# Air freight transport

## A strategic modelling approach on a global scale

GEORGIOS TZIMOURTOS

Master Thesis

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# Air freight Transport

## A strategic modelling approach on a global scale

By

**Georgios Tzimourtos**

Student number: 4185269
E-mail: George.tzimourtos@gmail.com

in partial fulfilment of the requirements for the degree of

**Master of Science**

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Thesis committee: **Prof.dr.ir. L.A. Tavasszy – TLO/TPM**

**Dr. Ron van Duin (J.H.R.) – TLO/TPM**

**Dr. Milan Janic – CiTG**

**Dr. B.F. (Bruno) Santos – ATO/L&R**

An electronic version of this thesis is available at http://repository.tudelft.nl/.

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*"Man must rise above Earth to the top of the atmosphere and beyond, for only then will he fully understand the world in which he lives"*

*Socrates (469-399 BC)*

# Preface

While I was studying for my diploma in civil engineering, I have seen how this field of study integrates with, supports and facilitates constantly every aspect of the human activity. Along the way it became clear to me that the common factor, the sole dimension that links all of these activities is time. Transportation and logistics is one of the very few, if not the only, ways to fiddle with time itself at a large scale, making it possible to perform more and more human activities within the same time. The same principal holds also when transport of goods is in question and, since that concept is something that fascinates me, I wanted to research the fastest of all modes, air transport. Unsurprisingly, the objective of this master thesis is can be summarised as follows:

*"To research the air transport industry and transport modelling methods in order to determine if and how can they be adapted towards developing a strategic model for global air freight flows."*

Although the task in hand seemed, in the beginning, very hard, through perseverance, dedication and hard work it was completed, resulting in a comprehensive analysis of transport modelling and the air freight industry as well as a strategic descriptive model that manages to capture global air freight realistically. While working on this thesis, I also noticed the existence of a gap in the literature, regarding transport modelling and air transport, as well as limited knowledge on the particular subject amongst my peers. For that reason, this thesis was structured in such a way that could serve as the starting point of anyone that would like to work on similar topics, containing all the necessary information in one place.

Besides hard work, this research would not be finished without the guidance of my assessment committee, the four of whom I wish to deeply thank. Professor Lori Tavasszy, who was always easy to reach, who gave me the opportunity to work on a topic that suits my interests and was always providing me with advice towards the right direction. Especially in the beginning, this was essential in keeping me focused. Ron van Duin who always had valuable, on-point remarks to give to me, helping me dearly in producing work of good quality. Bruno Santos, who kept me in check, questioning my decisions and forcing me to rethink, adapt and avoid mistakes. Besides the knowledge he brought to the table, he always sacrificed valuable time to review my work in detail, providing me with valuable remarks. Also, I would like to thank Milan Janic for being a part of this committee.

Last but not least, I would like to thank my family for their unconditional support and understanding throughout my studies, here at TU Delft as well as beforehand. All my friends and everyone who supported me in any way, shape or form, you mean the world to me. And finally, Min Lin, who, through her own work and ways, inspired me to push forward, kept me focused and made this journey a pleasant time, you are the best!

George Tzimourtos

May 10th, 2015

# Executive Summary

## *Background of the research*

Air transport provides a suitable way of transport for special types of freight such as emergency freight (spare parts, documents), high-value freight (gold, currency, and artwork) and perishables (pharmaceuticals, fresh food, cut flowers) as these products have very short shelf life and benefit from fast transit times. Air transport is also responsible for most of the value added. As stated by Boeing, even though air freight accounts for fewer than 2 per cent of total tonnage transported, it represents almost 40 per cent of aggregate value of total world trade, proving that it is a link of paramount importance for the global supply chains.

Descriptive models can aid decision makers in their understanding of the response of global air freight flows to external factors such as the global economy and technological innovation and provide a quantitative underpinning of forecasts and of business cases for investment. Although in the air freight transport business, use is often made of long term forecasts, there is little shared knowledge about which methods should be preferred, and hardly any literature at the scientific level.

Transport models were originally developed for passengers and ensuingly applied in freight. Although it is accepted that the four-step transport modelling methodology is a fitting framework for freight, many fundamental differences exist between them such as diversity in decision makers, commodities transported, mode properties, the networks etc. In the particular case of air freight transport, these elementary dissimilarities call for an adaptation of the existing methods, towards a modelling framework better suited for the airborne movement of goods. There lacks a strategic model for air freight flows at the global scale that overcomes the insufficiencies of passenger oriented models. This research contributes to the literature by formulating a model for global air freight demand and network flows.

## *Scope of the research*

This study considers international air freight transport at the global level. The definition of air freight included traded commodities that use this particular mode of transport thus leaving air mail outside of the scope. As the objective is set for the global scale, the level of detail will be limited on trade flows between world regions. Air transport at an intra-regional level is not taken into account. The focus is on air freight region-to-region flows, aggregated from a country level in order to leave the possibility for further detailing on specific routes if data become available. This study considers initially all types of commodities and two modes of transport, sea and air. A descriptive, technical approach is chosen from the perspective of the forwarder/shipper.

## *Research approach*

The main research question answered in this study is:

*"How can global air freight transport be modelled and how can traditional freight transport modelling methodologies be adjusted to model this particular transport industry?"*

The problem is addressed in four phases. The first consists of an in-depth literature review on two fronts, freight transport modelling and the air transport industry. The outcome of this first phase is the creation of an envelope that includes all the underlying important factors shaping the air freight landscape, ensuring that the following, more detailed steps, will be constructed within a realistic environment.

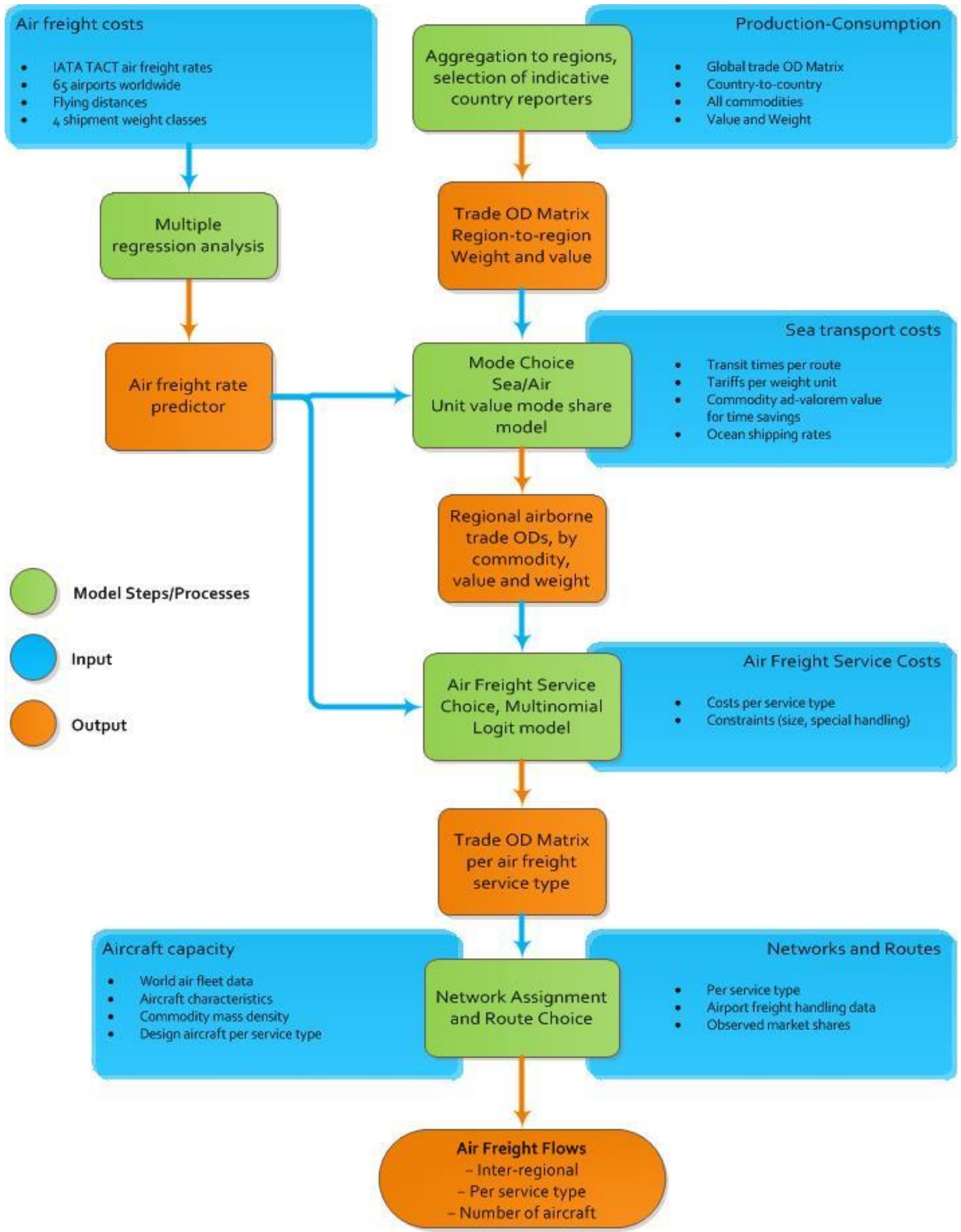
Secondly, a modelling framework that fits the objective of this master thesis is developed. This is accompanied by a multiple regression analysis on the relation of air freight rates with flying distance and shipment size, using data from IATA's The Air Cargo Tariff and Rules (TACT). Subsequently, the model is formulated in detail. Having developed the model, phase three commences. Here, after the model for air freight transport is run and calibrated, the results are presented, analysed and validated. Moreover, a sensitivity analysis is performed on key points of the model results to further test its validity and uncover any gaps and inconsistencies.

Finally, in phase four, the conclusions of this research are presented, based on the findings of the model as well as the knowledge gained from all previous phases. Alongside, recommendations for further research on the subject of air freight transport modelling are given.

## *Development of a modelling framework for air freight*

On the basis of an extensive literature review and research, the transport modelling techniques and methodologies are identified and the air freight transport industry is analysed. The general concept of the existing five-step freight transport modelling is found to be a proper foundation, upon which the model in question can be built with the necessary adjustments. More specifically, the dimension of time is inserted into mode choice with the integration of commodity-specific time savings, expressed in the form of percentage of commodity unit value. Moreover, another modification to the existing framework is that of the service choice step. This allows the model to adapt to the air freight transport environment in a mode-specific way and enables it to produce realistic results.

With the help of certain simplifications and assumptions, these are combined and synthesized into a model consisting of five steps namely 1) determination of demand for freight transport; 2) mode choice between sea and air transport; 3) service choice within air transport (i.e., between passenger aircraft belly cargo, cargo-only, and integrator services); 4) route choice; and 5) network assignment and flows. The model steps, inputs and outputs can be seen in the figure below.


Air freight costs
IATA TACT air freight rates
65 airports worldwide
Flying distances
4 shipment weight classes
Aggregation to regions, selection of indicative country reporters
Production-Consumption
Global trade OD Matrix
Country-to-country
All commodities
Value and Weight
Multiple regression analysis
Trade OD Matrix Region-to-region Weight and value
Air freight rate predictor
Mode Choice Sea/Air Unit value mode share model
Sea transport costs
Transit times per route
Tariffs per weight unit
Commodity ad-valorem value for time savings
Ocean shipping rates
Regional airborne trade ODs, by commodity, value and weight
Model Steps/Processes
Input
Output
Air Freight Service Choice, Multinomial Logit model
Air Freight Service Costs
Costs per service type
Constraints (size, special handling)
Trade OD Matrix per air freight service type
Aircraft capacity
World air fleet data
Aircraft characteristics
Commodity mass density
Design aircraft per service type
Network Assignment and Route Choice
Networks and Routes
Per service type
Airport freight handling data
Observed market shares
Air Freight Flows
– Inter-regional
– Per service type
– Number of aircraft

## Results

The model is calibrated firstly using observed global freight transport mode split figures for air, in terms of value and weight, and secondly with the use of air freight service type market shares taken from literature. The results are then presented at a global as well as region level.

At the global level, the result is a mode split for air freight of 42.5% in value and 2.9% in weight of total trade. Three main markets for air freight are identified, these of Europe, North America and Asia with the flows between them having the largest market share. Combined, these markets concentrate roughly 70% or the airborne trade in weight and value. Most of the air freight traffic is originating from the region of Asia, which amounts for almost half of total air freight tonkilometers, with Europe following with a quarter of the total. Results also show the imbalance in export and import air freight flows. Clearest examples there are the regions of Asia and North America with import to export weight ratios of 1:6 and 4:1 respectively. The regions of Europe and Middle East are the exceptions as the model shows they have an almost perfect balance in weight imports to exports. The same ratios in terms of value seem to be rather balanced throughout the global airborne trade, with the exception of Latin America where the import to export value ratio is 1:2.4.

