
A carbon footprint analysis of the Baggage as a Service: The case of Bagbooking

by

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A carbon footprint analysis of the Baggage as a Service: The case of Bagbooking

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With the knowledge I have gained through my academic pursuits, I hope to contribute to a more sustainable future.

Enjoy the read / Buona lettura!

Executive summary

Problem statement and Research gap

The quantity of air passengers handled by the global airline industry is increasing, and the process of checking in baggage at the airport can be a lengthy and cumbersome task. Moreover, Traveling over extended distances with substantial baggage can be both physically and mentally taxing. These reasons have led to the consideration of separating baggage from passengers in order to make air travel more convenient. This concept, known as Baggage as a Service (BaaS), is a new and innovative idea, but it is currently lacking in research about its potential impact on the environment. There is limited information available online about BaaS, and there have been no studies done on the environmental emissions produced by BaaS logistics.

The critical success factors for the widespread adoption of the Baggage as a Service (BaaS) concept are to alleviate the burden on travelers during their journeys while also considering its environmental impact. The latter aspect, particularly in terms of emissions, has yet to be thoroughly evaluated and quantified. For companies and others who want to venture out to offer this service, the goal is to achieve a carbon-neutral or even a reduced overall environmental impact compared to traditional travel with baggage. In order to strengthen the viability of BaaS and increase market penetration, it is crucial to gain a deeper understanding of the environmental impact of this new service. Given the pressing need to meet sustainability goals and the growing awareness and adoption of environmentally friendly solutions among consumers, it is essential to have a clear and concrete assessment of the environmental impact of BaaS. There are numerous elements to take into account in this modern, large-scale, socio-technical system, and technical, institutional, economic, and social expertise are required. For these reasons, the primary objectives of the MSc in Complex Systems Engineering and Management, Transport and Logistics track are covered in this thesis.

Research question, Study design, Methodology

The research project aims to examine the potential environmental impact of Baggage as a Service (BaaS) in the airline industry, answering the following main research question:

What is the CO2 footprint of the Baggage As A Service?

To achieve this goal, four sub-questions have been established to guide the study and provide useful insights for the scientific community and Bagbooking. These sub-questions will be addressed in a logical order and analyzed separately, in order to answer the main research question.

The first sub-question (SQ1) is “*Which elements are relevant for the BaaS emissions?*”. It aims to find all the elements that are important for the BaaS carbon footprint, following the three-scope methodology of the Greenhouse Gas Protocol. It is concerned with the development of rich conceptual models of the company's logistics system, of the passenger trip, and of the savings that may be from the optimization of cargo aircraft. This step is crucial because it provides the theoretical

foundations for the carbon footprint quantitative analysis that follows with the other sub-questions. To answer this SQ, a qualitative research approach is used, which consists of a literature review, consultations with professors with expertise in the field, and a survey of people who used BaaS before. The goal of SQ1 is to identify all the factors involved in the system of interest and to analyze the direct and indirect effects that occur when a trip takes place.

The second sub-question (SQ2) is *“How can the BaaS CO2 footprint be modeled?”*. It builds on the conceptual models developed in the SQ1, by formulating a mathematical model to calculate the CO2 emissions of the BaaS. This sub-question is answered using a quantitative approach, which involves a non-numerical analysis of the collected data to obtain a general formulation and algorithm.

The third sub-question (SQ3) is *“What is the CO2 footprint of the Bagbooking baggage service?”*. SQ3 uses the outputs of the previous sub-questions SQ1 and SQ2 to analyze a case study of the BaaS. This sub-question involves the numerical analysis of the Bagbooking services and is supported by qualitative data collected through repeated unstructured interviews with employees of the company. The collected data are manipulated using an Excel model, developed for this thesis, to calculate the number of emissions produced by the company's operations. It is first shown how the emissions are calculated for one sample customer, then all 87 Bagbooking's previous customers are studied and discussed.

Finally, the fourth sub-question is *“How is Bagbooking performing if compared to passengers traveling with their own baggage?”*. SQ4 compares the CO2 footprint of Bagbooking with the CO2 footprint of normal air travel. This sub-question is answered quantitatively using the Excel model, which analyses four different situations to determine if the company's services can perform better, worse, or the same as normal air travel.

Main findings

The study answers the main research question by starting by presenting a rich conceptual model that outlines two logistics chains, providing a foundation for further analysis and understanding of this innovative service. One for dissociated baggage and another for passengers traveling without it. The first investigates all the elements that are a source of emissions, with a focus on three options for baggage collection and three for distribution (i.e., using Collection Delivery Points CDPs, dedicated trips, and round tours), as well as four modes of transport and their impact on the environment (van, truck, train, plane). The second logistics chain explores changes in travel behavior and emissions resulting from using BaaS for passengers who travel without baggage. An exploratory survey revealed that despite using the service, individuals who traveled with a private vehicle would have still used it. However, 70% expressed a positive attitude towards bringing their baggage to a CDP to reduce emissions. Another key aspect is the cargo savings concept, which consists in utilizing the extra space in the aircraft created when passengers choose not to carry their baggage on board, reducing emissions by filling the space with cargo.

Moreover, the research provides an Excel model that was developed for calculating the CO2 emissions of a BaaS case study, making it straightforward for Bagbooking and future researchers to use. The model is used to validate the hypothesis that the separation of passenger and baggage flow

can lead to a lower CO2 footprint compared to traditional flight trips. The results show that Bagbooking is currently not particularly competitive in terms of emissions, polluting 56% more. The emissions of Bagbooking were assessed in a detailed manner, analyzing the emissions of each individual customer and identifying the various sources that contribute to the overall carbon footprint. The study also highlights the relative contribution of each stage in the logistics chain toward the total emissions. Based on the findings, the study identifies five distinct scenarios with varying degrees of effectiveness in terms of reducing emissions. The progressive approach to emission reduction in Bagbooking involves each situation building upon the previous one, ultimately reaching the emission levels of normal air travel, which is currently a less polluting alternative. The first measure to improve the current Bagbooking situation involves optimizing the collection and distribution of baggage in the first and last mile, resulting in a 46% increase in emissions compared to normal air travel. Encouraging passengers to use sustainable transportation when commuting to and from the airport reduces this percentage to 29%. Implementing the cargo savings concept would further reduce Bagbooking's emissions by 63% compared to normal air travel. The latter situation includes the adoption of trains for the baggage logistics chain, bringing this percentage to 98% or more in the case of the use of green vehicles.

Bagbooking recommendations

In his analysis, the researcher outlines the key points that Bagbooking should consider in order to reduce its carbon footprint. First and foremost, the integration of the cargo savings concept into the baggage logistics chain could reduce the average emissions of Bagbooking's customers by 62%. The possibility of reducing emissions by utilizing the extra space in the aircraft that is created when passengers choose not to carry their baggage onboard could be achieved by partnering with airlines.

Incentivizing customers to choose more sustainable means of commuting to and from airports is another critical action that the company could implement: The zeroing of emissions from the ground segment from the sources of emissions could decrease the current carbon footprint by 10%.

Another implementation would be optimizing baggage pick-up and delivery logistics, which could reduce emissions by 6%. Offering customers a less convenient or more expensive option at the time of payment, showing them nearby Collection Delivery Points, and incentivizing them to choose this option would be a good step. Bagbooking could also choose a logistics company prioritizing emissions, with green means of transport or a well-organized network, able to maximize every milk run. Using electric or hybrid transportation options could reduce the remaining 22% of emissions after the previous actions.

Strengthening communication with the logistics company for a more tailored dataset would be advisable. Bagbooking should also communicate its sustainability efforts to customers to improve its reputation and attract sustainable-minded customers. The survey of past customers showed that 75% of customers would use the service more if it was more sustainable than normal air travel.

Future research

The study provides new insight into the carbon footprint of baggage as a service (BaaS). However, the study has a set of limitations that offer opportunities for future research to improve upon.

The data used for the model are general and with some assumptions. The exact values of fuel combustion, mileage, stops of the logistics van, etc were not provided and therefore future research could use the model with tailored data. In the intermediate segments of the baggage chain, vans are used in the calculus, but trucks could have been used by Bagbooking. The research also did not keep into consideration the scenario with the high use of BaaS, increasing the traffic on roads, and its impact on emissions. Lastly, future research could include the impact of failed deliveries, eventual additional plastic packaging, and the use of ferries and BaaS as an intercontinental service.

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1. INTRODUCTION AND RESEARCH QUESTION

Nowadays, with the exception of the years of the Covid-19 pandemic, the quantity of air passengers handled by the global airline industry is increasing (IATA, 2022). Accordingly to a Pan-European survey (Berdowski et al., 2009), the mean mass of the weights of the checked baggage per person amounts to 16.7 kg. Therefore, passengers must reach the airport from their starting location carrying this baggage and probably additional kilos from hand baggage. Once at the airport, the travel process of checking baggage in requires a lot of time and can lead to delays (Baashirah & Elleithy, 2019). Airport companies suggest arriving even three hours before departure when traveling to an intercontinental destination. After landing, passengers can expect to see their checked bags anywhere from 15 to 45 minutes (Negroni C., 2016). Moreover, the separation and reuniting of passengers and baggage add to the complexity of handling the process and the design of terminals (Correia et al., 2010).

To bypass these problems, a futuristic envision of dissociating passengers from baggage was first proposed and discussed by Loskot and Ball (Loskot, P., & Ball, P., 2015). With this system, the baggage is delivered end-to-end completely independently of the travel of passengers and can be analyzed as a parcel delivery or cargo. In air transport, it is called Baggage-as-a-Service (BaaS) (Al-Hilfi, S. et al, 2018) and existing logistic networks for deliveries can be adopted for transportation.

A young and innovative company called Bagbooking has developed a door-to-door baggage service, utilizing the BaaS concept. It enables travelers to travel hassle-free, with luggage being collected from home or at an established location (e.g. at a post office) prior to the departure and delivered to its destination. Bagbooking has already been set up, and it proved itself to be a service with enough features to attract early-adopter customers and a concept that works successfully. The Bagbooking service is separating the movement of the baggage from the passenger compared to the standard flight trips in which passengers carry their baggage throughout the whole journey. The operations in the logistics chain are managed by third parties.

However, transportation activities affect climate change on a global scale and deteriorate air quality and human health in regional and urban areas. The sector is already one of the main sources of air pollution and every new activity should be carefully analyzed for the emissions produced. The mode which is used to move the cargo has a great impact on the total emissions. Among the type of transport, road transport primarily contributes to polluting cities (Grondys K., 2019) and, for instance, in the eventuality baggage are moved by truck, it might be more harmful even though aircraft usually emit more.

As an innovative service, Bagbooking is introducing a concept that has not been analyzed regarding emissions and environmental impact, which is done with this study. The proposed research envisages innovativeness and originality because it analyses this aspect that has not been done before. It has relevance for the private as it provides insights that are important for many aspects within the company, but also for the academic environment which could use the outcomes for further research and cases. The research includes many transportation network design challenges, such as bundling, modes/services, terminals/hubs, and form/routing decisions. It is a complex, contemporary large-scale and socio-technical system in a multi-actor environment with many variables to consider, and knowledge of technical, institutional, economic and social spheres are

needed. For these reasons, this thesis addresses the main aims of the program of the MSc in Complex Systems Engineering and Management, Transport and Logistics track.

1.1 Knowledge Gap

About the BaaS, not much information is available online. As a new concept, the knowledge of the dissociation of baggage from the passenger is weak, and not many studies have analyzed it. It seems that only Loskot and Ball (Loskot, P., & Ball, P., 2015) do consider it as an alternative method of travel. Moreover, the topic of emissions in logistics is not covered, lacking a complete view of how it would work and the involved source of emissions. There is no specific open-source tool that calculates the emissions of the Baggage as a Service or any theoretical framework that analyses the logistics chain of the service and how this influences passengers' travel behavior. This thesis will therefore reduce this knowledge gap in the literature, providing a conceptual model of BaaS and a model to calculate the emissions of moving a parcel from point A to point B, also compared to normal air travel. The data provided by Bagbooking will also function as a case study to analyze emissions of logistics operations and for decision-making in the BaaS sector.

1.2 Problem Definition and Research Question

The most important success factors for the BaaS concept to succeed are to unburden the traveler during the journey. However, it is also important to be aware of the emissions, and companies such as Bagbooking would like to achieve at least a carbon-neutral footprint -or even a minimal total environmental load - compared to traveling with luggage. This second success factor has not yet been examined in detail and cannot be substantiated as yet. In order to better consolidate the concept and expand in the market, it is important that Bagbooking has more insight into the elements that make up this impact. With the social mission of achieving sustainability targets and an ever-increasing acceptance and integration of this development into consumer behavior, it is very important to make this environmental load concrete.

Therefore, the main research question that this master thesis project aims to answer is:

What is the CO₂ footprint of the Baggage As A Service?

This question will be answered by using a specific research approach explained in the next sub-chapter. The company Bagbooking will be used as a case study and the generalisability of the findings will be discussed for the Baggage as a Service in the conclusion chapter.

1.3. Research Approach

In order to develop a logical order of research activities and guide the reader in the research project step-by-step, four sub-questions are stipulated (table 1). Moreover, answering the main research question will be useful insight for the company, but it will not be the only valuable data that they can find interesting. In fact, approaching the problem by answering sub-questions will provide

information and outcomes they can use to marketize themselves and use in their decision-making processes. Each of these will be analyzed and solved separately, as intermediary objectives to answer the main question.

Table 1: Sub-questions list

#	Research Question
SQ1	Which elements are relevant for the BaaS emissions?
SQ2	How can the BaaS CO2 footprint be modelled?
SQ3	What is the CO2 footprint of the Bagbooking baggage service?
SQ4	How is Bagbooking performing if compared to passengers travelling with their own baggage?

First, it is fundamental to understand all the factors that are included in the system of interest. When a trip occurs, there are direct and indirect effects that may occur, triggered by the new travel route. A conceptual model is designed to give an overview of the service and to locate the emission sources and eventual emission savings (sub-question 1). Once the determinants have been listed and discussed, the study has to address how to formulate them in a mathematical model to be calculated in real-world situations (sub-question 2). After that the problem is conceptualized theoretically, a case study is analyzed. With the help of Bagbooking and its logistics operators, the mathematical formulation will be used with numerical values. This leads to quantitative results of CO2 emissions generated by the company (sub-question 3). To have the relative importance of these outputs, it is useful to compare it with an estimation of how many emissions a passenger is producing when not using the BaaS but with a standard travel by plane (sub-question 4).

With the above main research question, Bagbooking expects to validate the hypothesis that the separation of passenger flow and baggage flow leads to a lower CO2 footprint through effective management and chain cooperation, thus, on balance, making a positive contribution compared with the CO2 footprint of the flight trips, showing the relative importance. The research concludes with final recommendations discussing this hypothesis and giving advice to the company on the topic.

1.4 Thesis Outline

The document is structured as follows. In chapter 2, an initial literature review is performed to seek previous knowledge about the main topics; In chapter 3, the methodology used for the whole document is explained; In chapter 4, the first sub-question is answered, developing the conceptual model of BaaS; Chapter 5 answers the second sub-question, providing the mathematical formulation for the calculations of BaaS emissions; In chapter 6, sub-question 3 is answered through a case study; In chapter 7, the last sub-question is answered, comparing the BaaS with a situation without BaaS. Answering the sub-questions logically leads toward the answer to the main research question and discusses the findings in chapter 8. In figure 1 a visual representation is made.

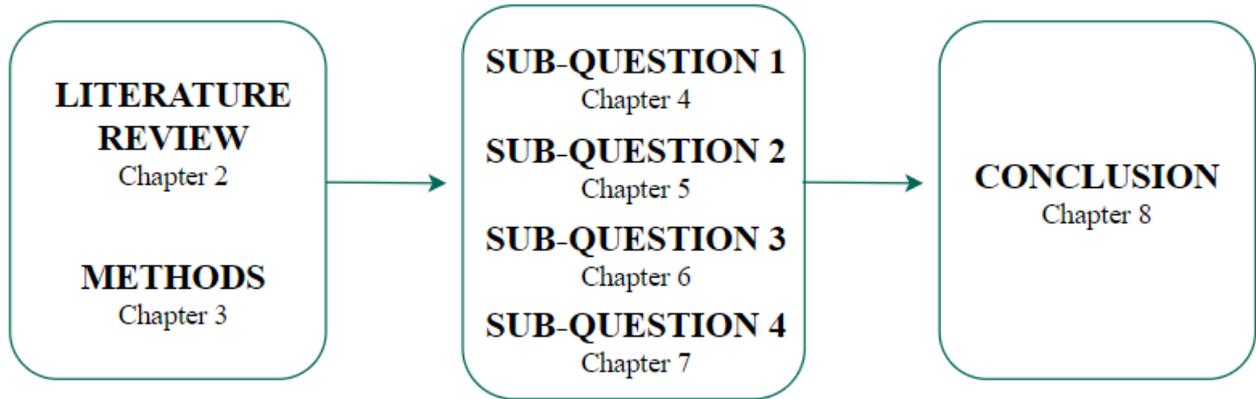


Figure 1: Thesis design

2. LITERATURE REVIEW

In this second chapter, the main core concepts related to this research are defined through an extensive literature review. Checking the available academic literature is crucial to have an initial understanding of how the system of interest works.

The literature review chapter is important to the reader and the author because it is seeking for what previous studies analysed in regards to the dissociation of baggage from the passengers (sub-chapter 2.2), followed by a sub-chapter that digs into how parcel delivery systems work in order to give to the reader a general understanding of its structure (sub-chapter 2.3). Subsequently, it is investigated how the emissions of this sector are analysed and calculated, seeking for existent methodologies to follow (sub-chapter 2.4). Withing the emissions topic, it is searched for existent data on the parcel transportation sector to find data about its pollution and data to utilize during the thesis' calculations (sub-chapter 2.4.1). Finally, a sub-chapter that shows the main findings is made (subchapter 2.5). The methodology followed for the literature review is explained in the first sub-chapter (sub-chapter 2.1).

2.1 Methods of the literature review

The review of the state-of-the-art scientific literature is based on the academic database Google Scholar. Screening of many papers has been done, which have been consulted and afterwards evaluated and selected, discarding the articles less relevant to the specific topic. The selection process started by searching specific keywords related to the core topics. It was fragmented on the different topics, to provide the necessary background knowledge for the identification of the consequent academic gap. However, much of the material was not correlated and only the ones providing pertinent insights to this document were used. Table 2 shows the keywords used to search related articles and papers divided by topic.

Table 2: Keywords for literature review by sub-chapter

2.2 Knowledge Gap	2.3 Parcel Delivery System	2.4 Emissions and Calculation Methods	2.4.1 Modes of Transport
Dissociation of passenger baggage	Parcel Delivery Network	Environmental impact parcel distribution	Transportation emission tool
Baggage delivery service	Parcel Delivery Network	Calculating parcels distribution emission	"Emissions" AND "Transportation modes"
"Baggage" AND "Freight"	"Parcel Delivery" AND "Urban freight"	Logistics emissions calculator tool	
"Baggage as a service" AND "Emissions"	"Parcel Delivery Service" AND "Network"	"Distribution network" AND "Emission"	
	Pickup and Delivery	"Parcel" AND "Distribution network" AND "Environment"	

	Vehicle Routing Problem	"Parcel delivery logistics" AND "Emissions"	
	"Pickup and Delivery Problem" AND "Emissions"		

2.2 Dissociation of baggage from the passenger

The dissociation of the baggage from the passenger is the key topic of this thesis, and since it is a new concept, not much information is available online. It seems that only Loskot and Ball (Loskot, P., & Ball, P., 2015) do consider it as an alternative method of travelling. Many keywords have been used to investigate if scholars analysed it in comparison with the standard way of travelling by plane in regards to the environmental footprint. However, the research did not find anything that could have been used for this graduation project.

2.3 Parcel Delivery System

If Bagbooking is delivering baggage as parcels, some background on how these systems work is necessary. The European Courier, Express and Parcel sector (CEP) is a very strategic and dynamic sector, and the biggest players sharing the market are DHL, FedEx and UPS (Ducret R., 2014). Every parcel is characterized by its origin (pick-up point), destination (delivery point) and delivery deadline. The delivery is usually organized through a hub delivery network, as the flows between hubs are characterized by economies of scale (Čupić A., & Teodorović D., 2014). Even if there are many existing distribution structures, parcel delivery networks can be categorized as point-to-point networks and hub-spoke networks. In the first category, small and medium-sized parcels are directly transported from the origin terminal to the destination terminal, and it does not require a large investment in the hub facility. In the second category, parcels in the terminal site are sent to its assigned hub facility so that the volume of parcels between hubs increases greatly, allowing the economy of scale. Therefore, a hub-spoke network is widely used for a large-scale parcel delivery network (Jin H. W., 2018). However, the existing infrastructures allow parcels to utilise a distribution network as visualized in Figure 1.

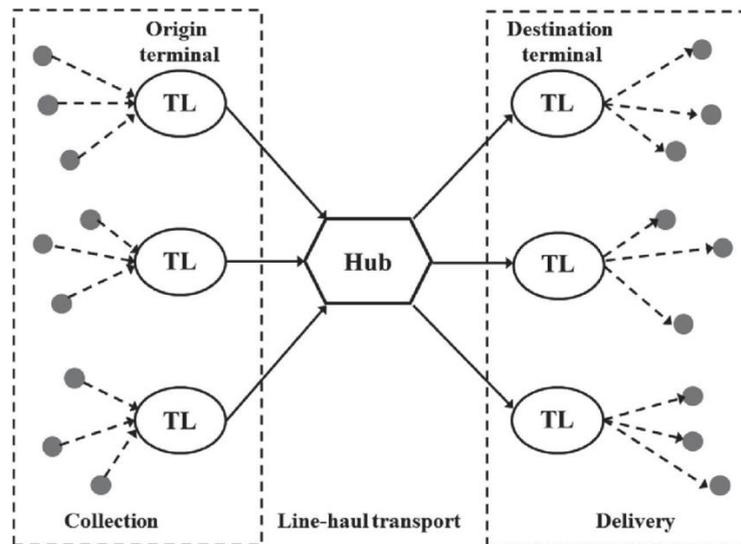


Figure 2: Typical Parcel Distribution Structure. [Source: Lim, H., & Koo, M. W. (2016)]

In fact, parcels are typically collected from the shipper at the local delivery centre (LDC), transported to the nearest terminal (TL), shipped to the hub (Hub) for consolidation and sorting, transported to the terminal (TL) near the destination, and finally brought to the LDC to be delivered to the receiver (Lim H., & Koo M. W., 2016). Every part of the logistics chain between hubs or depots/local hubs is called a “segment” or “leg”.

2.3.1 Pickup and Delivery Problem (PDP)

The pickup and delivery problem (PDP) involves the difficulty of finding the best route to transport the parcel from the origin to the destination and it is known to be NP-hard. The problem is faced by many companies and organizations in the sector and the literature about it is vast. Some examples of academic papers analyzing the problem are: Savelsbergh et Al (1995) discussed various characteristics of the problem and give an overview of solution approaches; Lu, Q., & Dessouky, M. (2004) consider the multiple vehicle pickup and delivery problem (MVPDP) with the objective of minimizing the total travel cost and the fixed vehicle cost; Dumas et Al. (1991) provide an algorithm that solves the problem with time windows, with multiple depots and types of vehicles; Xu, H. et Al. (2003) presented the problem with a set of practical issues of real-world logistics operations, such as multiple time windows, heterogeneous vehicle types, DOT rules. Based on which approach to the PDP is used, the optimal solution might be different, involving different routes that the parcel operator utilizes to collect and deliver the parcel.

Linking multiple locations is an even more difficult task if the emissions are considered and need to be minimized. Home delivery services are more and more common, a service that challenges the last part of the logistic process, the last mile delivery. With the volume of parcels increasing, the last mile delivery accounts for a significant share of the total costs and CO₂ equivalent (CO₂e) during delivery and pick up (Zhou L. et Al., 2016). Sustainable economies are increasingly focussing on improving their efficiency and reducing their carbon emissions. Jiang L. et Al. (2019) propose a travelling salesman problem with carbon emission reduction in last-mile delivery, aiming to reduce its total costs and carbon emissions by deciding on the allocation of parcel lockers while scheduling delivery routes. The scholars consider that a large number of home deliveries implies more freight traffic, hence more pollution and congestion. Therefore, an alternative to home deliveries in the first and last mile can be handling parcels at Collection-and-Delivery Points (CDP), which can reduce

missed deliveries and enable the consolidation of delivery schedules. In the Netherlands, the service point is the dominant form of CDP (Weltevreden, J. W., 2008). An analysis conducted in Sweden reveals that a considerable amount of trips for collection-delivery trips are made by car modes, but the probability of choosing that mode would decrease with the availability of a dense population and public transport network (Liu C. et Al., 2019). The largest environmental benefit would come when the collection or delivery is included in an existing car trip or alternative transport methods such as walking, biking and public transport are used, but however dedicated car trips could also increase (Collins AT, 2015). Stationary parcel lockers are also a solution, and a poll conducted in the city of Szczecin showed that 44% of the respondents collect the parcel on foot, 50% collect their parcel by car, on the way to another location, a 6% of respondents takes the car where the destination was the parcel locker itself (Moroz, M., & Polkowski, Z., 2016). A study compared the pick-up point alternative through parcel lockers with the home service delivery showing a 39% CO₂ emissions reduction (Saad S.M., Bahadori R., 2018). Exists also the last-mile logistics concept using cargo bikes which has been described in several studies (Zhang et Al., 2018) (Anderluh, A. et Al., 2019). Cargo bikes have the main advantage that they are emission-free but have low loading capacity and are not suited for long-haul transport.

2.4 Emissions and Calculation Methods

In 2020, the share of global emissions from logistics and transport was 24% of the total. Carbon measurement and reporting have been increasingly adopted within the global logistics industry (KPMG, 2014), and the world has gradually begun to focus on green development, increasing low-carbon investments and adopting new sustainable policies. Emissions may arise from air, rail, road, and marine transport and from the storage of products in warehouses, distribution centres and retail facilities. Companies have numerous reasons for cutting down carbon emissions, and there are many studies to reduce CO₂ in their logistics or optimize their strategies. However, models and resolutions to solve the PDP and the vehicle routing problem (VRP) (Cordeau et al., 2006) usually aim to find the shorter path or to reduce costs, and the main objective function does not aim to minimize emissions. Carbon measurement still represents a mainly voluntary organizational practice, and companies can choose which tools or guidelines to apply in order to measure sustainability and environmental performance (Hahn, Reimsbach & Schiemann, 2015). In this section, the literature review focuses on the emissions framework of parcel networks, consisting of the European standards and their mode of transport. With the keywords mentioned in Table 2, it is searched for studies that show how to calculate and analyze the emissions in the logistics of the CEP sector.

Tank-to-wheels (TTW) and well-to-wheels (WTW) are two different ways to measure the energy efficiency and environmental impact of different transportation fuels. TTW measures the energy used from the time the fuel is stored in the tank of a vehicle until the wheels turn. It includes the energy used to produce, transport and distribute the fuel, but doesn't take into account the energy used to extract and refine the fuel. TTW is used to compare the energy efficiency of different fuels when used in vehicles. WTW, on the other hand, takes into account the entire life cycle of a fuel, from the extraction and refining process to its use in the vehicle. WTW includes not only the energy used from the tank to the wheels, but also the energy used to extract and refine the fuel, and the

emissions produced during these processes. WTW is used to evaluate the overall environmental impact of different fuels.

The first report that is important to mention in an emission study is the Greenhouse Gas (GHG) Protocol (Wbcsd, W. R. I., 2004). It creates extensive, globally defined frameworks for managing greenhouse gas emissions from operations, value chains, and mitigation measures in the public and commercial sectors. Three categories, or "scopes," (1, 2, and 3) have been established for accounting and reporting on GHG emissions to distinguish direct and indirect sources, enhance transparency, and serve the needs of various types of organizations and climate-related initiatives. Scope 1 includes direct greenhouse gas emissions produced by a company through sources they own or control, such as combustion in boilers or vehicles. Scope 2 covers emissions from the generation of purchased electricity consumed by the company. These emissions occur at the facility where the electricity is generated. Scope 3 is an optional category that covers other indirect emissions that are a result of a company's activities but from sources not owned or controlled by them. Examples include the extraction and production of purchased materials, transportation of purchased fuels, and the use of sold products and services.

Given a framework, the emissions need to be calculated. Although the calculation of transportation emissions is conceptually simple, in practice is quite complex. On the web, it is possible to find some websites (such as Cevalogistics and CarbonCare) which, after having inserted some variables such as type of transportation or segment to travel, calculate the CO₂ equivalent emitted for that route. For instance, some emissions analyses using three different calculators, it was found different results and hence the need to unite emission factors like the united emission factor for CO₂ (Petro F. et Konečný V., 2017). However, many of these tools are not transparent on how calculations are made and are not precise for the BaaS, since the user has to insert the route manually and no conceptual model has been analyzed.

It is also important to state where these emissions are calculated. ICF Consulting (2006) states that CO₂ is emitted in direct proportion to fuel consumption, with some variation by type of fuel. The firm used the following formula to calculate it:

$$CO_2 \text{ emitted} = \text{Fuel Combusted} \times \text{Carbon Content Coefficient} \times \text{Fraction Oxidized} \times (44/12) \quad (1)$$

This calculation is complex since the data on the vehicle type are limited and because there are other factors such as model year, tire pressure, accelerations and others that are difficult to obtain. The paper of ICF Consulting also highlights that infrastructure construction and maintenance are not typically included in estimates. Finally, the document identifies some transportation greenhouse gas (GHG) calculation tools that can be used to quantify the emissions. There are 6 which focus solely on transportation sources and are designed to develop emission factors or estimates for gases emitted during vehicle use. These outputs rely on user-provided inputs. However, these tools are usable in the U.S. only and the algorithms for calculations are not open-sourced.

Although many logistics service providers claim to have environmentally friendly initiatives, they do not seem to take much interest or control over the emissions produced by their transportation operations. The results of the study by Nilsson, et Al. (2017) indicate that customers have not yet expressed genuine concern for environmental solutions that would negatively affect the cost and delivery time of logistics services.

2.4.1 Modes of Transport

With rapid global industrialization and ever-increasing demand for freight movements, freight transportation has become a major source of air pollution. The transportation of a parcel or baggage can occur in different ways which influence the length of the trip and the logistics challenges, as seen in the previous sub-chapter (2.2). One of the major factors that most influence the number of emissions released into the atmosphere is the transportation mode. The modes represent which vehicles are used between the origin and destination. 29.4% of global transport CO₂ emissions are from road freight, 2.2% from aviation, 10.6% from shipping and only 1% from rail (Ritchie H., 2020). When discussing baggage dissociation, Loskot divides baggage travel into three segments: the journey to and from the airport (ground segments), and the air travel between the departure and destination airports (Loskot, P., & Ball, P., 2015). However, this is not the only path that baggage can follow, and it is possible to use one type or a combination of transport modes (multimodal transport system). Each of these is producing a certain amount of emissions, based on many variables such as the year of production of the vehicle, average speed, fuel type, tires and others.

STREAM Freight Transport 2020 (CE Delft, 2021) provides emission factors for GHG per tonne-kilometre for key freight transport modes for use in analysis, intermodal comparison and carbon footprinting studies. The modes are road, rail, inland waterway, maritime shipping, and air transport within the Netherlands. The study classifies the emissions based on the most representative vehicles and vessels, and the representative types of freight (light, medium, heavy) carried.

