A Comparative Assessment of Life-Cycle Greenhouse Gas Emissions from Hypothetical Electric Airport Transportation Services in Thailand

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Abstract. Global warming is an increase of average temperature in the atmosphere, which causes adverse effects on the environment. Carbon dioxide (CO₂) from transportation sector is one of the main contributors of the overall greenhouse gases (GHG). To cope with this issue, electric car services are increasingly seen as popular alternative modes of green transportation especially for urban cities as it is more flexible, more environmentally-friendly, and less expensive than the use of conventional vehicles. The study analyses and compare the hypothetical electric car systems from airport transportation services. Center of Environmental Science of Leiden University (CML) 2001, the Life Cycle Impact Assessment (LCIA) method, is applied to convert life cycle inventory data into environmental impacts. The observed results showed that the electric shuttle bus had the highest impact in global warming potential (GWP) compared to other transportation types. Alternatively, this Life Cycle Assessment (LCA) study that evaluated different transportations provided important information for decision makers on quantifying the differences between each scenario.

1. Introduction
Innovation and creative industries are the core components to help Thailand to move towards ‘Thailand 4.0’ policy, ideally on a low carbon economic foundation. Its low-carbon economy roadmap can be consequently achieved by clean technologies. As transportation was ranked as the second largest contributor to greenhouse gas (GHG) emissions in Thailand [1], green vehicles are an important transportation option to reduce the amount of fossil fueled usage in today’s conventional vehicles [2]. At the end of March 2017, the Thai government launched its new electric vehicle policy to encourage the automotive industry to produce their next generation vehicles in Thailand [3]. As electric public vehicle services continue to rise, this study presents a life cycle assessment study on hypothetical electric airport transportation services in Bangkok, Thailand. This study aims to evaluate the environmental impacts of different types of the hypothetical electric airport transportation services using the Life Cycle Assessment (LCA) methodology. The electric cars and shuttle bus have been designed to run on the same route as the conventional cars and bus services. In recent decades, electric cars have been studied using the LCA methodology [4]-[7]; however, most of them focus on electric cars production and their raw material acquisition [8], [9]. There is a few focusing on the use phase; consequently, this study attempts to model the electricity use based on real life previous research data. This study is a gate-to-gate study focusing mainly on the use phase of public vehicles from Bangkok’s Suvarnabhumi airport to Don Mueang airport, Bangkok, Thailand. Center of Environmental Science of Leiden University (CML) 2001, the Life Cycle Impact Assessment (LCIA) method, is used to...
convert Life Cycle Inventory (LCI) data into Global Warming Potential (GWP) impact. This database is currently unavailable. As a result, this study will fill the gap and useful results will be produced.

2. Implementation of Life Cycle Assessment (LCA) method

2.1. Goal and scope definition

The goal of this study is to evaluate the GWP impact category over the use phase of different types of electric airport transportation. The LCA results are specific to AOT transportation services in Thailand. This study uses the LCA which provides information and database on the GHG effects of the process or product. This helps to improve understanding of the GWP implications in the use of hypothetic transportation services in Thailand.

2.2. Functional unit

One passenger-km road transportation (one passenger-kilometer-travelled (PMT)) was chosen as a functional unit for this study. This unit allows a significant comparison to be made since a shuttle bus normally uses much more energy to produce and operate while showing higher capacity in carrying passengers than a normal small car. Therefore, the functional unit selected in this comparative study is PMT.

2.3. System boundaries

Though there are different transportation options, especially for the transit passengers from Suvarnabhumi International airport to Don Mueang airport, this study focuses one three types of hypothetical electric transportation options, which include: (i) the taxi, (ii) the limousine, and (iii) the shuttle bus. This study is a gate-to-gate study that takes into account electric consumption through each vehicle use.

2.4. Temporal and geographical boundaries

The lifespan of the vehicles in this study is assumed to be 12 years and an assumed lifetime driven distance is 230,500 kilometers. These are the default expected life span values for a typical shuttle bus and car used in most research [5], [10], [11]. However, it is possible that the vehicles will be able to operate more than their design lives depending mostly on maintenance and sympathetic use [12].