Furthermore, as all commodities are initially taken into account, after the mode choice step the model gives results for the commodity mix of the airborne trade. On that front, it is found that commodities of SITC Rev.4 classes 5 (Chemicals and related products), 6 (Manufactured goods classified by material), 7 (Machinery and transport equipment) and 8 (Miscellaneous manufactured articles) are the main components of airborne trade. Combined, these types of commodities amount to almost 95% of the airborne trade mix both in value and weight. Amongst them, commodity class 7 has the highest share, with around 36% of the total air trade value and weight originating from that class. The analysis of the airborne trade commodity mix results showed an average value density of 21.63 US$/kg.

Additionally, the model gives results regarding the air freight service choice. Three types of services are considered namely freight transported in the cargo hold of passenger aircraft (Belly), freight transported with cargo-only aircraft (Cargo) and integrated services that cover the whole supply chain (integrators). It is found that belly has the highest share in terms of weight with 50% while cargo has the highest share in value with 59.6%. For these two service types, commodity classes 5 and 7 are found to be the major demand generators. Integrator services have a smaller market share of around 15% but is the only service type that has a higher share in value than in weight. The commodity mix for integrators is comprised by the higher, more expensive end of all the air freight commodity classes.

Finally, the general results are presented in the form of international air freight flows, followed by results on a regional level, sensitivity analysis and validation. The model is found to produce realistic results within the rational range set by observed air freight volumes.

## Conclusion

The conclusion of this research is that the existing freight transport modelling five-step framework can be adapted successfully to the air freight industry. The necessary adaptations are essentially two. First the dimension of time needs to be incorporated in the mode choice, as it lies in the heart of air transport. Choosing a mode based solely on the transport costs and the value of the goods to be transported is not adequate. The rate with which commodities lose their value is the key here, as this is the indicator of how valuable time savings from choosing a faster mode are. The unit value mode share model used for the purposes of this study provides us with a suitable tool for that purpose generating, on the other hand, the need to keep updated commodity-specific values as such. Secondly, the third, additional to the traditional methods, step that is described in the five step freight modelling methodology as logistics services, needs to be transformed into a service choice step. Because of the nature and structure of air freight transport, networks and routes are directly linked with the type of service and, therefore, demand has to be assigned to distinguished service types before moving forward. In this part, there is a lot of room for further research in order to clearly separate the different services and perform this step with better precision.

The model presented in this study is a rather simple modelling approach but, nevertheless, the results show the validity of the method. It is demonstrated the model has the ability to capture the air freight transport industry realistically, producing results that do not differ significantly from the observed values. To conclude, the research question of this thesis has been answered, by showing the appropriate adjustments, to the traditional methodology, needed for air freight, and has achieved its objective by developing a model for global air freight transport.

# Chapter 1: Introduction

Within the highly globalized economy of nowadays, global supply chains have emerged providing the ability to link demand and supply virtually from anywhere to anywhere. Physical barriers, time sensitive commodities, economic growth and technological innovations are continuously pushing for better, faster, bigger and cheaper modes of transport. The air freight industry, being in the forefront of modern transport, provides solutions that can meet the requirements of future freight transportation.

According to Boeing, air freight is defined as "*Property other than mail, express, or passenger baggage tendered to an air carrier for transportation"* (The Boeing Company, 2003), meaning shipments of heavy and/or large nature. In that, it is distinguished from the more general term "Air cargo" which includes all of the aforementioned types.

Air transport provides a suitable way of transport for special types of freight such as emergency freight (spare parts, documents), high-value freight (gold, currency, and artwork) and perishables (pharmaceuticals, fresh food, cut flowers). Because these products have very short shelf life, they benefit from fast transit times (Morrell, 2011). Air transport is also responsible for most of the value added. As stated by Boeing, even though air freight accounts for fewer than 2 per cent of total tonnage transported, it represents almost 40 per cent of aggregate value of total world trade, proving that it is a link of paramount importance for the global supply chains. This shows the very high value to weight ratio that characterizes air freight shipments, a fact that is expected when one considers that the transport costs by air can be up to ten times higher than those of other modes (Shaw, 2007).

The present document was prepared as part of the study program for the Master of Transport, Infrastructure and Logistics at TU Delft and accompanies the research undertaken for the purposes of the thesis project. In the next pages, the reader is introduced in the subject of this research as well as the methods used to achieve its objective.

## 1.1 Problem statement

Transport models were originally developed for passenger transport and ensuingly applied in freight transport. Although it is generally accepted that the four-step transport modelling methodology is a fitting framework for freight, many fundamental differences exist between the various transport modes such as diversity in decision makers, commodities transported, mode properties, the infrastructure and also the networks and their characteristics, both physical and theoretical. In the particular case of air freight transport, these elementary dissimilarities call for an adaptation of the existing methods, towards a modelling framework better suited for the airborne movement of goods. Moreover, modelling attempts in air transport so far have only been focused on passenger flows, usually in a microscopic scale. There lacks a strategic model for air freight flows at the global/intercontinental scale that overcomes the insufficiencies of passenger oriented models.

Furthermore, even parts that are found in both freight and passenger models such as mode choice, time of day and route choice they differ greatly and have diverse effects on the outcome. When air transport is considered thought, it has a unique characteristic because this is the mode of transport where the highest integration between passengers and freight is observed (Samar Ali, 2011). Although one can easily differentiate between cargo-only and passenger airlines, that divergence becomes more and more transparent, especially after the recent economic crisis, with belly capacity catching a big share of the market and even low cost passenger carriers increasingly entering the air cargo market (McCurry, 2013). Therefore, in order to capture the air freight industry, there is a need to review and adapt existing methodologies and incorporate both sides of transport modelling.

There is great uncertainty on the effect of future developments on the air freight transport sector. As environmental awareness becomes greater and plays a key role in decision making, a potential growth might not be sustainable. On the other hand, changes in flow volumes and/or direction can lead to problems such as overcapacity or lack thereof. Deeper insight on the matter is crucial for decision and policy making as well as for future investments. At the moment the available tools seem inadequate and developing a model approach can aid in improving this shortcoming by using existing methodologies and adapting them accordingly for the air freight sector.

Descriptive models can aid decision makers in their understanding of the response of global air freight flows to external factors such as the global economy and technological innovation and provide a quantitative underpinning of forecasts and of business cases for investment. Although in the air freight transport business, use is often made of long term forecasts, there is little shared knowledge about which methods should be preferred, and hardly any literature at the scientific level. This paper contributes to the literature by formulating a model for global air freight demand and network flows.

## 1.2 Research question and objectives

In order to address the challenge, the main objective of this research is to build a suitable framework that will be the guide to then developing a model, suitable for the global air freight transport industry. This will be made possible by defining the very specific needs and characteristics of that type of transport and then using and merging existing knowledge in transport modelling in such a way that will incorporate these special properties. Therefore, the research question for this thesis could be formulated as:

*“How can global air freight transport be modelled and how can traditional freight transport modelling methodologies be adjusted to model this particular transport industry?”*

Answering the above research question of course cannot be accomplished immediately. The path towards achieving that will be set by answering various sub-questions that are generated such as:

- How is air freight transport different from other modes?
- What other modes are in competition with air transport?
- Which are the commodities that are transported by air and why?
- Who are the key players and stakeholders in that environment?
- Which are the main trade routes associated with air-freight and why?
- What kind of network structures exist in air freight transport?
- What are the costs of air transport?
- What other factors affect the decision making regarding air transport?
- What kind of techniques and data can be used?

These questions will be categorized in appropriate research phases that start from a general overview of the industry and gradually focus in the more detailed aspects that will lead to an attempt towards modelling air freight transport.

The main objectives that this thesis will attempt to achieve are:

- To study in depth the air transport modes and the different air freight transport business models that can be utilized.
- To study and understand the air freight transport system as well as the specific commodity types that use this type of transport.
- To explore different types of freight models used and their applicability in the air-freight sector.
- To develop a model for global air freight transport.

## 1.3 Scope of this research

Inevitably, due to the time-restricted nature of this master thesis, it is necessary to determine the scope of this research in order to make this study manageable and realizable.

In terms of spatial coverage, this study will consider air freight transport at the global level. Due to the nature of this particular mode, which is used mainly for transport over long distances, the global scale is deemed as the most appropriate. As the objective is set for the global scale, the level of detail will be limited on trade flows between world regions. Air transport at an intra-regional level will not be taken into account as it introduces competition with modes of transport that cannot operate on a global scale and, therefore, are out of scope. Naturally, assumptions and simplifications will be made where necessary. The focus will be mainly on air freight region-to-region flows, aggregated from a country level in order to leave the possibility for further detailing on specific routes if data become available. Although literature provides a general idea about which are the “air-captive” goods, such as high value to weight ratio and physically perishable and/or time sensitive, this research considers all commodity classes as input. Given the global scope of this study, a technical approach is chosen from the perspective of the forwarder/shipper.

## 1.4 Approach and research methods

The problem is addressed in phases. The first consists of an in-depth literature research on two fronts, freight transport modelling and the air transport industry. The former has the purpose of reviewing the existing frameworks and methods in order to introduce the subject, provide the necessary context for the reader and gain knowledge, fundamental to building an arsenal of techniques to be used later for developing the model. The latter has the goal of acquiring the required understanding of the air transport industry on a global scale and with focus on air freight. This will lead to identifying the involved stakeholders and the underlying trends that shape the global demand. The outcome of this first phase is the creation of an envelope that includes all the underlying important factors shaping the air freight landscape, ensuring that the following, more detailed steps, will be constructed within a realistic environment.

Secondly, the focus will sharpen in order to build up an appropriate framework that fits the objective of this master thesis. This is achieved by synthesizing the findings of the previous phase into a conceptual modelling framework. Subsequently, the construction of the model will begin in detail. This phase will add precision to the scope and will help arrive at decisions regarding the correct methodology to be used, the data necessary, the modelling techniques that should accompany them and the assumptions and simplifications that are necessary. At the end of this phase, the final model will have taken form.

Having developed the model, phase three commences. Here, after the model for air freight transport is run and calibrated and the results are presented, analysed and validated. Moreover, a sensitivity analysis is performed on key points of the model results to further test its validity and uncover any gaps and inconsistencies.

Finally, in phase four, the conclusions of this research are presented, based on the findings of the model as well as the knowledge gained from all previous phases. Alongside, recommendations for further research on the subject of air freight transport modelling are given.

## 1.5 Thesis structure

The approach described above is structured in a number of chapters so as to create a comprehensive flow throughout the report and make as clear as possible how all the decisions were made and how the results were obtained.

The first chapter introduces the reader on the topic of this thesis and identifies the problem to be solved as well as the methods to be used and approach to be taken.

In the second chapter, the air freight transport industry is analysed in order to gain deep insight on how this type of transport operates. In combination with the knowledge obtained afterwards in chapter 3, it is made possible to shape a clear understanding on how air freight transport can be successfully integrated into and modelled with the freight transport modelling methodology. This chapter also provides necessary detailed information over the mode itself, information that is not found in combination with transport modelling literature.

The third chapter has two purposes. First it introduces the topic of transport modelling and the basic concepts that go with it. Secondly, it attempts to review and analyse the existing methodologies and techniques used, with a focus on freight transport modelling. In that sense, it serves as the first pillar of the structure of this study that, later, will be the basis of developing an air freight modelling methodology and achieving the objective of this thesis.

Chapter four synthesizes the findings of the previous two chapters in order to form a suitable methodology for a large scale air freight model. Additionally, the model is presented here accompanied with the data sources used and explanation over the simplifications and assumptions made in the process.

In chapter five, the results of the model are presented. More specifically, the outcome of the model is given so as to cover the subject of global air freight transport geographically (region-to-region as well as per region), economically (commodity-specific analysis with weight and value figures) and mode-wise (mode split, air freight service choice, aircraft flows). The analysis is also summed up in a global scale.

The final chapter concludes the report and contains the conclusions of the research as well as recommendations for further research on the subject of air freight transport modelling. Following, is a sketch of the thesis structure.