When choosing a certain mode, this influences the congestion for that route. Congestion has a great impact on CO₂ vehicle emissions and fuel efficiency. The research by Figliozzi focused on the analysis of CO₂ emissions for different levels of congestion and time-definitive customer demands. The results indicate that congestion impacts on commercial vehicle emissions are highly significant though difficult to predict (Figliozzi M.A., 2011).

2.5 Literature review findings

The literature review is important because helps the reader to have a general understanding of the main topic that is present in this study. Moreover, the chapter helps the author to seek existent data and studies that are helpful for gaining data and methodologies that may apply to the BaaS analysis.

The sub-chapter 2.2 remarks on the knowledge gap on the main topic, allowing the author to move on to related topics such as parcel delivery.

Since the baggage is seen as parcels, in the sub-chapter 2.3 the investigation moves to analyze how the parcel structure is made. The review shows that parcels are a researched topic in which scholars look for the optimal method to move them, and therefore introduce the reader to its complexity. The sub-chapter also shows how the logistics behind moving baggage work, introducing concepts such as hubs and depots/local hubs, and solutions such as the collection-delivery points (CDPs).

The parcel system leads the research to dig into the emissions that such logistics have, the other main topic of this thesis. Since the sub-questions to answer the main research question involve the calculation of the emissions of Bagbooking, the sub-chapter explains important arguments such as

the difference between Tank-to-wheels (TTW) and well-to-wheels (WTW) and introduces the reader to the methodology used in the Greenhouse Gas (GHG) Protocol. Moreover, a general formula used to calculate CO₂ emissions is shown. A focus on the emissions of the transportation industry is made to introduce how much the modes of transport affect the final footprint.

3. METHODS

After having stated the main research question and the four sub-questions, this chapter constitutes the section in which the methods used to conduct the research project are declared. In fact, each sub-question has its own method for collecting data and that helps with its outputs to the attainment of the knowledge that brings conclusions to the main question. Since a knowledge gap in the actual academic literature has been detected, data collection from other sources is needed.

3.1 SQ1: Which elements are relevant for the BaaS emissions?

The first problem to tackle is to identify the boundaries of the system and analyze its elements. In this part of the thesis, a conceptual model of the logistics of the company is developed, which represents the system of interest. The conceptual model shows how the emissions are allocated in the company's transport system and which are all the factors that have a role in polluting the environment with CO₂. The SQ1 is a fundamental step in the research because it provides the theoretical part that gives the bases on which the mathematical model (SQ2) is made. This first sub-question is therefore answered utilizing some qualitative method of research, consisting of observations encountered from the literature review, consultations with professors with expertise in the field, and a survey.

3.1.1 Expert consultations

For consultations, two professors have been contacted: Ir. J.A. (Joris) Melkert, an associate professor in aircraft technology with vast expertise in aircraft performances, structure, design, and sustainability; Dr. S. (Stefano) Fazi, an expert in logistics and transportation networks. The aim was to have different points of view from the airspace and logistics experts in order to include every factor. The interviews helped the author in understanding the current situation of the baggage system in the aviation sector and the consolidation of vans/trucks. The interviews were semi-structured (SSI), which are verbal interchanges where the interviewer attempts to elicit information on the topic through open-ended questions decided at an earlier time. This facilitates the conversation and the understanding of the perceptions of the interviewees. The data collected are consequently organized and structured. The interview with Ir. Melkert is transcribed in Appendix A.

3.1.2 Survey

To gain insights to understand and forecast customer behavior, a survey of 150 past customers of the Bagbooking company has been made. The aim was to compare their behavior when utilizing the BaaS service with a situation in which they do not use it. Due to a survey filling time limit, six questions with multiple-choice answers were asked. The questions are displayed in table 3.

Table 3: Bagbooking past customers survey questions

# Question number	Question text
Q1	If you travelled by plane, what mode of transport did you use to get to the airport during your trip with Bagbooking?
Q2	If you travelled by plane, what mode of transport would you have used to get to the airport if you did not use Bagbooking?
Q3	Would you be willing to take your baggage to a service point located between 0km and 2km to help reduce emissions?
Q4	How would you reach this service point?
Q5	If Bagbooking is more sustainable than travelling by plane, would you be more likely to choose to use Bagbooking?
Q6	Would you use Bagbooking if travelling by a mode of transport other than a plane?

The survey was sent by email to past customers by the company. Since the low response with only 37 people answering the survey, the results are used to make some assumptions and hypotheses, such as how the emissions could decrease with BaaS if passengers would reach the airport by public transport. The results of the survey are shown in Appendix B. However, it is considered a representative sample of a small subset group that seeks to proportionally reflect specified characteristics exemplified by the target users of BaaS.

3.1.3 Scopes of the Greenhouse Gas (GHG) Protocol

As a general framework and methodology to analyze the emissions, the Greenhouse Gas (GHG) Protocol has been followed. The literature review found in this protocol the division of emissions into three main categories, or "scopes," (1, 2, and 3) to distinguish direct and indirect sources.

3.2 SQ2: How can the BaaS CO₂ footprint be modelled?

The second sub-question needs to input the factors studied in SQ1. In this part of the thesis, a mathematical model for calculating the CO₂ emissions of the BaaS is provided. This sub-question is therefore answered utilizing a quantitative approach, consisting of the non-numerical analysis of the collected data to obtain a general formulation and algorithm. SQ2 is mainly supported qualitatively by literature. Such SQ1, also SQ2 is a fundamental step in the logical structure of the thesis and gives the bases to proceed to answer the sub-question 3.

3.3 SQ3: What is the CO₂ footprint of the Bagbooking baggage service?

The third sub-question merges the previous ones in a case study. It consists of the numerical analysis within the Bagbooking services. To proceed in applying the concepts in a real case, a qualitative approach to data collection is used. Repeated unstructured interviews with Bagbooking employees allowed for collecting data on the concluded deliveries that the company has made in the past, such as the cities and kilometres of the logistics chain of the baggage. Finally, the collected data are manipulated in an Excel model (see sub-chapter 3.5) using the mathematical model retrieved from SQ2, in order to obtain convincing values representing the number of emissions produced. The data

of the grams of CO₂ that a ton emits per kilometre for every mode of transport used in the model was taken by the CE Delft report.

3.4 SQ4: How is Bagbooking performing if compared to passengers travelling with their own baggage?

Finally, after having calculated the CO₂ footprint of Bagbooking, for the company is important to relate the emissions with a situation in which their service is not operating. The main concept of Bagbooking is the separation of the baggage from the passenger, in which the latter is using an aircraft to move from the origin to the destination. A sensitivity analysis helps for further decision-making and policies, and to understand if the company is performing better, equal, or worse than normal air travel. The situation without the use of BaaS is then analyzed quantitatively using the Excel model, and compared with four situations where BaaS is used. This sub-question combined with the previous ones answers the main research question.

3.5 The carbon footprint model

This thesis aims to analyze the carbon footprint of the BaaS. To do so, an Excel model that calculates the emission of its logistics chain is developed, based on the theoretical background developed to answer sub-question 1 and sub-question 2 (Chapters 4 and 5). The model is tested with the case study of the company Bagbooking. Even though it could be used within Microsoft Excel only, a Python algorithm has also been used for the author's simplicity to retrieve information such as airports near the customers' origin and destination points and distances between depots and hubs. This sub-chapter contains the explanation necessary for its understanding and its use by Bagbooking.

The Excel document contains three sheets that are called "Bagbooking Data", "Calcoli" and "Model".

3.5.1 Bagbooging Data sheet

The "Bagbooking Data" sheet contains data about customers (provided by Bagbooking), including their customer code, the weight of the baggage to transport, the origin and destination of the customer, the number of segments in between the origin and the destination, and the number of kilometres between each segment. These data are provided by Bagbooking and it is possible to add a new customer or substitute the ones present in the worksheet, with the only limitation that the pattern must not change: customer code, origin city, weight, paper emissions, distance between origin and the nearest airport, the distance between the destination and nearest airport have to be in the same cells. Only the number of cities/segments can vary per customer. Using Python, an application programming interface (API) reports in rows 21 to 24 the latitude and longitude of the origin and destination cities, and other APIs find the nearest airport from these coordinates and report their flying distance.

3.5.2 Calcoli sheet

The sheet "Calcoli" is a hidden sheet that reports the data used for the calculations regarding the grams of CO₂e emitted per ton per km, for every mode of transport analysed in the model. This sheet is used in the Model sheet formulations, and it should be modified only to update the data based on more specific data on the vehicles that the company uses. The data used to run the model

are taken from CE Delft (CE Delft, 2021), and the emissions account for the CO₂ equivalent. The measuring unit of the CO₂e emissions is in kilograms, while the distances are in kilometres. In the whole Excel model.

3.5.3 Model sheet

The "Model" sheet is a template that is used to calculate the carbon emission of transporting the customer's bags. It calculates with both TTW and WTW methods, accordingly to what is selected in the first row of the model. The Excel can be filled with a number of segments that goes from one to seven. The model can be filled manually, or automatically previously inserting the data in the Bagbooking Datasheet and then pressing the button below the template.

The button will run a macro that will calculate the emissions for all the customers and will insert the values on the table below the button. The template of the model is structured in a way in which once the number of segments that the customer's baggage is inserted, the corresponding number of rows will pop up. In these, the user must insert the kilometres and the mode of transport in order to visualize the emissions. Multiple variables can be changed: The fuel and road class for vans and trucks can be adjusted if the information is available, while for trains it is possible to adjust the advanced settings by selecting the answer "yes" in column L. After the macro button is pressed, in the table, all the customer codes will appear with multiple emission values. The table is structured as follows: first-mile emissions, last-mile emissions, mode, paper, and ground segments with no bags. The mode is meant as the longest segment, which is part of the logistics chain that usually corresponds to international travel. The ground segments with no bags refer to the part of the passenger's trip in which the customer commute to the airport and it is calculated using the distance from the origin point to the nearest airport summed with the distance between the destination point to its nearest airport.

Finally, the right-hand side of the table shows the BaaS emissions according to four different situations (explained in chapter 4) and the emissions that customers would put on the same route but without BaaS. There is also a display of the average difference between BaaS and no BaaS of all customers.

3.6 Main assumptions

This sub-chapter gives an extensive overview of the assumptions and author's choices present in this study, due to time and data constraints.

3.6.1 Netherlands to Europe

The analysis of this thesis is assumed to be located in Europe. The data about the g/tonKm are analyzed by CE Delft in the Netherlands, and the case study is made on a company based in the Netherlands with a European delivery range only. Many variables could be different if other continents would be included.

3.6.2 Data assumptions

The data used were not collected personally. For the calculation of emissions, the study follows the values calculated by CE Delft, which may need to be updated or changed depending on the means of transport used and the study country.

The data included in the model, on the other hand, is assumed to be accurate and relevant to reality. These were delivered by third parties to Bagbooking, and some information was collected using APIs that are assumed to be accurate.

3.6.3 Survey

The survey held in the research was sent by email to customers by the company, with a rubric of approximately 100 people. Since it got a low response, it is considered to be only exploratory, to make assumptions when answering the sub-questions of this thesis. It is assumed that the survey was only filled out by people who used the service and that they were sincere.

4. SQ1: THE BAAS CONCEPTUAL MODEL

To answer the first sub-question “Which elements are relevant for the BaaS emissions?”, this chapter develops the BaaS conceptual model that defines where emissions come from and which elements are important for calculating their environmental impact. To give an overview and a framework for the topics to be discussed in this chapter, an overarching conceptual model showing the structure and outputs is shown in figure 3. The Baggage as a Service will in fact be analysed according to 3 impact areas (the scopes of the Greenhouse Gas (GHG) Protocol), which lead to the sources of emissions or savings.

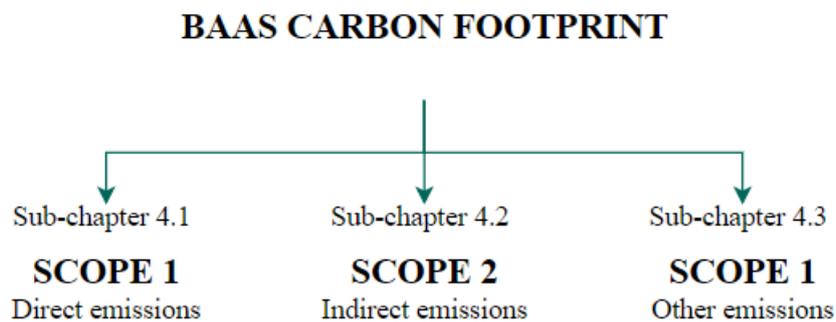


Figure 3: BaaS carbon footprint scopes overview

4.1 Scope 1: Direct emissions

Following the Greenhouse Gas (GHG) Protocol framework, this sub-chapter identifies the direct emissions from the BaaS. Figure 4, it is shown an overarching conceptual model of the structure of this sub-chapter.

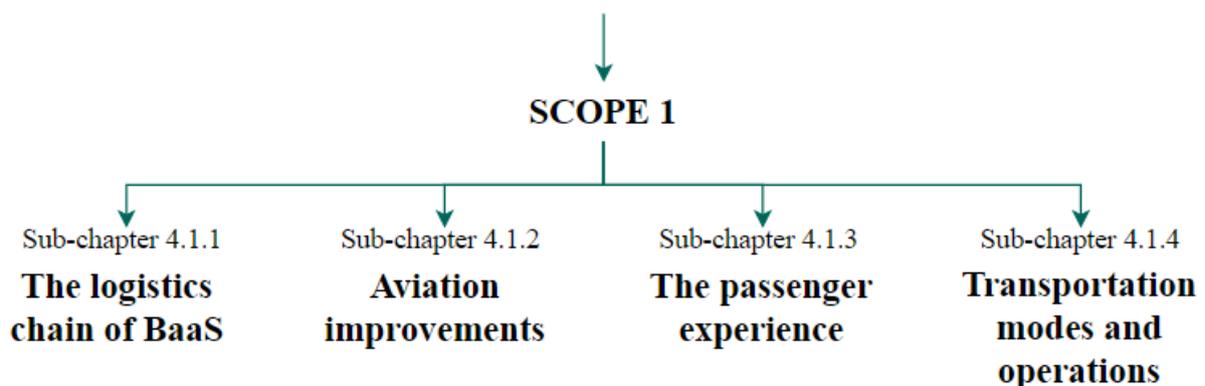


Figure 4: Scope 1 chapter overview

First, the BaaS service is analysed from a more logistical point of view, i.e. how the transport company must organise itself to collect the luggage and then distribute it within its network until it is delivered to its destination. The service operates as a combination of various transportation

segments. Each of these can be managed according to decision-making choices that have consequences for the pollution of the environment and the travel behaviour of people. Six options and three scenarios will be analysed.

Following this, a discussion is held on some improvements in aviation that the service could bring. It is important to analyse not only the service, but also which consequences that would occur with its implementation. The decrease in aircraft belly weight may lead to alternative use of these spaces, benefiting aviation emissions.

The third topic that is addressed concerns passenger behaviour and experience. With BaaS, people experience a new type of service that can change their travel behaviour, and their actions might also influence positively or negatively the sustainability of the service.

The last topic is more specific and goes into detail about which elements influence the emissions of each mode of transport. All these elements are potential sources of emissions and therefore important for the calculation of the CO₂ footprint of the service. Addressing these elements helps to understand how the scenarios differentiate. Moreover, other elements in the BaaS operations such as packaging, transshipment and consolidation are discussed.

4.1.1 The logistics chain of BaaS

The BaaS delivers the baggage of customers moving them from an origin point to a destination. The organization of the logistics includes several decision-making choices by the company handling the service on how to handle the baggage. In fact, there are various variables that affect the optimal route to use and through which transport options. Important variables are usually time and costs, but this sub-chapter will analyse the operations of BaaS in terms of environmental choices. A conceptual model with possible BaaS scenarios will be visualised and analysed, to give a full understanding of the handling options.

4.1.1 Collection and distribution of baggage

The logistic chain of this service starts with the collection of the baggage, while the last one is the distribution between destinations. The first and the last phases are usually handled through vans that pick it up and bring it to the closest local sorting point (also called “depot”) and the reverse process when distributing. As stated in the literature review, the PDP is a largely discussed problem and is very costly and pollutive. Therefore, the methodology used when the baggage is transported in these phases has a big influence on the overall emissions of the BaaS. Three options for the first mile and three for the last mile have been analysed (Figure 5). The figure shows 6 options, where the first three are collections and the last three are distributions. The choice of which method should be used to reduce emissions should be calculated using optimisation programmes, in which the environmental emission variable is minimised. Considering the number of vehicles to be used, the mileage and the maximisation of vehicle capacity, one method may be better than another depending on customer demand and location. In the literature review (sub-chapter 2.3.1), some papers analysing operational research to optimise routes were mentioned.

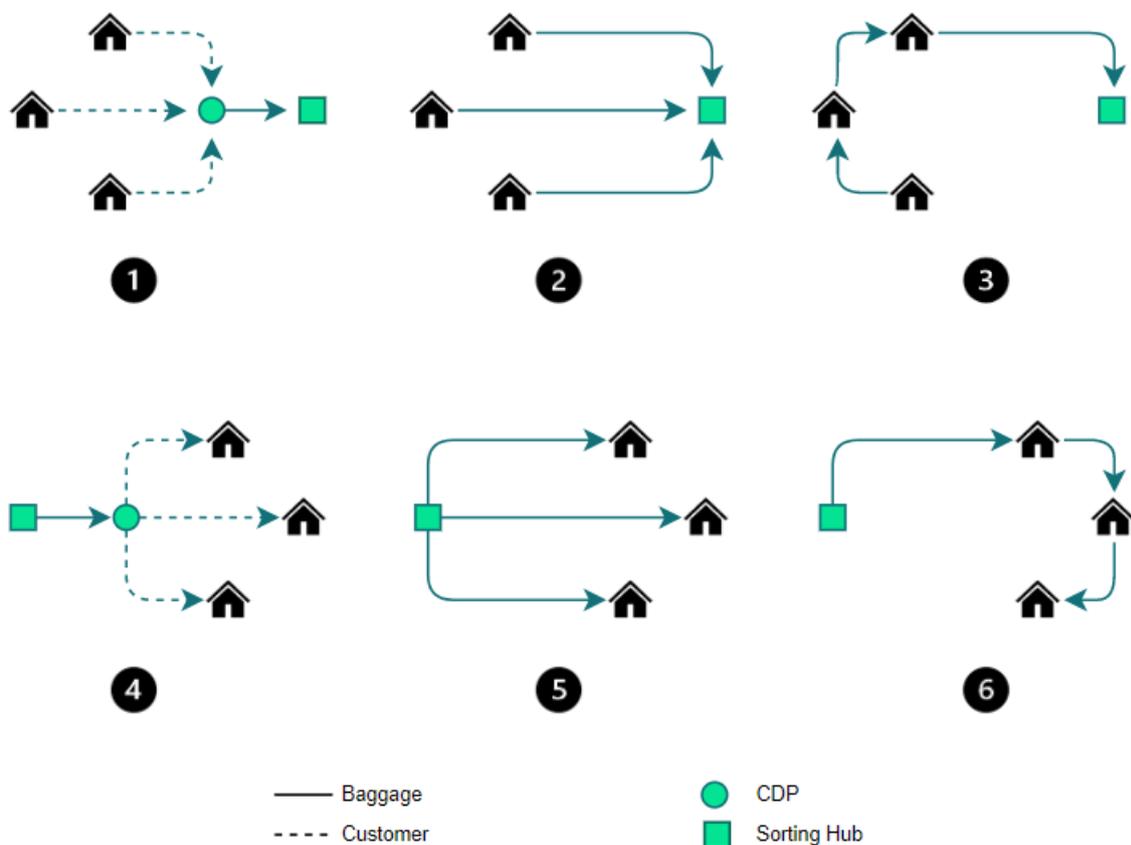


Figure 5: The first and last mile options

Option 1 represents the use of collection and delivery points (CDP), where the customer is bringing the baggage beforehand and where the party handling the transportation is picking it up. This option involves the company covering fewer kilometres with a van at the ends of the logistics chain, leaving the mileage to the customer. In comparison to the case where all parcels are delivered to home addresses, if 50% of these shifted to the pick-up points it would result in 33% fewer CO₂ emissions

in the last mile, without considering how customers reach the CDP (Davydenko et Al., 2020). As seen in the literature review (2.2.1), this method can be even more environmentally friendly, as there is the possibility to deliver the baggage in an already existing car trip, by bike, by foot or by public transport, as the location of the CDP should not be too far from the customer's home. However, in the case in which customers would use private vehicles, the CO2 footprint might be the same or increase: Studies performed in Poland and Belgium, it is shown that around 50% of the respondents collect their parcels by the car itself (Moroz & Polkowski, 2016; Rai H. et Al, 2020). It is plausible that the size and weight of goods can significantly affect an individual's mode choice and trip chaining choice (Liu C., 2019), and baggage is usually heavier and bulkier than the usual packages that are ordered or shipped. This option would probably increase the hassle for the passengers, but they could then choose to experience a service that is no longer totally hassle-free but choose to save a few emissions travelling a few kilometres to the CDP. This would still bring them significant time savings at the airport, with easier and faster boarding and having their luggage ready at their destination. In addition, option 1 could still be used with option 2 or 3 in case the home delivery fails, as it will be better described in sub-chapter 4.1.4.

Option 2 involves the collection at home. Here, a vehicle arrives at the customer's home and picks up the parcel and then takes it directly to the nearest sorting point. The number of vehicles used depends mainly on the demand and distance between customers. If in option 1 customers would all travel with their own vehicle, this option might be more environmentally friendly whether the vehicle is electrified, a cargo bike, or is consolidated with other services/goods.

Option 3 involves collecting baggage from multiple customers with the same vehicle. The van makes a round trip, reducing the mileage there would be if more vehicles were used. Depending on demand and the distance between customers, this option may be more or less environmentally friendly. However, this would allow for more consolidation of the vehicle and make it more likely that it would travel fully loaded.

Options 4,5 and 6 show how luggage can be delivered to the customer's destination. The methods are the same as for collection but at the other end of the logistics chain.

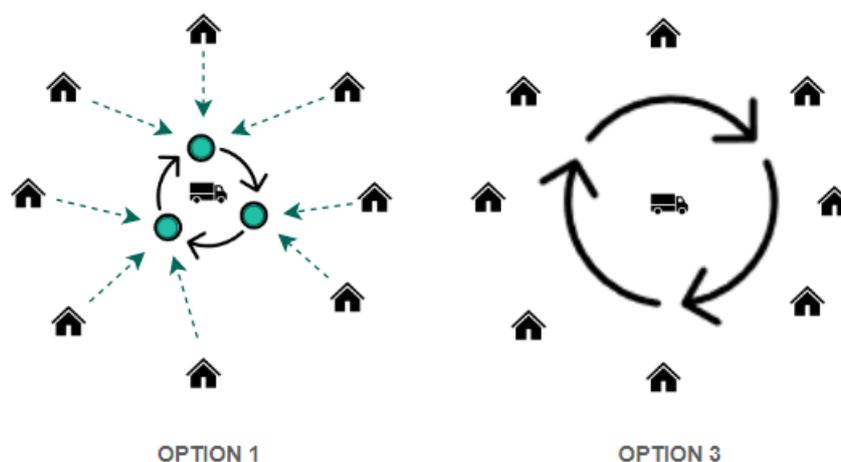


Figure 6: Illustration of the van mileage of options 1 (CDPs) and option 3 (round tour)

The option in which the passenger has to drop/pick up the baggage in a CDP (option 1 and 4) significantly reduce the route of the van of the logistics company since it has to pass in a reduced number of locations. In the options in which the round trip by the van of the logistics company stops at the origin points, the route is longer. A visual representation is in figure 6.

For this chapter, a survey was also conducted among people who used the BaaS. Since the service aims to make travel hassle-free and allow travellers to move without baggage, it would be natural to think that customers would prefer a home collection and home delivery. However, the interviewees were asked if they would be willing to bring their baggage to a service point between zero and two kilometres to help to reduce emissions. Surprisingly, 80% of the respondents answered positively. This result may make Option 1 (CDPs) an advantage compared to the other options from both an emission and a business perspective. Another question that was asked was how they would reach the eventual service point. The answers show that 7% would walk, 53% would use their own car, 7% would go by public transport, and the rest by other means. Since the majority would use a private vehicle, it would have to be studied on a case-by-case basis what the greatest environmental impact would be, depending on whether the additional kilometres travelled by the logistics company's van are more or less than those travelling by the customer. Another factor would also be whether the route taken to reach the CDP by the customer would be part of a journey that would have to be made anyway, or whether it would be a dedicated one.

4.1.2 Between Local Hubs

The first stop of baggage is the local hub or sorting hub. Here, all the packages are sorted out according to their delivery place and then shipped to the destination passing through other hubs. These logistics are made to maximise the consolidation and reduce as much as it is possible the trips. In figure 7, the conceptual model of the logistics of BaaS is shown.

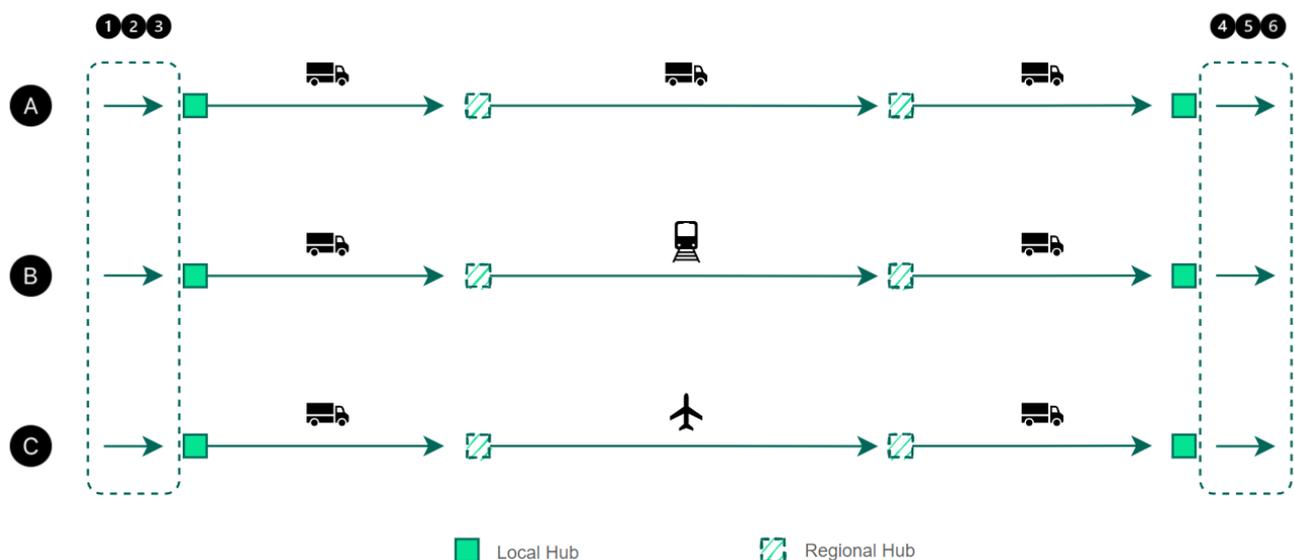


Figure 7: Logistics scenarios

The beginning and the end of the logistics chain are one of the six methods explained in the previous sub-chapter. Then, the current practice of logistics companies is based on a hierarchical logistic network. As visualized, after being collected, parcels are transported to a central sorting facility

(local hub) and then distributed to a destination-local hub. The conceptual model is simplified to four hubs, two locals and two regionals, but in between, there can be more or fewer hubs based on the facilities of the logistics company.

Three environmental scenarios between regional hubs are analysed. Due to the available infrastructure and the transshipment time and costs, only international transport is considered using a different mode rather than road transport. The three scenarios have different CO₂ emissions, depending on various elements that will be further analysed in the sub-chapter 4.1.4. In scenario A, road transport is used throughout the entire logistics process, from start to finish. Road transport is undoubtedly the slowest, but also the most widely used due to costs. In scenario B, after a consolidation of goods, transshipment from vans to a goods train takes place. This travels at high speed to the final country where the luggage is again loaded onto a van for distribution. Scenario C, on the other hand, makes use of a plane to make the greatest mileage. This means is the fastest but also the most polluting.

4.1.2 Aviation improvements

Freight is transported on airline networks in two ways: on dedicated freighter/cargo aircraft and in the belly space of passenger aircraft. While passenger demand drives the combined passenger and freight airline networks, freight transport demand drives the dedicated freighter network structure and intensity. In a scenario in which some or all passengers on board an aeroplane decide to use BaaS or carry only baggage in the cabin, there would be additional weight available for other uses. On busy routes, new aircraft could be designed to have an increased passenger capacity (i.e., two passenger floors), with a saving on emissions since the consolidation of passengers would reduce air traffic. Alternatively, the extra space available - in new or existing aircraft - could be used for combining cargo transportation with passenger traffic in order to maximize the use of available space on a flight.

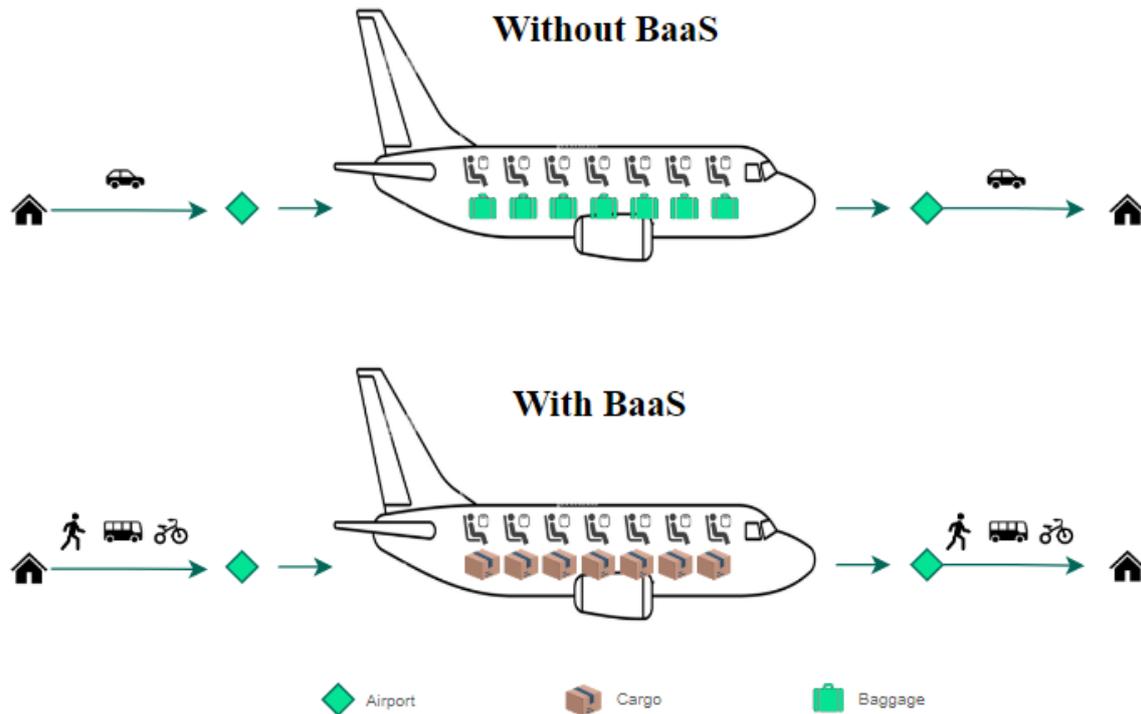


Figure 8: Conceptual model of the passenger experience with and without BaaS

Figure 8 shows at the top of the figure the passenger logistics chain without the use of BaaS, with below how this might change with the BaaS service if there were cargo in existing airplanes.

