Contributions from the Drone Delivery System in Thailand to Environmental Pollution

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Abstract. In recent years, the great development of science and technology together with social movements and commerce has shaped the design and use of commercial drones. This particular emerging technology has boosted the speed and ability of online shopping systems to provide customers ever faster delivery. In addition, Global Warming Potential (GWP) is the most serious impact to people and environment. Carbon dioxide ($CO_2$) from transportation is one of the main contributors contributing to GHG emissions which result in higher number of GWP. Drones should have a reduced GWP impact and other environmental impacts in which these help reduce the number of delivery trucks or other transportation options traveling on roads. In addition, as road infrastructure challenges especially in rural areas, drone delivery systems are able to transport freight across remote supply chain. The use of drones appears to be an important approach because they are not only inexpensive and easily available but can also travel on individual direct routes. In this study by establishing a life cycle assessment (LCA) framework, all emissions from a drone delivery system in rural areas in Chiang Mai, Thailand will be evaluated. The results show that the drone’s part production is the main contributor of all impact categories.

1. Introduction
With the pace of urbanization and population growth, e-commerce volumes grow is one of the megatrends of this 21st century. Thailand posted an impressive annual growth rate of 17.95 for its e-commerce market in 2016. This amounted to $3010 million in revenues and this is estimated to be reaching $5826.9 million by 2020 [1]. This market is extended across the country through not only in urban but also in rural areas. However, negative implications of this market especially in rural areas include different road and terrains, long destination, and pollution. Drones tend to have energy consumption and carbon dioxide emissions advantages over trucks [2,3]. As a result, drones are introduced to deliver parcels directly to customers at their doorsteps. Given the potential benefits, many delivery providers have been testing the use of drones for commercial package delivery [4]. Drones have also been used in different applications such as military purposes, parcel delivery, emergency deliveries of medication, etc. [4,5]. Regarding the LCA papers published on commercial drone production, most of them focused on battery and their use phase [6–8], while none of them have discussed different types of about drones’ full life stage. The analysis of the state of the art underline that the battery production and use phase were frequently evaluated, while a lack attention was paid to all parts production together with their use stage. Therefore, the aim of this study is to follow a “from cradle to grave” approach from an LCA perspective.
2. Methodology: LCA study of drone delivery services

2.1 Goal and scope definition

This study is to evaluate environmental impacts over a full life of a drone delivery system in rural areas in Chiang Mai, Thailand. The case study was chosen since the city is the largest city in northern Thailand providing a significantly increase in its economic growth but still has a rural lifestyle. The study takes a cradle-to-grave approach in which the environmental effects associated with coal mining, electrical generating station operations, drone raw materials, drone productions, drone use phase, and disposal will be taken into accounted.

2.1.1. Functional unit. The most common way to compare the life cycle impact of one vehicle to another is to measure emissions per kilometer driven over their lifetimes. Therefore, the functional unit selected in this comparative study is 1 km travelled. Even though running fuel is computed differently during on and off-peak times, this study assumed that the average electricity consumption rate is constant at any period of time.

2.1.2. System boundaries. The system boundary considers all unit processes included in the system under the study. This study covers the full life cycle of a drone delivery system or a cradle-to-grave study by considering the processes of resource extraction to produce drone, fuels, electricity, and resource depletion through the drone use phase. The system boundaries of the drone is shown in Figure 1.

![System boundaries for drone delivery system](image)

Figure 1. System boundaries for drone delivery system.

2.1.2.1. Temporal and geographical boundaries. Since there is no available design lifespan for drone delivery systems specific to the Thai context, the design lifespan for the purpose of this study is assumed that drones would be constructed and operated for 500 hours using the experts’ estimates. The 500 hours is mainly from drones’ operation. However, it is possible that the vehicles will be able to operate more than their design lives.

2.1.2.2. Technological boundaries. This study evaluates the modern transportation delivery technology and its emission impacts. There is one systems analyzed, which is a drone delivery for an online shopping system. This study evaluates the drone delivery services to compare it with other transportation options for an online shopping system in the future.