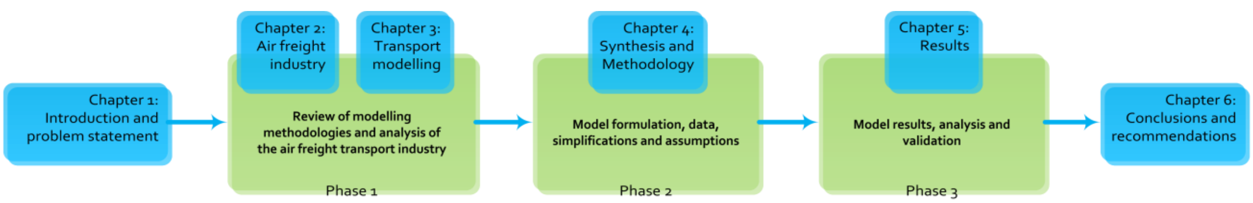



Figure 1: Schematic representation of the thesis structure

## 1.6 Contribution of this research

This research project is expected to produce a thorough and comprehensive analysis that will unveil the elemental features of air freight transport that differentiate it for other modes. Consequently, a matching framework will then be created that will nurture a model specifically designed for that type of transport. So far the norm is to use transport modelling methods that were originally developed to accommodate other modes of transport and adapt them for air transport. This research fills that gap and produces a tailored approach, specifically designed with air freight transport in mind. That can then be used by airlines and airports for better management and planning. Furthermore, it provides policy and decision with a necessary tool that can be used for determining future plans of infrastructure development etc. regarding the air transport sector.

# Chapter 2: The Air Freight Industry

In this chapter the air freight industry will be analysed in order to gain deep insight on how this type of transport operates. In combination with the knowledge obtained in chapter 3, afterwards it will be possible to shape a clear understanding on how air freight transport can be successfully integrated into and modelled with the freight transport modelling methodology. In the following paragraphs, the analysis will start with a brief introduction followed by a historical overview, identification of the players involved, the business models in air freight, the supply chain characteristics, the demand for air freight and the market around it, the aircraft as a mode of transport and finally the networks and routes that are used.

## 2.1 Introduction

Within the highly globalized economy of nowadays, global supply chains have emerged providing the ability to link demand and supply virtually from anywhere to anywhere. Physical barriers, time sensitive commodities, economic growth and technological innovations are continuously pushing for better, faster, bigger and cheaper modes of transport. The air freight industry, being in the forefront of modern transport, provides solutions that can meet the requirements of future freight transportation.

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## 2.2 A Historical Overview

Transport by air, as a concept, precedes the aircraft. Even then balloons were used to transport mail but the first air cargo movement as we understand it today, using aircraft, took place on the 7th of November in 1910 when 200 pounds of silk were transported by air, using a Model B airplane developed by the Wright brothers, from Dayton to Columbus, Ohio (Stimson, 2014), a distance of just 114 kilometres. The first steps towards a regular post service by air where taken in the following years but still, air freight was in its very early stages, just a mere fraction of the passenger market.

The technological advancements achieved during the Second World War gave air cargo a significant boost. New propeller aircraft were developed with longer range capabilities that allowed them to perform nonstop services and resulted in much higher traffic the years after the war. On top of that, the introduction of jet passenger aircraft, with the Boeing 707 being the first to offer a safe service in 1958, brought higher belly cargo capacity and speeds. By 1970, the first jet freighters and wide-body aircraft were already in service, signalling a steep increase in international air freight transport, supported by even higher capacity and much increased efficiency (The World Bank Group, 2009). The magnitude of the effect that these developments had on air freight traffic at that time is evident in Figure 2 where a steep increase in ton-km transported of slightly more than 20% is noted for the year 1974, just after the wide body aircraft introduction.

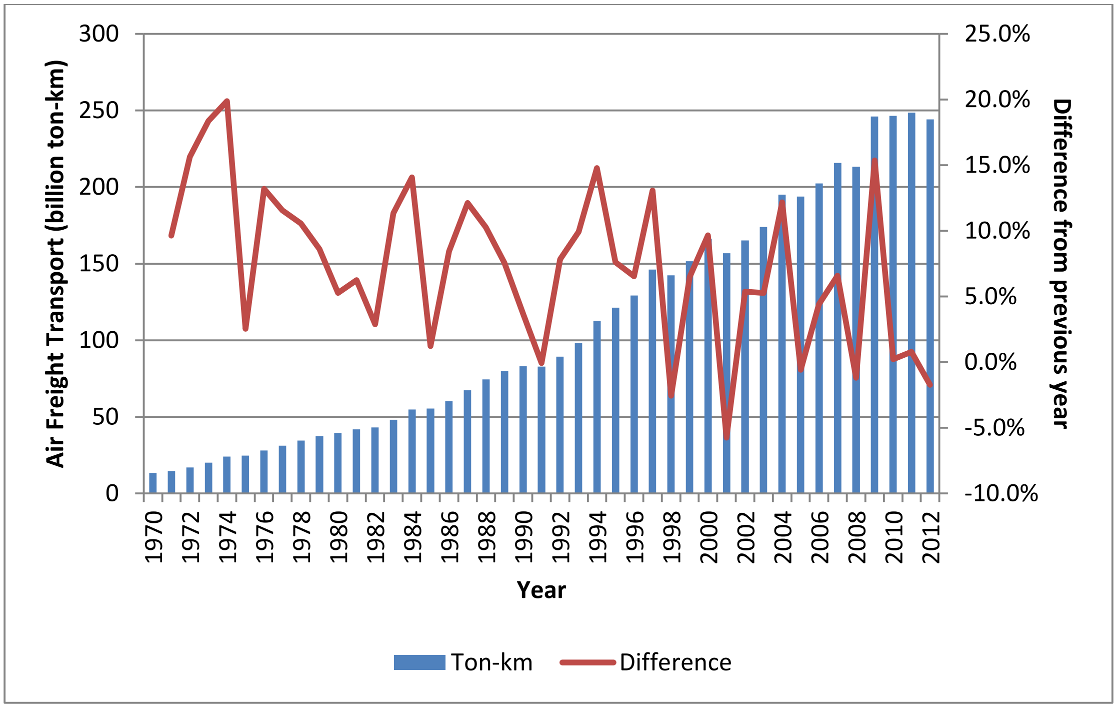



**Figure 2: Historical air freight transport volumes and the percentage of change from the previous year, compiled with data from The World Bank website (2014)**

Besides technological advancements, air freight was also assisted at that time by market deregulation in the United States with the Air Cargo Deregulation that was signed into law in 1977 moving to lift all economic controls in the industry (Bailey, 2008). That was the birth of the integrator business model with Federal Express expanding its network by shifting from small to larger aircraft and establishing an overnight express service. DHL, another major integrator, also has its roots at the same time. Moreover, another deregulation initiative followed later on with the open-skies agreements. These were implemented in order to remove restrictions that existed so far regarding the aircraft size, the number of flights and which airlines could be involved. The following years up to the 1990s where characterized by market forces in action, shaping the offered services and leading to a number of acquisitions and mergers between air cargo airlines and combination carriers. Later on, air courier services began expanding their network and including other modes such as road transport in their operations, shaping the dominant role of today's integrators.

Since then, air freight transport has shown substantial growth. Boeing (2012) in its world air cargo forecast reports 1738 freighter aircraft in operation throughout the world with 37% of them being large wide-body, 36% medium wide-body and 27% standard body aircraft. Boeing as well as Airbus projects the demand for the world freighter fleet to increase to around 3.000 airplanes by 2032 (Boeing, 2013) (Air Cargo World, 2013).

## 2.3 The Business of air freight

In this section, the key characteristics of the air freight business environment will be presented in order to make a comprehensive overview of the air freight industry. Specifically, the air cargo logistics chain, the actors as well as the types of carriers and business models found here will be discussed.

### The Air Cargo Logistics Chain and the Players Involved

The logistics chain of air transportation is set in motion right after the end customer (shipper) buys transport capacities through the freight forwarder, requesting transporting services. In total, the actors involved in that chain are the shippers or consignors, the freight forwarders, the ground handlers, the aircraft operators (or simply airlines) and the consignees. The roles and responsibilities of each will be now briefly explained.

The consignor, in other words the sender, makes the request for transport services, initiating the movement of the goods. Although consignor and shipper are terms used to depict different actions and roles, with shipper being the terminology designated for the entity that initiates the trade in goods, it is very common that those two functions are performed by the same party.

Right after the consignor/shipper com the freight forwarders as part of the transport logistics process within the supply chain and their main task is to arrange the transport of shipments from the shipper to the airport and from the airport to the consignee. One could say that they are the equivalent of a travel agent in passenger transportation. Freight forwarders are tasked with managing air shipments in such way that they are properly prepared for air transport by an aircraft operator, including any necessary consolidation of cargo. A forwarder usually does not act as carrier of goods, but instead as an organizer of the transport chain. Their offer a wide range of services that are relative to preparation, storage, carriage and final delivery of goods but can also include preparation of relevant documentation regarding customs and fiscal matters, declaring the goods for official purposes, obtaining insurance and payment collection.

The next player is the ground handlers, involved in operations between airside and landside. Quite often they can be found within the area of an airport and their services are required by freight forwarders and airlines when they do not possess the necessary equipment and/or facilities. Such services might include a variety of operational activities ranging from storage, handling and preparation of cargo to aircraft loading and unloading.

Following are the aircraft operators or more simply airlines. They are the ones that offer the actual air transport services, delivering the shipment from the airport of origin to the airport of destination. Air carriers can follow different business models and operate a variety of aircraft type and sometimes they also perform road transport for short distances using the same air waybill. Such road transport sections are also taken into account as flight segments. More regarding the air carriers will follow later in this chapter. Figure 3 represents the air cargo logistics chain in a simple and comprehensive flow chart, dividing the process in three parts.

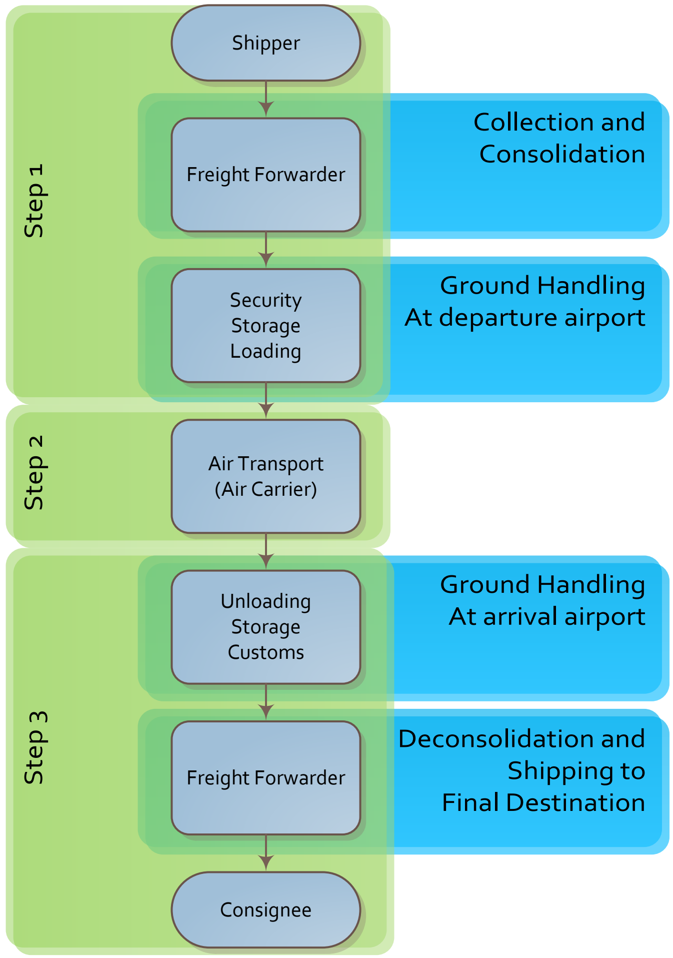



**Figure 3: The air cargo logistics chain**

In the first part, the freight forwarder arranges for the transportation of the cargo from the warehouse of the shipper to the departing airport. This part usually includes a middle node (trans-shipment centre) where the goods are first transported in order to be consolidated into larger or more suitable units. Ground handling at the departing airport takes place next, meaning the physical handling of the cargo from the storage to the aircraft.

The second step is the heart of the chain and includes the flight from the departing to the arriving airport. Completing this part is the responsibility of a variety of air carrier types, who will be discussed in the following chapters.

The third step is right after the aircraft lands at the arriving airport. It includes the ground handling and the deconsolidation and transporting of the goods to the consignee by the freight forwarder.