To understand the feasibility and dynamics of the process of substituting baggage with cargo, a semi-structured interview with the Ir. J.A. (Joris) Melkert was conducted. According to him, in the old past the cargo hold of passenger flights was full of suitcases, but nowadays more and more people started bringing carry-on baggage into the passenger cabin. This created extra space, and airports and companies started transporting on flights other things as well, depending on the number of people boarding and on the length of the flight: Inter European flights and low-cost airlines might have less baggage in the cargo hold compared with long-distance flights. Effectively, in 2019 air freight transported via belly cargo accounted for 47 percent of worldwide freight tons (Statista, 2021), while in the Netherlands passenger flights carried 43% (CBS, S. N., 2022). Since the existing process, there is not much logistics to change or aircraft to redesign.

In passenger flights, the proportion of baggage and cargo is not standard. In the aviation industry, aircraft are divided into short-medium-long haul and narrow-wide bodies. In Jardine, C. N. (2009)'s paper it is stated that most calculators, especially those created by offset firms, make assumptions about the percentage of overall weight that is attributable to freight in passenger aircraft because there aren't many publicly available industry data on freight load. However, typically wide-bodied aircraft often have freight factors of 15–30%, whereas narrow-bodied aircraft normally have freight factors of 0-10%. Interviewing a courier delivery services company employee (senior freight specialist), it has been told that for large aircraft such as B787 and B777, used in long haul routes, maximum baggage occupancy is no more than 30% (cargo space 70%), with an average of 25%. Instead, in smaller flights that are used in Europe such as B737 or Airbus 320, there is 75% baggage space and a max of 25% cargo with sometimes even 100% baggage.

Using dedicated cargo or belly freight also has different levels of pollution. A TNO analysis (Davydenko et A., 2020b) also states that current methodologies for CO₂ emission computations are incorrect, suggesting that to optimize the airline network operations it would be better to utilize belly freight capacity first. A freighter aircraft should only be utilized to transport freight on a given route if the aircraft's belly capacity has been used up, is inadequate, inappropriate for cargo, or is not available on the route. The report also provides an example in which authors show that moving the freights from passenger flights into a cargo aircraft would pollute more: reversing the example, it is therefore proven how using belly freight and having extra space from the use of BaaS would save emissions. In Figure 9, a graphic representation shows how the division of the cargo loaded in a cargo aircraft divided equally in three passenger aircraft could substitute a cargo aircraft, assuming to have a 33% of space in the latter gained by the use of BaaS.

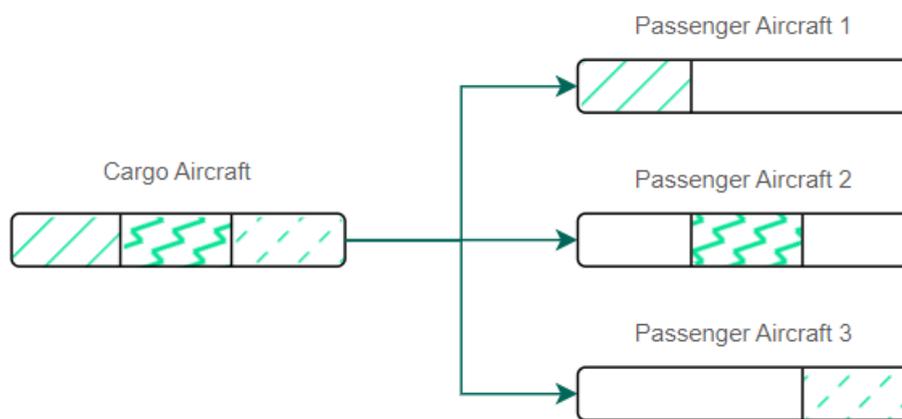


Figure 9: Cargo aircraft split

Moreover, data shows that the global volume of air freight increased rapidly in recent years with freight volumes reaching 66.2 million metric tons in 2021 and a forecast of 69.3 million metric tons in 2022 (IATA, 2021). Ir. J.A. (Joris) Melkert said that the increase of volumes and the restrictions in the number of flights of airports (for instance, Schipol airport in the Netherlands, which is going to be restricted even further next year) will push towards different solutions, among which probably putting more freight in the passenger belly freight. Therefore, the BaaS could decrease aviation emissions by creating extra space in aircraft operating passengers, reducing the number of cargo aircraft that could take off. This concept will be called the “cargo savings concept” from this chapter on.

Due to a large number of passenger flights and their regularity and continuity, there is the potential to increase the number of flights available for shipping (and thus reduce and expand services). Nahum et Al. (2019) present a model for the optimization of air transport using both cargo and passenger planes. In this research limitation, the authors consider passengers' cargo weight and volume as deterministic, while in reality, without BaaS, it is stochastic. With a full flight adopting the BaaS, it would be possible to eliminate the need to rerun the heuristic model every time, since there would be fixed weight and volume variables (none), optimizing the transportation costs of airline companies.

4.1.3 The passenger experience

Typically, the logistical chain of a person who wants to travel involves going to the airport with baggage. The logistics chain of BaaS described in the previous sub-chapter would replace the current one and modify the one of the passengers. This innovation, like many others, may have a slow transition and may change people's behaviour. The BaaS is an innovation that few users are utilising and the demand for the service could potentially grow. With proper implementation of the dissociation between passenger and baggage, the BaaS can be a valid alternative to the normal way of travelling, and even substitute it in the future. When such novelty emerges and spreads from this niche, it could bring substantial changes in the travel behaviour of people with multiple impacts in both the transport and logistics industry. In this sub-chapter, these eventual changes in behaviour are discussed.

Ground Segments

Air travel can be seen as a union of multiple segments: Passenger travel involves two ground segments and air travel between the departure and destination airports. The ground segments consider the first segment of air travel as the part of the trip in which the passenger leaves the starting point to reach the airport, while the other segment involves the passenger leaving the airport to reach the final destination. In 2019, an Air Passenger Survey (APS) asked air passengers traveling from Washington to Baltimore to indicate which mode of access they utilized to reach the airport (NCRTPB, 2019). Over half of all air passengers traveled by personal vehicle or rental car, while 24 percent used a ride-hailing service (National Capital Region Transport Planning Board, 2020). If for assumption we combine this American survey with the European Aviation Safety Agency (EASA) survey about the weights of the checked baggage (Berdowski et al., 2009), each of these people would have carried a 16.7 kg (the mean mass of checked baggage) baggage to the airport. There are no studies that relate the baggage and its weight to the choice of the mode of transport, but with the dissociation between passenger and baggage, people might be encouraged to use more efficient and ecological transport modes when going to the airport, such as public transport, bikes and trains. In figure 10, the two different ways to commute to the airport are visualized: on the left, passengers might use private vehicles or taxis when carrying baggage, and on the right, passengers might choose a green mode when free from weight. Because of the baggage, passengers may also ask familiars or friends to be driven to the airport, polluting not only on the way towards the departure but also on the way back of who drove.



Figure 10: Commuting to the airport segments.

The survey made to 21 Bagbooking customers deepened the knowledge of their travel behavior in this segment. They were asked two questions about how they traveled when they used the BaaS service, and how they would have traveled if they had not used the service. The survey results show that 67% (14 customers) used a private car to get to the airport, while 19% opted for a green option (Q1, Appendix B). However, the same percentage of people answered the survey saying they would have taken the car without using the service, while the percentage of people who would have used public transport would increase from 19% to 29% (Q2, Appendix B). This percentage was taken from those who answered 'other' in Q1. It can be concluded that, with Bagbooking, the BaaS did not push customers to change their travel behavior, which stayed the same.

A similar situation that might work as an example of how the BaaS could reduce emissions could be by comparing it to grocery home deliveries. Grocery generally generates personal car travel due to its bulky nature of purchases. A study made in the UK suggests that, with a realistic level of take-up, a probable reduction of 70% or more in the kilometers traveled per shopping load would occur (Cairns, S., 2005). Similarly, the BaaS could therefore greatly contribute to the reduction of CO₂ footprint and more sustainability, changing the travel behavior of users. Another case study by Siikavirta et al. (2003), in Finland, indicates that home delivery service has a significant potential for traffic reduction when compared to customer self-pickup. The GHG emissions could decrease in the range of 18–87%.

Air Segment

The other segment is air travel. Here, another change that would occur that would affect the travel behaviour of passengers would be the duration of the trip. Instead of arriving hours earlier to check in baggage and several minutes after landing to wait at the belt in the arrival hall, passengers would go straight through security and then to the gate. As also Loskot & Ball state in their study, dissociating passenger travel and baggage delivery within the air segment can bring changes to the current airline and airport procedures and regulations (Loskot, P., & Ball, P., 2015). This would create fewer delays and inconveniences, facilitating the logistical processes of airports. Taking a plane would be faster and more people would choose this mode of transport.

4.1.4 Transportation modes and operations

After discussing the logistics chains of the logistics company and passengers, this sub-chapter goes into the operations specifications. The different modes of transport that can be used within the introduction of the BaaS are discussed. This part is relevant because helps to answer sub-question one, completing the extensive analysis to identify every element that has an impact on the BaaS

footprint. Moreover, it shows why different modes pollute in different ways and which variables should be evaluated when emissions are analysed.

In the transportation sector, the emissions result mainly from the combustion of fuels and therefore this sub-chapter is divided by the modes of transport that directly pollute the environment, which are road transportation (trucks, cars, etc), trains and aeroplanes. Due to this research focusing on Europe and the time constraints of this kind of service, barges are excluded from the analysis. Finally, the role of the transshipment, and the consolidation is discussed.

4.1.4.1 Road

The first mode of transport that is analysed is the one on the road, which in 2020 accounted for 77.4 % of the total inland freight transport in Europe (Eurostat, 2022). Long-distance road transport is typically accomplished using truck trains and articulated trucks, while the distribution in cities is handled with smaller sizes of vans. The emissions from this mode vary based on certain elements that are following listed and explained.

Fuel

The first element to consider is the fuel that the vehicle uses. The choice of the type of vehicle to use is also very important since every brand has different engines, weight and consume different amount of fuel. Since the emissions of the transportation sectors are mainly sourced from the fuel consumed, the CO₂ emission factor of a specific fuel has high relevance to the carbon footprint. In figure 11, the indices for alternative fuels and technologies for empty vans (2000-2500kg) are shown.

Table 11 - Indices for alternative fuels and technologies, vans, empty weight 2,000-2,500 kg (indexed to Euro 6d = 100)

Fuel/technology	MJ/km	TTW emissions (g/km)			WTW emissions (g/km)		
		CO ₂ -eq	PM ₁₀	NO _x	CO ₂ -eq	PM ₁₀	NO _x
Diesel, Euro 6d	3.5	245	0.002	0.14	325	0,014	0,26
Index of average 2018 diesel rel. to Euro 6							
Diesel, average 2018	102%	102%	1264%	751%	102%	223%	456%
Index (Euro 6 = 100)							
Diesel, Euro 5	102%	102%	100%	1020%	102%	100%	603%
Diesel, Euro 6a	100%	100%	100%	223%	100%	100%	167%
Diesel, Euro 6d	100%	100%	100%	100%	100%	100%	100%
Diesel, plug-in hybrid, Euro 6	88%*	76%	180%	80%	86%	95%	87%
GTL, Euro 6	100%	104%	100%	100%	104%	103%	103%
Biodiesel, Euro 6, 97% FAME-3% HVO	100%	1%	100%	100%	15%	211%	122%
HVO, Euro 6	100%	1%	100%	100%	11%	211%	122%
CNG, Euro 6	97%	84%	228%	41%	73%	27%	30%
BioCNG, Euro 6	97%	5%	228%	41%	29%	51%	43%
Electric, average mix	47%**	0%	0%	0%	70%	54%	61%
Electric, wind/solar	47%**	0%	0%	0%	2%	0%	0%
Hydrogen	71%	0%	0%	0%	80%	328%	127%
Hydrogen, electrolysis with wind/solar/hydroelectric	71%	0%	0%	0%	7%	0%	0%

* 76% of MJ diesel, 12% electric; ** Tends towards 41% in urban traffic. For small vans (<1.5 t) this factor is 35% relative to diesel and the other indices are also 75% of the value given.

Figure 11: Indices for alternative fuels for vans. Diesel Euro 6d=100%. [Source: CE Delft]

Distance

The length of the segments that each vehicle travels greatly influences the amount of fuel consumed. The more distance a vehicle travels, the more fuel will be consumed, and the more CO₂ will be emitted. The lengths depend on where the infrastructures of the logistics company operating the travel are located, such as terminals and hubs. The more these facilities are strategically located, the more efficient baggage travel will be. However, kilometres are not always directly proportioned with the emissions: In order to prioritize intermodality and use less polluting or faster modes of transport, more kilometres might be travelled. The intermodality allows more than one form of the carrier during a single journey, sometimes at the expense of travelling more routes.

Speed

When a vehicle is moving, it consumes a certain quantity of fuel. This quantity varies also based on some characteristics of the vehicle such as tires and style of driving. These variables cannot be measured precisely in absence of technologies that can share live this information and assumptions on the optimal status of the vehicles need to be done. However, based on the itinerary that every vehicle travels, it is possible to consider the average speed of the various roads when calculating the consumption of fuel. However, while the mass of CO₂ produced by (diesel) trucks is clearly proportional to the distance travelled, it is not proportional to the average speed. The speed/CO₂ emission graph produces a U-shaped pattern, showing that the least amount of CO₂ is emitted at around 60–80 km/h (Kim N. S. & Van Wee B., 2009). Operating conditions also affect the total speed: there are different emission factors for urban driving, rural driving and highway driving and the degree of congestion per road type.

Load

The weight of the vehicle and of the freights that are transported have an influence on the consumed fuel. It is also dependent on the type of fuel of the vehicle. For instance, it was demonstrated that the fuel consumption penalty imposed by increased vehicle weight is significantly lower in hybrid-electric vehicles than in equivalent conventional internal combustion engine vehicles: A 100 kg change in vehicle weight increases fuel consumption by only 0.4 l/100 km in the hybrid-electric vehicles, compared with 0.7 l/100 km in combustion ones (Reynolds & Kandlikar, 2007). Another study states that a 10% reduction in the truck's weight can reduce fuel consumption by up to 2.65% (Ehsani M. et Al., 2016).

Other elements

To add to these previously mentioned elements, other characteristics can increase the quantity of emissions and are more difficult to predict and calculate.

Each vehicle must travel on roads that have different inclinations. Depending on cities and latitudes, this gravitational acceleration and the rolling resistance can be irrelevant as well as very influential on vehicle traction and therefore on the amount of fuel consumption and carbon dioxide emissions. For example, a 10% reduction in a car's rolling resistance can reduce fuel consumption by up to 0.33% (Ehsani M. et Al., 2016).

Something impossible to predict is the human error caused by contextual factors, including personal and environmental ones. Mistakes may occur at any time, leading to freight impairment and/or delays in transit times, with a downgrade of the level of service provided and the customers'

satisfaction. Mistakes made by the drivers for example can also make the routing gets longer than optimal, increasing the emissions.

As another human factor, it is possible also to include the driving style: variables such as accelerator pedal usage and average gear level are significantly correlated with fuel consumption (Lee & Son, 2011). For instance, it is important to avoid hard acceleration and braking and use air conditioning sparingly. It is theoretically and practically proven that a fluent driving style is more efficient and that, aside from this mentality shift of the way of driving, controlled speed together with traffic measures (such as roundabouts or phased traffic lights) improves traffic conditions, reducing further emissions (Van Mierlo, J et Al., 2004). If there is a 10% improvement in driving style in cars reduces 8.81% of fuel consumption (Ehsani M. et Al., 2016).

The tire is another element that influences vehicle fuel consumption, and its most important characteristic which affects its performances is the inflation pressure (Soltani, A. et Al., 2015).

Home deliveries can also fail. It can happen that the customer is not at the destination or there is no way to store the baggage before his arrival (i.e. the hotel has no reception). In this case, the additional mileage made by the customer or by the logistics company in the second delivery attempt needs to be calculated, since can increase the CO₂ emissions by between 9 and 75% (mainly from the personal trip that the customer must do to pick the parcel up at the local hub). Therefore, Edwards J. et Al (2009) analyse the CDPs (option 1) as a more environmentally friendly alternative. In fact, utilising CDPs when a delivery fails would be a significant CO₂ reduction. This is due to the shorter distance compared to having the van going back to the local hub and repeat the delivery on a new date. Moreover, there could be even greater CO₂ savings if the collection by the customer is incorporated into a normal travel routine.

Furthermore, road transport may come across tolling systems. Ehsani M. et Al. studied the effect of three types of tolling systems, namely, free-flow, traditional tolling and electronic toll collection (ETC) by considering different fuels. The results indicated that the traditional tolling system has a higher fuel consumption than ETC, because of the change in speed and acceleration of the vehicle and thus, a larger amount of carbon dioxide will be produced. Overall, the electronic tolling system emits twice less than the amount of carbon dioxide emissions emitted by the traditional tolling system. The carbon dioxide of traditional tolling system for cars considering non-renewable fuels such as gasoline and diesel in the stopping stage is 5.45% and 5.38%, respectively (Ehsani M. et Al., 2016).

As mentioned, the elements in this sub-chapter are very difficult to measure without the help of specific technology. However, some of these can be reduced or controlled: Logistics operations mistakes and consequences can be reduced through the application of RFID (Radio Frequency Identification) technology (Mingxiu, Z. et Al., 2012, Cepolina et al., 2018); Active tire pressure management, through an automatic, electro-pneumatic, central tire inflation system, is mean that can be used for improving fuel consumption in passenger vehicles (D' Ambrosio & Vitolo, 2018); Internet of Things (IoT) gives real-time information and it can be used to collect and process of data like location, vehicle speed, engine compartment temperature, fuel consumption (Desai, M., & Phadke, A., 2017); Autonomous cars technology can make more convenient and less energy-intensive, reducing the travel time and CO₂ emissions (VanDung Nguyen et Al, 2016).

4.1.4.2 Rail

Another transport mode that can be used to transport baggage is rail. In 2020, rail freight transport accounted for 16.8 % of the total inland freight transport in Europe (Eurostat, 2022). However, rail freight transport is not used as the only mode of transport, but it is part of the intermodal freight systems, which is commonly defined as the movement of goods consisting of two or more modes of transport used in door-to-door trips for consolidated loads. Studies reveal that there is a substantial emission reduction using intermodal rail/road transport instead of road-only transport (Lin, B. et Al., 2017; Heinold A. & Meisel F., 2019). The emissions from this mode vary based on certain elements that are following listed and explained.

Fuel

Here, the two most common types of locomotives can be considered: diesel and electric. For Diesel-powered trains, the direct emissions come directly from the consumed fuel, which varies depending on the type of vehicle. For electric vehicles, generally, the direct emissions at the vehicle level do not exist, while the emissions at the power plant level are significantly based on the electricity power-generating source: if power plants use only coal or oil fuel sources, intermodal systems using electric trains could emit more CO₂ than their competitors (Kim N. S. & Van Wee B., 2009). Therefore, the emissions also vary from country to country and from its eco-friendly energy production.

Distance

As for the other mode of transport, distance is an element that influences the amount of CO₂ emitted. The emitted CO₂ is almost proportional to the distance, but naturally the more the distance is travelled, the more fuel will be consumed (Kim N. S. & Van Wee B., 2009).

Speed

For both diesel-powered and electric-powered locomotives, the emitted CO₂ is also almost proportional to the average speed. In other words, CO₂ mass from train-based freight systems is less sensitive to speed than other modes of transport (Kim N. S. & Van Wee B., 2009).

Load

The weight that a train can carry in a single trip is significantly more than using another mode of transport. Depending on the number of wagons, it is possible to carry more freight and therefore reducing the circulation of air cargo and road transport. Also, the vehicle and the number of wagons will increase the total weight.

Other elements

Also for the rail freight system, some other specific elements can influence the final CO₂ footprint. The number of stops, the altitude profile along the route, the vehicle mileage, or the ambient temperature can make a difference (Heinold, A., 2020), but these are very specific to the railways or the condition of the vehicle at the moment of use.

4.1.4.3 Aeroplane

Air cargo stands out as the mode with the highest emissions by far (European Environment Agency, 2021) and the least efficient in terms of air emissions, partly because it carries low-weight cargo. It emits 35 times more CO₂ than rail and 18 times more than road transportation on a ton-mile basis

(Horvath A., 2006). The emissions from this mode vary based on certain elements that are following listed and explained.

Fuel

The fuel that air cargo utilizes is kerosene. As mentioned, this mode of transport is not much energy-CO₂ efficient, since the specific CO₂ factor is high. The amount of fuel burned is dependent on the aircraft serving a given route. The most polluting stage of a flight is typically considered to be takeoff and climb (CE Delft, 2021), as this is when aircraft engines produce the highest emissions. During takeoff and climb, the aircraft is using a lot of fuel to generate the necessary power to gain altitude, leading to high levels of emissions such as carbon dioxide, nitrogen oxides, and particulate matter. Additionally, the emissions produced during this stage are released into the lower atmosphere where they have a greater impact on local air quality and climate.

Distance

As with the other mode of transport, the distance increases the fuel consumed. The Air cargo freight system is also part of an intermodal transport system, since aircraft can only fly from one airport to another one, and it is needed another mode of transport in the ground segments. There are three typologies of flights, depending on the distance between the airports. It is considered a short-haul flight when it is less than 1400km, medium-haul when it is between 1500 and 6000, and long-haul when it is more than 6000 km.

Speed

An aircraft has a different speed based on the flight phase. There are multiple phases: takeoff cycle, climb to 3000 feet to cruise altitude, cruise, and descent from 3000 feet. There is a correlation between fuel consumption and speed, and in a study, optimizing speed alone resulted in a 2.4% reduction in cruise fuel burn (Lovegren, J., & Hansman, R. J., 2011).

Load

Emissions of aircraft are related to the fuel consumed and therefore from the weight of the aircraft. The vehicle has to create enough lift to match the drag it will encounter, and the higher the weight more is the more fuel burned. However, this variable may be similar if cargo is loaded instead of baggage. Some airlines have made an effort to decrease the gross takeoff weight of their aircraft by reducing the number of onboard amenities and the permitted amount of checked luggage for passengers. Over the course of a 1,000-mile journey, it is predicted that lowering the luggage allowance will reduce carbon emissions by 2 kg per person (Filippone, A 2008). Naturally, this consolidation of baggage placed in the hold on planes that would otherwise remain empty would be much more eco-friendly than having dedicated spaces.

The dimension of the aircraft increases the total weight and the number of passengers or/and freights it can carry. There are two types of vehicles: narrow-body ones and larger wide-body. Depending on the type of aircraft, the weight of cargo varies and can be stored differently in two different ways: On narrow-body or small to medium aircraft, the bags are usually loosely loaded on the cargo compartment/cargo hold floor, while on wide-body aircraft, bags are stored on containers or unit load devices (ULDs) which are loaded as units using deck loaders.

Every aircraft has also a freight load factor per flight. More goods are transported, and more fuel is burnt. Usually, cargo that is transported by plane is highly valuable items or perishable goods (e.g. flowers, food, etc), which need to reach the destination quickly.

Another element that makes the aircraft consume more fuel is the passenger occupancy rate: when a vehicle is taking off, not always all the seats onboard are occupied. The TNO analysis (Davydenko et Al., 2020b) shows that the emission allocated to a tonne of freight is quite sensitive to the passenger load factor.

4.1.4.4 Ferry

The BaaS does not tend to use large ships to consolidate luggage, as it would take an enormous amount of time. Moreover, this study is limited to Europe only. However, there are situations in which the customer requires baggage to be sent to locations on the islands, so a change of means may be necessary. For example, if the final destination was Ibiza, there would be two possible travel scenarios: fly to the island and then take a van for the last mile, or use the van-ferry-van scenario. In some locations, the first scenario may not be possible due to the size of certain islands. For this study, the part of the trip that could be travelled by ferry is considered to be travelled by van.

4.1.4.5 Warehousing and Transshipment

With the possibility of an intermodal transport system, it's important to address not only transportation but the warehousing and transshipment processes as well. In warehouses, goods are stored and moved (e.g. parcel sorting), while transshipment is the process in which freights are unloaded from a mode of transport and loaded on another mode of transport (e.g. rail to truck). A changing mode may be convenient for mileage, avoiding natural obstacles and time. However, at the intermodal terminals or in warehouses, direct emissions are emitted since multiple pieces of equipment (machines and tools), electricity and personnel are needed to facilitate the movement of freights. Moreover, transshipment and storage could sometimes include additional stops or lengthen the travel route. Even with these additional emissions and possible extra miles, it does not necessarily mean more emissions if the means of transportation is greener, and indeed intermodal transport is considered a possible solution to increase the performance of the supply chain and shows the impact of this solution on lowering GHG emissions (Mirzapour Al-e-hashem, S. M. J., & Rekik, Y., 2014). European rail-based intermodal systems are potentially more environmentally sustainable than unimodal freight systems (Kim, N. S., & Van Wee, B., 2009). As practiced by CarbonCare, such emissions could be measured globally and allocated as fixed values, with some differences between Europe and Asia. However, transshipping emissions represent a minor share of all emissions (Wild, P., 2021).

4.1.4.6 Consolidation and Empty Trips

Consolidation is when shippers combine multiple freight into a single load to the destination point. In fact, when using the BaaS, it might not be necessary to use a dedicated vehicle to move baggage. Instead, both for reducing the company's costs and CO₂ emissions, consolidation with other freights or parcels can be made. Therefore, when calculating the emissions, it is important to see when the baggage is moved in consolidated shipments and the emissions produced by the vehicle are divided, or the service is moving a vehicle only for one customer. Currently, around 6% of trucks move to depart with not many orders and with not the whole load space filled, a number that could decrease with the willingness of the customer to wait longer for the shipment (Mohan, A., & So, S. L., 2019).

Moreover, multiple studies show that freight consolidation provides a significant contribution to reducing the negative impacts of freight transport to city centres, given the fuel reduction and emissions savings based on trips reduction (Paddeu Daniela, P. et Al., 2014; Pan, S., Ballot, E., & Fontane, F., 2013). A half-loaded truck uses more than 90% of the fuel used per kilometre by a fully-loaded truck (N. Adra et Al., 2004). Numerical experiments on freight consolidation in intermodal networks with reloads also show an average reduction in CO₂ emissions of 30 % compared to direct road transport (Van Heeswijk, W. J. A. et Al., 2018).

Another consideration regards the empty back-haul rate of vehicle kilometres without goods (i.e. loading factor for returning). When a vehicle reaches the end of its trip, usually it must go back to its origin and often it can be empty or half full. Therefore, the BaaS have to optimize the logistics operations and ensure the vehicles do not waste fuel.

4.2 Scope 2: Indirect emissions

After having analysed the sources of direct emissions, the second scope includes the emissions from the generation of purchased electricity that is consumed in the owned or controlled equipment or operations of the company.

Electricity used in offices and lighting can represent a large source of GHG emissions. For the BaaS emissions, both consumptions of the company which provides the service and the logistics operator need to be considered.

The system's energy use of each mode is also emitting CO₂. This regards rail signals, airports, infrastructures, traffic lights, and everything which supports the utilization of the modes of transport.

4.3 Scope 3: Other indirect emissions

The third scope that the GHG protocol mentions usually contains optional emission sources. It analyses indirect emissions from activities of upstream constructors, the company's electricity providers, waste disposal, and various life cycles. For instance, the emissions from the production/generation of the fuels that each vehicle utilised in transportation, or the life cycle of these vehicles. These elements can be relevant when calculating emissions, especially when considering the life cycle of means of transport. However, due to the level of detail of this analysis, we delineate the boundary up to their use and not the upstream emissions.

One of the elements that are however important to consider for the BaaS emissions analysis is the additional traffic that extra vehicles might generate. More trucks on the roads will increase traffic jams and the period in which people keep their personal vehicles turned on. Scholars found that when the traffic flow decreases its speed from 40 km/h to the traffic jam with a speed of 10 km/h, the fuel consumption will be doubled and 2–4 times the environmental load will be produced (Zhang, L.-D., & Zhu, W.-X., 2015).

Another indirect element is the movement of personnel commuting to and from the workplace. Adding a new service, additional offices and workers are needed. If workers emit CO₂ going to work, the overall footprint increase, even if probably of a very low percentage.

4.3.1 Paper packaging

Logistics companies are widely known for utilizing plastic and various forms of packaging that contribute to pollution. When baggage is picked up and transported, it can be packed with a variety of materials. For the purpose of this study, the paper will be included in the calculation of emissions. However, the paper does not pollute when used, but it does its production. The exact amount of emissions can vary depending on the type of paper being produced and the specific production methods used. However, for primary corrugated board, a common type of paper packaging, emissions have been shown to range between 0.49 and 2.46 kg CO₂-eq/kg of material in 17 data sets. This means that for every 1 kilogram of primary corrugated board produced, between 0.49 and 2.46 kilograms of CO₂-equivalent emissions are released. It's important to note that these numbers may vary depending on the specific production method, location and the type of paper being produced (Brogaard, L. K. et Al, 2014).

Despite this, it is important to consider that there are other types of paper packaging materials and alternative packaging materials that may have a lower environmental impact and should be further researched and considered as potential options for reducing emissions within the logistics industry. For instance, the greenhouse gas emissions of recycled cardboard boxes are 28.1% lower than primary source cardboard boxes (Carbon Footprint of a Cardboard Box - Consumer Ecology, n.d.).

4.4 Results of the Chapter

This chapter presents an analysis of the elements contributing to BaaS emissions. Two logistics chains have been identified: one for baggage and one for passengers. The analysis of the baggage chain examines various options for collecting and distributing baggage in the first and last mile, as well as different scenarios for transporting baggage between depots or hubs. An extensive discussion on the environmental impact of different transportation modes is also included.

The passenger supply chain is analyzed in terms of how the use of the service affects the travel experience. The concept of "cargo savings," which refers to the utilization of extra space in the belly hold of passenger aircraft, is also examined.

In addition to the development of this theoretical conceptual model, which is not present in the existing literature, the study shows how business services in the BaaS could impact various stakeholders in the system of interest. Companies providing BaaS services could influence people's travel behavior, encouraging them to use more sustainable means of transportation. Moreover, the application of the "cargo savings" concept could have a positive impact on the aviation industry, leading to emissions reduction and optimization in the sector.

However, the Bagbooking case study survey reveals that current measures are inadequate to push passengers to use green modes, and further efforts are necessary.

5. SQ2: MATHEMATICAL FORMULATION

After having provided the conceptual model of the Baggage as a Service and analysed the elements that are relevant in its carbon footprint analysis, the second sub-question “*How can the BaaS CO2 footprint be modelled?*” is answered. The SQ2 provides the base to subsequently develop a model to calculate the BaaS emissions when data are provided. The mathematical formulation explains how to calculate all the emissions coming from each part of the logistics chain in a non-numerical manner.

According to the structure of the conceptual model, sub-question 2 is answered as follows. Sub-chapter 5.1 regards the mathematical formulation for the emissions from the logistics chain; Sub-chapter 5.2 for the passenger trip; Sub-chapter 5.3 analyses the formulation for scopes 2 and 3.

5.1 Formulation for the logistics chain

The calculation starts with the direct emissions of scope 1. Since there are different scenarios (figure 7) and different pick-up and delivery options (figure 5), there is a need for a formula that includes all these possibilities. Then, it will be up to the BaaS company to evaluate with other models which options are the best based on the demand for the service, customer requirements, their distance to local hubs and available infrastructure. The following mathematical model is discussed as a general model, not intended to apply to every BaaS company. Each logistics company has more or less local hubs and regional hubs, or for example other modes of collection and delivery. The formulation may therefore have to be slightly modified on a case-by-case basis.

