

DETERMINATION OF THE PUBLIC TRANSPORT POLICIES FOR ESKISEHIR CITY THROUGH LIFE CYCLE ASSESSMENT

Müfide Banar^{1*} Alp Özdemir² Zerrin Çokaygil¹ Aysun Özkan¹

¹Anadolu University, Faculty of Engineering, Department of Environmental Engineering,
İki Eylül Campus, 26555, Eskisehir / Turkey

mbanar@anadolu.edu.tr

²Anadolu University, Institute of Transportation Science, Eskisehir/Turkey

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ABSTRACT

In this study, it was aimed to make an environmental assessment of current public transport system and alternative systems by using LCA method in order to support decision makers. To realize this aim, three new public transport systems were developed as an alternative to current public transport system in accordance with the further policies of Eskisehir Greater City Municipality. The public transport options in current system (in the year of 2012) and alternative scenarios for the years of 2014, 2020 and 2023 are given as S₁, S₂, S₃, S₄, respectively. In LCA, scenarios were compared using CML 2 baseline 2000 method for the selected impact categories. According to the total results, human ecotoxicity, fresh water aquatic ecotoxicity and terrestrial ecotoxicity would be reduced by almost 1.8, 1.6, 1.4 times by S₄ scenario compared to S₁ scenario. Also, S₄ scenario has been detected the lowest environmental impact in these impact categories.

INTRODUCTION

In literature, several studies were carried out by using life cycle assessment for transportation systems. In order to effectively reduce environmental impacts from transportation modes, life cycle environmental performance should be considered to operate the vehicles. Chester, Horvath and Madanat (2010) were performed a LCA for existing transit modes in three different large metropolitan areas of the United States; New York City, Chicago and Los Angeles. Oua, Zhang, and Chang (2010) were examined the life cycle GHG emissions and energy use for several alternative fuel buses including several different fuel technologies in China from a well to wheels (WTW) approaches. Ally and Pryor (2007) were conducted a study for the Sustainable Transport Energy Program for the government of Australia focusing on life cycle impacts of diesel, natural gas and hydrogen fuel cell buses. The other studies (Bartolozzi, Rizzi, & Frey, 2013; Chester et al., 2012) by using life cycle assessment were performed to evaluate the environmental performance of urban/public transportation model including vehicle, infrastructure and fuel inventories.

In this study, it was aimed that to realize an environmental assessment of current public transport system and alternative systems for Eskisehir city by using LCA method in order to

support decision makers. For this aim, LCA analysis was carried out at three stages; goal and scope, life cycle inventory and life cycle impact assessment. In the first step, the system boundaries and functional units were determined. In the second step, materials and energy components with releases of pollutants were formed on the basis of functional unit. In the last part of the study, the environmental impacts of compartments (vehicles, infrastructure and energy) of public transport scenarios have been calculated based on CML baseline 2000 method for selected impact categories by using licensed SimaPro 7.3.3 PhD version.

METHODOLOGY

In this study, the daily percentile distribution of public transport options in current system (in the year of 2012) and alternative scenarios for the years of 2014, 2020 and 2023 are given as follow: S_1 (2012): (37.5% tram + 37.5% bus + 25% minibus), S_2 (2014): (75% tram + 20% bus + 5 % minibus), S_3 (2020): (75% tram + 12.5% hybrid electric bus + 12.5% bus) and S_4 (2023): (75% tram + 25% hybrid electric bus). In **S_1 scenario**, daily 240,000 passengers are carried by 23 trams, 200 buses and 211 minibuses. The total length of tramline is 16 km (double line) and total main road’s length is about 200 km. In **S_2 scenario**, daily 250,000 passengers would be carried by 33 trams, 100 buses and 65 minibuses. The total length of tramline is planned to be extended along 34 km (double line) in 2014 whereas there is no extension plan for main road’s length (200 km). In **S_3 scenario**, it is expected to transport daily 272,000 passengers by 33 trams, 68 buses and 25 electric hybrid buses. For **S_4 scenario**, daily 282,000 passengers are expected to be carried by 33 trams and 50 electric hybrid buses. It was assumed that the total length of tramline and road’s length in S_2 , S_3 and S_4 scenarios were the same. These data were obtained by Eskisehir Greater City Municipality personnel.

In the case of public transport, summary of the system boundaries are given in Fig.1. Daily passenger number has changed with the population, vehicle types and simultaneously road types have changed with the technology and the economical capability of the municipality, electricity production mix has changed with the government policies. For these reasons, in this study, *functional unit* was distinguished into three parts: daily public transport in Eskisehir was considered as “operational functional unit”; number of vehicles to transport was taken into account as “vehicle functional unit” and the total length of tram rail and road were considered as “infrastructure functional unit.”