When we look at these steps as parts of the total transport time, the first step is estimated to account for 26%, the second for 17% and the third step for 57% of the total time needed for the transport to be completed (Scholz, 2012).

### Types of Air Freight Carriers and their Business Models

In order to understand the sector of air transport it is necessary to how the air freight carriers operate within this business environment. To achieve that, this section contains an overview the business models used in the air cargo sector. The types of airlines that operate here vary considerably with one another. Some international airlines are occupied solely with the transport of freight around the globe. Such well known examples are FED-EX, UPS and Cargolux. Most common though are business models of airlines that offer international services of transportation of both freight and passengers on the same routes and on the same aircraft. Of course, there is great variance in the degree of involvement in freight transport with some airlines producing more than half of their total revenue kilometres with freight transport (Doganis, 2010).

Cargo airlines are firstly examined by their coverage of the logistics chain. Vertically integrated carriers, the so called Integrators, offer door–to–door services that cover every step of the air cargo logistics chain between shipper and receiver, whereas airport–to–airport carriers focus on the core part of the chain. Apart from distinguishing between door–to–door and airport–to–airport providers, a third business philosophy can be differentiated the so–called Aircraft, Crew, Maintenance, Insurance Providers (ACMI Provider). ACMI providers lease their entire aircrafts (including crew) to air cargo airlines and do not offer transport services to end customers. Integrators' main customers are end customers whereas airport–to–airport providers primarily serve freight forwarders. Figure 4 gives an overview of air cargo business models.

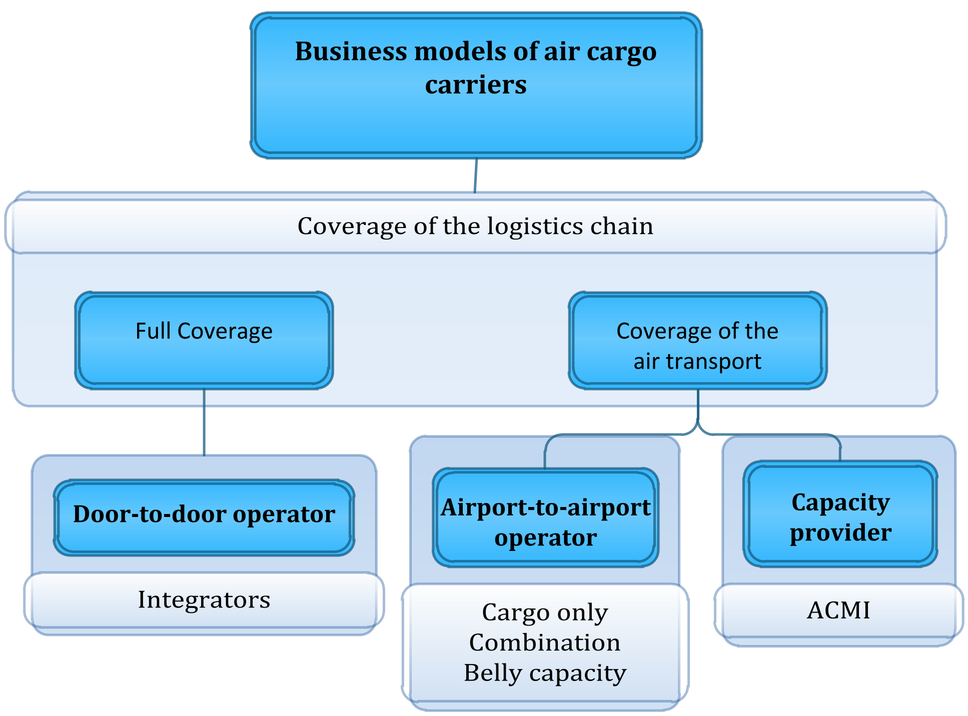



Figure 4: Cargo airlines business model classification scheme, adapted from Scholz (2012)

The figure has two steps. The first step distinguishes the business models on their coverage of the logistic chain. The second step distinguishes business models on their positioning principle in the market. These are strategies to manage a strong market position in a competitive environment, originally identified by Michael E. Porter (1998). The strategies are: cost leadership, differentiation strategy or niche strategy.

Cost leadership in a competitive market implies a very lean service and it requires easily–manufactured products (standardized products), an efficient and inexpensive distribution system and a high output level. In the air cargo sector such properties are possessed by the so–called bulk providers.

The strategy of differentiation aims for a clear distinction from competitors in order to tie customers by the added value of the offered products. Premium providers fall under that strategy category. Niche providers concentrate on services for an explicit group of customers, for a special part of the logistics chain or/and for a geographically limited market. Niche providers "can achieve their strategically limited goal more effectively and efficiently than competitors who are situated in the broad competition" (Scholz, 2012). In the following paragraphs, a brief description of these business models will be given.

### *Integrators*

Integrators are vertically integrated transport providers that cover and serve the complete air cargo logistics chain from the door of the shipper to the door of the recipient (consumer–to–consumer). The largest Integrators are FedEx, DHL, UPS and TNT. Integrators are focused on freight transport only. Therefore, only pure cargo fleets (so–called freighter aircrafts) are used which are operated on scheduled services.

### *ACMI Providers*

ACMI (Aircraft–Crew–Maintenance–Insurance) providers do their business by leasing aircrafts to airlines. ACMI providers do not sell cargo capacities to end customers but operate the transport service from the origin to the destination airport on behalf of their customer airline. The business risk of the cargo transport (e.g. utilization, rates) stays completely with the customer airline. ACMI providers bear the risk of sufficient leasing contracts for their aircrafts. The network and routing of ACMI aircrafts solely depend on the customer airline's strategy. Hereby, the ACMI operated flights are fully integrated in the network concept of the customer airline. ACMI providers and cargo airlines are therefore no competitors. ACMI providers are e.g. ABX Air, ASTAR Air Cargo and Atlas Air.

### *Airport-to-airport carriers*

The airport-to-airport carriers can be divided into several models with different strategies. Under this category, business models such as bulk, premium, niche and by-product providers can be found. Bulk providers are airport–to–airport operators with a strategy of offering under–average priced services to achieve the cost leadership in the market, through economies of scale with scheduled services, high capacities, high frequencies, efficient distribution systems and standardized products and aircrafts. Premium providers emphasize on quality and service in the area of express, special and standardized cargo and operate mostly on well-established routes. Niche providers are airport–to–airport carriers which concentrate on specialized products, that need special handling, or on selected geographical markets. Finally, by-product providers, otherwise referred to as combination carriers, are airlines focused on passenger transport, carrying at the same time limited cargo, only to achieve higher profit margins on existing flights.

## 2.4 The networks

Air freight transport operates mostly between three core markets, Asia, Europe and North-America, with Asia being the most important. (Crabtree, et al., 2006) It is inevitable then, that the air cargo network structure is built around these markets.

The two main aircraft characteristics are capacity and range, the variety of which creates network models that are better suited to serve the specific needs of each market. The very evolution of the aviation industry is largely centred on the evolution of these two parameters, which sometimes happens rapidly and other times in a slower pace. Especially the increase in aircraft range allowed the creation of new routes and connections that were formerly not possible, opening new horizons in air transport. However, capacity soon became the dominant feature of air travel. This led to the airline industry being structured in such a way where bigger aircraft ensured higher productivity, better load factors and reduced costs. The initial routes with high capacity aircraft were first established between destinations where the demand was higher. Soon, however, there were additional networks created, supplementary to these busy routes, where transferring was possible through a hub airport. This enabled passengers and cargo to be consolidated and travel longer end-to-end distances. These so-called hub-and-spoke networks were originally developed mainly in the USA and later in Europe, based on a series of mega-airports, which had the necessary infrastructure to function as incoming and outgoing gates.

This model of network structure became one of the most common in the airline industry. The key characteristic of a hub-and-spoke type of operation is the ability to consolidate traffic. Passengers and cargo are collected at the hub airport and then merged and transferred to another aircraft, usually larger that will take them to their final or intermediate destination (another hub airport). Although this can lead to major cost savings from higher aircraft utilization, it can be difficult to operate properly and efficiently as it can be affected by factors such as delays and might prove sensitive to external factors like continuous bad weather.

In recent years, some major airports have been developed as a hubs facilitating the interchange of passengers and goods, such as Frankfurt, London Heathrow and Paris CDG in Europe. Companies exploit this fact and use these hubs as bases for development and management of freight activity. They collect the goods, sort them by destination, incorporating them into large shipments of cargo and load them onto their aircraft for transport. This procedure reduces the cost per transported kg, because grouped cargo leads to higher utilization of assets. Goods can either originate from the surrounding area of airport or transferred to it by air or by road, with trucks or private Road Feeder Services from other parts of the planet.

The Road Feeder services are essentially flying trucks that have been assigned with a flight number and are subject to all procedures, obligations and rights of air transport operators. This service is offered by airlines that want to provide their customers the opportunity to send goods by air, although the airline does not serve the airport nearest to the customer. In that case the hub and spoke structure is still the same, but spreads in networks of different modes of transport. Documentation is the bonding factor here, with the form accompanying the shipment is the same as that for the air transport (AWB: Air Waybill).

From and airline business model perspective, combined carriers mostly operate network structured with Hub & Spoke configuration. The main reason for that is to integrate the air-freight transport characteristics such as demand imbalance and independence from passenger behaviour. The freighter-fleet network differentiates form the main airline in being less centralized around one hub. Integrators operate similar network configurations of global coverage, organized as a multiregional hub–and–spoke system with departures and arrivals taking place in waves. This allows them to take advantage of large scale economies between main hubs. Pure cargo airlines have network configurations that are much more robust than of combined carriers and integrators, with the round–trip structure being the major characteristic of their network configuration (Scholz, 2012).

Airlines that fly cargo and operate out of large hub airports, which they consider as their base, develop and manufacture large freight stations, so they can easily manage high volumes of goods. Typical examples are Lufthansa Cargo out of Frankfurt Airport, the Cargo Mega Terminal (CMT) of Emirates SkyCargo in Dubai, the logistics centre of DHL in Leipzig / Halle, the SAS Cargo terminal in Stockholm and Ascentis cargo terminal of British Airways World Cargo in London Heathrow.

## 2.5 The Fleet

Transporting cargo by air can be achieved with a number of different types of aircraft. The main distinction is made according to the size and the configuration of the aircraft. The available aircraft for that purpose can be distinguished in three main categories namely passenger, Combi and freighter aircraft. In this section a brief summary of each type will be given followed by more extensive description of the characteristics of the most commonly used aircraft.

### Passenger aircraft

The first available choice facilitates the transport of cargo with passenger aircraft by making use of the storage capacity in the designated cargo area underneath the passenger cabin. This cargo holding area is commonly referred to as the “belly” of the aircraft. This way, passenger airlines acquire an extra revenue stream without having to suffer significant costs as they are already covered by the passenger ticket fare. Another advantage for that type of operation is that it allows airlines to tap into cargo markets that are too small to justify a pure cargo connection. On the other hand, there are some disadvantages. Firstly, the available capacity in such aircraft is relatively small and the payload weight limit is easy to reach. Besides that, the available cargo capacity fluctuates a lot, given that it is dependent on the number of seats that have been booked and the amount of luggage that the passengers will be carrying. Furthermore, if for operational or other reasons the take-off weight of the aircraft needs to be lowered, then cargo items are the first to be unloaded as disembarking passengers is way more costly because it includes remuneration costs and tickets for the next available flight. Typical examples of such aircrafts are the Airbus A320, the Boeing 737 etc.

## Combi aircraft

The second way freight is transported is with the use of Combi aircraft on scheduled flights. In this type of aircraft, the configuration allows for cargo to be transported, besides the "belly", also on the main deck, behind the passenger area where the rear of the cabin is isolated and properly configured to transfer goods on pallets or containers, while the front retains the passenger configuration. That way it is possible to carry a significant amount of cargo and passengers without requiring the use of two different aircraft types. During the 1980s and 1990s some airlines involved both in transport of passengers and cargo chose this interim solution of Combi for the B747 and DC-10. At that time, this configuration was quite popular, especially towards destinations where the revenue from passengers was low and demand was inelastic (for example flights between Europe and sub-Saharan Africa). Consequently airlines used Combi configurations to grow their revenue at a relatively low cost. The main advantage here is the much higher transportable volume with a typical example being the Boeing 747-400M Combi.