5.1.1 Options 1 & 4 (through CDPs)

Before formulating the emissions of the three scenarios analyzed the emissions of the three-baggage collection and delivery options (figure 5) must be calculated. Option 1 and 4 evaluate the presence of CDPs, where one segment of the route is traveled by the customers who drive themselves to deposit their baggage, while the other part is traveled by a van of the logistics company to collect or deliver them all.

5.1.1.1 The customer

In the segment through which the customer must travel, the route traveled can be via various means of transport. The greenest ways are by bicycle (not feasible with baggage) or walking, while the least environmentally friendly are by car and bus. In this sub-chapter, the formulation retrieved in the paper of Brown J. R. & Guiffrida A. L. (2014) will be used. Effectively, while comparing carbon emissions from traditional shopping versus e-commerce home deliveries, they calculate the carbon footprint for customer pickup. Their model considers both the case in which the customers make other stops before the pickup or not.

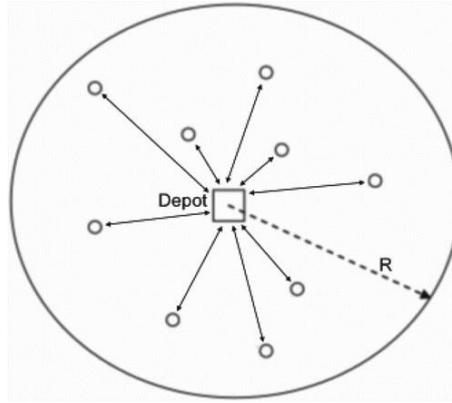


Figure 12: Visualisation of distribution of customers around a depot. [source: Brown J. R. & Guiffrida A. L. (2014)]

In the development of their equations, they consider the customers' homes uniformly and randomly distributed in a circular area of radius R around a CDP (figure 12). In this area, it is defined the expected roundtrip distance that customers travel using the Manhattan distance metric. The expected Manhattan distance D between a customer and the CDP can be calculated mathematically with the following formula:

$$\bar{D}_M = \left(\frac{\int_0^{2\pi} \left(\frac{2}{3} |\sin(x)| + \frac{2}{3} |\cos(x)| \right) dx}{2\pi} \right) R = \frac{8R}{3\pi} \quad (2)$$

In Equation (2), x equals the angle in radians from 0 to 2π (the whole circumference). To also consider the mileage that the customers travel on the way back home, the distance must be doubled.

As discussed in the previous chapter, customers could also take baggage on an already planned trip, e.g. to the grocery store or on their way to work. In this case, only part of the journey should be considered in the emission analysis, since the trip would occur anyway. Therefore, the paper calculates the distance proportion (P) with the following formula:

$$P = \frac{\sum_{i=1}^n (d_{i,x} - d_{i,z} / 2d_{i,o})}{n} \quad (3)$$

Where:

Table 4: Distance proportion variables explanation

Notation	Description
P	Distance proportion, P ($0 \leq P \leq 1$). With $P=1$ if the customer would not have made the trip
i	index for each customer from 1 to n
$d_{i,x}$	the total distance of the trip with all stops
$d_{i,z}$	The distance the customer would travel without going to the CDP
$d_{i,o}$	Distance from the customer's home to the CDP
n	Number of customers

Once the mileage to the CDP that each customer travels (P) is estimated using empirical data, Brown J. R. & Guiffrida A. L. multiply it to Equation (2) to have the expected total mileage (to go and go back):

$$D = \frac{16nPR}{3\pi} \quad (4)$$

The carbon footprint (C) is then defined as the total kilos of CO2 emitted in Equation (5),

$$C = cF = \frac{cD}{f} = \frac{16cnPR}{3\pi f} \quad (5)$$

Where:

Table 5: CO2 emissions formula notation

Notation	Description
F	total gallons of fuel consumed
f	average fuel economy in miles per gallon (MPG)
D	expected total mileage for n customers
n	number of customers
c	average CO2 emitted per gallon of fuel

Since passengers need to carry baggage, for these two options only car and van are considered. The bus is considered a green mode and therefore the formulas are used to calculate the emissions of private vehicles.

5.1.1.2 The logistics company

Still following the delivery structure described in the previous chapters, after being deposited and consolidated at a CDP, the baggage is transported to the local hub by a van. It is assumed that it will depart from the depot arrive at the CDP and then return with the baggage.

To determine emissions, therefore, the calculation is made by multiplying the distance traveled between the round trip and the amount of fuel consumed by the emission factor of CO2 the fuel type the van emits per litre.

$$\sum_{t=1}^{t=\#vans} d_t \times e_t \quad (6)$$

Where d is the distance and e is the emission factor

However, it is more logical to assume that the logistics company van will collect parcels from multiple CDPs before going to the depot, called roundtrip or milk run. This is better analyzed in the next chapter, for options 3 and 6.

5.1.2 Options 3 & 6 (round tours)

Options 3 and 6 consist of home deliveries. Here, one or more vans leave from a local hub to go house to house to collect luggage. For the calculation of emissions, again the paper of Brown J. R. &

Guiffrida A. L. will be used for the formulation of CO2 emissions by the logistics company on this route.

Company’s vans T typically leave from a depot that in this case is considered to be located at the centre of the circular demand region with a radius of R used in subchapter 5.1.1.1. From there, one or more vehicles do a tour in this region passing by a number of customers N . The expected distance traveled per day μ_T is therefore a function of the number of vans utilized and the number of delivery points (including the local hub). The paper analyses the circular area with the number of customer houses N ranging from 2 to 160 and the number of vans T ranging from 1 to 5 (dividing the circular area equally between the number of vans analyzed). The general form for the expected tour distance for $T=1, 2, \dots, 5$.

$$\mu_T = (\beta_{1T} + \beta_{2T}\sqrt{N})R \quad (7)$$

Where b_{1T} = y-intercept coefficient (for $T=1,2,\dots,5$) and b_{2T} = slope coefficient (for $T= 1,2,\dots,5$).

Table 6: Statistical information of distance equation [Source: Brown J. R. & Guiffrida A. L. (2014)]

$T =$	Mean			Standard deviation		
	Equation μ_T	R^2	Sig.	Equation σ_T	R^2	Sig.
1	$(0.017 + 1.871\sqrt{N})(R)$	.998	< .0001*	$(0.990 - 0.064 \ln(N))(R)$	.528	.0075*
2	$(1.862 + 1.744\sqrt{N})(R)$	.999	< .0001*	$(1.591 - 0.199 \ln(N))(R)$	.832	.0308*
3	$(2.776 + 1.770\sqrt{N})(R)$	.999	< .0001*	$(1.864 - 0.245 \ln(N))(R)$	.871	.0206*
4	$(3.721 + 1.706\sqrt{N})(R)$	.998	< .0001*	$(2.336 - 0.367 \ln(N))(R)$	.861	.0229*
5	$(4.666 + 1.794\sqrt{N})(R)$	.989	.0005*	$(2.789 - 0.434 \ln(N))(R)$	.940	.0063*

*Statistically significant ($p < .05$).

From the distance μ_T , they use Equation (8) to estimate the total CO2 emissions:

$$C = \frac{C_D(\beta_{1T} + \beta_{2T}\sqrt{N})R}{f_D} \quad (8)$$

where

Table 7: Notation of CO2 emission formula for options 3 and 6

Notation	Description
C_D	the average kilos of CO2 emitted per gallon of diesel
f_D	the average fuel economy for a delivery vehicle in MPG

5.1.3 Options 2 & 5 (dedicated trips)

In options 2 and 5, where the van also departs from the local hub to go directly to the customer's individual home and back, without passing through additional stages. Therefore, it is used the same procedure as in the previous sub-chapter (X), utilizing Equation X but with $T=1$ (since only one van will be used for one delivery) and $N=2$ (one dwelling and the local hub). The van route is then calculated one by one for each house, but instead of being a roundtrip, it is the summation of multiple trips.

5.1.4 Scenarios

Once at the hub, baggage is moved via one (or in some cases more) of the scenarios shown in Figure 7. The elements described in the previous chapter mean that one means of transport is more polluting than another, and it is up to the logistics company to determine which one to use. In any case, a formula is needed that calculates the emissions of this logistics segment regardless of the chosen means of transport. You then multiply the distance to be traveled by the fuel consumed by the vehicle by the CO₂ emission factor of the fuel used. The formula is therefore as follows:

$$\sum_{s=1}^{s=\text{scenario}} \sum_{t=1}^{t=\#\text{vans}} d_{t,s} \times e_{t,s} \quad (9)$$

Where d is the travel distance, e is the emission factor, and $1 \leq s \leq 3$.

5.1.5 Cargo Savings

The next calculation to do involves savings in cargo emissions. In the 'aviation improvements' subchapter, the conceptual model to transport freights in the extra space in the aircraft is explained. Emissions are mostly related to the fuel consumed and therefore from the weight of the aircraft since the vehicle has to create enough lift to match the drag it will encounter.

To know the CO₂ savings, it is needed to know the extra kilograms that are gained by removing the baggage in the passenger plane. Since this weight will be used by cargo and the total weight of the aircraft is assumed to be the same, the savings will come from the less weight and therefore emissions yield by the dedicated air cargo. Formula 10 calculates the CO₂ savings given the weight of the baggage, the flying distance, and the emission factor. The emission factor and the flying distance refer to the cargo aircraft which would transport the cargo that is now transported in the belly hold of the commercial flight of the customer using BaaS. The weight of the baggage is used because it is assumed that the cargo in the commercial flight would be heavier than the baggage removed.

$$CO_2\text{saved} = \text{flying distance(km)} * \text{baggage weight(kg)} * \text{emission factor (g/tkm)} \quad (10)$$

5.2 Calculation of the passenger trip

As explained in response to SQ1, BaaS not only does create an additional logistics chain by modifying the traditional trip, but it could also change passenger travel behaviour. Since this could either

reduce or increase the emissions that would normally occur without the use of the service, they must be calculated.

To calculate passenger emissions, there are many scenarios to be analysed. The best case for the environment and emissions would be for them to walk, cycle or bus to the airport. In the latter, the emissions per person are very low and therefore negligible in this analysis. If, on the other hand, the passenger used a private car or taxi, the emissions would be calculated using Equation 9. It multiplies the distance by and the amount of fuel consumed by the emission factor of CO₂ the fuel type the vehicle emits per liter. If the passenger used a car belonging to a second person, such as a friend or family member, the emissions would have to be doubled as the vehicle also has to make the return journey.

5.3 Scope 2 & Scope 3

In addition to the direct emissions of scope 1, the ones from scope 2 and 3 must be calculated. For emissions from electricity, it is necessary to analyse the facilities the company uses and to observe the annual consumption generated by the use of light and services. The CO₂ produced is based on domestic production and the share of energy sources.

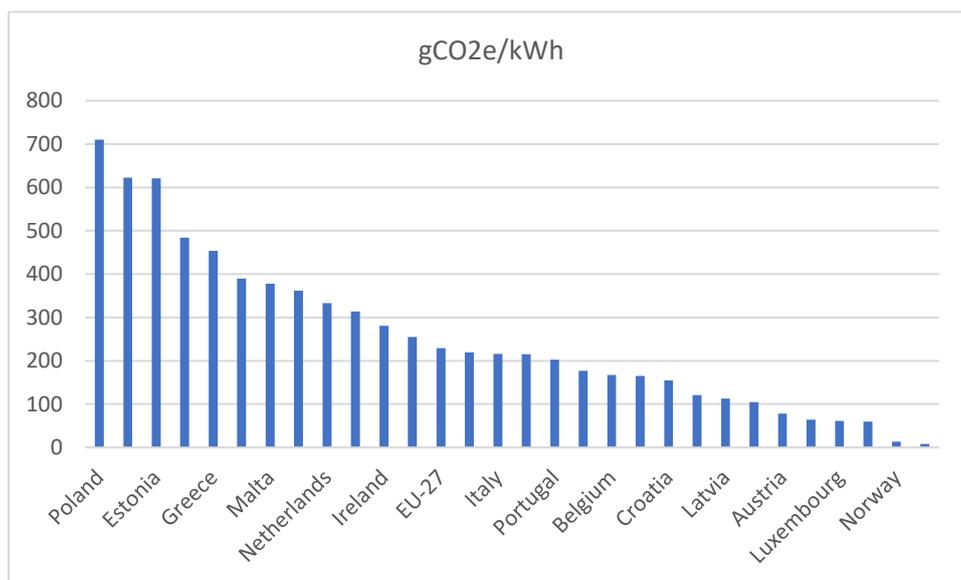


Figure 13: gCO₂e/kWh per country

In figure 13 there is an average of how many emissions are produced per gram per kWh of electricity for each individual country. To calculate the CO₂ emissions of scope 2 then, the mathematical formulation will be:

$$\sum_{f=1}^{f=\text{facility}} c_f \times e \quad (11)$$

Where c is the kWh consumed by facility f and e are the gCO₂e/kWh of the country.

About scope 3, the providers, waste disposal and life cycle emissions must be added to the total CO₂ emissions. For this analysis, the boundaries are set at the use of the vehicles and not at an upstream analysis of their construction. However, data on the WTW method can be used instead of

the ones of the TTW, providing additional emissions. Employees going to work, on the other hand, can be calculated by estimating an average of the distance they have to travel to the office and multiplying this by the emissions of the vehicle they use. The following formula can therefore be used:

$$\sum_{m=1}^{m=employee} d_m \times e_m \quad (12)$$

where d_m is the distance traveled by the employee m and e_m are the emissions of the mode of transport used.

6. SQ3: THE CASE STUDY

After having provided a general framework of the Baggage as a Service and formulated the mathematical model for calculating its carbon footprint, this chapter put theory into practice. The BaaS CO₂ emissions are calculated in a quantitative way through the analysis of the case study of the company Bagbooking. The emissions of each Bagbooking customer are here calculated one by one inserting the data in an Excel model, answering the third sub-question “*What is the CO₂ footprint of the Bagbooking baggage service?*”. Their emissions are calculated using the 6 different options and the 3 scenarios discussed in the conceptual model.

The chapter is structured as shown in figure 14.

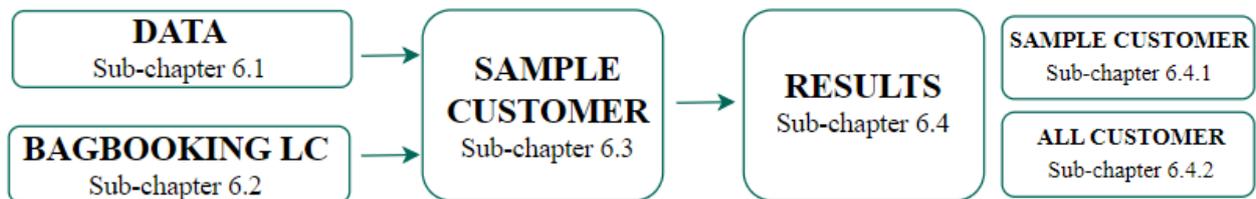


Figure 14: Outline chapter 6.

6.1 Data

In this chapter, the main source of data was Bagbooking, which provided its own data of past customers in order to proceed with the application of the concepts analyzed in the previous chapters in a real case study. In particular, 87 customers were analyzed, collecting information regarding their baggage movements and the intermediate stops made before reaching the destination. The specific data per each customer were the kilograms and volume of the baggage, the origin and destination address, and the intermediate stops of the logistics. The exact kilometers of travel between destinations have been measured using Google Cloud API and therefore with a margin of error.

Concerning emissions, the data used were retrieved from literature, specifically from STREAM Freight Transport 2020 (CE Delft, 2021). It is a handbook providing emission factors for key freight transport modes for use in (policy) analysis, intermodal comparison, and (carbon) footprinting studies. It is representative of transport operations within the Netherlands or starting or ending there. It provides the main air pollutants expressed per tonne-kilometer for road, rail, inland waterway, maritime shipping, and air transport. A tonne-kilometer is a measurement unit that corresponds to the transport of one ton over a distance of one kilometer, establishing a direct relationship of emissions with transport performance, for a given trip, the product of the weight transported (in metric tonnes), and the distance traveled (in km). For road transport, it is important to mention that the paper assumes the van has an empty weight of 2000-2500kg, while the gross vehicle weight (maximum permissible vehicle weight, including load) of the truck is less than 10 tons.

The data about how customers reach the airport were explored through the survey of past Bagbooking customers. However, due to the low rate of responses, it is chosen to assume that every customer reaches the airport utilizing a green transport mode when using the BaaS.

6.2 Bagbooking logistics chain

Every company in the BaaS sector could use different methods to provide the service. Bagbooking relies on two different logistics companies to handle the operations, one takes care of the first mile and the other one of the rest. In this sub-chapter, the logistics chain of Bagbooking is analyzed, explaining the service from the collection of the baggage to the delivery at the customer's destination.

6.2.1 First mile

For the logistics operations, Bagbooking relies on third parties that transport the baggage of the customers for them. As far as the first mile is concerned, Bagbooking relies on a logistic company that takes care of the collection at the origin point. This company is headquartered in Schipol, from where their vans leave to go to where baggage origin is (anywhere in the Netherlands) and bring it to a second logistic company that manages the rest of the operations.

This choice by Bagbooking to manage the first mile with a separate company rather than the second logistics company is due to increasing customer service. This method allows Bagbooking to communicate to the customers the pick-up time slots of their baggage, an option that would not be possible with the second, larger, logistics company. The customers will be contacted a few days before departure when the first logistic company can collect the baggage, giving them the possibility to decide in advance which part of the day suits the customers best. The period of the collection depends on the service that customers choose between the two options in table 8. Then, on the selected day on which the first logistic company comes to collect the baggage, the customer will be called by the courier 30 minutes before arrival. Here, the courier will pack and seal the baggage in a box and the customer will receive a certificate of delivery and ownership.

Table 8: Bagbooking types of collection services

Standard service	Express service
Depending on the destination, the baggage will be collected a few working days before the departure date. It is possible to choose a date and time period for this, including weekends.	Depending on the destination, the baggage will be collected 2 to 3 working days before the departure date. It is possible to choose a date and time period for this, also during the weekend.

The first logistic company does both dedicated trips and round trips collecting goods from various stops. However, this option choice depends on the demand, the time and the volume of the goods to deliver. Even if the logistics company tries to add as many stops as it can to the road trip, for this analysis it is assumed that most of the trips are dedicated (option 2).

6.2.2 Intermediate trip

The first logistics company brings the baggage to the second logistics company chosen by Bagbooking, at the Schipol depot. Once the baggage is the responsibility of the second logistics

company, it will be shipped to the destination region according to the service chosen in table 8. In the case of standard service, the baggage will be transported by van (Scenario A), with the resulting travel time. In the case of express service, the baggage will be transported by plane (Scenario C), with a faster travel time. The difference for the customers will be both on the final price to be paid (higher on the express) and the numbers of days of collection of the baggage before the departure, as the longer travel times of the standard service require an earlier baggage collection. It is also assumed that the logistics company does move the packages (and baggage) with a truck in the longest segment of the logistics chain (between countries), while by van in the other segments.

6.2.3 Last mile

In the last mile, the courier delivers the baggage through a round trip (option 3), with some exceptions when the destination is located in a remote area far from urban areas. Such as the first mile, in this last part of the logistics chain, the mode of transport is assumed to be the van.

Bagbooking ensures that the customers' hotel or accommodation is aware of the arrival of the baggage and monitors the receipt of the luggage. Bagbooking also informs the hotel or accommodation where the customers will be staying, so that even if they are not there yet, they do not have to worry about their baggage. When the customers arrive at their destination, they collect them, and when they check in at the hotel or accommodation, their luggage is already waiting.

6.2.4 Scopes 2 & 3

Bagbooking is a new company that counts fewer than ten employees. For this reason, the office energy used by the company is negligible at its current size. As for the companies that manage the operations, on the other hand, the electricity dedicated to Bagbooking is also negligible, as it is a very small percentage compared to their logistics load.

Scope 3, instead, is applicable by selecting the setting WTW rather than TTW in the Excel model. Included in the WTW the emissions are coming from the paper packaging.

6.2.4.1 Packaging

When the logistics company reaches the house of the customer, the baggage is sealed inside paper boxes. Based on the dimensions of the baggage, a certain amount of paper is used. In below table 9, the height, width and length of the boxes are shown.

Table 9: Paper boxes dimensions

Box size	Height (cm)	Width (cm)	Length (cm)
Large	86.80	59.50	37.30
Medium	78.80	52.50	33.30
Small	75	47	28

According to Bagbooking, the thickness of the paper boxes is 5mm. Assuming that cardboard weighs 0.689 grams per cubic centimeter, table 10 it is calculated the weight of the large, medium and small boxes.

Table 10: Assumed paper boxes' weight

Box size	Assumed weight (g)
Large	731.83

Medium	586.31
Small	478.23

In sub-chapter 4.3.1, it was stated that for primary corrugated board, the emissions have been shown to range between 0.49 and 2.46 kg CO₂-eq/kg of material. For this case study the average will be used, 1.475 kg CO₂ -eq/kg.

6.3 Customer sample and Excel model application

To explain how to use the mathematical and the developed Excel model to calculate the company's average emissions, customer BAG-0002250 is taken as a sample. The customer has as his departure location Benthuisen, in the Western Netherlands. The destination location is Rota, Spain.

Bag-0002250								
Origin (O)	Depot (1)	Mode	Distance O-1	Depot (2)	Mode	Distance 1-2	Depot (3)	Mode
Benthuisen	FedEx Schipol	Van	55	Arnhem Hub	Van	96	Madrid	truck

Bag-0002250					
Distance 2-3	Depot (4)	Mode	Distance 3-4	Destination (D)	Mode
1782	El puerto de santa maria	Van	641	Rota	Van

Figure 15: Customer sample inputs

Figure 15 shows the delivery information of the chosen customer, BAG-0002250. From its origin, the baggage passes through four intermediate depots, before arriving at its final destination. Between each of these stops is shown both the mileage and the vehicle used for the transportation. The customer has to move some 17 golf bags for a total weight of 884kg.

As previously mentioned, a first logistic company takes care of the first mile. It is not known which collection option is used by the company, therefore it is assumed the preferred one is a dedicated trip (option 2). A van has to leave from the first logistic company's Schipol headquarter to reach the logistic chain's origin, in Benthuisen.



Figure 16: Visualisation of the first mile, segments 1 and 2 of the customer sample

This first part of the logistics chain is visualized in figure 16. It is possible to see that the van of the first logistics company is beginning the travel from its headquarters, which should be an additional segment of this delivery. However, for the analysis of the emissions of BaaS, it is assumed that both logistics companies managing the operations have optimal management of their network, without having empty trips.

Once the baggage has been collected, the first logistics company transports it to the second logistics company hub in Schipol depot and the baggage enters their network. It is assumed then that the baggage is sent to Arnhem (Hub 2) by a van, where various parcels are consolidated before the international travel. From here, the baggage of the customer BAG-0002250 is sent to Madrid (Hub 3), always assuming through the use of a truck with a gross vehicle weight of fewer than 10 tons. From Madrid, the second logistics company will then distribute the luggage to its destination in Spain via a single sorting depot (depot 4), starting using vans. Lastly, it is hypothesized that the company delivers to the final destination through a round trip (option 6).

6.3.1 Customer first-mile

When the options that the courier uses for delivery are assumed to be dedicated trips, the calculus made is the following. It is assumed the company uses vans propelled by diesel euro 6d, and that it travels mostly on urban roads. With these assumptions, CE Delft states that an EW 2000-2500 kg van emits 1115.8 g/tkm. For a distance of 55 km, the emissions of 884 kg will be 54,25 kg of CO₂ equivalent.

6.3.2 Customer intermediate segments

For this customer, the intermediate segments are 3. It is assumed that most of the kilometers are traveled by van diesel euro 6d on motorways, except for using a truck for the longest leg of the

logistics chain. According to CE Delft, the emission on a ton per kilometer with these assumptions are 1078.4g

6.3.3 Customer last-mile

To calculate the last mile, it is assumed that the second logistics company that Bagbooking relies on uses round trips (option 3). The advanced setting is left as default, therefore with the number of stops that the van does set to 30, and 0.03% of the round trip dedicated to Bagbooking, while the road class is assumed to be “urban”.

6.3.4 Customer cargo savings and transshipment

To calculate how much CO₂e the customer is saving using the BaaS, the emissions that goods of the same weight as the baggage would emit by traveling on air cargo have to be addressed. To do so, it is assumed that the customer travels by plane departing from the commercial airport closest to the origin and landing at the commercial airport closest to Rota, with the cargo in the belly hold instead of the customer’s baggage. Utilizing an API, the coordinates of these airports are found and the flying distance is calculated (see table 11). The km in the table represents the distance for which a commercial flight is transporting cargo, instead of being transported on a dedicated cargo flight. The distance is therefore multiplied by the weight of the cargo (assumed to be the same as the baggage, 884, and by the emissions that a cargo flight would emit. Since the distance is more than 1400 km, the flight is considered a medium-haul route, and CE Delft indicates emissions for 435 g/tkm (in a full-freight aircraft). The resulting emissions are removed from the total logistics emissions of the customer.

Table 11: Nearest airport coordinates and km

	Latitude	Longitude
Nearest Airport to Benthuisen	51.95	4.44
Nearest Airport to Rota	36.64	-6.35
Distance between airports (km)	1901.97	

Every time that a vehicle reaches a depot or hub, a transshipment happens. Because of storage or for changing vehicles, transported goods are moved using tools and machines that pollute. These can be alimented by diesel or electrified, and this can be selected in the model (pre-set as diesel). According to CE Delft, the transfer of bulk load is 1.3 kWh/t, and the average emission factor for diesel fuel is 779 g/kWh. Since for this logistics chain, there are three segments, three transshipments are considered.

6.3.5 Other options and scenarios

For a comparison between options, also options 1 (through CDPs) and 3 (round trip) need to be assessed. It is here explained how the other options and scenarios are calculated.

6.3.5.1 Options 1 & 4

Options 1 and 4 involve the BaaS customer bringing the baggage to a CDP. In order to calculate the emissions of those going to pick up or drop off at the CDP, it would be necessary to know the mode of transportation being used and whether the displacement is entirely devoted to this operation or is part of another trip. Given the type of service, it is ruled out that the possibility that the move to

a CDP is made via bicycle. From what was said in chapter 4, it is possible to realistically assume that in case consumers use this option, they use the car or more rarely a bus. In the sample case, customer BAG-0002250 is 2.5 km from the nearest CDP. This would mean that 5 km would have to be driven. Since the weight of the baggage is 884kg, it is assumed that these kilometers are traveled by a van.

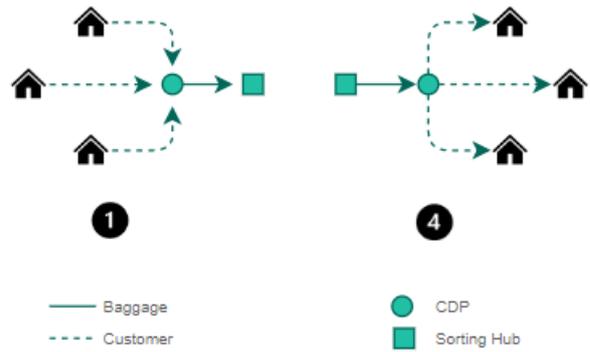


Figure 17: Options 1 and 4 (through CDPs)

Since it is not possible to know whether the customer is going to the CDP on a dedicated trip or as part of another trip, the route is calculated with three options: stand-alone trip, part of 2 errands of equal length, stop made along a route that would have been made anyway. Since the mileage was calculated using Google Maps, the Manhattan distance is not calculated, while the distance proportion in equation (3) will respectively equate $P_0=1$ for the option where the customer would not have made the trip, $P_1=0.5$ for the two errands considering the collection/pick up as half of the trip made, and $P_2=0$ for the trip that would have occurred anyway. Consequently, the distances will be: $D_0=5$; $D_1=2.5$; $D_2=0$; Considering 122.3 gCO₂/km the average CO₂e emission of a private car (European Environment Agency, 2022)(c/f), using the equation (5), the results are:

Table 12: Sample proportion range

Trip proportion	Emissions
$P_0=1$	$C=D*(c/f)= 5*122.3$
$P_1=0.5$	$C=D*(c/f)= 2.5*122.3$
$P_2=0$	$C=D*(c/f)= 0*122.3$

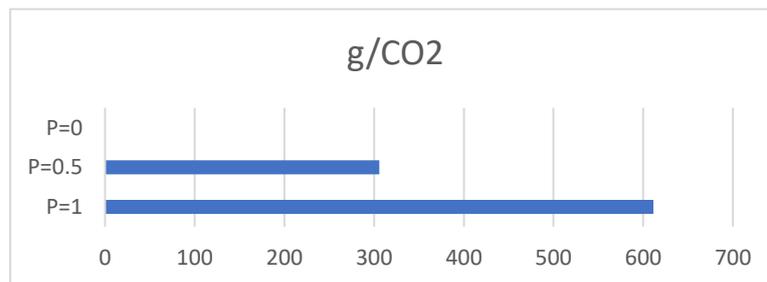


Figure 18: Emission difference based on trip proportion

Depending on the purpose of the trip, going to the CDP can be more or less polluting. In the model, however, $P=1$ is used as the default value in order to catch the maximum of the emissions a customer could emit with this option.

The second part consists in calculating the emissions from the logistics company side. In the already mentioned study by Saad S.M. & Bahadori R. (2018), it is shown how the presence of CDP can reduce emissions by 39%. While in the TNO report (Davydenko et Al., 2020), it is shown that if 50% of the deliveries/picks up shifted to the CDP, it would result in 33% fewer CO₂ emissions in the last mile, (without considering which transport mode customers would reach them). Given these studies and

considering not only Bagbooking but that other parcels are also collected by the same means, in this study it is assumed there are enough goods to be collected/deposited at the CDP such that there is a 30% emission savings by the logistics operator. Regarding the emissions of the customer when going to the CDP, it is therefore summed the 70% of the round tour that the logistics van would do passing by the origin point. Figure 6 in sub-chapter 4.1.1 visualizes the situation. The round tour is calculated utilizing equation (8) and assuming a ray R of 55km (assuming that the Bagbooking stop is the furthest from the origin point).

6.3.5.1 Options 3 & 6

For the options in which the delivery van makes a roundtrip, information on how many stops this makes is needed to divide the emissions by the percentage of the additional route made for the sample customer. In the absence of this data, three different values are assumed to represent a range of emissions that may be present in the presence of this option. It is then considered the presence of only one van on service, and that it reaches 10, 50, and 100 first/last points.