2.5. Technological boundaries

This study evaluates road-vehicle types and their effects of greenhouse gas (GHG) emissions. EV covers various vehicle types such as hybrid EVs and battery EVs. Hybrids have a combustion engine and an electric while battery EVs have an electric motor and a battery [13]. In this study, a battery EV in use phase have been chosen and investigated for its GHG impacts.

3. Life Cycle Inventory (LCI) analysis

In this study, most of the data included in the system boundaries are specific to Bangkok/Thailand. The assumptions about electricity consumption and emissions emitted from different types of vehicles are mainly derived from [14], [15], and Ecoinvent. Nevertheless, the data is taken from several literature reviews.

3.1. Description of airport transportation service using electric taxi

The automobile is generally considered as the most convenient commuter transport and consumes inexpensive cost of fuel compared to other transportation forms. In Bangkok, Thailand, there is an overwhelming number of taxis and the country's best-selling car model for taxi drivers is Toyota Corolla Altis. The airport provides taxi service to various destinations in Thailand and the most widely used alternative fuels are Liquefied Petroleum Gas (LPG) and Compressed Natural Gas (CNG) [16]. The average number of passengers per riding is 2.21 [17]. In this study, the number of passengers is assumed to be 1 and 2 at a time. The main operating parameters of the electric taxi is shown in Table 1.
Table 1. Main operating parameters of electric taxi.

| Parameter                  | Value | Unit     | Reference/comment |
|----------------------------|-------|----------|-------------------|
| Driving behavior           | -     | -        | Cautious          |
| Type of road               | -     | -        | City              |
| Slope of the road          | -     | -        | Flat              |
| Acceleration               | 0     | m·s⁻²    |                   |
| Total weight (kg)          |       |          |                   |
| - with 1 passenger         | 1380  | kg       |                   |
| - with 2 passengers        | 1430  | kg       |                   |
| Average passengers per round| 1-2  | passengers | [17]            |
| Rolling friction of the tires | 0.02 | -        | www.engineeringtoolbox.com |
| Temperature at time of the travel | 35 | c        | Expert’s estimate |
| Density of air at 35 °C    | 1.15  | kg·m⁻³   | www.engineerstudent.co.uk |
| Aerodynamic drag coefficient| 0.32 |          | [18]              |
| Frontal area of the vehicle| 1.775×1.46 | m×m     | www.sgcarmart.com |
| Velocity                   | 22.2  | m·s⁻¹    | Expert’s estimate |

3.2. Description of airport transportation service using electric limousine

Airports of Thailand Public Company Limited (AOT) offers the official limousine service for passengers at the Suvarnabhumi International airport. Though the airport transfers services across Thailand with various types of vehicles, which include Isuzu MU-7, Toyota Camry, BMW Series 7, Mercedes-Benz E 300, and Toyota Commuter [19]. This study focuses on serving passengers from Suvarnabhumi International airport and Don Mueang airport using Isuzu MU-7 as the hatchback size vehicles tend to fall in to most people price points and the average number of passengers per riding is between 1 and 3 based on the information from the AOT’s staff. The energy use for the conventional limousine is from the combustion of diesel. The operating parameters are summarized in Table 2.

Table 2. Main operating parameters of electric limousine.

| Parameter                  | Value | Unit     | Reference/comment |
|----------------------------|-------|----------|-------------------|
| Driving behavior           | -     | -        | Cautious          |
| Type of road               | -     | -        | City              |
| Slope of the road          | -     | -        | Flat              |
| Acceleration               | 0     | m·s⁻²    |                   |
| Total weight (kg)          |       |          |                   |
| - with 1 passenger         | 2040  | kg       |                   |
| - with 2 passengers        | 2090  | kg       |                   |
- with 3 passengers 2140 kg
Average passengers per round 1-3 passengers www.rotmaethai.com
Rolling friction of the tires 0.02 - www.engineeringtoolbox.com
Temperature at time of the travel 35 c Expert’s estimate
Density of air at 35 °C 1.15 kg·m⁻³ www.engineerstudent.co.uk
Aerodynamic drag coefficient 0.328 www.clubcobra.com
Frontal area of the vehicle 1.8 × 1.805 m × m www.cardekho.com
Velocity 22.22 m·s⁻¹ Expert’s estimate

3.3. Description of airport transportation service using electric shuttle bus

Suvarnabhumi Airport offers a free shuttle bus service for passengers. The shuttle buses are operated by an internal provider named AOT and runs on a schedule. The shuttle bus service operates everyday between 5am to midnight. The buses used for this route are the Euro II buses.