A variation of the above type is the use of aircraft in which the configuration of the fuselage can be modified for the carriage of passengers or cargo (convertible), the so-called QC (Quick Change) aircraft. In this case, after the aircraft has completed the daily schedule passenger flight routine, the engineers remove the configuration of the passenger compartment creating more available room for cargo. Then the aircraft can be used during the night for cargo-only flights and, at the end of the night, the process is reversed and the passengers can once again embark for the first passenger flight of the day. Examples of such aircraft type that showed remarkable success are the BAe 146/Avro RJ(X) and Boeing B727. The use of smaller aircraft for longer distances and various developments in the field of aviation, led many airlines to rethink their fleet and resulted in limited use of Combi aircraft. In addition, the new security-related flight regulations regarding for example fire risk, made the construction of new dual-use (passenger-cargo) aircraft uneconomic, as the extra safety modifications increase the weight of the empty aircraft (Operating Empty Weight) and reduce load capacity.

## Cargo aircraft, Freighters

Such aircraft are specifically built to carry only cargo on all available holding areas and are used to carry large quantities or oversized cargo loads over long distances. The biggest of them are usually fitted with special cargo lifting equipment such as on board cranes and can be loaded through an opening nose or by side loading, through large cargo doors. Two major categories can be distinguished here, the first includes those manufactured as passenger and later converted to cargo after they were withdrawn from operational use and the second, which is growing rapidly, refers to those built from the beginning as cargo transport aircraft (Freighters). Typical examples of such aircraft are the Antonov AN-124 Ruslan, the Boeing 767-300F, the Airbus A330-200F and the Fokker F27.

At this point it is necessary to also mention another important distinction between aircraft that are narrow bodied and wide bodied. The point of reference here is whether there is one or two aisles between seats in the passenger cabin. Typically, narrow bodied have a fuselage of three to four meters in diameter while wide bodied aircraft range between five and six meters. Other measures used to classify aircraft include wingspan, outer main landing gear width, tail height and approach speed.

## The aerospace industry players

The two largest aircraft manufacturing companies are the American Boeing and the European Airbus. The conflict and competition between the two sides has a history of more than 50 years, while the prevalence of Airbus versus Boeing first taking place in 1999. Nevertheless, none of the two have a controlling share of the aircraft manufacturing market. In the 1980s and 1990s Boeing had clearly the upper hand as they offered a wider range of aircraft compared to Airbus while in the following decades, competition is neck to neck. The B737 model continues to dominate sales in its class, with hundreds of aircraft still being ordered. Another successful product of Boeing remains the B777, both with passenger as well as freight configuration, bridging the gap until the arrival of B787 in 2011. The unexpectedly high success B787 forced Airbus to redesign and provide the A350 XWB (Extra Wide Body) which was quite successful for a couple of years after it came out in 2006 but the showed a drop in demand and some 100 cancellation with the most recent being that of Emirates for 70 aircraft in June 2014 (BBC, 2014). Airbus bounced back mainly with the A380 which, despite some problems and delays during production, has recorded some 135 orders until 2014. Figure 5 illustrates historically the aircraft orders and deliveries for both manufacturers.

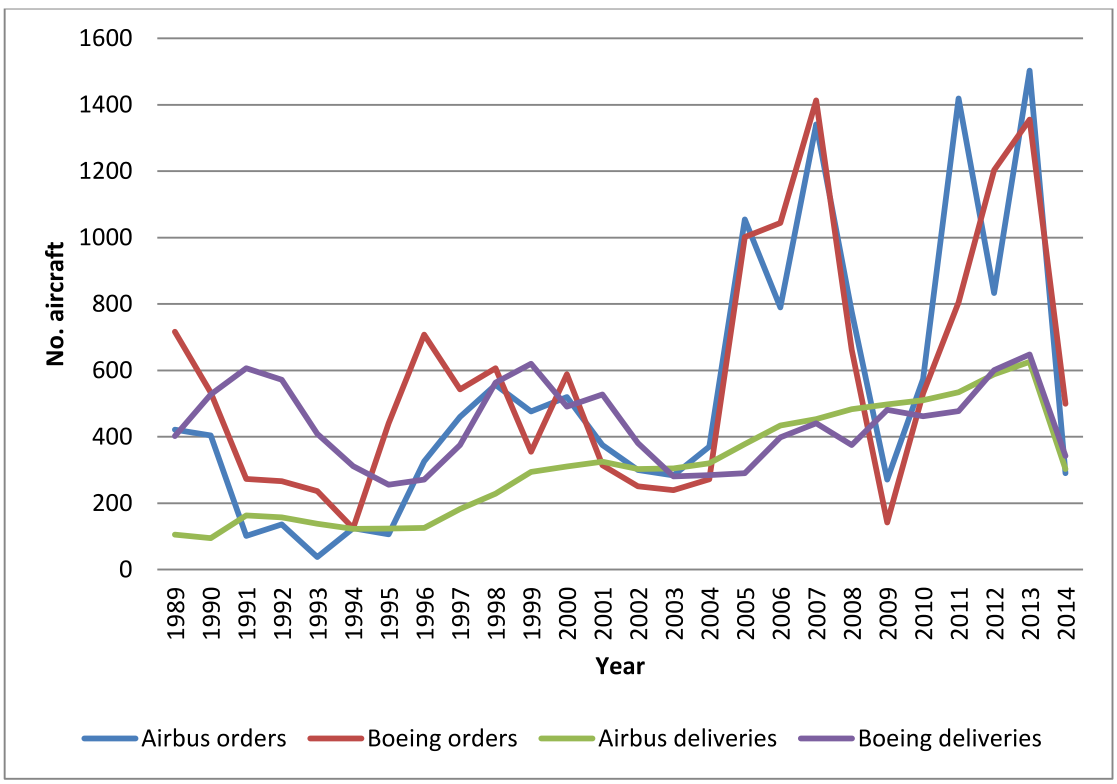



**Figure 5: History of Airbus and Boeing orders and deliveries, compiled with data from (Boeing, 2014) (Airbus, 2014)**

In terms of aircraft type, narrow-body aircraft dominate the demand, accounting for 74% of the total ordered aircraft. As far as market share is concerned, in the latest years Boeing shows better performance with wide-body aircraft and Airbus is stronger in the narrow bodied aircraft market as show in Table 1.

Table 1: Orders per type of aircraft for Boeing and Airbus

| Decade | Boeing | | | Airbus | | |
|---|---|---|---|---|---|---|
| | Narrow-body | Wide-body | Total | Narrow-body | Wide-body | Total |
| **1980s** | 1747 | 624 | 2371 | 74 | 402 | 476 |
| **1990s** | 2466 | 1232 | 3698 | 1068 | 563 | 1631 |
| **2000s** | 2974 | 966 | 3940 | 2983 | 827 | 3810 |
| **2010s** | 1603 | 585 | 2188 | 1770 | 488 | 2258 |
| **Total** | 11910 | 3821 | 15731 | 5895 | 2361 | 8256 |

Within the aircraft families of Boeing and Airbus the two most successful ones are the B737 and the A320, accounting together for 66% of them.

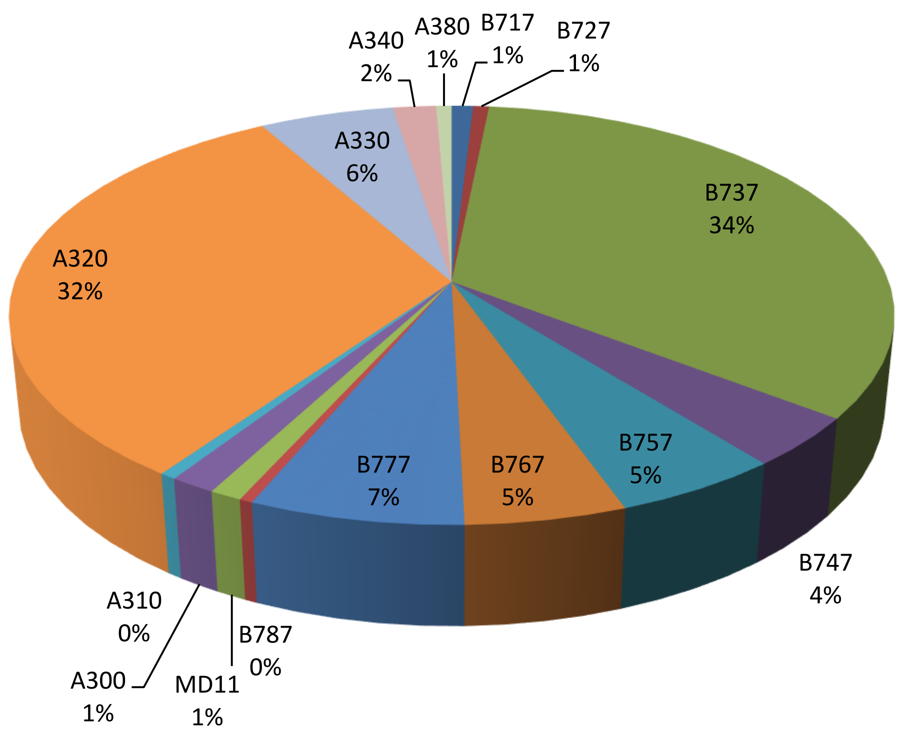



Figure 6: Shares of aircraft types within the Boeing and Airbus product families for the year 2013, compiled with data taken from Flightglobal (2013)

In the specific field of cargo market (Freighters), Boeing offers a series of aircraft that covers a variety of size, weight and type of loads from 20 tonnes with the B737-700C to 55 tons with the B767-300F, 100 tonnes with the B777F up to 135 tons with the B747-8F. In general, Boeing holds a stronger position in the freighter market, especially after Airbus abandoned the development program of A380F, the freighter version of A380.

Naturally, there are also other aircraft manufacturers that usually avoid to get in the middle of the fight between the two aerospace giants. Bombardier tried to penetrate the lower end of the market with the C-Series aircraft family, without much success (Bloomberg, 2014). The Brazilian Embraer has halt its intentions to enter the market of larger passenger aircraft, holding the ERJ and E-Jets aircraft family at the regional commuter airline level. In Russia, the airline industry tries to get on its feet with the help and support of the Russian government, with UAC working on designing and building new aircraft for the domestic and international markets. Finally, the Chinese made their first step in the area of civil aircraft manufacturing with the ARJ21 (Advanced Regional Jet for the 21$^{st}$ century). In the following paragraphs, a more detailed description of the characteristics of the most used aircraft will be given, grouped by manufacturer.

### *Airbus*

Airbus SAS has since October 2006 been 100% under the ownership of EADS (European Aeronautic Defence and Space company), now renamed as Airbus Group and consists of Airbus, Airbus Helicopters, and Airbus Defence and Space. Airbus has developed "families" of aircraft in an effort to maintain a level of homogeneity between aircraft. Below the properties of each aircraft family will be presented.

- Airbus A318/319/320/321

The A320 was the aircraft that established Airbus as a major player in the aerospace industry. The original aircraft was developed as a replacement for the Boeing 727, with wider fuselage of one aisle, larger space for cabin luggage and most importantly, a more spacious cargo holding area with wider access doors. Furthermore, it was the first passenger aircraft to incorporate fly-by-wire technology among other innovations.

**Table 2: Characteristics of the A320 aircraft family (AIRBUS, 2014a) (2014b) (2014c) (2014d)**

| | A318-100 | A319-100 A319LR A319CJ | A320-200 | A321-200 |
|---|---|---|---|---|
| **Seating capacity** | 132 | 156 | 180 | 220 |
| **Cargo capacity** | 21.21 m$^3$ | 27.62 m$^3$ | 37.41 m$^3$ | 51.73 m$^3$ |
| | | 4× LD3-46 | 7× LD3-46 | 10× LD3-46 |
| **Length (m)** | 31.44 | 33.84 | 37.57 | 44.51 |
| **Wingspan** | 34,1 or 35,8 with sharklets | | | |
| **Fuselage width** | 3.95 | | | |
| **Maximum landing weight(MLW) (t)** | 57.5 t | 62.5 t | 66 t | 77.8 t |
| **Maximum take-off weight (MTOW) (t)** | 68 t | 75.5 t | 78 t | 93.5 t |
| **Cruising speed** | Mach 0.78 (828 km/h) | | | |
| **Maximum speed** | Mach 0.82 (871 km/h) | | | |
| **Maximum range, Fully loaded (km)** | 5.900 | 6.900, LR: 10.400, CJ: 12.000 | 6.100 | 5.900 |

- Airbus A330

The A330 was the result of a development program, launched in 1987, aimed at developing a twin-engine brother aircraft for the long-haul four-engine A340. The A330 eventually evolved into two models, the basic A330-300 that entered service in 1994 and the smaller A33-200 which followed in 1998. This family type also comes with freighter configurations.