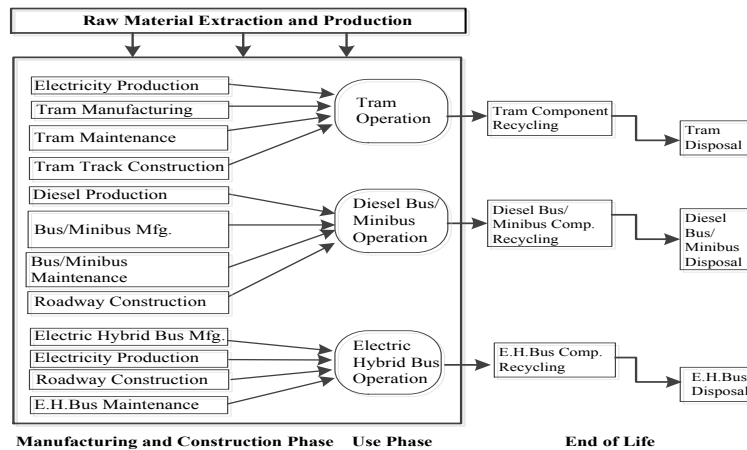


Figure 1. System boundaries of the study

Life cycle inventory (LCI)

The data regarding to tram and bus were obtained from the Ecoinvent databases in SimaPro 7.3.3 software. The data related to other vehicles were calculated based on the literature EEA (2007) and adapted from Ecoinvent database. Infrastructure data for tram line and roadway were obtained from Ecoinvent database. Energy production data were obtained from Spielmann, Bauer, Dones, & Tuchschnid (2007) and Banar, Özdemir, Çokaygil, & Özkan (2013).

Manufacturing of vehicles (bus, minibus and hybrid electric bus) processes related to energy, materials and emissions data were gathered from Ecoinvent database and it was adapted to Eskisehir public transportation system. In operation of vehicles processes, fuel/energy consumption of vehicles was calculated as kg fuel or kWh per kilometers. According to these calculations; bus, minibus, tram and hybrid electric bus consume 0.139 kg diesel, 0.916 kg diesel, 1.75 kWh electricity and 0.05 kWh electricity per kilometer, respectively. The emissions and other pollutants sourced from bus and minibus operation process were calculated based on the EEA (2007); Spielmann et al. (2007) emissions inventories and the other vehicles (tram and electric hybrid bus) operation emissions data were calculated based on Ecoinvent database.

Energy, materials and emissions data regarding to construction and maintenance of roadway and tram line was obtained from the literature (Spielmann et al., 2007). It was considered that the tram line consists of double line that each has 6.5 m and the roadways lines have three layers consisting of gravel, concrete and bitumen.

Turkey electricity mix for the years of 2012, 2014, 2020 and 2023 were estimated according to “Electricity Energy Marketing and Security of Supply Strategy Paper” (2009) and Banar et al. (2013).

RESULTS

The LCA calculations were carried out by using licensed SimaPro 7.3.3 PhD version. In the impact assessment step, the CML2 2000 baseline method was applied. According to the percentiles of normalized impact rates (calculated from normalization results) impact categories (abiotic depletion, acidification, eutrophication, global warming, human toxicity, freshwater aquatic ecotoxicity and terrestrial ecotoxicity) with impact rates equal and over than 4% have been selected for further investigations. Additionally, the radar graphs of four different scenarios were plotted in Fig.2. According to Fig. 2, environmental impacts resulted from vehicles and infrastructures have the almost same effect for S_1 . On the other hand, the effect of vehicles decrease while the effect of infrastructure increased from 2014 (S_2) through 2023 (S_4) scenario.

CONCLUSIONS

According to results, generally it was observed that manufacturing of vehicles, electricity or fuel consumption and infrastructure are components of the public transportation system that would affect the results. The results show that all impact category values of S_2 (75% tram + 20% bus + 5% minibus) show an increase with respect to the S_1 (37.5% tram + 37.5% bus +

25% minibus) excluding the values of total toxicity. It was thought that these increases resulted from the increasing number of trams and tram line extension while the buses and minibuses were still in operation. Although there was a reduction on the number of buses and minibuses, this reduction had no considerable effect in the whole scenario. Human ecotoxicity, fresh water aquatic ecotoxicity and terrestrial ecotoxicity would be reduced by almost 1.8, 1.6 and 1.4 times, respectively, by S₄ scenario compared to S₁ scenario due to the reduction on the number of total vehicles and electricity production from renewable resources in 2023. As a conclusion, although the S₄ scenario (75% tram + 25% hybrid electric bus) seems to be the best scenario, future study that would be focus on economic, social and technical effects should be carried out by application of Multi Criteria Decision Making (MCDM) to give a certain decision for the public transport system.

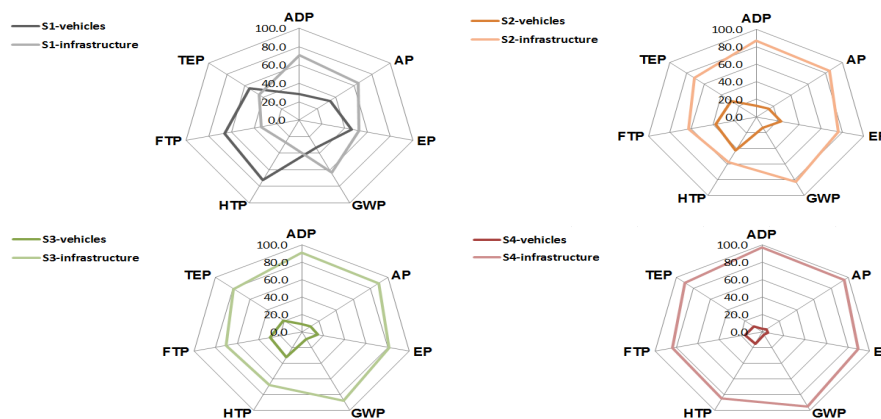


Figure 2. Life cycle impact assessment of different scenarios

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