 1999; Li et al., 2013; Wu and Huo, 2014; Keuken et al., 2014; Lin and Xie, 2014; Zhou and Yang, 2014; Yuan et al., 2015), Australia (Stanley et al., 2011), Canada (Steenhof et al., 2006), Europe (Berkowicz et al., 2006; Andrew et al., 2009; Tunç et al., 2009; Achour et al., 2011), and the United States (Kite, 2010; Venugopal, 2010; Ozguven et al., 2013), along with the Organization for Economic Cooperation and Development nations (Greening et al., 1999; Kamakaté and Schipper, 2009).

In order to determine the best methods for mitigating the environmental impact of land transportation, various strategies have been analyzed in terms of vehicle efficiency, alternative fuels, travel management, road capacity, public transportation, and taxation (Javid et al., 2014). Research has found that energy-intensity improvement decreases energy consumption and CEs in the transportation sector (Michaelis and Davidson, 1996; Timilsina and Shrestha, 2009), as do high-efficiency vehicles (Yang et al., 2009; Skippon et al., 2012). In addition, alternative fuels — biofuel, electricity, and hydrogen — noticeably influence CE abatement in the transportation field (Yang et al., 2009; Leighty et al., 2012).

By the same token, the expansion of public transportation improves air quality by reducing the CEs generated from the private transportation sector (McCollum and Yang, 2009; Almselati et al., 2011; Stanley et al., 2011), while proper travel management (McCollum and Yang, 2009) and road-capacity increase (Chapman, 2007; Chandran and Tang, 2013) have some effect on the CE abatement in the land-transportation sector. In addition, some research studies found that a carbon tax on fuel is an effective strategy for decreasing the CEs produced in the transportation sector (Chapman, 2007; Van Dender, 2009; Yan and Crookes, 2009; Kim et al., 2011; Solaymani et al., 2015).

A review of the relevant literature on the transportation sector indicates that several strategies can decrease the total CEs caused by transportation activities while also decreasing energy consumption. However, to date, little research has endeavored to estimate the CE abatement amount of the Korean transportation industry by the focus year, 2030. Thus, the objective of this study is to build a CE-abatement model to measure the total emission amount and the requisite CE abatement amount from 2016 to 2030, while satisfying the specific CE-abatement goal assigned to the transportation industry by the government. The results of this study can be used as basic data for government officials to estimate the corresponding amount of CEs in the transportation industry under the four CE plans, as well as the optimal transportation volume of truck and rail. As a result, environmental policy makers will be able to determine which plan to implement and which mix of freight-transport modes should be promoted in order to reach the desired emission control and economic stimulus goals.

3. Methodology

Following the authors' previous study on the carbon emission goals of an apartment building (Sim and Sim, 2016), a similar methodology is applied to analyze the requisite CE abatement in the truck-freight transportation sector under the suggested four CE-abatement plans by the year 2030, while developing a CE-abatement model using a system dynamics modeling framework. The total amount of CEs generated from the truck-freight transportation sector is estimated from three types of trucks: light trucks, medium trucks, and heavy trucks. In addition, this study further formulates a simple mathematical model to determine the optimal transportation volume of truck transport and rail transport under the projected acceptable CE amounts of the four plans by the year 2030.

3.1. Truck-freight transportation

Because South Korea has a small territory size, road transportation has been the major transportation mode for moving domestic freight, which not only contributes a large portion of economic development but also causes continuous traffic congestion and air pollution (Lee and Yoo, 2016). Because the gross output of the nation's transportation sector has annually grown by an average of 5.8% from 2000 to 2010, both rail and road transportation for domestic freight and passenger service are anticipated to continue growing for the next several decades (Lee and Yoo, 2016).

79.6% of the total South Korean domestic freight volume was transported by road in the year 2010 (Lee and Yoo, 2016). Therefore, truck-freight transportation is considered a critical area to be managed in order to mitigate the environmental impacts of the transportation industry. To assess the CE impact of truck-freight transportation, the first task is to quantify the total CEs generated from truck-freight activities, CE_{Trans}. This is estimated by multiplying the total transported amount of truck freight by the CE