**Table 3: Characteristics of the A330 aircraft family (AIRBUS, 2014e)**

<table>
<tr><th></th><th>A330-200</th><th>A330-200F</th><th>A330-300</th></tr>
<tr><td>Seating capacity</td><td>375</td><td>12</td><td>375</td></tr>
<tr><td rowspan="2">Cargo capacity</td><td>136 $m^3$</td><td>475 $m^3$</td><td>162,8 $m^3$</td></tr>
<tr><td>26xLD3</td><td>9 AMA cont.+ 4 pallets main deck, 26×LD3 lower deck</td><td>32xLD3</td></tr>
<tr><td>Length (m)</td><td colspan="2">58,82</td><td>63,69</td></tr>
<tr><td>Wingspan</td><td colspan="3">60,3</td></tr>
<tr><td>Fuselage width</td><td colspan="3">5,64</td></tr>
<tr><td>Maximum landing weight(MLW) (t)</td><td>182</td><td colspan="2">187</td></tr>
<tr><td>Maximum take-off weight (MTOW) (t)</td><td>242</td><td>233</td><td>242</td></tr>
<tr><td>Cruising speed</td><td colspan="3">Mach 0.82 (871 km/h)</td></tr>
<tr><td>Maximum speed</td><td colspan="3">Mach 0.86 (913 km/h)</td></tr>
<tr><td>Maximum range, Fully loaded (km)</td><td>13.400</td><td>7400 (65t payload)</td><td>11.300</td></tr>
</table>

- Airbus A340

The development of long-range aircraft was included in the plans of Airbus since the early 1980s. The A340 program was launched in June 1987 alongside the A330, with both aircraft sharing the same wing, slightly differentiated fuselage and cockpit developed for the A320. The A340-300 was the first entered service with Air France in March 1993, followed by the smaller -200 in April of the same year by Lufthansa. The A340-500/600 program started in December 1997, reinforcing the key feature of the A340, the possibility to fly very large distances, with the first A340-600 entering service with Virgin Atlantic in August 2002 and the first A340-500 with Emirates in late 2003. Some models of the A340 will remain in production until at least 2015, with the future intention to replace them with versions of the A350. As it can be seen in Table 4, these aircraft have quite significant cargo transporting capabilities, combined with high range.

Table 4: Characteristics of the A340 aircraft family (AIRBUS, 2014f) (2014g)

| | A340-200 | A340-300 | A340-500 | A340-600 |
|---|---|---|---|---|
| Seating capacity | 375 | 375 | 375 | 440 |
| Cargo capacity | 162,8 $m^3$ | 162,8 $m^3$ | 153,9 $m^3$ | 207,6 $m^3$ |
| | 26xLD3 | 32×LD3 | 30xLD3 | 42xLD3 |
| Length (m) | 59,39 | 63,6 | 67,9 | 75,3 |
| Wingspan (m) | 60,3 | | 63,45 | |
| Fuselage width | 5,64 | | | |
| Maximum take-off weight (MTOW) (t) | 275 | 276,5 | 372 | 368 |
| Cruising speed | Mach 0.82 (871 km/h) | | | |
| Maximum speed | Mach 0.86 (913 km/h) | | | |
| Maximum range, Fully loaded (km) | 15.000 | 13.700 | 16.060 | 14.350 |

- Airbus A350XWB

To A350 XWB (extra Wide Body) is to a twin-engine wide-body aircraft designed for long distances. Along with some of the bigger A340, it fills the gap between the A330 and the A380. This aircraft has a fuselage 31 cm wider than the A330 and is slightly wider compare to the B787, its main rival. The A350 family includes a total of four members, three passenger and one freighter aircraft. Table 5 gives an overview of the properties of this family of aircraft.

Table 5: Characteristics of the A350XWB aircraft family (AIRBUS, 2013) (2014h)

| | A350-800 | A350-900 | A350-900F | A350-1000 |
|---|---|---|---|---|
| Seating capacity | 440 | 440 | 2 | 475 |
| Cargo capacity | 136,6 $m^3$ | 172,4 $m^3$ | 90 tons | 208,2 m3 |
| | 28xLD3 | 36×LD3 | | 44xLD3 |
| Length (m) | 60,54 | 66,89 | 66,89 | 73,88 |
| Wingspan (m) | 64,8 | | | |
| Fuselage width | 5,96 | | | |
| Maximum take-off weight (MTOW) (t) | 259 | 268 | 372 | 308 |
| Cruising speed | Mach 0.85 (903 km/h) | | | |
| Maximum speed | Mach 0.89 (945 km/h) | | | |
| Maximum range, Fully loaded (km) | 15.300 | 14.350 | 9.250 (90 tons payload) | 14.800 |

- Airbus A380

The largest and most technically complex passenger aircraft, the A380-800, entered service in October 2007 with Singapore Airlines. Despite development costs approaching 14 billion and delays due to production problems that pushed the delivery date by 12 months, the airplane is proving to be successful with demand coming from many airlines (Emirates, Qatar, Singapore, Thai, China Southern, Etihad, Kingfisher, Korean, Malaysia, Qantas, Lufthansa, Air France, Virgin Atlantic, British Airways) (Flightglobal, 2013). The A380 offers as the main advantage that of increasing the available capacity at a lower cost per passenger. Despite initial orders, Airbus announced it would gradually delay and then completely froze the development of the freighter version A380-800F. FedEx, one of the companies that had ordered 10 aircraft of this version, bought instead 15 B777F, while Emirates switched their order for passenger models.

**Table 6: Characteristics of the A380 (AIRBUS, 2014i) (2013a)**

| | A380 |
|---|---|
| Seating capacity | 853 |
| Cargo capacity | 184 $m^3$ |
| | 38xLD3 |
| Length (m) | 72,72 |
| Wingspan (m) | 79,75 |
| Fuselage width | 7,14 |
| Maximum take-off weight (MTOW) (t) | 560 |
| Cruising speed | Mach 0.85 (903 km/h) |
| Maximum speed | Mach 0.89 (945 km/h) |
| Maximum range, Fully loaded (km) | 15.700 (83t payload) |

### *Boeing*

Boeing as we know it today is the result of a series of mergers and acquisitions during the 1990s that reshaped the entire aerospace and defence industry in the USA. The process that led to the current form began in 1996 with the acquisition of Rockwell, becoming Boeing North American Inc. bringing back one of the historic names in American aviation scene, that of William E. Boeing. Following that was the merger with McDonnell Douglas, which was the third largest passenger aircraft manufacturer at the time, leaving Boeing the only manufacturer of its kind on the North American continent. After that, the only comparable competitor was the European Airbus. In the following paragraphs, the aircraft produced by Boeing and are still in operation will be presented.

- Boeing B717

The B717 was originally the McDonnell Douglas MD-95 which was announced in 1991 but remained on paper until the August of 1997, when McDonnell Douglas merged with Boeing. Its salvation is probably due to the fact that this model had no rival aircraft within Boeing at the time and for this reason the design was used to maintain their position in this market. Nevertheless, especially after September 11$^{th}$ 2001 and its impact on air transport, the B717 had little chance to survive, fighting against new aircraft families with standardized designs. The last B717 aircraft left the plant in April 2006 but there are still a few in operation, mostly in North/South America operated by Southwest airlines (Flightglobal, 2013).

**Table 7: Characteristics of the B717-200 (Boeing, 2001)**

| | B717-200 |
|---|---|
| Seating capacity | 106 |
| Cargo capacity | 26,5 $m^3$ |
| Length (m) | 37,8 |
| Wingspan (m) | 28,4 |
| Fuselage width | 3,4 |
| Maximum take-off weight (MTOW) (t) | 49,94 |
| Payload (t) | 12,9 |
| Cruising speed | Mach 0.77 (811 km/h) |
| Maximum speed | - |
| Maximum range, Fully loaded (km) | 2.690 |

- Boeing B727

The evolution of the B727 was aimed at meeting the needs of the major, at the time, airlines of the U.S.A and resulted in a final design of an aircraft with three engines, which later proved to be one of the most successful airplanes of all time. The three-engine design gave the advantage of using small airports while maintaining the ability to fly medium-haul flights. It so allowed non-stop connections between destinations that would otherwise be served through a hub airport. Besides the American market, the B727 was also successful in international flights, connecting smaller towns worldwide.

When these aircraft became available on the global market as second-hand, they were absorbed mostly by charter and cargo airlines. A characteristic example of this is FedEx that, initially, used a fleet of B727 before eventually replacing them with B757 Cargo aircraft. The development of larger newer aircraft in combination with noise regulations and the fact that the B727 needed a crew of three, led to airlines turning towards other solutions. Nevertheless, the B727 was a big success both as a passenger as well as a freighter aircraft, in a variety of versions and is still in use, with a total of 109 being in operation as of July 2013 (Flightglobal, 2013).

Table 8: Characteristics of the B727 aircraft family (Boeing, 1978)

| | B727-100 | B727-200 |
|---|---|---|
| Seating capacity | 125 | 189 |
| Cargo capacity | 25 $m^3$ | 43 $m^3$ |
| Length (m) | 40,59 | 46,68 |
| Wingspan (m) | 32,92 | 32,92 |
| Fuselage width | 3,76 | 3,76 |
| Maximum take-off weight (MTOW) (t) | 72,6 | 78,5 |
| Payload (t) | 13,8 | 17,4 |
| Cruising speed | 900 km/h | 900 km/h |
| Maximum speed | - | - |
| Maximum range, Fully loaded (km) | 3.500 | 4.000 |

- Boeing B737

The Boeing 737 is, without doubt, the most successful passenger jet of all time, with more than 12.000 orders and 8.000 deliveries throughout the 737 family. This model was developed from Boeing to fight the competition of the already existing Douglas DC-9 in the short-haul market. Boeing accelerated the design and production process by using as basis the structure of the B727 giving it the advantage of higher capacity, compared with other aircraft at the time. The first B737-100 came into service with Lufthansa in February 1968, with the continuously evolving aviation market leading almost directly to the development of the larger B737-200. The first customer for the new model was the United Airlines, which put the plane into service in April 1968. There were also cargo versions of the aircraft, the B737-200C, model that can be converted into a freighter with a side loading door, and the B737-200QC, a quick configuration change model.

Table 9: Characteristics of the early generations of the B737 aircraft family (Boeing, 2007)

| | B737-100 | B737-200 | B737-300 | B737-400 | B737-500 |
|---|---|---|---|---|---|
| Seating capacity | 96 | 124 | 134 | 159 | 122 |
| Cargo capacity | 18,4 $m^3$ | 24,8 $m^3$ | 30,2 m3 | 38,9 m3 | 23,3 m3 |
| Length (m) | 28,6 | 30,53 | 33,4 | 36,4 | 31,01 |
| Wingspan (m) | 28,3 | 28,35 | 28,88 | 28,88 | 28,88 |
| Fuselage width | 3.76 | 3.76 | 3,76 | 3,76 | 3,76 |
| Maximum take-off weight (MTOW) (t) | 44 | 45,4 | 56,4 | 62,8 | 52,4 |
| Payload (t) | 10,4 | 11,4 | 16,1 | 18 | 15,1 |
| Maximum speed | 779 km/h | 779 km/h | 790 km/h | 790 km/h | 790 km/h |
| Maximum range, Fully loaded (km) | 3,340 | 2,960 | 3,000 | 4,000 | 3,300 |

The second generation of B737-300/-400/-500 evolved based on a second generation turbofan engine, which offered increased thrust in combination with less fuel consumption compared to its predecessor. On top of that these versions came with aerodynamic improvements and an electronic flight instrumentation system borrowed from bigger aircraft families. This generation was extensively converted to freighter versions later on.