As a carsharing, all the fuel consumptions and emissions are distributed across the number of passengers each round and at a given time. However, this study assumed that 35 passengers will be on the bus each round. The assumptions and operating parameters of the shuttle bus are summarized in Table 3.

Table 3. Main operating parameters of electric shuttle bus.

| Parameter                  | Value | Unit | Reference/comment |
|----------------------------|-------|------|-------------------|
| Driving behavior           | -     | -    | Cautious          |
| Type of road               | -     | -    | City              |
| Slope of the road          | -     | -    | Flat              |
| Acceleration               | 0     | m·s⁻²|                   |
| Total weight (kg) (with 1 to 3 passengers) | 16750 | kg   | [21]              |
| Average passengers per round | 35   | passengers | www.rotmaethai.com |
| Rolling friction of the tires | 0.01 | -    | www.engineeringtoolbox.com |
| Temperature at time of the travel | 35  | c    | Expert’s estimate |
| Density of air at 35 °C    | 1.15  | kg·m⁻³| www.engineerstudent.co.uk |
| Aerodynamic drag coefficient | 0.65 |       | www.clubcobra.com |
| Frontal area of the vehicle | 2.447 × 3.44 | m × m | [22] |
| Velocity                   | 22.22 | m·s⁻¹| Expert’s estimate |

Taking steps to convert the bus fleet to all electric will be challenges for AOT; as a result, effective planning is required to make the change nearly invisible to passengers [23].
4. Life Cycle Impact Assessment (LCIA)

The CML2001 life cycle impact assessment methodology was applied in this study. The CML2001 methodology produced assessment results on the midpoint impact categories; however, GWP is taken into account in this study. In addition, GaBi 7, an easy-to-understand structure and friendly user interface software tool produced by PE International, Germany, is used in this study.

5. Global Warming Potential (GWP) Results

In this study, the GWP is 0.097 and 0.048 kg CO₂-Equiv. in the taxi services with 1 and 2 passengers. The airport transportation service system using limousine showed a total GWP impact of 0.133, 0.067, 0.048 kg CO₂-Equiv for 1, 2, and 3 passengers, respectively. A total number in the environmental impact category of GWP is 0.018 kg CO₂-Equiv in the electric bus system. The main substances that contributed to the global warming category include CO₂, methane (CH₄), and nitrous oxide (N₂O), which accounted for 95.13%, 1.08%, and 3.79%, respectively. The GWP impact was highest for the limousine without sharing the ride compared to the taxi and bus services. However, the limousine with 2 passengers was shown to require less electricity consumption and showed lower GWP impact compared to the taxi without sharing the ride. In addition, there was the least electricity consumption, net total CO₂, and GHG emissions in shuttle bus transportation services since there was a carsharing service system sharing more number of passengers than other airport transportation services. This helps lower energy output and lower CO₂ emissions emitted to the atmosphere. The study showed that GHG emissions varied depending on loads and types of transportation services. The transportation services’ impacts on the GWP impact category are shown in Figure 1.

6. Conclusions

As changing the entire vehicle systems to electric vehicles would result in a reduction of emissions, the objective of this study was to examine the GHG effects of different types of the hypothetical airport transportation services. Carsharing is becoming an increasing attractive approach by allowing users to share travel miles and costs and also save in travel-time because of less vehicles on the road. Therefore, reducing traffic density and simultaneously reducing fuel consumption per person per kilometer. In this study, the services ran from Suvarnabhumi airport to Don Mueang airport and it was found that this action decreased an impact in all impact categories compared to a private car. The reductions in concentrations of CO₂ accounted for the benefits in the environment impact category of GWP. This shows that shuttle bus served during the day allows for an efficient car-sharing and consequently contributes to a reduction in a number of emissions compared to today’s private cars.
This means that using carsharing is significantly better than using a private car service. However, electricity consumption will vary based on variables such as car model, load, climate, etc. It is recommended for future work that this study should be extended to take sensitivity analysis into consideration.

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