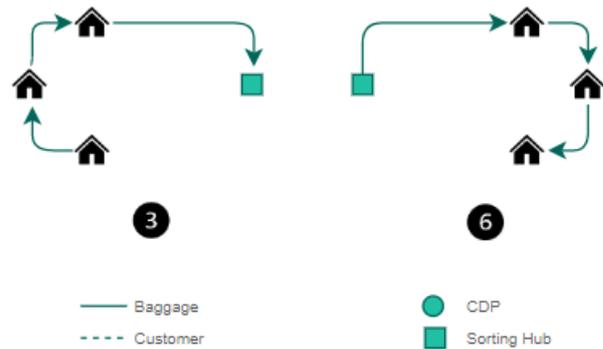


Figure 19: Options 3 and 6 (round trips)

Utilizing equation (7) and assuming a ray R of 55km (assuming that the Bagbooking stop is the furthest from the origin point), the expected tour distance for $T=1$ would be:

Table 13: Example of distance calculation for options 3 and 6 with different numbers of stops in the road tour

# Road tour stops	Distance (μ_T)
N=10	$(0.017+1.871\sqrt{10})\cdot 55$
N=30	$(0.017+1.871\sqrt{30})\cdot 55$
N=100	$(0.017+1.871\sqrt{100})\cdot 55$

Calculated the distance traveled by the logistics van, this must be multiplied by the proportion of the trip that the customer sample takes over the whole trip. In the model, this percentage is fixed to be always equally proportional among the stops. A realistic estimation of the average stops of the second logistics company that manages the distribution is $N=30$, and therefore the proportion of the Bagbooking customer on the whole trip is 0.03%. The result of the multiplication is the mileage dedicated for the Bagbooking baggage, and it must be multiplied by the emissions that the van emits (g/tkm) and multiplied by the weight carried.

6.3.5.2 Scenarios

Between the segments of every customer, the longest one is analyzed with the different modes of transport. The aim is to compare the modes of transport that could be used in the segment that usually corresponds to the international leg, and see which one is the more sustainable. For the customer sample, the 2nd segment is part of the logistics chain where the baggage is moved from the Netherlands to Spain, and the emissions are calculated by multiplying the distance for the weight of the baggage and the emission factor of train, truck, van, and plane.

6.3.6 Paper packages

The paper that the sample customer delivery uses do not pollute in the TTW analysis. However, if it is calculated from the production, the paper has an impact on the total emissions. The customer’s baggage is carrying 17 bags of medium dimensions and 17 bags of small dimensions. Using the assumed weights of table 9, the total weight is 18 kg of paper boxes. The emissions would therefore be 26.69kg of CO2 equivalent.

6.4 Results

This sub-chapter shows and discusses the results from the entry of the customer sample data analyzed in the previous sub-chapter, and the data entry of all Bagbooking customers. In the customer sample, the data were entered into the model manually, also modifying the road classes. When inputting all customers, on the other hand, the data was entered automatically while retaining the pre-entered options.

6.4.1 Sample customer results

In this sub-chapter, the results of the calculations previously explained are shown and discussed. Both methods TTW and WTW are used.

The TTW analysis of customer BAG-0002250 is shown below in figure 20. The total logistics carbon footprint using the BaaS is 673.30kg of CO2e.

Type of analysis							
TTW							
Baggage (kg)	Number of segments						
884	3						
1st mile	Option	Distance (km)	Mode	Fuel	Road class	Emissions (kg)	
	2	55	Van	Diesel Euro 6d*	Urban	54.25	
1st segment	Distance (km)		Mode	Fuel	Road class	Emissions (kg)	
	96		Van	Diesel Euro 6d*	Motorway	91.52	
2nd segment	Distance (km)		Mode	Fuel	Road class	Emissions (kg)	
	1782		Truck	Diesel Euro 6d*	Motorway	600.50	
3rd segment	Distance (km)		Mode	Fuel	Road class	Emissions (kg)	
	641		Van	Diesel Euro 6d*	Motorway	611.07	
Last mile	Option	Distance (km)	Mode	Fuel	Road class	Emissions (kg)	Advanced settings
	3	23	Van	Diesel Euro 6d*	Urban	7.76	No
Cargo savings	Distance (km)		Emissions saved (kg)				
	1901.97		731.38				
Transshipment	Equipment's fuel		Emissions (kg)				
	Diesel		3.58				
Total KM	2597						
Total CO2e (kg)	637.30						

Figure 20: Emission model visualization for customer sample TTW

The WTW analysis of customer BAG-0002250 is shown below in figure 21. The total logistics carbon footprint using the BaaS, considering also scope 3 and paper boxes, is 896.11kg of CO2e.

Type of analysis							
WTW							
Baggage (kg)	Number of segments						
884	3						
1st mile	Option	Distance (km)	Mode	Fuel	Road class	Emissions (kg)	
	2	55	Van	Diesel Euro 6d*	Urban	71.58	
1st segment	Distance (km)		Mode	Fuel	Road class	Emissions (kg)	
	96		Van	Diesel Euro 6d*	Motorway	120.76	
2nd segment	Distance (km)		Mode	Fuel	Road class	Emissions (kg)	
	1782		Truck	Diesel Euro 6d*	Motorway	791.74	
3rd segment	Distance (km)		Mode	Fuel	Road class	Emissions (kg)	
	641		Van	Diesel Euro 6d*	Motorway	806.33	
Last mile	Option	Distance (km)	Mode	Fuel	Road class	Emissions (kg)	Advanced settings
	3	23	Van	Diesel Euro 6d*	Urban	10.24	No
Cargo savings	Distance (km)		Emissions saved (kg)				
	1901.97		934.83				
Transshipment	Equipment's fuel		Emissions (kg)				
	Diesel		3.58				
Paper	Emissions (kg)						
	26.69						
Total KM	2597						
Total CO2e (kg)	896.11						

Figure 21: Emission model visualization for customer sample WTW

As mentioned, the three options at the first and last mile as analyzed, and four scenarios (van, truck, train, plane) for the longest segment as well. In figure 22 the results are shown, keeping “average” for the road class.

BAG #	First mile			Last mile		
	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
BAG-0002250	23.07	54.25	32.19	5.97	22.69	7.76

Mode			
Van	Truck	Train	Plane
1698.79	600.50	46.47	685.25

Figure 22: Comparison options and scenario for customer sample (Kg CO2e)

From the model, it is possible to compare the four options together. For this customer taken as a sample, it appears more sustainable to collect and deliver utilizing option 1 (using CDPs) in both the extremity of the logistics chain. The emissions of this option could potentially be even lower if the number of stops the van of the logistics company in the first mile would make would be higher. In fact, in the first mile, it is assumed that the first logistics company would make 10 stops, while in the last mile, the number of stops is set as 30. This is due to the fact that it is known that the second logistics company that handles the last mile owns a better network with higher demand.

Regarding the mode of transport of the main leg, which usually coincides with the movement from the origin country to the destination country, the most sustainable would be the use of the train. In the eventuality this mode of transport is not included in the logistics company modes, the truck is resulting as the second-best mode. The value is lower than a van since the capacity for goods is higher, resulting in fewer emissions for the same load transported.

The difference between TTW and WTW comes from the inclusion of emissions from production and thus with a broader approach. In addition, emissions from paper packaging are also included.

6.4.2 All customer emissions results

Now that it was explained how the calculations are made on the sample customer, all 87 customers that the company provided are analyzed. Using the macro on the Excel model, all the customers are inserted in the carbon footprint model and the results are saved in a table as made for the customer sample. In Appendix C, the table is shown. For every customer, the Excel model is used keeping the advanced setting as default, with “average” as road class, “diesel 6d” as fuel, N=10 for the first mile, and N=30 for the last mile.

6.4.2.1 Options comparison

The option chosen per every customer by the logistics company is not known or interchangeable customer by customer, therefore all three options are calculated. The resulting emissions of the three options are shown in the figures below.



Figure 23: First mile options emissions comparison



Figure 24: Last mile options emissions comparison

As can be seen from the two graphs, option 2 (where the trip is dedicated) pollutes much more than the other two options for both the first and last mile. However, remember that the calculations for CDPs and roundtrips are based on assumptions about both the CDP-home distance of the customer and the number of stops the company van travels. Results may therefore vary, but both remain less polluting than option two, and option 1 (with CDPs) is usually better than option 3 (round tour among houses), as also confirmed by other case studies in the literature review.

Between the first and last mile, there is a not-inconsiderable difference in the kilograms of CO₂e emitted. The first mile emissions are between 0,5kg and 11kg, while between 0 and 35 kg for the last mile. The difference can be explained by looking at the data received from Bagbooking. In fact, it happens that the last mile is entered on the Excel model with a very high mileage, which is unlikely given the extensive network that the distribution company has. Usually, home delivery is optimized from a depot in at least the same city as the destination.

The error in mileage distribution leads to a higher emission in the last mile, but benefits total emissions. Having a last mile with a very high distance means that the mileage is divided equally with the number of stops the van of the logistics company is assumed to make (N=30).

6.4.2.2 Scenarios comparison

For the different scenarios comprising the three means of transport analyzed in the conceptual model (road transport is here divided into van and truck), the longest route for each customer was analyzed. In figure 25, the graph shows that the van is the most polluting means of transport, while the train is the most environmentally friendly. These results can be explained by observing that the reference study for emission values (CE Delft) uses lower emission values to match this plot.

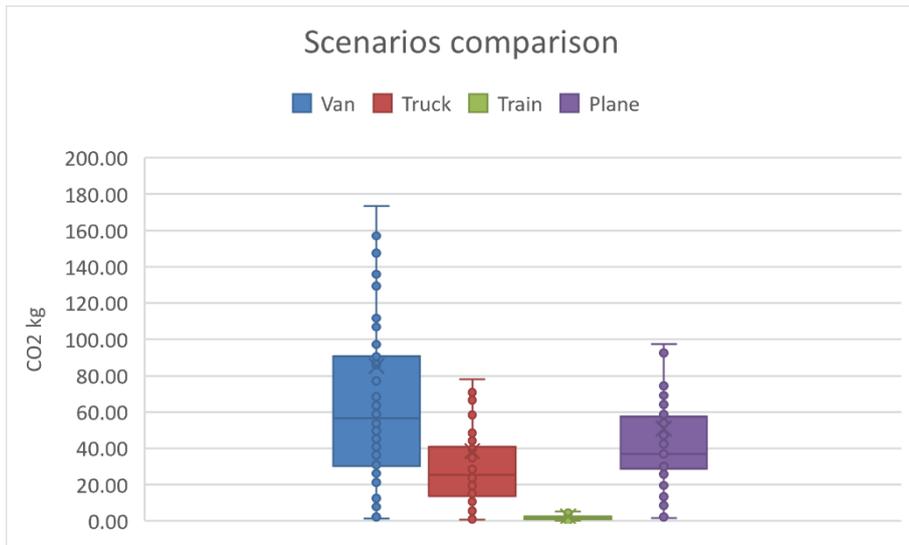


Figure 25: Scenarios of emissions comparison

The most surprising value of this graph is to see that the aircraft is not the most polluting mean, which is the van instead. These values are explained by the fact that the aircraft consumes a lot of emissions in take-off and landing, and by the difference in tones that these two vehicles can carry.

6.4.2.3 Emissions breakdown

The emissions of Bagbooking customers have been analyzed to determine the most environmentally friendly options for the first and last mile of the logistics chain, as well as the emissions associated with different modes of transport for the longest leg of the journey. However, to effectively mitigate emissions, it is crucial to understand the contribution of each part of the logistics chain to the overall emissions. To this end, figures 26 and 27 provide a breakdown of Bagbooking’s customers' emissions, highlighting which parts of the logistics chain are responsible for the greatest emissions and can thus be targeted for action. The model generated the graphs based on the pre-set parameters (dedicated trips for the first mile, round tour for the last mile, and truck as mode of transport for the intermediate and longest leg).

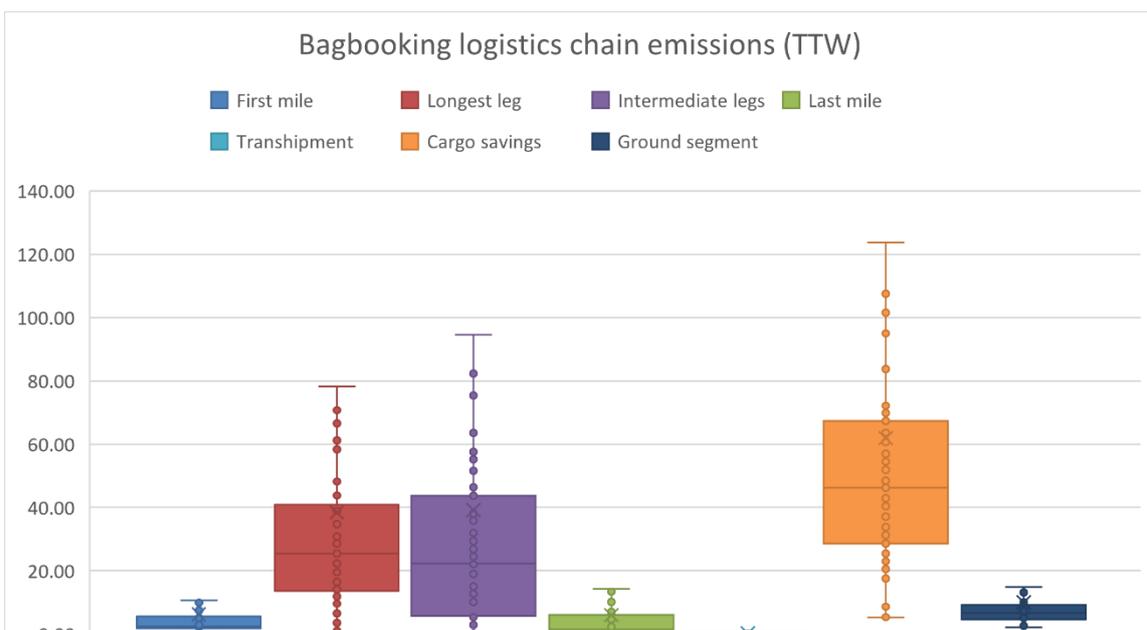


Figure 26: Bagbooking logistics chain emissions breakdown Kg CO2e (TTW)

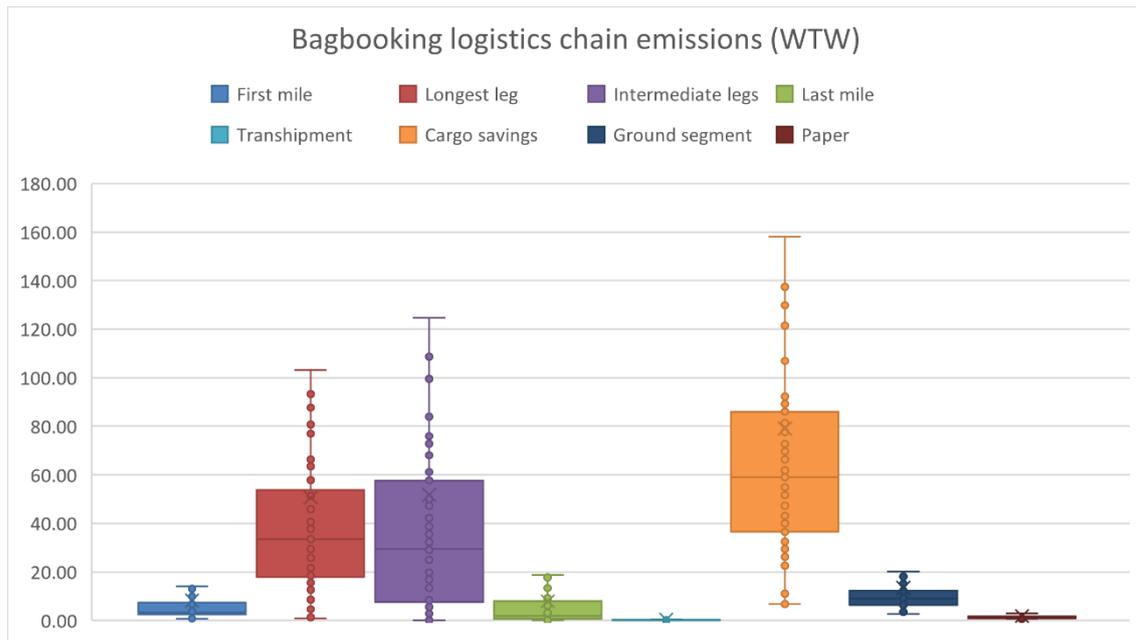


Figure 27: Bagbooking logistics chain emissions breakdown Kg CO2e (WTW)

The graphs reveal that the longest leg (indicated in red) and the intermediate legs (shown in purple) are the main sources of emissions, far outweighing those associated with baggage collection and delivery (shown in blue and light blue, respectively). Notably, the orange box represents the emissions that can be offset by utilizing the extra space created in the aircraft hold to transport cargo, which can account for a big part of the emissions of the whole logistics chain. The ground segment (shown in black) represents the emissions that passengers emit by traveling to the airport without baggage, which accounts for more than the first or last mile.

The logistics chain components that should be prioritized for emissions reduction are therefore the longest segment and the intermediate legs, with the potential to incorporate the concept of cargo savings.

6.4.2.4 Bagbooking total emissions: five situations

In the Excel model, the last columns of the table are colored differently from the others and represent Bagbooking emissions according to five situations (figure 28).

BaaS emissions				
Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions

Figure 28: Bagbooking total emissions - Five situations

1) The first situation calculates the Bagbooking situation as it is assumed at the current moment, thus using option 2 (dedicated trips) for baggage collection, option 3 (round trips) for delivery, and van in all the segments in the exclusion of the longest one in which a truck is used. In this situation,

the ground segment (the part of the trip in which passengers commute to the airport) is included, while the cargo savings concept is not included.

2) The second situation considers the best baggage collection and delivery option. Here too, the ground segment is included, while the cargo savings concept is not included.

3) The third situation removes the ground segment from the previous situation. Here, passengers are assumed to use green modes of transport to reach the airport, not adding pollution.

4) The fourth situation adds the use of extra space in the aircraft belly to the emissions calculated in situation 3, showing how emissions change if cargo savings are included.

5) The fifth and last situation shows the emissions of customers in case the best baggage collection and delivery option is used at the first and last mile, the passengers use green modes to reach the airport, and also including the best means of transport in the longest segment (best scenario). Cargo savings are also included.

Out of the five scenarios presented, the last one (Min emissions) always yields the best results. 56% of customer emissions are negative, indicating a positive impact on the environment by avoiding CO2 emissions from air cargo transportation. Instead, when the best options for the first and last mile are selected, the passengers use green modes to reach the airport, and the cargo savings are included (Situation 4, "Bagbooking with cargo savings"), 42% of the customer orders result in negative emissions. Instead, the first three scenarios (representing Bagbooking's emissions in their current state and the situations in which are not included the ground segment and the best options are included) emit a significant amount of CO2e into the air. The values of these situations give a relative feeling of the number of emissions produced, and therefore they will be compared to the emissions without the use of BaaS in the subsequent chapter.

All the results of the 87 customers are in Appendix D. Figure 29 displays a snapshot of the five situations for six randomly selected Bagbooking customers (every row represents a customer).

The results presented in the first column of the figure depict Bagbooking's current operational model, followed by the other scenarios where a

	BaaS emissions				
	Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions
	1430.14	1400.55	1397.97525	666.59	2.35
	101.15	100.08	96.127218	51.26	18.87
	137.77	134.35	121.231857	59.83	15.72
	132.57	130.08	116.965498	55.56	11.23
	25.41	18.34	11.6001938	-17.60	-11.75
	42.67	22.62	15.8837285	-13.32	-7.16

Figure 29: Snapshot of six random customers total emissions in the five situations (Kg CO2e).

gradual reduction in total emissions is observed for all customers. The last two columns contain two rows colored green, indicating a positive environmental impact. By switching from option 2 (dedicated collection) and option 3 (round trip), currently used by Bagbooking, to more eco-friendly alternatives or encouraging customers to reach the airport sustainably, there is an additional reduction in emissions, albeit limited to a few kilograms (columns 2 and 3). However, to achieve a significant decrease in emissions, it is crucial to select the most environmentally friendly

transportation mode for the longest logistics chain leg and/or employ the cargo savings concept, as shown by the emissions reduction from column 3 to columns 4 and 5.

A sensitivity analysis shows that if the distance between the two airports decreases, the emissions of the situations in which the cargo savings concept is included benefit greatly. This discrepancy in CO₂ savings can be attributed to the findings of CE Delft, which have determined that the emissions of a full-freight aircraft on short-haul routes (less than 1400km) are 1095 g/tkm, whereas for medium-haul routes (between 1500km and 6000km), the emissions are 435 g/tkm. Therefore, it follows that the reduction in CO₂ emissions for a distance of 1300km is greater than that for a distance of 1902km, with a reduction of 1260 g CO₂/km compared to 731.38 g CO₂/km, respectively.

7. SQ4: BAAS vs NO BAAS COMPARISON

Once the BaaS emissions have been calculated using Bagbooking as a case study, all that remains is to compare it with standard air travel without using the service. This chapter then answers the last sub-question: "*How is Bagbooking performing if compared to passengers traveling with their own luggage?*".

In the sub-chapter 7.1, it is explained how the emissions of the situation in which the BaaS is not used are calculated; In the sub-chapter 7.2, there is the comparison of BaaS with the non-BaaS situation, calculated with the TTW method in sub-chapter 7.2.1 and with the WTW on in sub-chapter 7.2.2.

7.1 No BaaS calculations

To make the comparison between the use and the not-use of BaaS, the same data used in the case study is used to calculate the emissions that Bagbooking's customers would emit without the use of Bagbooking.

To perform the calculation, it is assumed that the flight taken by the customers originates from the airport nearest to their location and lands at the airport nearest to their destination. The airline distance between the two airports is then multiplied by the weight of the baggage and the emissions associated with the belly hold, as defined by CE Delft. Notably, in contrast to cargo emissions, this calculation uses the emissions generated by a passenger aircraft rather than a full-freight aircraft.

In addition to these emissions, there are those emitted by passengers on their way to or from the airport. Assuming they are traveling by car and counting only one way to the airport (i.e. parking their car at the airport and not being dropped off by friends or family, which would imply a second trip on the way back), it is multiplied by the distance times the weight of the luggage by the average emissions of a petrol car. The result of each customer is shown in Appendix D.

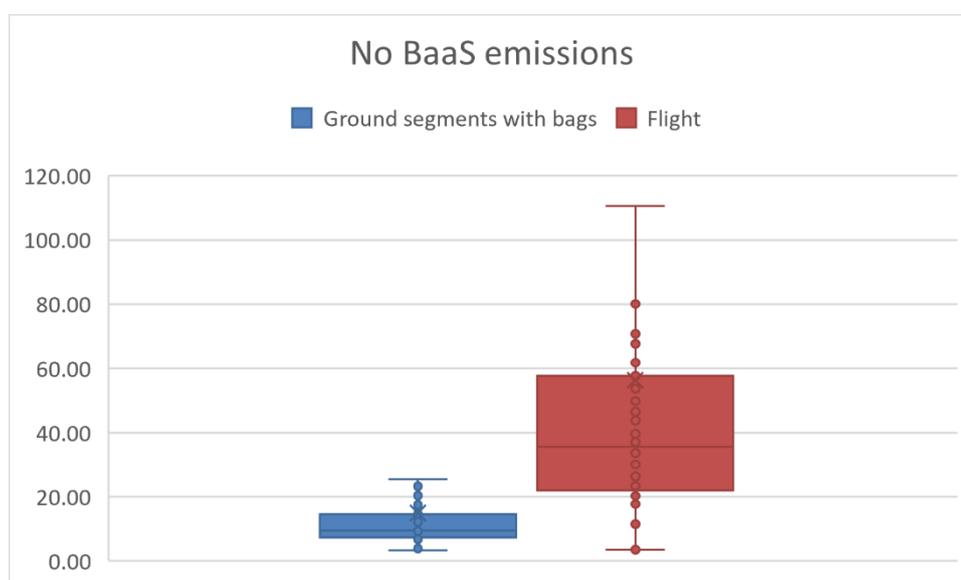


Figure 30: No BaaS emissions breakdown (Kg CO2e)

Figure 30 shows the sources of emissions from traditional air travel, therefore without the use of BaaS. It can be seen that a large portion of emissions come from the aircraft, while a small portion comes from passengers moving with their baggage to the airport.

7.2 Results: Comparison between BaaS and No BaaS

The previous chapter (6.4.2.4) described the total emissions of Bagbooking through five situations, differentiating by taking into account or not certain elements. In this sub-chapter, these situations are compared to the situation in which the same customers do not use the BaaS service.

These scenarios are: "Bagbooking," which represents the current Bagbooking options for the first and last mile with the ground segment and without cargo savings; "Best options" which includes the best options for the first and last mile, with the ground segment emissions included and no cargo savings; "No ground segment," which assumes that passengers use sustainable transport modes to travel to and from the airport, removing the emissions of this part of the logistics chain from the total; "Bagbooking with cargo savings," in which the concepts of cargo savings is included; Lastly, "Minimum emissions" which combines the best options for the first and last mile with the best mode of transport for all segments, cargo savings and do not count the ground segment. The aforementioned situations are compared to a baseline scenario where customers do not utilize the BaaS service.

This comparison is crucial not only for Bagbooking as a company but also for customers. According to the survey made of past customers, 75% of them would use the service more often if it were more sustainable than regular air travel (as mentioned in Q5 of Appendix B).

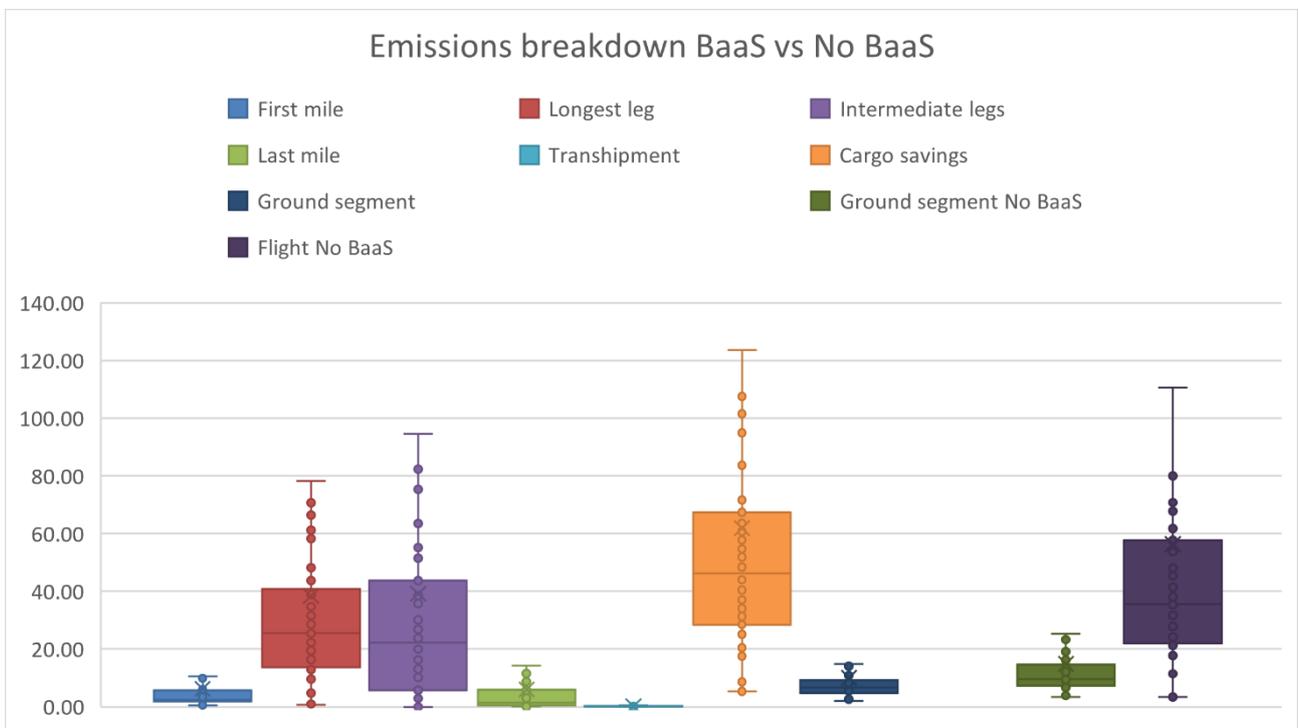


Figure 31: Emissions breakdown BaaS vs No BaaS (Kg CO2e)

In Figure 31, the emissions resulting from Bagbooking (on the left) are compared with the emissions that would occur if the company's customers did not use the service (the two boxes on the right). The emissions of the aircraft in the absence of Bagbooking are comparable to those of cargo savings, although not identical due to the variation in emission factors when transporting baggage in the belly hold versus through air cargo. The emissions generated by the ground segment when using BaaS, which refers to customers commuting to and from the airport, are nearly equivalent to the combined emissions from the company when collecting and distributing the baggage at the first and last mile.

7.2.1 Tank-To-Wheel

The comparison between different methods begins with the Tank-To-Wheel approach, as shown in Figure 32. The figure displays an example of how the results appear in the Excel model for a sample customer, while the complete results for all customers can be found in Appendix E.

Comparison Baas vs No BaaS %					
Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions	No BaaS
71%	67%	67%	-20%	-100%	0%

Figure 32: Comparison of BaaS vs No BaaS in the percentage of the customer sample.

The emissions generated by using BaaS can be compared by considering the situation without its use as the reference point (0%). The emissions are indicated in green cells if they are lower, indicating that BaaS is more environmentally friendly. Conversely, red cells indicate higher emissions, indicating that BaaS increases CO2 emissions. For instance, the figure illustrates that the sample customer emits 71% more CO2 by using Bagbooking than if they traveled without it. However, if the company would choose the best option for collecting and distributing the baggage, the percentage would drop to 67%. From this, the extra space created in the belly hold of the aircraft in which the passenger would travel is filled with cargo, Bagbooking emissions would be 20% less than traditional air travel. Additionally, if the customer baggage is moved using the best possible mode of transportation in the longest segment of the logistics chain, BaaS would be 100% less polluting than the No-BaaS situation.

Comparison overview %				
Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions
56%	46%	29%	-63%	-98%

Figure 33: TTW comparison BaaS vs No BaaS, the average percentage of all customers

Figure 33 illustrates the average percentages of all customers, highlighting that Bagbooking's goal is to achieve the last two situations. It is evident that, on average, the only way to be more environmentally friendly than traditional air travel is to implement all possible measures to reduce emissions. However, it should be noted that the last situation, which involves the use of the best mode of transport in the longest segments, is highly optimistic due to the fact that it requires the use of trains, a mode of transportation that is typically not supported by parcel logistics operators.

Currently, Bagbooking generates 56% more emissions than a typical flight with self-baggage handling. However, optimizing the logistics chain and pushing the customers more on a sustainable choice could make the emissions dropping down of 27%.

7.2.2 Well-To-Wheel

If the calculus is repeated by selecting 'WTW' in the first cell of the Excel template, the values that are used for the calculations change. In these emissions, the company's paper packaging is also counted. The list of the comparison of all customers using the WTW method is included in Appendix F.

Comparison overview %				
Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions
62%	51%	33%	-57%	-93%

Figure 34: WTW comparison BaaS vs No BaaS, the average percentage of all customers.

Figure 34 shows the average percentage comparison between BaaS and no BaaS. It can be noted that the percentages do not vary much from the results found with the TTW method.

8. CONCLUSIONS

In this chapter, the conclusion of the thesis is given. Sub-chapter 8.1 provides the answer to the main research question, sub-chapter 8.2 highlights the takeaway for the company, and sub-chapter 8.3 reflects on the study. The chapter ends with the limitations and future research.

8.1. Main research question

The main research question that this thesis aims to answer is “*What is the CO2 footprint of the Baggage As A Service?*”. As this question cannot be answered with a numerical value, a detailed conceptual model is used to illustrate the elements that impact emissions, along with a comprehensive analysis of the emissions sources in a case study, compared to a scenario where the same customers do not use the BaaS.

The conceptual model identifies two logistics chains, giving the scientific community a framework and analysis of this new concept, shown in figure 35.