**Table 10: Characteristics of the early generations of the B737 aircraft family (Boeing, 2007)**

| | B737-600 | B737-700 | B737-800 | B737-900 |
|---|---|---|---|---|
| Seating capacity | 130 | 148 | 184 | 189 |
| Cargo capacity | 20,4 $m^3$ | 27,4 $m^3$ | 44,1 m3 | 52 m3 |
| Length (m) | 31,24 | 32,18 | 39,47 | 40,67 |
| Wingspan (m) | 34,32 | 34,32 | 34,32 | 34,32 |
| Fuselage width | 3.76 | 3.76 | 3,76 | 3,76 |
| Maximum take-off weight (MTOW) (t) | 56,2 | 60,3 | 70,5 | 74,3 |
| Payload (t) | 15,1 | 17 | 20,1 | 19,8 |
| Maximum speed | 832 km/h | 832 km/h | 832 km/h | 832 km/h |
| Maximum range, Fully loaded (km) | 5,650 | 6,040 | 5,440 | 5,080 |

In the early 1990s, the threat of the A320 family from Airbus became apparent in the short range market where the B737 was dominant. Therefore, Boeing radically renewed the aircraft and developed B737 NG (NG: Next Generation), with a 25% larger wing area, aerodynamic improvements, wing extensions and other redesigned elements that in combination with more powerful and economical engines provided higher travel speeds and longer ranges. It was decided from the outset the development of at least four versions (B737-600/-700/-800/-900), which would cover a wide range of seat capacity.

- Boeing B747

To B747 Jumbo Jet remained for decades the world's biggest passenger jet, at least until the arrival of the A380. In the 1960s, when the largest customer of Boeing, Pan American airlines, requested an aircraft with twice the capacity of the B707, Boeing responded with a double-decker design. After issues regarding safety and the ability to evacuate the aircraft quickly were surpassed, the final could accommodate up to 452 passengers, more than double the B707. Although it was an innovative, for the time, design, history proved it to be a success with more than 1500 orders up till today. The freight-oriented versions of the B747 are:

- The B747-100 which was not offered in a freighter version by Boeing but was converted to such as a second-hand aircraft and operated mostly by courier airlines.
- The 747-200C which allows the conversion from passenger to freighter aircraft. Some are equipped with front left door loading, while others have an opening tip.
- The Boeing 747-200 Combi which is practically the same as the version above, with the difference of being able to carry passengers and cargo simultaneously, with the use of partition to divide the space in the main cabin, leaving room for 200 passengers and the rest for cargo.

- The Boeing 747-200F which is the pure freighter version that can be equipped with either an opening nose or a side loading door.
- The B747-300 and -300 Combi which offered a slightly increased capacity, having a bigger area on the upper deck.

**Table 11: Characteristics of the early generations of the B747-100/-200/-200F/-300/-SP (Boeing, 1984)**

| | B747-100 | B747-200 | B747-200F | B747-300 | B747-SP |
|---|---|---|---|---|---|
| Seating capacity | 452 | 480 | - | 608 | 331 |
| Cargo capacity | 178 $m^3$ | 178 $m^3$ | 695 m3 | 178 m3 | 110 m3 |
| | 30xLD1 | 30xLD1 | 30x96/125in pallet+30xLD1 | 30xLD1 | - |
| Length (m) | 68,60 | 68,60 | 70,70 | 70,70 | 56,31 |
| Wingspan (m) | 59,64 | 59,64 | 59,64 | 59,64 | 59,64 |
| Fuselage width | 6,5 | 6,5 | 6,5 | 6,5 | 6,5 |
| Maximum take-off weight (MTOW) (t) | 322,1 | 351,5 | 351,5 | 322,1 | 147,6 |
| Payload (t) | 76,2 | 65,9 | 112,4 | 66,3 | 38,2 |
| Cruising speed | 895 km/h | 895 km/h | 895 km/h | 895 km/h | 895 km/h |
| Maximum range, Fully loaded (km) | 9,800 | 10,500 | 5,680 | 10,360 | 11,000 |

The Boeing 747-400, in a variety of versions, are the only that remain still in production, along with the newest B747-8. The freight transporting versions of -400 family are:

- The B747-400F is a freighter version that uses the fuselage of the B747-200, combining it with all the other improvements of the -400 version.
- The B747-400 Combi features the ability to carry both cargo and passengers on the main deck and is equipped with a side loading door at the back.
- The B747-400ERF (Extended Range Freighter) is a version of the -400F which has strengthened fuselage and landing gear and can carry additional fuel, being able to carry about 10 tons more and has a range of almost 1000 km more than the normal B747-400F.
- The B747-400BCF (Boeing Converted Freighter) which is the converted to freighter version of the B747-400

The main characteristics of the B747-400 freighter family can be seen in Table 12. The commonality throughout this type of aircraft is evident with the main dimensions being the same and significant differences only seen in cargo capacity and range.

Table 12: Characteristics of the early generations of the B747-400 freighter editions (Boeing, 2002)

| | B747-400 | B747-400C | B747-400F | B747-400ERF | B747-400BCF |
|---|---|---|---|---|---|
| Seating capacity | 524 | 266 | - | - | - |
| Cargo capacity | 170,5 $m^3$ | 295 $m^3$ | 779 m3 | 779 m3 | 779 m3 |
| | 30xLD1 | - | 30 pallets+3 2xLD1 | 30 pallets+3 2xLD1 | 39 pallets |
| Length (m) | 70,6 | 70,6 | 70,6 | 70,6 | 70,6 |
| Wingspan (m) | 64,4 | 64,4 | 64,4 | 64,4 | 64,4 |
| Fuselage width | 6,5 | 6,5 | 6,5 | 6,5 | 6,5 |
| Maximum take-off weight (MTOW) (t) | 396,9 | 396,9 | 396,9 | 396,9 | 394,6 |
| Payload (t) | 63,9 | 62,5 | 112,6 | 112,6 | 112,6 |
| Cruising speed | 913 km/h | 913 km/h | 901 km/h | 901 km/h | 913 km/h |
| Maximum speed | | | | | |
| Maximum range, Fully loaded (km) | 11,000 | 11,000 | 8,230 | 9,200 | 7,590 |

The relatively new B747-400 LCF (Large Cargo Freighter) Dreamlifter first flew in September 2006 and was developed as a solution for the logistics problem of carrying around the world production parts of the B787. In its final form, the B747-400LCF is equipped with an opening and rotating tail, which allows for easier direct entry of long loads. The result is more than twice the capacity of a B747-400F. Overall, Boeing produced three such airplanes to accommodate the needs of the B787 production program and there is no indication of offering it in a commercial basis.

In 2004, Boeing released plans for an airplane called B747-8 with two versions, a passenger (B747-8I) and a freighter (B747-8F), the specifications of which can be seen in Table 13.

Table 13: Characteristics of the B747-800I and B747-8F (Boeing, 2012a)

| | B747-800I | B747-800F |
|---|---|---|
| Seating capacity | 467 | 266 |
| Cargo capacity | 180 $m^3$ | 873,7 $m^3$ |
| | 7 pallets+16LD1 | 46 pallets+2LD1 |
| Length (m) | 75,24 | 75,24 |
| Wingspan (m) | 68,4 | 68,4 |
| Fuselage width | 6,5 | 6,5 |
| Maximum take-off weight (MTOW) (t) | 447,6 | 442,2 |
| Payload (t) | 76 | 131,7 |
| Cruising speed | 913 km/h | 913 km/h |
| Maximum range, Fully loaded (km) | 14,815 | 11,000 |

- Boeing B757

To original B757 was designed as a replacement for the B727 and could carry 20% more passengers for 50% longer distances. These increased capabilities where exactly the main problem with this type as it was deemed too large and too heavy, especially when compared with the B737 family. That became even more evident in the post September 11 era, as the load factors began to fall and airlines where exposed to serious financial risk. At that point smaller aircraft could handle the volumes and where more economical to run at the same time, displacing aircraft similar to the B757. In 1985 the freight version of the B757, the B757-200PF (PF: Package Freighter) was presented, with the first delivery being for UPS. It had a fuselage with no windows or passenger doors. Cargo could be loaded in cargo containers or pallets through a side door at the left side of the aircraft (Boeing, 1999). The inability of this family type to meet the main passenger market demand led to the conversion of many B757 into freighters, with 213 aircraft (B757 SF, PF and Combi) being in use in 2013, with the most intense operators being FedEx and UPS (Flightglobal, 2013).

**Table 14: Characteristics of the B757 aircraft family (Boeing, 1999)**

| | B757-200 | B757-200PF | B757-300 |
|---|---|---|---|
| Seating capacity | 228 | - | 280 |
| Cargo capacity | 43,3 $m^3$ | 52+187 $m^3$ | 67,1 $m^3$ |
| | | 15 ULDs | |
| Length (m) | 47,32 | 47,32 | 54,50 |
| Wingspan (m) | 38,05 | 38,05 | 38,05 |
| Fuselage width | 3,76 | 3,76 | 3,76 |
| Maximum take-off weight (MTOW) (t) | 115,68 | 115,68 | 122,4 |
| Payload (t) | 25,2 | 39 | 30,9 |
| Cruising speed | 843 km/h | 843 km/h | 843 km/h |
| Maximum range, Fully loaded (km) | 7,222 | 5,834 | 6,287 |

- Boeing B767

The Boeing B767 came as the successor to the B707 and the wide-body brother to the B757. That duo gave the opportunity to Boeing to advertise aircraft standardization as both types have similar cockpits, offering airlines the ease of transferring crew between the two. But as it happened with the B757, the dramatic changes in the airline market deemed it uneconomical leading to a very low number of orders for that type of aircraft. Nevertheless, another market was developed for the B767, that of conversion to freighter with Boeing offering a BCF package (Boeing Converted Freighter) for the -200 and -300 series. Freight transport airlines quickly moved to take advantage of the good payload/range performance of the -300ER with UPS being the first to order the freighter version with a B767-300F.

Table 15: Characteristics of the B767 aircraft family (Boeing, 2005) (Boeing, 2014a)

| | B767-200ER | B767-300ER | B767-300F | B767-400ER |
|---|---|---|---|---|
| Seating capacity | 290 | 290 | - | 409 |
| Cargo capacity | 86,9 $m^3$<br>22 LD2s | 114,1 $m^3$<br>30 LD2s | 432,8 m3<br>24 pall.+30 LD2 | 138,9 m3<br>38 LD2s |
| Length (m) | 48,51 | 48,51 | 55 | 61,37 |
| Wingspan (m) | 47,5 | 47,5 | 47,5 | 51,92 |
| Fuselage width | 5.03 | 5.03 | 5.03 | 5.03 |
| Maximum take-off weight (MTOW) (t) | 152 | 180 | 185,06 | 204,1 |
| Payload (t) | 32,5 | 40 | 52,7 | 46,5 |
| Maximum speed | 850 km/h | 850 km/h | 850 km/h | 850 km/h |
| Maximum range, Fully loaded (km) | 12.300 | 11.400 | 6,025 | 10.440 |

- Boeing B777

Boeing, in an attempt to fill any gaps in their already existing range of aircraft and to replace older types such as the McDonnell Douglas DC-10, consulted a number of their major customer airlines and started developing the B777. The result was a family that included three types, the -200, -300 and freighter, with the first two being distinguished further by their range into ER (Extended Range) and LR (Long Range) versions. As far as the freighter versions is concerned, the B777F combines characteristics from both -200 and -300 versions and aims to replace older freighters such as the B747F and the MD-11F. It can carry 103 tons of cargo for a maximum of 9200 km and was operated first in February of 2009 for Air France Cargo.

Table 16: Characteristics of the B777 aircraft family (Boeing, 1999) (Boeing, 2009)

| | B777-200ER | B777-200LR | B777-300 | B777-300ER | B777F |
|---|---|---|---|---|---|
| Seating capacity | 524 | 266 | - | - | - |
| Cargo capacity | 170,5 $m^3$<br>30xLD1 | 160,2 $m^3$<br>- | 779 m3<br>30 pallets+32x LD1 | 213,8 m3<br>30 pallets+32x LD1 | 633,5 m3<br>39 pallets |
| Length (m) | 62,94 | 62,94 | 73,08 | 73,08 | 62,94 |
| Wingspan (m) | 60,93 | 64,8 | 60,93 | 64,8 | 64,8 |
| Fuselage width | 6,2 | 6,2 | 6,2 | 6,2 | 6,2 |
| Maximum take-off weight (MTOW) (t) | 297,5 | 347,4 | 300 | 351,5 | 347,8 |
| Payload (t) | 63,9 | 63,9 | 112,6 | 63,9 | 103,7 |
| Cruising speed | 895 km/h | 895 km/h | 895 km/h | 895 km/h | 895 km/h |
| Maximum speed | | | | | |
| Maximum range, Fully loaded (km) | 14.300 | 17.450 | 11.000 | 14.600 | 9.200 |

- Boeing B787

The B787 Dreamliner is a medium size twin-engine passenger aircraft and is the most recent addition to Boeing's range. It incorporates numerous new technologies operation-wise, such as aircraft status self-monitoring, as well as production-wise with new assembly methods that involve 99% less holes drilled on to the fuselage in comparison with a 747 (Boeing, 2014a) and a high percentage of composite materials being used in order to save weight and lower maintenance and operating costs. This also shows the shift in the way of thinking for aircraft manufacturers as bigger and faster has been replaced by cheaper and more robust. The response from the airlines was very positive resulting in a total of 760 orders until the 31st of July 2014 (Boeing, 2014) combined for the three types of the family, the 787-8, -9 and -10.