2.1.3. Life Cycle Impact Assessment (LCIA) method. The CML 2001 method has been accepted and widely used by the Thailand Environment Institute (TEI) and Thai government [9,10]. CML 2001 is used in this study together with GaBi 7, an LCA software product of PE International, Germany.

3. Model description

Since drones are designed for use in different environments and they vary in size depending on the number of packages and their weight. These result in different energy use and distance to be traveled. The model description of the drone delivery system is presented as follows.

- Drones that can autonomously operate during flights that can last up to 30 minutes [11]
- Drone with its capacity of carrying products up to 5 kgs
- The order must be smaller than 12 inches long, 12 inches width, and 10 inches high to fit in the cargo box.
- The delivery location must be within a 10 mile radius of the order fulfillment center [11]
4. Results

4.1 Global Warming Potential (GWP)

This section presents only the Global Warming Potential (GWP) result of the full life cycle of the drone for home delivery system. The environmental impact in GWP impact category is shown in Figure 2. Global warming is the increase of average temperature in the atmosphere, which causes adverse effects on human health and the environment. The primary GHG that contribute to global warming include not only CO$_2$, but also methane (CH$_4$), nitrous oxide (N$_2$O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF$_6$). In this study, the global warming impact is 0.079 kg CO$_2$-Equiv. in the drone delivery system. The impact was primarily due parts production, which accounted for 99.2% of the impact. The main substances that contributed to global warming include CO$_2$, CH$_4$, and N$_2$O, which accounted for 20.47%, 17.67, 15.72%, and 15.37%, respectively.

![](image.png)

**Figure 2.** Global warming potential from part productions, transportation, and drone use phase.

5. Discussion

The impact in all impact categories was mainly due to parts production ranging from 93 to almost 100% of the impact. The results from the GHG emissions of the drone delivery system shows that the dominant contributor to GWP impact category is the parts operation. Parts operation consists of (1) coal mining in which parts operation requires coal as an input for electrical generating station operation, (2) electrical generating station operation, and (3) parts production. The drone delivery system is consequently environmentally friendly especially when they are under operation. This will achieve substantial energy savings during the drone operation.

6. Sensitivity analysis

As carbon fibers production for the cargo box and Li-ion production for the battery showed highest contribution to all impact categories, carbon fibers production was selected as a case study to illustrate the significance of operational factors in this study.
In Figure 3, the X axis demonstrates the carbon fibers consumed, while the Y axis shows the percentage changes of the LCIA results. If more carbon fibers are consumed, more emissions are emitted and consequently, increases in all impact categories will occur. Carbon fibers production is the main contributor to the impact category of Human Toxicity Potential (HTP), Freshwater Aquatic Ecotoxicity Potential (FAEP), Marine Aquatic Ecotoxicity Potential (MAEP), and Terrestrial Ecotoxicity Potential (TETP). This is because of the amount of heavy metals emitted to the environment.

7. Conclusions
A drone delivery system has potentially becoming one of the key delivery options to operate such deliveries to customers in remote areas. This is because of their key advantages, which include 1) speed, 2) the ability to traverse difficult terrain or fly over water, and 3) their reduced environmental impact. Even though drones are widely known as a delivery tool to enable rural people’s participation in the global economy, there is a lack of research on their environmental impact. As its advantages in reducing numbers of environmental impacts, this study evaluated its emissions over its full life stage using an LCA. LCA result from this study indicate that the parts production, consisting of carbon fibers and Li-ion productions for cargo box and battery, respectively, dominate the most to GWP impact category. The main recommendation would be to further improve the material used for cargo box and increase efficiencies of battery. This will lead to decrease in emissions and wastes that contribute to each impact category. A full sensitivity analysis will be conducted in order to identify all important parameters that affect the most of the LCA results. In addition, governments can affect the adoption of the drone delivery system. These will allow for drones to be widely used in rural areas. To achieve filling these gaps, drones would be one of the best delivery options to offer home delivery service even though this widespread usage still needs time.

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