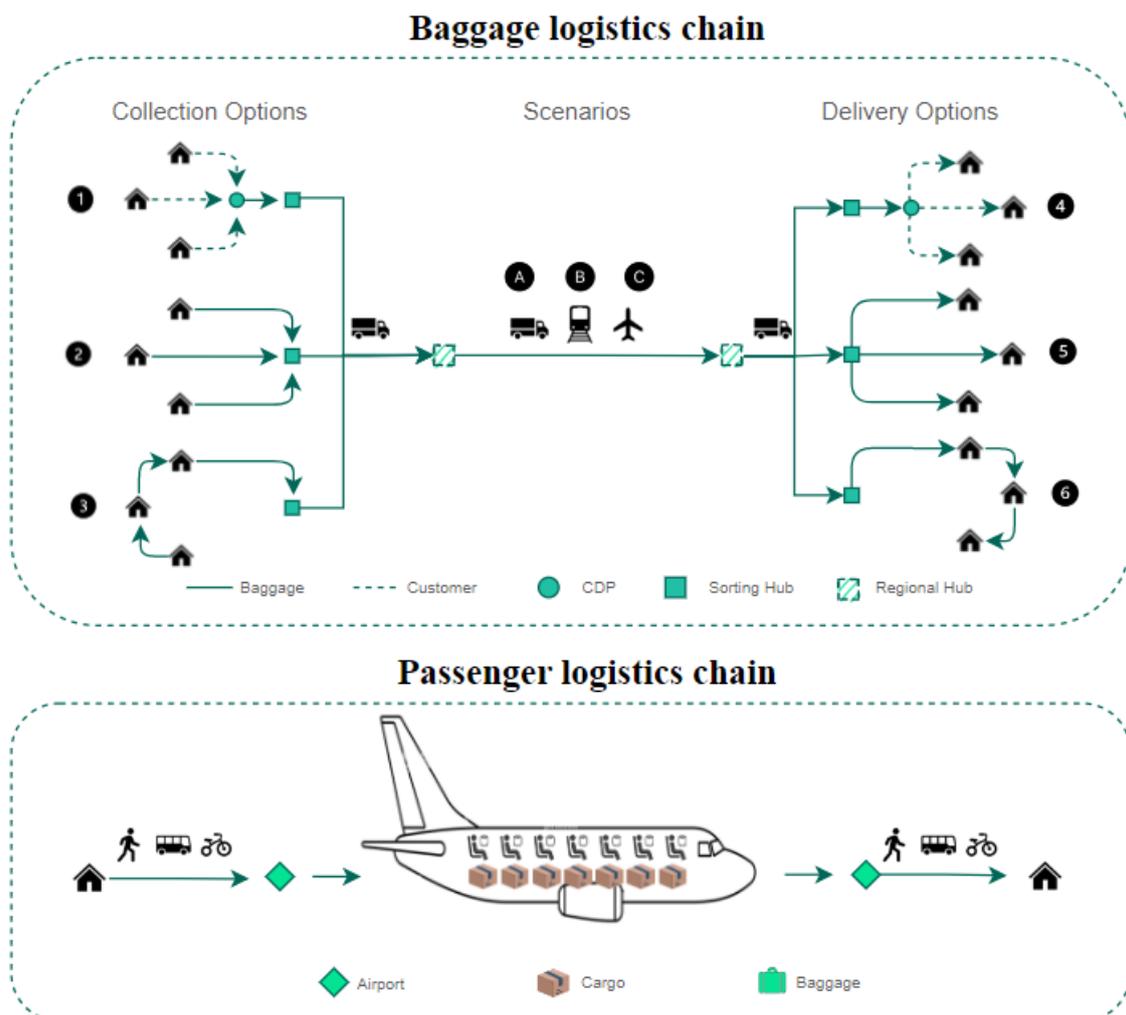


Figure 35: Dissociation Baggage-Passenger conceptual model

The two logistics chain proposed are one for the dissociated baggage and one for the passenger traveling without it. The conceptualization of the baggage logistics chain evaluates three options for baggage pickup and three options for distribution (i.e., using CDPs, dedicated trips, and round tours), as well as three scenario modes of transportation and their environmental impact (van/truck, train, plane).

The study also investigates the logistics chain of the passenger who travels without baggage. It explores potential changes in travel behavior and emissions resulting from the use of the service, such as switching to green modes of transport when commuting to and from airports. However, an exploratory survey conducted on a case study found that individuals who traveled with a private vehicle without BaaS would have still used it when using Bagbooking. However, 70% of the surveyed individuals expressed a positive attitude towards bringing their baggage to a CDP to help reduce emissions. Another key aspect of this logistics chain is the examination of the possibility of reducing emissions by utilizing the extra space in the aircraft that is created when passengers choose not to carry their baggage on board. By filling this space with cargo, it would be possible to reduce the total emissions because this weight would not travel with a dedicated air cargo but in the belly hold of a passenger aircraft instead of the baggage.

The exhaustive evaluation of emission sources related to Bagbooking provides additional parameters for comprehending the carbon footprint of the BaaS. The Carbon Footprint Excel model utilizes inputs provided by past Bagbooking customers to determine quantitatively the emissions by source throughout the logistics chains.

Figure 36 illustrates the average emissions comparison between a Bagbooking customer utilizing the service and a customer traveling without it (i.e., normal air travel). The predominant contributors to emissions in the Bagbooking logistics chain are the intermediate segments, which are the segments between depots and hubs, and the longest leg between hubs. The intermediate segments are however calculated using vans as a mode of transport, while the longest leg is driven by truck.

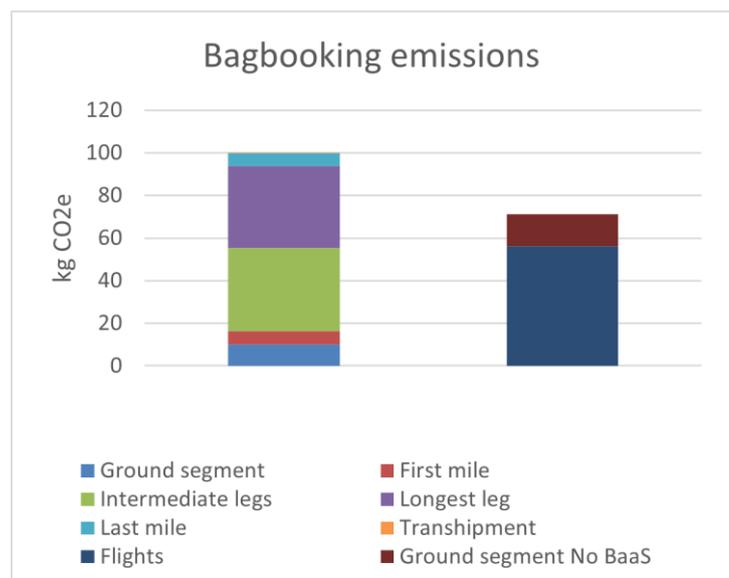


Figure 36: Bagbooking customer average emission sources BaaS vs No BaaS

Overall, at the actual state, results show that Bagbooking pollutes 56% more than if the same trips would have been traveled as normal air travel. With some implementations, it can however manage to pollute 98% fewer. In the calculations, it turns out that between the TTW and WTW methodologies, there are negligible differences.

8.2. Company recommendations

The findings of this study could lead to decision-making actions by the company aimed at improving its carbon footprint.

Through an examination of the sources of emissions generated by Bagbooking, a prioritization of actions can be determined based on their impact on the overall emissions. Figure 37 illustrates the proportion of emissions reduction that can be achieved by certain actions out of the total average of 100kg CO₂e emitted by a Bagbooking customer. It is evident that the integration of the cargo savings concept, as presented in this study, would result in a 62% of reduction of its total emissions (62%). In these regards, Bagbooking could create a partnership with air service operators, so that both parties benefit. At the time of purchasing an airline ticket, there could be an advertisement that refers to the Bagbooking website: on the one hand, the airline company would know that there is more space for goods that may be more profitable and would decrease their emissions, on the other hand, Bagbooking would have advertising at the time of purchasing an airline ticket and the guarantee that the extra space would be used for goods.

Bagbooking emissions optimisation (Kg CO₂e)

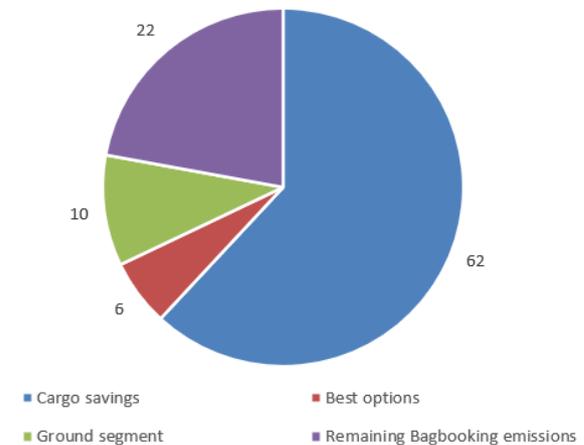


Figure 37: Impact of the implementation of the situations on Bagbooking's emissions

The next significant measure that would help reduce Bagbooking's emissions by 10% is the elimination of emissions from the ground segment. These emissions, which refer to customers commuting to and from the airport, are nearly equivalent to the combined emissions from the company when collecting and distributing the baggage at the first and last mile. BaaS not only provides passengers with greater comfort but also has the potential to encourage the use of sustainable modes of transportation. However, according to the survey conducted, there is currently no evidence of this trend. Thus, Bagbooking should consider offering more incentives to its consumers to opt for sustainable modes of transportation, which could lead to a reduction in its emissions. A first recommendation is to make the sustainability survey mandatory for all new customers. Understanding what efforts your customers would be willing to make the service more sustainable is important and would provide valuable insights for the company. Moreover, understanding how their travel behaviors have changed and evolved would provide more precise data and help improve the outcomes of the excel model. It is important to add the emissions that customers emit when commuting to the airport since in the study it is assumed they always utilize a green mode when using BaaS. Additionally, by making the sustainability survey mandatory, the company would show its commitment to sustainability and the environment. This would improve their reputation and intentions, also attracting customers who are looking for sustainable travel options. By taking this step, the company would also demonstrate its responsibility and accountability to the environment and its customers. Bagbooking could also communicate all its efforts to its customers by providing transparent information on the company's website. This would

make an impact since the survey of past customers showed that 75% of customers (appendix B) would use the service more if it was more sustainable than normal air travel.

Another 6% of Bagbooking emissions could be reduced if the baggage pick-up and delivery logistics are optimized. It could be a good idea to offer the customer, at the time of payment for the service, the option to choose a less convenient or more expensive option to reduce emissions. By showing the customer the Collection Delivery Points near the point of origin and incentivizing them to choose this option, Bagbooking would already be taking steps forward. From the logistics company's point of view, Bagbooking could choose a company that prioritizes emissions by choosing green means of transport (bicycle cargo, electric vehicles) to zero out emissions, or even just choose a company that has a well-organized network with a high number of stops. It is also advisable to strengthen communication with the logistics company so that they are more specific about their depots, vehicles used and kilometers traveled, to have a more reliable and tailored dataset for the Carbon Footprint Excel model.

The remaining 22% of emissions can be further reduced by more sustainable choices of the means of transport used. As seen, the longest leg and the intermediate segments that are now driven by truck emits the predominant part of the emissions. Between the scenarios that have been analyzed, the one in which the baggage is moved by train would be ideal, but for now, it may be a bit utopian. However, many logistics companies are investing in electric or hybrid fleets, which could drop significantly the total emissions. Furthermore, given that the intermediate segments are assumed to be driven by vans, it is recommended that the model be rerun with inputs that exhibit greater precision regarding the transportation modes. Segments in which trucks replace vans would result in reduced pollution.

8.3. Reflection

This thesis represents the first comprehensive study dedicated to BaaS and contributes to the academic community by shedding light on the current state of BaaS and its potential for future development. While it is currently observed that BaaS generates more emissions than traditional air travel, the potential for the service to gain traction in the future could accelerate its decarbonization. Taking a strategic and holistic approach towards reducing emissions can result in significant reductions in Bagbooking's carbon footprint. In fact, as demonstrated by this study, the service has the potential to contribute positively towards reducing air-cargo emissions.

It is worth noting that the electrification of road vehicles appears to be progressing at a faster pace than the transition of other modes of transportation, including airplanes. Despite the challenges associated with decarbonization, leaders in the road freight industry believe that a zero-emission technology pathway is emerging, which includes the adoption of both hydrogen and battery electric vehicles. It is expected that both these technologies will be deployed on a global scale in the coming decade. The implementation of environmentally friendly measures in Bagbooking's operations such as these ones could make BaaS a valuable solution for contributing to decarbonization efforts in various areas.

However, the survey conducted for this study revealed that some Bagbooking customers use other means of transportation besides airplanes. In such cases, BaaS may result in significantly higher

emissions compared to train travel. Future research could further investigate this aspect of the thesis.

8.4. Limitations and future studies

This study provides opportunities for future research that can have a starting point from its limitations, which may open doors for advancements and improvements to be made.

8.4.1 Data on vehicle and emission factors

The emission factors used for the calculations of this thesis are taken from CE Delft. They analyzed certain vehicles with certain conditions. In order to have precise data for the carbon footprint calculation, the exact values of the fuel combustion would be needed. For this study, the vehicle models and fuel types that the logistics company is using when delivering the baggage were not provided. Also, weather conditions, driving style, etc are all variables that may increase or decrease the emissions at every delivery. To have precise estimations, technologies that collect real-time data would greatly improve the results of this work. For simplicity, in the model, the fuel diesel euro 6d and the average between road classes values were pre-set as default values when running the macro button in Excel. Specifically, the supposition that each of the intermediate segments is operated exclusively by a van constitutes a considerable assumption that lacks precision. The logistics company should strive for greater specificity concerning the modes of transportation employed to ensure that emissions are accurately accounted for. It is important to note that the disparity in emissions resulting from using either a van or a truck to traverse the same distance is noteworthy.

In addition, the number of emissions that the emission factors from CE Delft give as output appears higher compared with other sources. Future research can therefore re-run the Carbon Footprint Excel model with other inputs, and more specific data, tailored to the company that is managing the operations.

8.4.2 Mileage and airports

In the “Bagbooking Data” sheet, for every past customer, there are the depots and hubs of the logistics chain of baggage. These data were taken from the company's dashboard, which was provided by the distribution company. The mileage between the cities was calculated through an API by a Bagbooking employee. The kilometers traveled by the logistic company could therefore be different from the ones reported in the Excel. Moreover, the mileage reported in the first mile and last mile can be higher than what they may be. This is due to the lack of information regarding the specific depots: for instance, for the customer BAG-0002220 (2), the first mile is Emporeion to Athens, and the kilometers in the ‘Bagbooking Data’ sheet are set as 2493 km. This mileage cannot be a first mile, and therefore the dataset should be adjusted.

The mileage could also differ when calculating the cargo savings. In the model, this value was calculated with an API that finds airports nearby the origin and destination. This algorithm assumes that the customer would choose these airports when traveling, without considering flight times and prices. The airports have been selected between the commercial ones with an IATA code, excluding heliports and minor airports. Moreover, the API also assumes that between the two airports, the desired traveling route exists.

8.4.3 Survey response ratio and ground segment

The consumer survey in the case study had a low response rate. To get better insights into their change in travel behavior, the number of participants should be higher.

8.4.4 Pickup and delivery options

The model compares three pickup and delivery options. Options 1 and 3 utilize data that are difficult to collect and that are different every time.

When calculating option 1, in the cell 'Advanced settings' it is possible to make some changes. There, the distance between the customer house and the CDP is pre-set as default to be 2.5km. Of course, this is a big assumption since when the house is located in the countryside it can be higher, and lower when in big cities. The transportation mode that the customer uses to reach the CDP is pre-set as 'car' but can also be manually modified to 'van'. Another assumption made is the proportion of the trip: In the advanced setting, the value is pre-set at 1 (dedicated trip), but it can be changed to any value between 0 and 1. The proportion has a big impact on the emissions whether the trip is dedicated or completely part of a scheduled trip, but the information can only be communicated by the customer. Moreover, the mileage traveled by the logistics company when driving between the CDPs is multiplied by 0.7. This assumption comes from an average literature review about emission savings using CDPs as an option.

Some assumptions are made for option 3 as well. In the cell 'Advanced settings', it is possible to make some changes regarding the roundtrip of the logistics company's van, such as the number of stops (N) and percentage of the stop on the total tour. The reason is that the van does make various stops during the route and the more it does the less the baggage has a significant impact on its total emissions. As default, 30 stops are pre-set, with 0.03% of the total trip. Another assumption is the ray (R) in which the van does the round trip: The R is the mileage of the first mile, therefore assuming that the Bagbooking customer is the furthest away and that the land mileage is the same as the crow flies.

8.4.5 High-demand

A scenario that this study is not considering is the eventuality of the high demand for the service. In case the BaaS would be a successful service, eco-friendly or not, it may increase road traffic. With high demand, all the baggage that would travel in the belly hold would travel by van instead. There might be many new vans would be on the roads to collect house by house (or CDP) from the passengers' houses. Since the aviation sector counts millions of passengers, these extra vans could increase the traffic in the urban areas, increasing the traveling time of the other vehicles. The more time cars and buses stay at traffic lights or are blocked in the traffic jam, the more the emissions would be.

Another hypothesis is that a high-demand scenario could lead to an increase in passengers and flights. The increased ease and speed of boarding at the airport combined with being hassle-free could attract more and thus, in the long run, have more emissions.

8.4.6 Geography of the study and empty trips

The analysis of this thesis is limited to baggage that departs and arrives from the Netherlands only. The assumptions and calculus (such as the emissions values of CE Delft) are aligned to work in Europe. Many variables could be different if other continents would be included.

For instance, if many customers would like to travel to Florida departing from the Netherlands, an aircraft would be always needed, and the carbon footprint analysis would be different.

Another example is the distribution network. In some countries, the logistics company might not have depots and hubs and therefore might rely on other companies. The more the network is fragmented, the more delivery failures may occur, with the associated extra emissions. When the economy of scale is lost, efficiency in transportation decreases, as more empty trips or reduced capacities. In some countries then, vehicles may not comply with current legislation in Europe, with emission values far from those used in the model.

Empty trips are a limitation that may vary depending on the geographical area and demand for the service. In remote locations or if there are no goods to be picked up at the destination point, they may cause vans or trucks to return with low consolidation. These avoidances were not analyzed in this study.

8.4.7 BaaS and aviation

This thesis is studying the concept of BaaS when passengers travel by plane. Many things would be different if customers would use another transport mode. The conceptual model regarding the ground segment of the passenger behavior, the air segment with cargo savings, and the whole excel model would be different. However, this is a limitation because the BaaS can be adapted to every mode of transport, and a specific study for each of them would give different emission results.

8.4.8 Ferries

Even though ferries are considered in the conceptual model, this mode of transportation is not present in the excel model. The main reason is that the data of the customers do not provide the modes of transport used by the logistics company, nor the kilometers traveled. The kilometers have been calculated through an API, which did not consider the distance on the water.

8.4.9 Plastic

Although plastic is one of the most talked about materials in the field of environmental pollution, this study was not considered. Nowadays, plastic is used almost everywhere, from offices to airports, and especially in various packaging. Whenever parcels are moved by the first or second logistics company that Bagbooking utilizes, some plastic may be used. Due to a lack of data, this material was not considered at all.

8.4.10 Option choice

When choosing the option to collect or deliver the baggage, the option choice does not keep into consideration the capacity limitations of the truck or van. For customers that have a lot of baggage, option 2 of dedicated transport may be the only option available. For instance, if a golf club is moving the equipment of 30 people, the movement will necessitate a dedicated trip.

8.4.11 Failed deliveries

The model does not keep into consideration the increase in emissions that can occur in a logistics operation of this type. Missed deliveries to the destination can lead to luggage being taken back to the last depot, triggering second or third delivery trials that increase the kilometers traveled and thus emissions. Other baggage ownership handovers frequently occur during baggage handling and delivery (e.g., loading and unloading), also between different companies (first or second logistics

company utilized by Bagbooking), and errors are plausible. The greater change in media and locations could indicate a higher error rate than at airports.

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APPENDICES

APPENDIX A: Interview transcript

00:00:13 Interviewer

Let's start with the aircraft.... nowadays, is the space in aircraft entirely occupied by luggage or there is something else also carried in, uh, every flight, you know, a normal flight where the passenger goes because I understood that there are two ways of storing luggage in a plane, depending on the type of aircraft. There are loose storage loading or Unit Load Devices. In the first one, the bags are loosely loaded on the floor of the cargo compartment and it happens in narrow-body aircraft or smaller medium aircraft. In the second method, ULD is used on the large wide body and they are stored in these ULD. Is it right? and in the first case, are these just packages or indeed other things?

00:01:12 Ir. J.A. (Joris) Melkert

Uh, yeah that's right and uh, you have a whole series of standardized cargo containers which you can use for different types of aircraft. Uh, uh, they look a bit peculiar. They have these cropped corners. They're not square. But they've scrubbed corners, so they followed the belly shape of the aircraft. You can use them for literally everything, but for the larger aircraft where there is space for them, so not in everybody's aircraft, and then you put either cargo or luggage in there and it used to be in the old past that the cargo hold was full with the suitcases on passenger flights. But more and more people started using carry-on luggage so they brought their own back into the passenger cabin that made sure after a while that there was not enough space in the overhead luggage bin so they were increased in size. Uh, so you see less and less cargo is in the less the luggage is in the cargo hold. Uh, so that means there's also space for other things, so a lot of air cargo nowadays travels on passenger aircraft. The cargo hold is no longer full of luggage, but there are other things there as well. Containerized, containerized on the pallet. The fact that people use much more carry-on luggage freed up space.

00:02:54 Interviewer

OK. Thank you. So the next question can be: There is this container, ULD in the aircraft. my question was... when does a passenger who does not want to board luggage, create space for something else... is there a break-even point? So how many passengers should not board for optimization solutions to be considered? So if I can reshape these questions since your previous answer, usually is this like one ULD in which there is baggage, or like they optimize it based on like how much baggage there is in that flight. So if there is for example only one passenger with one baggage, then they just put the baggage there and then fill all the rest by cargo. Or for example, the aircraft is already preloaded when the passenger arrives, and maybe there is no time anymore for filling it...

00:04:19 Ir. J.A. (Joris) Melkert

You cannot give a general answer to that, if you use this if you use the containers, then they are normally ready before the aircraft arrives and they're waiting on the platform, and in some of them there will be luggage, in others, there will be cargo. There's no way to optimize this. It really depends on how many passengers will be on board, and how much carry-on luggage they will bring, and you will see that if the flight gets longer, the chances are less likely that there will be no cargo in the cargo hold or no luggage in the cargo hold. Because the further people travel, the more luggage they bring. On short flights, inter European flights, for instance, lower cost airlines, You will see almost no luggage anymore in the cargo hold. More or less, everything is carried in the luggage.

00:05:18 Interviewer

In the big flights?

00:05:20 Ir. J.A. (Joris) Melkert

No, and they enter European flights or small flights. The low-cost airlines.

00:05:33 Interviewer

Ok, so the next question is, is the cargo traffic very consolidated? Because from what I understand then like is not so much right?

00:05:43 Ir. J.A. (Joris) Melkert

It is a relatively small fraction and dedicated cargo aircraft are more for dedicated cargo, which is too large to put underneath the floor or, uh, and then you have companies like DHL and FedEx. They have their own fleet of dedicated cargo aircraft which is stuffed with all kinds of pack packages because we like so much online shopping. So that's a separate market. But more and more you see that that, uh, yeah, cargo travels on passenger aircraft as well because of their space.

00:06:22 Interviewer

Who does use the passenger flights? like if indeed FedEx and DHL use it on their own? who is putting cargo in the normal ones?

00:06:34 Ir. J.A. (Joris) Melkert

It can be anyone. It's just a market and that space is sold. Uh, so probably the company will sell that space? I'm not an expert there, but probably that there are maybe even FedEx and DHL that book containers on passenger aircraft. Does it make sense to do large shipments across the Atlantic with a large cargo aircraft, but every outstation yet it gets less and less and less of course.

00:07:06 Interviewer

OK, so is it technically possible to use cargo instead of baggage in any aircraft, right? So they are designed to do so or there would be changes and new designs to be needed to do so.

00:07:23 Ir. J.A. (Joris) Melkert

In principle, it's just an empty space in the aircraft which you can fill with everything and as long as large enough you can put a container in there, and otherwise loose, they can be bulk cargo like a suitcase and just stuff them manually.

00:07:48 Interviewer

OK, so now this was the first part about the aircraft. So now these next questions would be more about the formulations to correct the CO2 savings.

Would it be correct to calculate the CO2 saved by dividing the emissions that the air cargo would emit at full load, taking into account and proportioning these with the volume load that goes in the luggage space? So, I take an aircraft, I will find how much this cargo can emit, and I divided the volume of the belly of the aircraft by the luggage that is not there (in the passenger aircraft). So, like, uh, making a proportion to understand how CO2 emissions I could save.

00:09:23 Ir. J.A. (Joris) Melkert

Uh, I think you cannot do this by volume. You have to do this by weight.

00:09:28 Interviewer

OK...

00:09:29 Ir. J.A. (Joris) Melkert

Because it's the weight that determines how much lift you need to create with your aircraft. And the lift you created is linked to the drag you will encounter and the drag is related to the thrust the engines need to give you. And the thrust of the engines is linked to the amount of fuel you need to consume for that, and the amount of fuel you consume determines how much emissions you have. So it's weight and not volume.

00:09:57 Interviewer

OK, but the ULD is not about the volume? I guess since like the standardizes, the volume, not the load.

00:10:19 Ir. J.A. (Joris) Melkert

Yeah, The thing is, it is the volume telling us how many cubic meters are in there, and there's probably a maximum weight the thing can carry, but the amount of fuel consumption, and thus the emissions, are linked to the mass.

00:10:34 Interviewer

Yeah, so when they are loading an aircraft is more important how much weight there is there rather than how much volume is occupied.

00:10:47 Ir. J.A. (Joris) Melkert

Yeah, yeah yeah, it's the weight that it's way to determine so where you can take off or not. If the actor is too heavy you're not allowed to take off the volume can also be restricted if you have very lightweight cargo they say, OK, well there's not enough volume available in the aircraft and then the weight is not an issue but the number of emissions is coupled to the weight.

00:11:11 Interviewer

So it's more common that the airport stopped loading an aircraft because the weight is exceeded rather than because there is no space anymore.

00:11:24 Ir. J.A. (Joris) Melkert

Well, that well for the image, it depends on what type of cargo. Yeah, it depends on the cargo density and they do the calculation beforehand. They don't just stop halfway saying "it's full now", it is calculated upfront. But if you look at the emissions and then you want to look at CO2 reductions, you need to talk about weight instead of volume. Or you need to find a standardized density of the cargo with cargo that can be anything. It can be heavy stuff and can be very lightweight stuff. But the dimensions are coupled to the weight.

00:11:57 Interviewer

Okay.. about finding a standardized density of the cargo, I also bit struggled about finding the most common plane used so I could use it as a reference for my calculations. Uh, do you have any suggestions about that?

00:12:16 Ir. J.A. (Joris) Melkert

And not really there. They have very different, uh, planes available in the world. You could choose a widebody (?) or a narrowbody aircraft and then you could choose either a Boeing or Airbus. So you could say as a narrow-body Boeing 737 aircraft and as a wide-body 787 or 767 or 777. There are still many choices there, and for Airbus, you have the A320 as the narrow body and for the widebody, you have the uh, yeah, all the way up until the 8380 aircraft, so there is no such thing as a standard aircraft there.

00:12:55 Interviewer

But since I indeed liked it, I took calculated emissions so that I could save right from the baggage that is used that is not there, and to fill it in cargo, I had indeed to find a model, an aeroplane, that is my sample and analyze these its calculations and use it to divide for the in this case, uh, the weight that I can move in the passenger aircraft. So indeed, do you think it's I can just take out one, random aircraft as a sample? There is no one better than another one?

00:13:35 Ir. J.A. (Joris) Melkert

Yeah, there, there are no standards there, so you need to make a choice and you could choose one wide-body and one narrow-body. Uh, that will be as good as it gets, I fear.

00:13:47 Interviewer

And, so like in these flights are, again talking about consolidation, do they reach their maximum weight?

00:14:04 Ir. J.A. (Joris) Melkert

Further than maximum weight but they will not always take off with maximum weight, but that is a hard limit you you are not allowed to take off beyond the maximum takeoff weight which is published in the aircraft manual.

00:14:20 Interviewer

OK, but if I choose the narrow-body 737 as a sample and then I would, for my calculation, check the maximum load of that flight. But indeed I would need the percentage of consolidation. The average that I tried to look for them, but I didn't find it. Do you have any suggestions? Because if I take of course the 100% but then all the flights are like a field by the 80%, it would be less reliable.

00:15:00 Ir. J.A. (Joris) Melkert

Yeah yeah, but that is probably confidential information. Uh, and you will not be able to find that easily, I fear.

00:15:20 Interviewer

Ok, so I guess I just hypothesize an 80%. What do you think?

00:15:28 Ir. J.A. (Joris) Melkert

Yeah, your guess is as good as mine, I fear. You might want to ask an airline, but they probably will not give you that information.

00:15:38 Interviewer

OK, OK. Uh, my last one about this on this topic. Is there space or weight limitations in commercial aircraft compared to aircraft dedicated solely to cargo transport? So which risks on additional elements should I take into consideration when I needed to talk about filling a passenger aircraft with cargo?

00:16:11 Ir. J.A. (Joris) Melkert

Well, there there are limitations. There are weight limitations. You may not make the aircraft heavier than the maximum takeoff weight. And then how much space does leave for cargo depends on how many passengers are on board and how much luggage they take, and how much fuel the aircraft take for the mission. It all adds up to the maximum takeoff weight or less. And if you have very lightweight cargo then volume might also become limiting, but that really depends on the type of cargo you have. If you have all kinds of up boxes filled with precious electronics which are packaged in lots of Styrofoam, you need a lot of volumes and the weight is not an issue where. Uh, if you transport other things like flowers which are wet, and they're probably heavier and then the weight may become an issue and space not that much. That really depends on what type of cargo you want to transport.

00:17:10 Interviewer

But so, there are no differences between cargo aircraft or passengers about for example the risks of having people? because there are people on the floor upstairs.. maybe for example on the type of items I can bring... Maybe on an aircraft like there are the same limitations, for example, of what I can board on an aeroplane or not, while on a cargo can board...

00:17:43 Ir. J.A. (Joris) Melkert

I'm in principle there not much, maybe, uh, there's a couple of things which are called dangerous goods that they may be limited. Uh, only to cargo planes, but even then you have to probably comply with the same regulations. I would doubt if there are really big differences 'cause they all certify against the same uh airworthiness standards.

00:18:09 Interviewer

OK, and so these are the last six questions about talking about the big picture and the feasibility of this. OK so, how is the demand for cargo? Is it increasing? are solutions being proposed? and would using this extra space instead of the baggage help cover this demand? What do you think? Which is your opinion?

00:18:42 Ir. J.A. (Joris) Melkert

Yeah, I would say, uh, there is an increasing demand for cargo, but it is strongly related to the economic situation, if there is a recession economically speaking, then there will be less demand. If there is economic growth there's more demand for both passenger and cargo transport, so it's linked to the economy, yeah, but in general it has gone up over the years.

00:19:14 Interviewer

OK, but if the demand is growing, you said, is also the space growing? Because I guess the number of aircraft is increasing, but uhm, what about cargo aircraft? And what happens when there is not enough space in the plane? Would using adding additional space in the commercial passenger flights would help these?

00:20:00 Ir. J.A. (Joris) Melkert

Uh, it helps, It helps in that you have seen a shift from only dedicated cargo to also both Echobelly freight. So you have seen that development. And then when he called me gross further, you will see that that growing and when airports are going to get restricted in the number of flights, for instance, Schipol airport in the Netherlands is going to be restricted even further next year, yeah, and then people will start to find options, so if I cannot fly that many cargo flights anymore, I can probably put even more in in the passenger aircraft belly freight. You know people will optimize that further, and yet the amount of aircraft will grow in the future.

00:20:52 Interviewer

So there is a need for more options, and new solutions to move the cargo.

00:21:00 Ir. J.A. (Joris) Melkert

Uh, yeah, because the economy will grow worldwide, so you need more cargo aircraft and more passenger aircraft as well.

00:21:10 Interviewer

Uhm, OK, and do you think there would be an economic return from having more space in the passenger flights? For both airports and also the companies who move cargo.

00:21:27 Ir. J.A. (Joris) Melkert

Uh, yeah, because there's money to be earned. So there is an economic return on that. And otherwise, that space would fly empty and bring no money in there at all.

00:21:39 Interviewer

Yeah, because would it be profitable for the airport to have this additional cargo space and the external companies handling baggage? because, for example, let's say people don't bring baggage anymore in the aircraft, but the packages are handled by a third party, so maybe through trucks. Will it be profitable for the airport? having the process of the check-in, luggage roller when you land off or these parts maybe will be reduced or not exist anymore. So how would these do you think would affect the airports?

00:22:32 Ir. J.A. (Joris) Melkert

Depending on how that cargo is handled and if it still needs to go via an aircraft, then change is minimal. So then it doesn't make much more sense. So if it's being trucked or via rail then that burden is taken off the airport, and then when the aircraft operators can sell that space, it will help them and will also probably ease the logistic processes on the airport as well, because if you don't need to do the check-in. But that's only a very small fraction of their work, so I would expect that changes will be marginal.

00:23:14 Interviewer

OK. But the fact that you have to load those in the passenger cargo doesn't it would take more time for a loaded aircraft? Will the logistics for both passengers and the airport increase?

00:23:32 Ir. J.A. (Joris) Melkert

Well, if you don't have the luggage to board any more, you lose that so you can save there. But the question is what comes in return: the cargo also needs to be put into the belly of the aircraft. And let's suppose the density is the same, they need to put the same amount of volume. It doesn't really change.

00:23:56 Interviewer

So the operations of loading baggage or loading cargo is a is similar, so it's not more time-consuming.

00:24:04 Ir. J.A. (Joris) Melkert

No, no no. It's either you put it in by hand if it's bulk or you put it in with the high loader within it, uh, containerized. So the logistics in that sense are similar or largely similar, I would say.

00:24:33 Interviewer

Do you think that the increase in travelling outweighs the reduction in cargo? so do you think it could save CO2? for example, if there is a cargo plane and there is a passenger plane with more space instead of baggage, and some cargo goes in these passengers' extra space. Do you think after a tot of passenger aeroplanes one cargo plane will not take off? am I saving I'm reducing aircraft or not? Or just like the demand would be increasing, so they will just put more cargo in the same plane instead of moving it somewhere in another way?

00:25:30 Ir. J.A. (Joris) Melkert

It makes sense to put aircraft that fly as fully as possible so you don't waste space. So that it makes sense. Uh, what are you really gonna save overall? Depends on the demand and demand will be growing. It will of course depend on economic situations, but it will generally grow so. And maybe make things a bit more efficient. But overall, emissions will anyhow grow. But you make the flight more efficient, you transport that cargo maybe more efficiently.

00:26:11 Interviewer

So do you think that I cannot calculate this space...saying that I'm saving, uh, because I would like to write that I'm saving X amount of cargo in an aeroplane. So if it is this way, every 3 passenger flights without baggage I'm saving emissions since I'm avoiding one cargo flight to take off.

00:26:41 Ir. J.A. (Joris) Melkert

Yeah, yeah If that holds then you could do that, but then the question is: how is the luggage being transported if it also goes by near across? the effect is zero? and if it has to go by train or truck then you need to think what is your the life cycle of CO2 emission because in that sense aviation is very simple. You just need a runway at the beginning and a runway at the end of the trip if you need it by train that there has to be a railroad track, or if it goes by truck, has to be a road all throughout the journey and just building roads and especially building railroad tracks. And even more specifically, building high-speed railroad tracks is a drama for CO2 emissions, so your benefit may not be as large as you think are if you could do a full life cycle analysis.

00:27:37 Interviewer

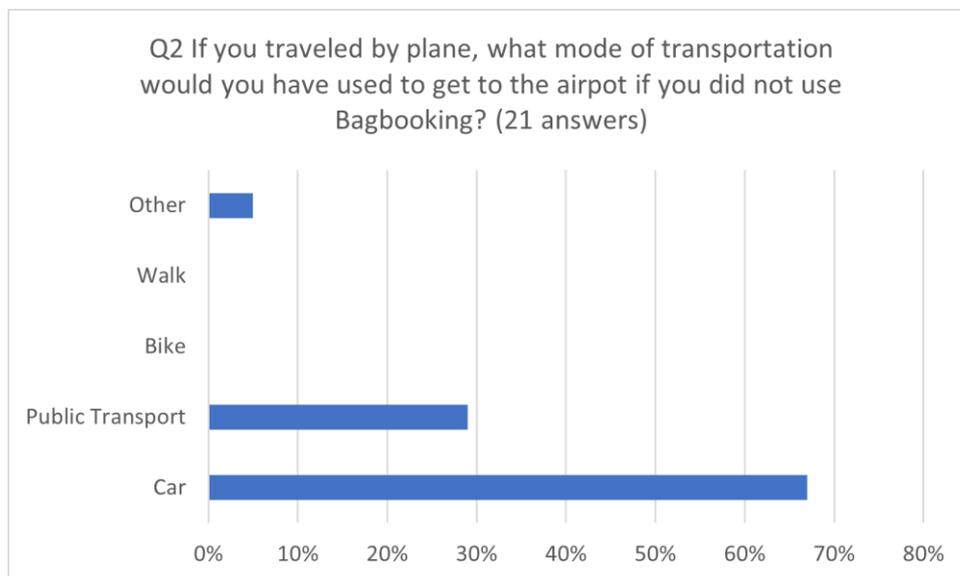
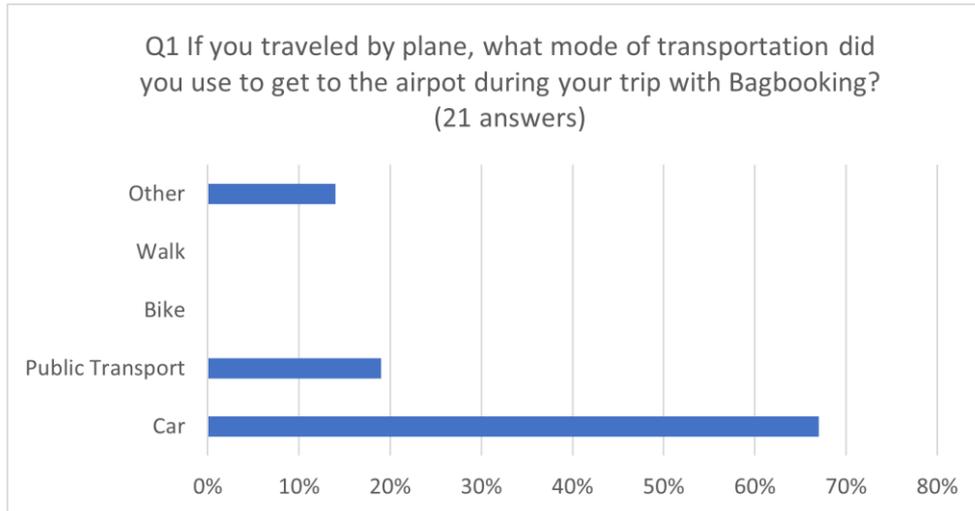
Okay, the two last general questions and then we are done. I would also like to ask you about the future of the decarbonization of flights. So do you think since indeed this solution might decrease the emissions, but also there is a future in which we see the

decarbonization of trucks, such as the electrification of trucks and cars and buses and so on or also the increasing use of railways, but also there will be the decarbonization of aircraft. We know that Airbus they are working on the flying V, which is using hydrogen and so on. So do you think that the cargo moving in a different direction than aircraft, or since the decarbonization is happening also in aircraft, it will be altogether so there will not be a shift in transportation modes?

00:28:50 Ir. J.A. (Joris) Melkert

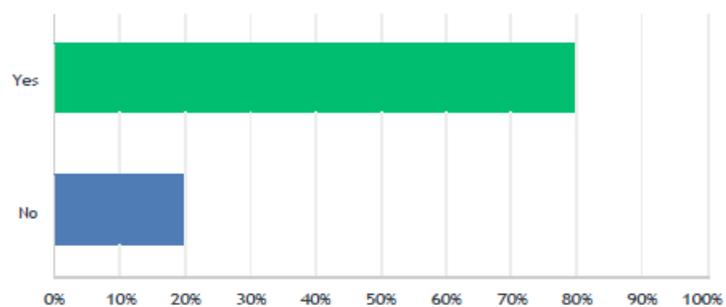
Yeah, well, I think that's again an economic question. The two things you need to consider if you want to, uh, ship things fast, because they're perishable, like flowers, fresh fruit, etc. or if they're very precious, it makes sense to transport things by aircraft. And if that's not the case, the easiest way to transport things is by ship. Life here is not precious and it's not time-sensitive shipping is the best thing to do, and flying is the most expensive one to do, but it will highly depend on how much it will cost, but you will decide well this bunch flowers go by aircraft or I'll track it.

APPENDIX B: Survey Results



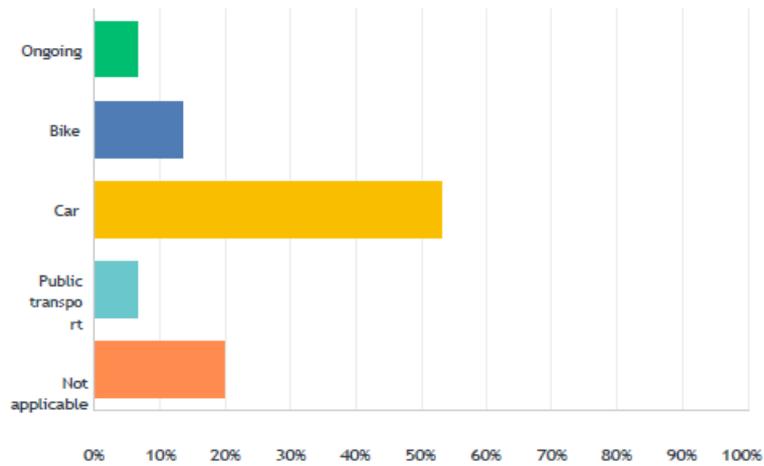
Q3 Would you be willing to take your luggage to a service point between 0 km and 2 km to help reduce emissions?

Answered: 15 Skipped: 0



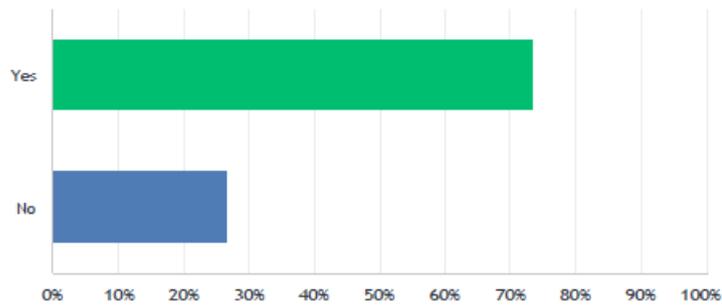
Q4 How would you reach this service point?

Answered: 15 Skipped: 0



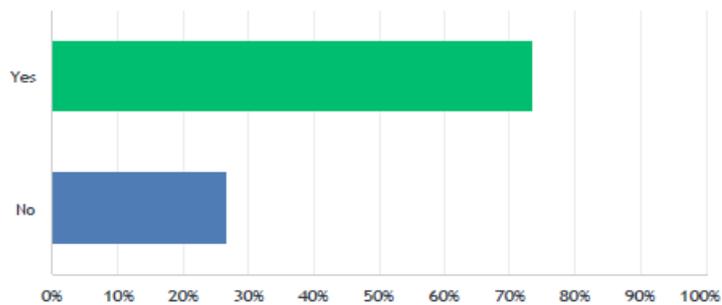
Q5 If Bagbooking is more sustainable than travelling by plane would you be more likely to choose to use Bagbooking?

Answered: 15 Skipped: 0



Q6 Would you use Bagbooking if travelling by a mode of transport other than plane?

Answered: 15 Skipped: 0



APPENDIX C: Customers emissions analysis (Options, Scenarios, Paper, Ground segments)

TTW:

BAG #	First mile			Last mile			Mode				Paper	Ground segments
	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3	Van	Truck	Train	Plane		
BAG-0002250	20.84	48.87	29.00	5.44	20.44	6.99	1583.32	713.29	46.47	685.25	0.00	3.47
BAG-0002236	0.77	1.78	1.05	0.24	0.89	0.30	86.29	38.87	2.53	37.35	0.00	5.32
BAG-0002232	2.27	5.34	3.17	1.03	4.07	1.39	135.87	61.21	3.99	58.80	0.00	17.65
BAG-0002232 (2)	1.78	4.16	2.47	0.45	1.63	0.56	136.41	61.45	4.00	59.04	0.00	17.65
BAG-0002227	2.63	6.30	3.74	7.97	33.21	11.36	2.12	0.96	0.06	2.31	0.00	9.07
BAG-0002227 (2)	13.86	33.35	19.79	1.35	5.57	1.91	1.39	0.63	0.04	1.52	0.00	9.07
BAG-0002225	0.84	1.93	1.15	0.21	0.72	0.25	129.72	58.44	3.81	56.14	0.00	16.14
BAG-0002224	0.47	1.09	0.64	9.99	41.64	14.25	36.64	16.50	1.08	39.91	0.00	15.31
BAG-0002220	0.90	2.12	1.26	14.58	60.81	20.81	47.56	21.43	1.40	20.59	0.00	4.83
BAG-0002220 (2)	22.91	55.13	32.71	0.53	2.17	0.74	70.25	31.65	2.06	30.40	0.00	4.83
BAG-0002219	3.58	8.49	5.04	1.35	5.40	1.85	49.53	22.31	1.45	53.96	0.00	18.15
BAG-0002218	1.64	3.86	2.29	0.60	2.35	0.80	58.86	26.52	1.73	64.12	0.00	3.96
BAG-0002217	0.32	0.72	0.43	0.20	0.75	0.26	29.07	13.09	0.85	31.67	0.00	7.95
BAG-0002214	2.72	6.45	3.83	0.20	0.66	0.23	43.90	19.78	1.29	47.83	0.00	5.02
BAG-0002213	1.11	2.62	1.56	3.82	15.89	5.44	45.29	20.40	1.33	19.60	0.00	4.27
BAG-0002212	13.16	31.60	18.75	0.31	1.15	0.39	107.47	48.41	3.15	46.51	0.00	10.25
BAG-0002212 (2)	0.51	1.15	0.68	7.10	29.49	10.09	106.92	48.17	3.14	46.28	0.00	10.25
BAG-0002211	2.44	5.79	3.44	13.77	57.35	19.62	90.58	40.81	2.66	39.20	0.00	12.29
BAG-0002211 (2)	23.86	57.35	34.03	1.45	5.91	2.02	90.94	40.97	2.67	39.36	0.00	12.29
BAG-0002209	0.90	2.12	1.26	0.22	0.86	0.30	7.78	3.51	0.23	8.48	0.00	5.91
BAG-0002208	0.73	1.67	0.99	2.16	8.89	3.04	78.50	35.37	2.30	33.98	0.00	9.52
BAG-0002208 (2)	0.99	2.30	1.36	0.66	2.61	0.89	51.27	23.10	1.50	55.86	0.00	9.52
BAG-0002207	1.99	4.70	2.79	12.36	51.44	17.60	29.07	13.09	0.85	31.67	0.00	4.22
BAG-0002206	0.90	2.12	1.26	0.98	4.02	1.38	47.56	21.43	1.40	20.59	0.00	16.17
BAG-0002205	0.46	1.06	0.63	0.80	3.26	1.11	23.58	10.62	0.69	25.69	0.00	10.67
BAG-0002201	0.97	2.23	1.32	1.67	6.77	2.32	111.71	50.33	3.28	48.35	0.00	19.01
BAG-0002200	0.74	1.69	1.00	0.21	0.72	0.25	30.82	13.88	0.90	33.57	0.00	2.80
BAG-0002199	1.97	4.71	2.79	0.08	0.29	0.10	36.51	16.45	1.07	15.80	0.00	8.37
BAG-0002198	2.16	5.16	3.06	1.89	7.81	2.67	37.72	16.99	1.11	41.10	0.00	10.95
BAG-0002198 (2)	3.19	7.63	4.53	0.78	3.17	1.08	33.98	15.31	1.00	37.02	0.00	10.95
BAG-0002197	1.90	4.51	2.68	7.60	31.62	10.82	43.30	19.50	1.27	47.17	0.00	10.41
BAG-0002194	0.90	2.12	1.26	3.29	13.67	4.68	33.70	15.18	0.99	14.58	0.00	8.90
BAG-0002193	2.65	6.33	3.76	0.65	2.65	0.91	28.59	12.88	0.84	31.14	0.00	4.57
BAG-0002192	0.93	2.17	1.29	0.13	0.44	0.15	66.43	29.92	1.95	28.75	0.00	8.75
BAG-0002191	0.82	1.93	1.15	3.84	15.95	5.46	69.35	31.24	2.04	30.02	0.00	4.88
BAG-0002189	2.36	5.64	3.35	10.43	43.45	14.87	2.95	1.33	0.09	3.22	0.00	11.53
BAG-???	0.67	1.57	0.93	0.76	3.11	1.06	26.56	11.97	0.78	28.94	0.00	12.57
BAG-0002188	0.91	2.12	1.26	8.11	33.74	11.55	52.76	23.77	1.55	57.48	0.00	8.69
BAG-0002188 (2)	12.30	29.54	17.53	0.15	0.53	0.18	30.21	13.61	0.89	32.91	0.00	8.69

BAG #	First mile			Last mile			Mode				Paper	Ground segments
	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3	Van	Truck	Train	Plane		
BAG-0002187	1.21	2.83	1.68	1.65	6.75	2.31	98.06	44.18	2.88	42.44	0.00	8.91
BAG-0002181	0.48	1.13	0.67	0.11	0.42	0.14	28.90	13.02	0.85	31.49	0.00	5.90
BAG-0002180	0.79	1.77	1.05	0.46	1.68	0.58	157.62	71.01	4.63	68.21	0.00	6.79
BAG-0002178	0.84	1.93	1.15	7.65	31.78	10.87	90.58	40.81	2.66	39.20	0.00	6.32
BAG-0002176	0.90	2.12	1.26	0.07	0.22	0.08	10.97	4.94	0.32	11.95	0.00	5.52
BAG-0002175	0.38	0.84	0.50	5.88	24.46	8.37	36.44	16.42	1.07	39.70	0.00	3.63
BAG-0002174	2.79	6.63	3.94	0.73	2.89	0.99	219.63	98.95	6.45	95.06	0.00	14.64
BAG-0002173	0.26	0.60	0.35	9.37	39.07	13.37	10.66	4.80	0.31	11.61	0.00	7.42
BAG-0002172	1.99	4.70	2.79	4.23	17.49	5.98	71.95	32.41	2.11	78.38	0.00	4.39
BAG-0002171	1.45	3.34	1.98	2.22	8.99	3.08	157.00	70.73	4.61	67.95	0.00	19.67
BAG-0002170	1.22	2.89	1.72	0.09	0.30	0.10	14.53	6.55	0.43	15.83	0.00	331.51
BAG-0002169	2.54	6.03	3.58	1.29	5.25	1.80	56.45	25.43	1.66	61.50	0.00	5.67
BAG-0002168	2.73	6.47	3.84	0.38	1.41	0.48	97.21	43.79	2.85	105.91	0.00	3.55
BAG-0002168 (2)	0.63	1.41	0.84	0.67	2.60	0.89	131.87	59.41	3.87	57.07	0.00	3.55
BAG-0002167	1.69	3.96	2.35	0.25	0.82	0.28	88.19	39.73	2.59	96.08	0.00	9.55
BAG-0002166	1.79	4.11	2.44	68.43	285.38	97.65	129.49	58.34	3.80	141.07	0.00	12.29
BAG-0002165	0.82	1.93	1.15	0.44	1.75	0.60	40.86	18.41	1.20	44.51	0.00	11.13
BAG-0002164	0.66	1.51	0.89	3.49	14.41	4.93	173.56	78.19	5.09	75.12	0.00	4.99
BAG-0002162	2.16	5.13	3.04	2.57	10.61	3.63	77.13	34.75	2.26	33.38	0.00	8.21
BAG-0002162 (2)	0.21	0.44	0.26	0.41	1.59	0.54	30.21	13.61	0.89	32.91	0.00	8.21
BAG-0002161	0.83	1.96	1.16	1.33	5.46	1.87	26.23	11.82	0.77	28.58	0.00	7.64
BAG-0002160	0.87	2.03	1.21	0.20	0.71	0.24	77.30	34.83	2.27	33.46	0.00	13.48
BAG-0002159	5.26	12.60	7.48	11.36	47.32	16.19	78.81	35.50	2.31	34.11	0.00	8.81
BAG-0002158	5.66	13.48	8.00	54.74	228.29	78.11	224.84	101.29	6.60	97.31	0.00	7.45
BAG-0002157	0.81	1.87	1.11	4.04	16.70	5.72	90.58	40.81	2.66	39.20	0.00	7.30
BAG-0002156	0.60	1.42	0.84	0.62	2.52	0.86	12.38	5.58	0.36	13.49	0.00	19.99
BAG-0002155	1.01	2.35	1.40	2.46	10.14	3.47	63.45	28.58	1.86	69.13	0.00	9.83
BAG-0002154	0.81	1.87	1.11	0.21	0.72	0.25	64.53	29.07	1.89	70.30	0.00	14.42
BAG-0002153	0.84	1.93	1.15	0.09	0.24	0.08	99.57	44.85	2.92	43.09	0.00	20.04
BAG-0002150	2.73	6.39	3.79	1.84	7.36	2.52	214.93	96.83	6.31	93.02	0.00	12.43
BAG-0002150 (2)	3.18	7.48	4.44	1.58	6.27	2.15	213.85	96.34	6.28	92.55	0.00	12.43
BAG-0002149	0.99	2.30	1.36	7.84	32.61	11.16	68.31	30.77	2.00	74.42	0.00	9.77
BAG-0002147	0.87	2.05	1.22	0.68	2.77	0.95	31.21	14.06	0.92	34.00	0.00	10.96
BAG-0002146	0.45	1.02	0.60	11.35	47.28	16.18	28.92	13.03	0.85	31.51	0.00	6.92
BAG-0002145	0.78	1.84	1.09	3.84	15.95	5.46	53.73	24.21	1.58	23.26	0.00	8.47
BAG-0002143	1.25	2.95	1.75	0.35	1.39	0.47	29.43	13.26	0.86	32.06	0.00	8.52
BAG-0002143 (2)	0.63	1.48	0.88	0.37	1.48	0.51	34.16	15.39	1.00	37.22	0.00	8.52
BAG-0002142	0.78	1.84	1.09	10.87	45.29	15.50	2.89	1.30	0.08	3.15	0.00	8.94
BAG-0002141	1.04	2.43	1.44	0.52	2.08	0.71	28.92	13.03	0.85	31.51	0.00	13.50
BAG-0002140	4.14	9.91	5.88	0.30	1.15	0.39	66.43	29.92	1.95	28.75	0.00	21.76
BAG-0002140 (2)	0.39	0.88	0.52	6.14	25.52	8.73	66.69	30.04	1.96	28.86	0.00	21.76
BAG-0002139	1.64	3.89	2.31	1.19	4.86	1.66	66.69	30.04	1.96	28.86	0.00	7.33
BAG-0002139 (2)	2.07	4.91	2.91	0.14	0.49	0.17	3.45	1.55	0.10	3.76	0.00	7.33
BAG-0002138	1.75	4.16	2.47	0.99	4.02	1.38	59.88	26.98	1.76	65.24	0.00	15.15
BAG-0002136	1.36	3.23	1.91	0.09	0.30	0.10	45.29	20.40	1.33	19.60	0.00	9.86
BAG-0002135	4.46	10.58	6.28	5.62	23.19	7.93	147.58	66.49	4.33	160.78	0.00	8.92
BAG-0002134	0.38	0.84	0.50	0.99	4.02	1.38	78.81	35.50	2.31	34.11	0.00	9.21
BAG-0002133	1.79	4.25	2.52	0.09	0.27	0.09	21.32	9.60	0.63	23.22	0.00	4.17

WTW:

BAG #	First mile			Last mile			Mode				Paper	Ground segments no bags
	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3	Van	Truck	Train	Plane		
BAG-0002250	27.32	64.48	38.26	7.00	26.97	9.23	2089.30	940.60	61.44	875.86	0.00	3.47
BAG-0002236	1.01	2.34	1.39	0.31	1.17	0.40	113.87	51.26	3.35	47.73	0.00	5.32
BAG-0002232	2.98	7.04	4.18	1.34	5.37	1.84	179.29	80.72	5.27	75.16	0.00	17.65
BAG-0002232 (2)	2.34	5.49	3.26	0.57	2.15	0.74	180.01	81.04	5.29	75.46	0.00	17.65
BAG-0002227	3.47	8.32	4.93	10.51	43.83	15.00	2.80	1.26	0.08	2.95	0.00	9.07
BAG-0002227 (2)	18.29	44.00	26.11	1.77	7.35	2.52	1.84	0.83	0.05	1.94	0.00	9.07
BAG-0002225	1.09	2.55	1.51	0.27	0.95	0.33	171.17	77.06	5.03	71.76	0.00	16.14
BAG-0002224	0.61	1.43	0.85	13.18	54.95	18.80	48.34	21.76	1.42	50.99	0.00	15.31
BAG-0002220	1.18	2.80	1.66	19.23	80.24	27.46	62.76	28.26	1.85	26.31	0.00	4.83
BAG-0002220 (2)	30.23	72.74	43.16	0.70	2.86	0.98	92.70	41.73	2.73	38.86	0.00	4.83
BAG-0002219	4.71	11.20	6.65	1.76	7.12	2.44	65.36	29.43	1.92	68.94	0.00	18.15
BAG-0002218	2.15	5.09	3.02	0.78	3.10	1.06	77.67	34.97	2.28	81.93	0.00	3.96
BAG-0002217	0.41	0.95	0.57	0.26	0.99	0.34	38.36	17.27	1.13	40.46	0.00	7.95
BAG-0002214	3.57	8.51	5.05	0.25	0.88	0.30	57.93	26.08	1.70	61.11	0.00	5.02
BAG-0002213	1.46	3.46	2.05	5.04	20.97	7.17	59.76	26.91	1.76	25.05	0.00	4.27
BAG-0002212	17.36	41.70	24.74	0.40	1.51	0.52	141.81	63.84	4.17	59.45	0.00	10.25
BAG-0002212 (2)	0.66	1.51	0.90	9.36	38.91	13.31	141.09	63.52	4.15	59.15	0.00	10.25
BAG-0002211	3.21	7.64	4.53	18.16	75.68	25.89	119.53	53.81	3.51	50.11	0.00	12.29
BAG-0002211 (2)	31.47	75.68	44.90	1.90	7.80	2.67	120.00	54.03	3.53	50.31	0.00	12.29
BAG-0002209	1.18	2.80	1.66	0.29	1.14	0.39	10.27	4.62	0.30	10.83	0.00	5.91
BAG-0002208	0.95	2.21	1.31	2.84	11.72	4.01	103.59	46.64	3.05	43.43	0.00	9.52
BAG-0002208 (2)	1.29	3.03	1.80	0.86	3.45	1.18	67.66	30.46	1.99	71.37	0.00	9.52
BAG-0002207	2.61	6.21	3.68	16.29	67.88	23.23	38.36	17.27	1.13	40.46	0.00	4.22
BAG-0002206	1.18	2.80	1.66	1.29	5.31	1.82	62.76	28.26	1.85	26.31	0.00	16.17
BAG-0002205	0.60	1.39	0.83	1.05	4.30	1.47	31.11	14.01	0.91	32.82	0.00	10.67
BAG-0002201	1.27	2.94	1.75	2.18	8.93	3.06	147.42	66.37	4.33	61.80	0.00	19.01
BAG-0002200	0.96	2.23	1.32	0.27	0.95	0.33	40.66	18.31	1.20	42.89	0.00	2.80
BAG-0002199	2.59	6.22	3.69	0.10	0.38	0.13	48.17	21.69	1.42	20.20	0.00	8.37
BAG-0002198	2.84	6.80	4.04	2.49	10.31	3.53	49.78	22.41	1.46	52.50	0.00	10.95
BAG-0002198 (2)	4.20	10.07	5.97	1.02	4.18	1.43	44.84	20.19	1.32	47.30	0.00	10.95
BAG-0002197	2.50	5.95	3.53	10.02	41.73	14.28	57.13	25.72	1.68	60.26	0.00	10.41
BAG-0002194	1.18	2.80	1.66	4.33	18.03	6.17	44.47	20.02	1.31	18.64	0.00	8.90
BAG-0002193	3.49	8.36	4.96	0.86	3.50	1.20	37.72	16.98	1.11	39.79	0.00	4.57
BAG-0002192	1.21	2.86	1.70	0.17	0.58	0.20	87.65	39.46	2.58	36.74	0.00	8.75
BAG-0002191	1.08	2.55	1.51	5.06	21.05	7.20	91.51	41.20	2.69	38.36	0.00	4.88
BAG-0002189	3.11	7.44	4.41	13.75	57.34	19.62	3.90	1.76	0.11	4.11	0.00	11.53
BAG-???	0.88	2.07	1.23	1.00	4.10	1.40	35.05	15.78	1.03	36.98	0.00	12.57
BAG-0002188	1.19	2.80	1.66	10.69	44.53	15.24	69.62	31.34	2.05	73.44	0.00	8.69
BAG-0002188 (2)	16.22	38.98	23.13	0.19	0.70	0.24	39.86	17.94	1.17	42.04	0.00	8.69

BAG #	First mile			Last mile			Mode				Paper	Ground segments no bags
	Option 1	Option 2	Option 3	Option 1	Option 2	Option 3	Van	Truck	Train	Plane		
BAG-0002187	1.59	3.74	2.22	2.17	8.91	3.05	129.39	58.25	3.80	54.24	0.00	8.91
BAG-0002181	0.63	1.49	0.88	0.15	0.55	0.19	38.14	17.17	1.12	40.23	0.00	5.90
BAG-0002180	1.02	2.33	1.39	0.58	2.22	0.76	207.99	93.63	6.12	87.19	0.00	6.79
BAG-0002178	1.09	2.55	1.51	10.08	41.94	14.35	119.53	53.81	3.51	50.11	0.00	6.32
BAG-0002176	1.18	2.80	1.66	0.08	0.29	0.10	14.47	6.52	0.43	15.27	0.00	5.52
BAG-0002175	0.49	1.11	0.66	7.76	32.27	11.04	48.09	21.65	1.41	50.72	0.00	3.63
BAG-0002174	3.67	8.75	5.19	0.95	3.82	1.31	289.82	130.48	8.52	121.50	0.00	14.64
BAG-0002173	0.34	0.79	0.47	12.36	51.56	17.64	14.06	6.33	0.41	14.83	0.00	7.42
BAG-0002172	2.61	6.21	3.68	5.56	23.08	7.90	94.94	42.74	2.79	100.14	0.00	4.39
BAG-0002171	1.90	4.41	2.62	2.90	11.86	4.06	207.18	93.27	6.09	86.85	0.00	19.67
BAG-0002170	1.60	3.82	2.27	0.11	0.40	0.14	19.18	8.63	0.56	20.23	0.00	331.51
BAG-0002169	3.34	7.96	4.72	1.69	6.92	2.37	74.49	33.53	2.19	78.57	0.00	5.67
BAG-0002168	3.59	8.54	5.07	0.49	1.86	0.64	128.28	57.75	3.77	135.31	0.00	3.55
BAG-0002168 (2)	0.82	1.86	1.11	0.87	3.44	1.18	174.01	78.34	5.12	72.95	0.00	3.55
BAG-0002167	2.22	5.22	3.10	0.31	1.09	0.37	116.37	52.39	3.42	122.75	0.00	9.55
BAG-0002166	2.33	5.43	3.22	90.28	376.58	128.85	170.87	76.93	5.02	180.24	0.00	12.29
BAG-0002165	1.08	2.55	1.51	0.57	2.31	0.79	53.91	24.27	1.59	56.87	0.00	11.13
BAG-0002164	0.86	1.99	1.18	4.59	19.02	6.51	229.03	103.11	6.73	96.01	0.00	4.99
BAG-0002162	2.84	6.77	4.02	3.38	14.01	4.79	101.77	45.82	2.99	42.67	0.00	8.21
BAG-0002162 (2)	0.27	0.58	0.35	0.53	2.10	0.72	39.86	17.94	1.17	42.04	0.00	8.21
BAG-0002161	1.09	2.59	1.53	1.74	7.20	2.46	34.62	15.58	1.02	36.51	0.00	7.64
BAG-0002160	1.14	2.68	1.59	0.25	0.93	0.32	102.01	45.92	3.00	42.76	0.00	13.48
BAG-0002159	6.93	16.63	9.87	14.98	62.44	21.37	103.99	46.82	3.06	43.59	0.00	8.81
BAG-0002158	7.45	17.79	10.56	72.22	301.25	103.08	296.70	133.57	8.72	124.38	0.00	7.45
BAG-0002157	1.06	2.47	1.46	5.32	22.04	7.54	119.53	53.81	3.51	50.11	0.00	7.30
BAG-0002156	0.79	1.87	1.11	0.81	3.33	1.14	16.34	7.36	0.48	17.24	0.00	19.99
BAG-0002155	1.32	3.10	1.84	3.24	13.38	4.58	83.73	37.69	2.46	88.32	0.00	9.83
BAG-0002154	1.06	2.47	1.46	0.27	0.95	0.33	85.15	38.33	2.50	89.82	0.00	14.42
BAG-0002153	1.09	2.55	1.51	0.11	0.32	0.11	131.38	59.15	3.86	55.08	0.00	20.04
BAG-0002150	3.58	8.44	5.01	2.40	9.71	3.32	283.62	127.68	8.34	118.90	0.00	12.43
BAG-0002150 (2)	4.17	9.87	5.86	2.06	8.28	2.83	282.18	127.04	8.30	118.29	0.00	12.43
BAG-0002149	1.29	3.03	1.80	10.34	43.04	14.73	90.14	40.58	2.65	95.08	0.00	9.77
BAG-0002147	1.14	2.71	1.61	0.90	3.66	1.25	41.18	18.54	1.21	43.44	0.00	10.96
BAG-0002146	0.58	1.34	0.80	14.97	62.38	21.35	38.17	17.18	1.12	40.26	0.00	6.92
BAG-0002145	1.03	2.43	1.44	5.06	21.05	7.20	70.90	31.92	2.08	29.72	0.00	8.47
BAG-0002143	1.64	3.90	2.31	0.46	1.83	0.63	38.83	17.48	1.14	40.96	0.00	8.52
BAG-0002143 (2)	0.83	1.95	1.16	0.49	1.95	0.67	45.08	20.30	1.33	47.55	0.00	8.52
BAG-0002142	1.03	2.43	1.44	14.33	59.76	20.45	3.82	1.72	0.11	4.03	0.00	8.94
BAG-0002141	1.36	3.21	1.90	0.68	2.74	0.94	38.17	17.18	1.12	40.26	0.00	13.50
BAG-0002140	5.46	13.07	7.76	0.39	1.52	0.52	87.65	39.46	2.58	36.74	0.00	21.76
BAG-0002140 (2)	0.51	1.17	0.69	8.09	33.67	11.52	88.00	39.62	2.59	36.89	0.00	21.76
BAG-0002139	2.16	5.14	3.05	1.56	6.42	2.20	88.00	39.62	2.59	36.89	0.00	7.33
BAG-0002139 (2)	2.72	6.48	3.84	0.18	0.64	0.22	4.55	2.05	0.13	4.80	0.00	7.33
BAG-0002138	2.31	5.49	3.25	1.30	5.31	1.82	79.02	35.57	2.32	83.35	0.00	15.15
BAG-0002136	1.79	4.26	2.53	0.11	0.40	0.14	59.76	26.91	1.76	25.05	0.00	9.86
BAG-0002135	5.87	13.96	8.29	7.40	30.60	10.47	194.74	87.67	5.73	205.42	0.00	8.92
BAG-0002134	0.49	1.11	0.66	1.30	5.31	1.82	103.99	46.82	3.06	43.59	0.00	9.21
BAG-0002133	2.35	5.60	3.32	0.11	0.35	0.12	28.13	12.66	0.83	29.67	0.00	4.17

APPENDIX D: Customers emissions analysis – Five scenarios

TTW:

BAG #	BaaS emissions				
	Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions
BAG-0002250	1430.14	1400.55	1397.975	666.59	2.35
BAG-0002236	101.15	100.08	96.12722	51.26	18.87
BAG-0002232	137.77	134.35	121.2319	59.83	15.72
BAG-0002232 (2)	132.57	130.08	116.9655	55.56	11.23
BAG-0002227	25.41	18.34	11.60019	-17.60	-11.75
BAG-0002227 (2)	42.67	22.62	15.88373	-13.32	-7.16
BAG-0002225	137.49	136.36	124.3777	67.76	25.12
BAG-0002224	81.84	76.97	65.59293	43.18	39.12
BAG-0002220	80.36	72.90	69.31783	46.33	29.88
BAG-0002220 (2)	173.82	141.40	137.813	114.82	88.82
BAG-0002219	61.44	56.03	42.54433	-21.65	-29.03
BAG-0002218	78.09	75.66	72.72066	-10.99	-32.83
BAG-0002217	40.10	39.64	33.72576	-10.30	-16.63
BAG-0002214	36.82	33.05	29.32622	-44.66	-59.42
BAG-0002213	34.62	31.49	28.32132	7.30	-8.60
BAG-0002212	125.96	107.44	99.82081	51.42	13.77
BAG-0002212 (2)	103.39	99.76	92.14769	43.74	6.33
BAG-0002211	92.24	83.04	73.90777	-119.40	-148.42
BAG-0002211 (2)	126.30	92.24	83.10593	-110.20	-139.37
BAG-0002209	13.59	12.28	7.894915	-0.76	0.35
BAG-0002208	104.90	103.08	96.00649	47.22	21.23
BAG-0002208 (2)	43.82	42.27	35.19754	-13.59	-28.11
BAG-0002207	44.51	36.55	33.41463	-36.40	-45.51
BAG-0002206	63.90	62.27	50.25535	32.00	23.98
BAG-0002205	44.81	43.89	35.97132	2.23	0.23
BAG-0002201	115.64	113.73	99.6031	47.68	14.76
BAG-0002200	81.77	80.78	78.69724	14.69	3.79
BAG-0002199	51.26	48.51	42.29203	22.55	13.39
BAG-0002198	43.60	39.82	31.68734	2.52	-5.23
BAG-0002198 (2)	35.63	30.88	22.74107	-6.43	-12.61
BAG-0002197	81.05	75.22	67.48235	35.47	24.97
BAG-0002194	41.82	39.20	32.58672	1.32	-6.26
BAG-0002193	23.57	19.64	16.2407	-11.04	-19.68
BAG-0002192	68.37	67.12	60.61647	30.31	8.83
BAG-0002191	61.28	58.56	54.92936	29.54	3.96
BAG-0002189	30.46	22.74	14.1777	-20.28	-12.96
BAG-???	44.47	43.27	33.93443	1.33	-0.53
BAG-0002188	48.27	43.62	37.16508	-34.57	-50.34
BAG-0002188 (2)	86.54	69.27	62.81061	-8.93	-15.19

BAG #	BaaS emissions				
	Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions
BAG-0002187	243.13	240.86	234.2352	148.81	114.14
BAG-0002181	43.26	42.59	38.20535	20.61	12.82
BAG-0002180	134.03	132.93	127.8881	55.77	-5.56
BAG-0002178	64.27	59.96	55.26498	12.33	-21.13
BAG-0002176	22.16	20.92	16.82662	-0.80	-1.33
BAG-0002175	32.70	29.75	27.05633	-27.66	-40.31
BAG-0002174	331.84	327.74	316.8584	259.03	177.41
BAG-0002173	26.47	22.14	16.62434	-1.05	-0.03
BAG-0002172	56.79	52.32	49.06213	-14.56	-41.60
BAG-0002171	157.31	154.56	139.9444	-30.31	-81.82
BAG-0002170	257.29	255.61	9.337126	-36.89	203.26
BAG-0002169	53.27	49.28	45.06564	-127.89	-147.45
BAG-0002168	136.10	132.26	129.6211	68.62	30.32
BAG-0002168 (2)	104.07	103.07	100.4285	39.43	-13.47
BAG-0002167	146.09	143.79	136.7015	80.22	50.17
BAG-0002166	182.36	150.82	141.6951	17.96	-27.45
BAG-0002165	32.19	30.92	22.64927	-11.37	-20.31
BAG-0002164	120.54	118.25	114.5465	61.11	-8.28
BAG-0002162	53.99	49.95	43.85204	-23.49	-49.87
BAG-0002162 (2)	76.02	75.65	69.55243	2.21	-4.41
BAG-0002161	43.48	41.81	36.13963	-71.40	-76.77
BAG-0002160	85.28	84.08	74.061	13.30	-9.25
BAG-0002159	98.66	86.49	79.94437	25.44	-1.20
BAG-0002158	353.66	322.47	316.9333	183.98	94.82
BAG-0002157	59.79	57.06	51.6289	-43.36	-76.08
BAG-0002156	39.14	38.08	23.22717	4.70	14.34
BAG-0002155	46.88	44.53	37.22882	-19.65	-39.07
BAG-0002154	93.77	92.67	81.95841	-13.37	-29.83
BAG-0002153	126.65	125.55	110.6662	91.54	64.50
BAG-0002150	190.84	186.50	177.2594	75.70	-5.58
BAG-0002150 (2)	191.55	186.68	177.4437	75.89	-4.94
BAG-0002149	81.91	77.28	70.02419	28.24	6.73
BAG-0002147	53.07	51.62	43.47449	21.35	16.36
BAG-0002146	57.79	52.39	47.25208	12.93	5.89
BAG-0002145	40.78	38.10	31.81366	6.72	-9.62
BAG-0002143	35.38	33.55	27.2179	-1.30	-7.36
BAG-0002143 (2)	29.16	28.18	21.85353	-6.66	-14.72
BAG-0002142	25.34	19.66	13.01304	-27.40	-21.98
BAG-0002141	41.15	39.57	29.54056	-7.51	-9.67
BAG-0002140	71.65	65.79	49.62722	20.51	8.70
BAG-0002140 (2)	91.83	88.74	72.5775	43.46	31.54
BAG-0002139	76.86	74.14	68.70171	63.38	40.74
BAG-0002139 (2)	12.16	9.29	3.852388	-1.47	2.52
BAG-0002138	48.23	45.44	34.18806	-18.46	-32.43
BAG-0002136	51.26	49.38	42.05581	22.39	10.64
BAG-0002135	116.29	107.86	101.2292	-7.65	-63.17
BAG-0002134	72.38	71.53	64.68835	27.09	0.74
BAG-0002133	20.26	17.81	14.71347	-5.78	-11.66

WTW:

BAG #	BaaS emissions				
	Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions
BAG-0002250	1912.15	1872.77	1869.298	934.47	58.77
BAG-0002236	135.04	133.62	128.2947	70.95	28.35
BAG-0002232	184.57	180.01	162.3624	83.88	26.09
BAG-0002232 (2)	177.71	174.38	156.7324	78.25	20.16
BAG-0002227	34.40	25.06	15.98897	-21.32	-13.42
BAG-0002227 (2)	57.17	30.72	21.64169	-15.67	-7.36
BAG-0002225	183.35	181.84	165.7018	93.34	37.45
BAG-0002224	109.09	102.65	87.34438	58.70	53.66
BAG-0002220	106.79	96.94	92.11194	62.73	41.14
BAG-0002220 (2)	230.12	187.32	182.4942	153.11	118.93
BAG-0002219	84.15	76.97	58.82217	-23.20	-32.55
BAG-0002218	104.75	101.53	97.565	-9.38	-38.10
BAG-0002217	53.88	53.26	45.30615	-10.94	-19.13
BAG-0002214	50.32	45.33	40.30897	-54.21	-73.57
BAG-0002213	46.59	42.45	38.17784	11.30	-9.57
BAG-0002212	168.02	143.56	133.3061	71.44	22.02
BAG-0002212 (2)	138.24	133.43	123.1811	61.31	12.20
BAG-0002211	123.59	111.43	99.13824	-147.79	-185.79
BAG-0002211 (2)	168.54	123.57	111.2757	-135.65	-173.86
BAG-0002209	18.72	16.99	11.0831	0.02	1.61
BAG-0002208	140.09	137.66	128.1385	65.81	31.74
BAG-0002208 (2)	59.49	57.43	47.90771	-14.42	-33.37
BAG-0002207	60.47	49.95	45.72926	-43.47	-55.39
BAG-0002206	85.29	83.14	66.96478	43.63	33.39
BAG-0002205	60.14	58.92	48.2521	5.15	2.72
BAG-0002201	155.10	152.55	133.5395	67.17	24.15
BAG-0002200	109.57	108.24	105.4433	23.66	9.35
BAG-0002199	68.47	64.83	56.46103	31.22	19.32
BAG-0002198	58.56	53.56	42.61285	5.34	-4.65
BAG-0002198 (2)	48.05	41.77	30.81882	-6.45	-14.37
BAG-0002197	108.49	100.78	90.36703	49.45	35.82
BAG-0002194	56.03	52.57	43.66244	3.71	-6.09
BAG-0002193	32.03	26.82	22.25299	-12.60	-23.90
BAG-0002192	91.71	90.03	81.28355	42.55	14.41
BAG-0002191	81.76	78.15	73.2697	40.82	7.19
BAG-0002189	41.27	31.07	19.54096	-24.48	-14.59
BAG-???	59.74	58.15	45.5825	3.92	1.74
BAG-0002188	65.22	59.06	50.37173	-41.28	-61.89
BAG-0002188 (2)	115.71	92.90	84.20757	-7.44	-15.53

BAG #	BaaS emissions				
	Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions
BAG-0002187	322.62	319.59	310.6791	201.54	156.01
BAG-0002181	57.86	56.96	51.06429	28.58	18.43
BAG-0002180	179.65	178.16	171.3677	79.19	-1.54
BAG-0002178	86.57	80.85	74.53776	19.66	-24.32
BAG-0002176	30.02	28.38	22.86783	0.34	-0.23
BAG-0002175	44.57	40.66	37.03904	-32.86	-49.47
BAG-0002174	439.70	434.26	419.6189	345.73	238.42
BAG-0002173	35.76	30.03	22.60816	0.01	1.52
BAG-0002172	76.65	70.73	66.34069	-14.94	-50.50
BAG-0002171	210.91	207.24	187.5689	-29.95	-97.46
BAG-0002170	346.87	344.64	13.12944	-45.93	277.51
BAG-0002169	72.05	66.76	61.09264	-159.84	-185.51
BAG-0002168	181.78	176.69	173.1322	95.17	44.74
BAG-0002168 (2)	139.55	138.20	134.6446	56.68	-12.99
BAG-0002167	195.21	192.14	182.5957	110.40	70.98
BAG-0002166	244.93	203.27	190.9775	32.82	-26.80
BAG-0002165	43.51	41.82	30.69494	-12.77	-24.33
BAG-0002164	160.74	157.70	152.7113	84.41	-6.98
BAG-0002162	72.74	67.40	59.1859	-26.85	-61.47
BAG-0002162 (2)	101.82	101.32	93.10388	7.06	-1.49
BAG-0002161	58.33	56.12	48.48284	-88.88	-95.81
BAG-0002160	114.13	112.51	99.03444	21.40	-8.04
BAG-0002159	131.69	115.61	106.7974	37.16	2.22
BAG-0002158	469.67	428.47	421.0237	251.09	133.69
BAG-0002157	80.68	77.04	69.7397	-51.62	-94.61
BAG-0002156	52.70	51.30	31.30612	7.64	20.75
BAG-0002155	63.55	60.43	50.60009	-22.07	-47.47
BAG-0002154	125.62	124.15	109.7332	-12.06	-33.47
BAG-0002153	169.13	167.67	147.6323	123.20	87.96
BAG-0002150	255.29	249.51	237.0774	107.27	0.36
BAG-0002150 (2)	256.23	249.76	237.321	107.51	1.21
BAG-0002149	109.76	103.63	93.85711	40.45	12.29
BAG-0002147	71.05	69.13	58.16942	29.90	23.53
BAG-0002146	77.75	70.61	63.69175	19.82	10.68
BAG-0002145	54.79	51.25	42.78285	10.71	-10.66
BAG-0002143	47.67	45.24	36.71842	0.29	-7.54
BAG-0002143 (2)	39.46	38.16	29.63787	-6.79	-17.25
BAG-0002142	34.46	26.95	18.00412	-33.63	-26.30
BAG-0002141	55.92	53.82	40.32015	-7.02	-9.58
BAG-0002140	96.30	88.56	66.79669	29.58	14.46
BAG-0002140 (2)	122.91	118.83	97.06686	59.85	44.58
BAG-0002139	102.94	99.33	92.00943	85.21	55.51
BAG-0002139 (2)	17.57	13.77	6.447221	-0.35	5.06
BAG-0002138	65.28	61.59	46.4405	-20.82	-38.93
BAG-0002136	68.63	66.14	56.28205	31.15	15.86
BAG-0002135	156.69	145.52	136.595	-2.51	-75.53
BAG-0002134	97.02	95.88	86.66597	38.61	4.06
BAG-0002133	28.17	24.91	20.74356	-5.44	-13.11

APPENDIX E: Comparison BaaS vs No BaaS in percentage by customer. TTW.

BAG #	Comparison Baas vs No BaaS %					
	Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions	No BaaS
BAG-0002250	71%	67%	67%	-20%	-100%	0%
BAG-0002236	81%	79%	72%	-8%	-66%	0%
BAG-0002232	48%	44%	30%	-36%	-83%	0%
BAG-0002232 (2)	42%	40%	26%	-40%	-88%	0%
BAG-0002227	-7%	-33%	-57%	-165%	-143%	0%
BAG-0002227 (2)	57%	-17%	-42%	-149%	-126%	0%
BAG-0002225	68%	66%	52%	-17%	-69%	0%
BAG-0002224	106%	94%	65%	9%	-1%	0%
BAG-0002220	169%	144%	132%	55%	0%	0%
BAG-0002220 (2)	481%	373%	361%	284%	197%	0%
BAG-0002219	-8%	-16%	-37%	-132%	-143%	0%
BAG-0002218	32%	28%	23%	-119%	-156%	0%
BAG-0002217	10%	9%	-7%	-128%	-146%	0%
BAG-0002214	-32%	-39%	-46%	-183%	-210%	0%
BAG-0002213	26%	15%	3%	-73%	-131%	0%
BAG-0002212	91%	63%	51%	-22%	-79%	0%
BAG-0002212 (2)	57%	51%	40%	-34%	-90%	0%
BAG-0002211	-59%	-63%	-67%	-153%	-166%	0%
BAG-0002211 (2)	-44%	-59%	-63%	-149%	-162%	0%
BAG-0002209	24%	12%	-28%	-107%	-97%	0%
BAG-0002208	147%	143%	126%	11%	-50%	0%
BAG-0002208 (2)	3%	0%	-17%	-132%	-166%	0%
BAG-0002207	-12%	-27%	-34%	-172%	-190%	0%
BAG-0002206	83%	78%	44%	-8%	-31%	0%
BAG-0002205	39%	36%	12%	-93%	-99%	0%
BAG-0002201	41%	38%	21%	-42%	-82%	0%
BAG-0002200	82%	80%	75%	-67%	-92%	0%
BAG-0002199	74%	64%	43%	-24%	-55%	0%
BAG-0002198	48%	35%	7%	-91%	-118%	0%
BAG-0002198 (2)	21%	5%	-23%	-122%	-143%	0%
BAG-0002197	74%	61%	45%	-24%	-47%	0%
BAG-0002194	47%	38%	15%	-95%	-122%	0%
BAG-0002193	6%	-11%	-27%	-150%	-189%	0%
BAG-0002192	59%	56%	41%	-30%	-79%	0%
BAG-0002191	86%	78%	67%	-10%	-88%	0%
BAG-0002189	-9%	-32%	-58%	-160%	-139%	0%
BAG-???	33%	30%	2%	-96%	-102%	0%
BAG-0002188	-14%	-22%	-34%	-162%	-190%	0%
BAG-0002188 (2)	55%	24%	12%	-116%	-127%	0%

BAG #	Comparison Baas vs No BaaS %					
	Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions	No BaaS
BAG-0002187	268%	264%	254%	125%	73%	0%
BAG-0002181	74%	71%	54%	-17%	-48%	0%
BAG-0002180	50%	48%	43%	-38%	-106%	0%
BAG-0002178	16%	9%	0%	-78%	-138%	0%
BAG-0002176	35%	27%	2%	-105%	-108%	0%
BAG-0002175	-17%	-25%	-31%	-170%	-202%	0%
BAG-0002174	503%	496%	476%	371%	223%	0%
BAG-0002173	0%	-16%	-37%	-104%	-100%	0%
BAG-0002172	22%	12%	5%	-131%	-189%	0%
BAG-0002171	12%	10%	0%	-122%	-158%	0%
BAG-0002170	-27%	-27%	-97%	-111%	-42%	0%
BAG-0002169	-73%	-75%	-77%	-165%	-176%	0%
BAG-0002168	88%	83%	79%	-5%	-58%	0%
BAG-0002168 (2)	44%	43%	39%	-45%	-119%	0%
BAG-0002167	93%	90%	81%	6%	-34%	0%
BAG-0002166	15%	-5%	-11%	-89%	-117%	0%
BAG-0002165	-2%	-6%	-31%	-135%	-162%	0%
BAG-0002164	85%	81%	76%	-6%	-113%	0%
BAG-0002162	3%	-5%	-17%	-145%	-195%	0%
BAG-0002162 (2)	45%	44%	32%	-96%	-108%	0%
BAG-0002161	-65%	-66%	-71%	-157%	-162%	0%
BAG-0002160	58%	56%	37%	-75%	-117%	0%
BAG-0002159	120%	93%	78%	-43%	-103%	0%
BAG-0002158	123%	103%	99%	16%	-40%	0%
BAG-0002157	-15%	-19%	-27%	-162%	-208%	0%
BAG-0002156	30%	26%	-23%	-84%	-52%	0%
BAG-0002155	-2%	-7%	-23%	-141%	-181%	0%
BAG-0002154	19%	17%	4%	-117%	-138%	0%
BAG-0002153	249%	246%	205%	153%	78%	0%
BAG-0002150	43%	40%	33%	-43%	-104%	0%
BAG-0002150 (2)	44%	40%	33%	-43%	-104%	0%
BAG-0002149	43%	35%	22%	-51%	-88%	0%
BAG-0002147	51%	47%	24%	-39%	-53%	0%
BAG-0002146	27%	15%	4%	-72%	-87%	0%
BAG-0002145	13%	6%	-12%	-81%	-127%	0%
BAG-0002143	32%	25%	2%	-105%	-128%	0%
BAG-0002143 (2)	9%	5%	-18%	-125%	-155%	0%
BAG-0002142	-27%	-44%	-63%	-178%	-163%	0%
BAG-0002141	7%	3%	-23%	-119%	-125%	0%
BAG-0002140	29%	18%	-11%	-63%	-84%	0%
BAG-0002140 (2)	65%	60%	31%	-22%	-43%	0%
BAG-0002139	581%	556%	508%	461%	261%	0%
BAG-0002139 (2)	8%	-18%	-66%	-113%	-78%	0%
BAG-0002138	-4%	-10%	-32%	-137%	-164%	0%
BAG-0002136	63%	57%	34%	-29%	-66%	0%
BAG-0002135	37%	27%	19%	-109%	-174%	0%
BAG-0002134	40%	39%	25%	-48%	-99%	0%
BAG-0002133	14%	0%	-17%	-133%	-166%	0%

APPENDIX F: Comparison BaaS vs No BaaS in percentage by customer. WTW.

BAG #	Comparison Baas vs No BaaS %					
	Bagbooking	Best options	No ground segment	Bagbookin g with cargo savings	Min emissions	No BaaS
BAG-0002250	78%	75%	74%	-13%	-95%	0
BAG-0002236	88%	86%	79%	-1%	-60%	0
BAG-0002232	53%	49%	35%	-30%	-78%	0
BAG-0002232 (2)	47%	45%	30%	-35%	-83%	0
BAG-0002227	-3%	-29%	-55%	-160%	-138%	0
BAG-0002227 (2)	62%	-13%	-39%	-144%	-121%	0
BAG-0002225	73%	71%	56%	-12%	-65%	0
BAG-0002224	111%	99%	69%	14%	4%	0
BAG-0002220	177%	152%	139%	63%	7%	0
BAG-0002220 (2)	498%	387%	374%	298%	209%	0
BAG-0002219	-4%	-12%	-33%	-127%	-137%	0
BAG-0002218	38%	34%	29%	-112%	-150%	0
BAG-0002217	15%	13%	-3%	-123%	-141%	0
BAG-0002214	-28%	-35%	-42%	-178%	-206%	0
BAG-0002213	32%	20%	8%	-68%	-127%	0
BAG-0002212	98%	69%	57%	-16%	-74%	0
BAG-0002212 (2)	63%	57%	45%	-28%	-86%	0
BAG-0002211	-57%	-61%	-66%	-151%	-164%	0
BAG-0002211 (2)	-42%	-57%	-61%	-147%	-160%	0
BAG-0002209	30%	18%	-23%	-100%	-89%	0
BAG-0002208	155%	150%	133%	20%	-42%	0
BAG-0002208 (2)	8%	4%	-13%	-126%	-161%	0
BAG-0002207	-7%	-23%	-29%	-167%	-186%	0
BAG-0002206	87%	82%	47%	-4%	-27%	0
BAG-0002205	44%	41%	15%	-88%	-94%	0
BAG-0002201	45%	43%	25%	-37%	-77%	0
BAG-0002200	90%	88%	83%	-59%	-84%	0
BAG-0002199	79%	70%	48%	-18%	-49%	0
BAG-0002198	52%	39%	11%	-86%	-112%	0
BAG-0002198 (2)	25%	9%	-20%	-117%	-137%	0
BAG-0002197	80%	67%	50%	-18%	-41%	0
BAG-0002194	52%	43%	18%	-90%	-117%	0
BAG-0002193	12%	-6%	-22%	-144%	-184%	0
BAG-0002192	65%	62%	46%	-23%	-74%	0
BAG-0002191	93%	84%	73%	-4%	-83%	0
BAG-0002189	-5%	-29%	-55%	-156%	-133%	0
BAG-???	38%	34%	5%	-91%	-96%	0
BAG-0002188	-10%	-18%	-30%	-157%	-186%	0
BAG-0002188 (2)	60%	29%	17%	-110%	-122%	0

BAG #	Comparison Baas vs No BaaS %					
	Bagbooking	Best options	No ground segment	Bagbooking with cargo savings	Min emissions	No BaaS
BAG-0002187	278%	275%	264%	136%	83%	0
BAG-0002181	80%	77%	59%	-11%	-43%	0
BAG-0002180	56%	55%	49%	-31%	-101%	0
BAG-0002178	22%	14%	5%	-72%	-134%	0
BAG-0002176	40%	33%	7%	-98%	-101%	0
BAG-0002175	-12%	-20%	-27%	-165%	-198%	0
BAG-0002174	515%	507%	487%	384%	234%	0
BAG-0002173	5%	-12%	-34%	-100%	-96%	0
BAG-0002172	28%	18%	11%	-125%	-184%	0
BAG-0002171	16%	14%	3%	-116%	-154%	0
BAG-0002170	-26%	-27%	-97%	-110%	-41%	0
BAG-0002169	-71%	-73%	-76%	-164%	-174%	0
BAG-0002168	96%	91%	87%	3%	-52%	0
BAG-0002168 (2)	51%	49%	45%	-39%	-114%	0
BAG-0002167	100%	97%	87%	13%	-27%	0
BAG-0002166	20%	0%	-6%	-84%	-113%	0
BAG-0002165	2%	-2%	-28%	-130%	-157%	0
BAG-0002164	92%	88%	82%	1%	-108%	0
BAG-0002162	7%	-1%	-13%	-140%	-191%	0
BAG-0002162 (2)	50%	49%	37%	-90%	-102%	0
BAG-0002161	-63%	-65%	-70%	-156%	-160%	0
BAG-0002160	63%	61%	42%	-69%	-112%	0
BAG-0002159	127%	99%	84%	-36%	-96%	0
BAG-0002158	130%	110%	107%	23%	-34%	0
BAG-0002157	-11%	-15%	-23%	-157%	-204%	0
BAG-0002156	32%	29%	-21%	-81%	-48%	0
BAG-0002155	2%	-3%	-19%	-135%	-176%	0
BAG-0002154	23%	21%	7%	-112%	-133%	0
BAG-0002153	253%	250%	208%	157%	83%	0
BAG-0002150	49%	46%	38%	-37%	-100%	0
BAG-0002150 (2)	49%	46%	38%	-37%	-99%	0
BAG-0002149	48%	40%	27%	-45%	-83%	0
BAG-0002147	56%	52%	27%	-34%	-48%	0
BAG-0002146	33%	20%	9%	-66%	-82%	0
BAG-0002145	18%	10%	-8%	-77%	-123%	0
BAG-0002143	37%	30%	6%	-99%	-122%	0
BAG-0002143 (2)	13%	10%	-15%	-120%	-150%	0
BAG-0002142	-24%	-40%	-60%	-174%	-158%	0
BAG-0002141	11%	7%	-20%	-114%	-119%	0
BAG-0002140	33%	22%	-8%	-59%	-80%	0
BAG-0002140 (2)	69%	64%	34%	-18%	-39%	0
BAG-0002139	588%	564%	515%	469%	271%	0
BAG-0002139 (2)	17%	-8%	-57%	-102%	-66%	0
BAG-0002138	0%	-6%	-29%	-132%	-159%	0
BAG-0002136	69%	62%	38%	-23%	-61%	0
BAG-0002135	43%	33%	25%	-102%	-169%	0
BAG-0002134	46%	44%	30%	-42%	-94%	0
BAG-0002133	22%	8%	-10%	-124%	-157%	0