**Table 17: Characteristics of the B787 aircraft family (Boeing, 2014a)**

| | B787-8 | B787-9 | B787-10 |
|---|---|---|---|
| Seating capacity | 375 | 408 | 469 |
| Cargo capacity | 136,7 $m^3$ | 153 $m^3$ | 175$m^3$ |
| | 28 LD3 | 36 LD3 | |
| Length (m) | 55,91 | 62,81 | 68 |
| Wingspan (m) | 60,12 | 60,12 | 60,12 |
| Fuselage width | 5,77 | 5,77 | 5,77 |
| Maximum take-off weight (MTOW) (t) | 227,9 | 250,8 | 252,6 |
| Payload (t) | 43,3 | - | - |
| Cruising speed | 895 km/h | 895 km/h | 895 km/h |
| Maximum range, Fully loaded (km) | 14.500 | 15.372 | 13.000 |

### *Other aircraft manufacturers*

The Soviet Union had an extensive tradition in the designing and manufacturing of transport aircraft for military purposes. Manufacturers such as the Ukrainian Antonov and the Russian Ilyushin continue these activities and offer aircraft in the commercial field, mainly for air transport of very large and bulk loads. Additionally, there are the American aircraft manufacturers Lockheed Martin and McDonnell Douglas that, although they are at the moment not involved in the commercial market, their aircraft are still in use.

- Antonov

The Antonov An-124 Ruslan was developed to become the Soviet Air Force air transport solution with capabilities similar to the American C-5. The aircraft, in its newest edition the An-124-200, has the capacity to transport 150 tons (Antonov, 2014) and is equipped with an opening nose tip and a sliding ramp at the back to facilitate loading (Antonov, 2014). Today, the 22 remaining An-124-100 offer their services to a variety of clients, such as NATO, Boeing, Airbus and heavy industries around the world. The range is completed with special cargo or super heavy transport aircraft such as the An-225 Mriya. These types are not included in this research as they come in very limited supply and cater only very special transport needs.

Table 18: Characteristics of the Antonov transport aircraft (Antonov, 2014)

| | An-124-100 | An-124-200 |
|---|---|---|
| Seating capacity | - | - |
| Cargo capacity | 1040 $m^3$<br>Non-palletized floor | 1040 $m^3$<br>Non-palletized floor |
| Length (m) | 69,1 | 69,1 |
| Wingspan (m) | 73,3 | 73,3 |
| Cargo cabin width | 6,4 | 6,4 |
| Maximum take-off weight (MTOW) (t) | 392 | 402 |
| Payload (t) | 120 | 150 |
| Cruising speed | 850 km/h | 850 km/h |
| Maximum range, Fully loaded (km) | 4.800 | 3.200 |

- United Aircraft Corporation (UAC)

The Russian government has launched an ambitious plan to pool all aircraft design and manufacturer firms in Russia resulting in the founding of the United Aircraft Corporation (UAC) in February 2006. The intention is to gather under the umbrella of UAC all Russian aircraft manufacturers such as Irkut, Ilyushin, Sukhoi, Tupolev, Yakovlev, and Mikoyan. UAC is tasked with maintaining general oversight over the participating companies, managing their finances, rebuilding their departments and coordinating their activities, so as to avoid any overlap and competition between them. The main commercial aircraft projects include the Ilyushin Il-76 and Il-96, Tupolev Tu-154 and Tu-204/-214, Yakovlev Yak-42, Beriev Be-200, Sukhoi Superjet 100 and MC-21. As far as cargo aircraft are considered the most important examples of the UAC range are the Ilyushin IL-76TD/TF with 116 currently operational, the IL-96-300/-400T with 12 and the smaller Tu-204 with 27 aircraft (Flightglobal, 2013).

Table 19: Characteristics of the UAC transport aircraft (Tupolev, 2014) (UAC, 2014) (UAC, 2014a)

| | Tu-204-120CE | IL-76TD | IL-76TF | IL-96-400T |
|---|---|---|---|---|
| Seating capacity | - | 6(crew) | 5(crew) | 2(crew) |
| Cargo capacity | 164.4+43(bulk) $m^3$ | 321 $m^3$ | 432,8 m3<br>24 pall.+30 LD2 | 776 m3<br>38 LD2s |
| Length (m) | 46,14 | 46,6 | 53,2 | 72,9 |
| Wingspan (m) | 41,8 | 50,5 | 50,5 | 60,11 |
| Fuselage width | 4,1 | 4,8 | 4,8 | 6,08 |
| Maximum take-off weight (MTOW) (t) | 103 | 190 | 210 | 270 |
| Payload (t) | 27 | 50 | 60 | 92 |
| Maximum speed | 850 km/h | 800 km/h | 850 km/h | 850 km/h |
| Maximum range, Fully loaded (km) | 2.950 | 3.600 | 4.000 | 5.000 |

- Lockheed Martin & McDonnell Douglas

The American firms Lockheed Martin and McDonnell Douglas although now absent from the civil aircraft manufacturer scene, their products still continue to fly and offer their services. The L-1011 Tristar was the world's third political wide body jet that entered service, after the Boeing B747 and McDonnell Douglas DC-10, and the last civilian aircraft built by Lockheed, having now withdrawn from this particular market. The civilian version of the C-130, the Lockheed L-100 Hercules is still in operation with 30 aircraft, mostly operating in Africa and North/South America (Flightglobal, 2013).

McDonnell Douglas entered a declining course during the 1990s which led eventually to the acquisition/merger with Boeing in 1996. As a result, almost all airplanes marked as MDD ceased to exist. The only development program that survived was the MD-95, which was implemented by Boeing as B717-200. Also, after the merger, it was decided to maintain production of the transport version of the MD-11. The last MD-11F was delivered to Lufthansa Cargo in February 2001.

Table 20: Characteristics of the McDonnell Douglas MD-11F (Boeing, 1998)

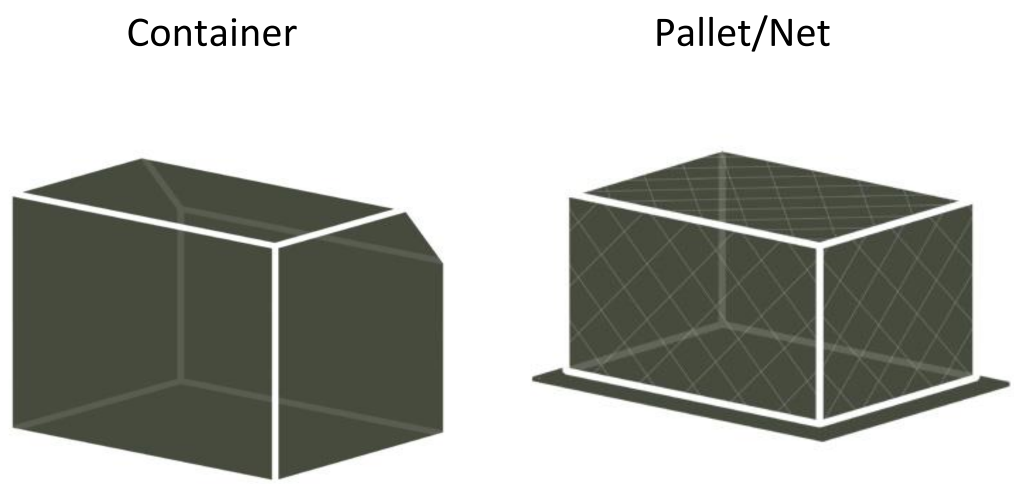
| | MD-11F |
|---|---|
| Seating capacity | - |
| Cargo capacity | 609,7 $m^3$ |
| | 32 LD3s |
| Length (m) | 61,6 |
| Wingspan (m) | 51,97 |
| Fuselage width | 6,0 |
| Maximum take-off weight (MTOW) (t) | 273,2 |
| Payload (t) | 91,9 |
| Cruising speed | 850 km/h |
| Maximum range, Fully loaded (km) | 3.700 |

## Aircraft loading equipment

The development of air freight follows closely that of the passenger transport. So, from casual air fields and simply throwing a mailbag on the back of an airplane, air freight operations now take place at specialized sites, to ensure the safety, quality and profitable economics of related services. Furthermore, air transport of goods often requires special ground as well as aircraft loading machinery and equipment, primarily to manage, transfer and load the goods.

The aircraft related equipment are vital components of the clustering and unitization process of goods, so they are ready for loading on board of the aircraft through its cargo management system (transportation, installation, securing). Depending on the type of goods, specific so-called unit loading devices (ULDs) are used, which are pallets or special containers, certified for air transport and capable of being directly hooked on the aircraft loading and locking system interface. An aircraft can be loaded with pallets, containers or a combination of both depending on the aircraft type, its configuration, the availability of ULDs and other relevant equipment and facilities. ULDs are loaded on the aircraft under specific regulations and according to the proper weight allocation throughout the fuselage. Besides that, every aircraft has a bulk cargo compartment where various items can be transported in bulk. Each type of aircraft is compatible with specific types of air containers and each hold has defined locations where they can be placed and secured. The floor of the cargo hold area is equipped with special wheels (rollers), to avoid any damage during loading, and latches with which the containers become part of the aircraft and are secured.

ULDs are identified by an alphanumerical code name that is assigned to them. According to IATA standards, that code comprises of a three letter prefix, that determines their type (class, base dimensions, shape and compatibility), followed by a four or five-digit unique number, allocated by the airline, and finally two letters, indicating the owner of the ULD that can be the airline or sometimes a container leasing company (Skybrary, 2014). For example a ULD labelled as «AKN 12345 KL» designates an LD-3 container type with forklift holes (Boeing, 2012a) and specific dimensions and load capacities such as volume and weight, with code 12345, which belongs to KLM Royal Dutch Airlines (IATA code: KL).




| | |
|---|---|
| **Easier loading and unloading** | **Cheaper than containers** |
| **Protection against weather** | **Can take unusually shaped cargo** |
| **Protection against aircraft and cargo damage** | **Accepts special cargo that needs open pallets** |
| **Prevention of unauthorised access** | **Easier to store because they are stackable** |

**Figure 7: Key characteristics of aircraft containers and pallets, adapted from VRR Aviation web site (2014)**

Air transport containers have a frame made out of aluminium and walls out of composite materials that are lightweight and structurally strong. Clearly, they are much lighter than the ones used for surface transport (maritime, road, rail), as airlines haul goods with low weight and higher unit cost. Moreover, they require careful handling during transport and loading onto the aircraft. For example, ocean containers can be stacked one on top of the other while in the case of air containers that is prohibited. Air containers are usually not transported by forklift truck, as that can easily damage them, unless their specifications permit doing so. Finally, they are loaded in the cargo hold of the aircraft with the help of a lift, only one at a time, in the specific place indicated for each one of them.

As most ULDs cannot be handled with the use of forklifts, a special type of platforms is used, called dolley, which is a simple platform with rollers onto which the container can be secured. Such platforms and their lifting mechanisms can snap on the lower end of the cargo door, making the process of loading the aircraft rather simple, just by pushing the container on the rollers and into the cargo hold area. As the cost of an air container is quite high and therefore unusable due to damage units can prove expensive for an airline, handling of ULDs is done with great care and always using the appropriate tools and vehicles. Table 21 shows the main characteristics of various types of ULDs and pallets.

**Table 21: The most commonly used air containers and pallets and their characteristics (Boeing, 2012a)**

| Common Designation | IATA Codes Associated | Dimensions (w × d × h) (cm) | Tare Weight (kg) | Max. Gross Weight (kg) | Volume ($m^3$) |
|---|---|---|---|---|---|
| **Containers** | | | | | |
| **LD-1** | AKC,AVC,AVK | 156 / 234 × 153 × 163 | 70-170 | 1.588 | 5,0 |
| **LD-2** | DPE,APA,DPN | 119 / 156 × 153 × 163 | 92 | 1.225 | 3,5 |
| **LD-3** | AKE,AVA,DVA | 156 / 201 × 153 × 163 | 82 | 1.588 | 4,5 |
| **LD-3 Reefer** | RKN,RVN | 156 / 201 x 153 x 163 | 210 | 1.588 | 4,5 |
| **LD-4** | ALP,AWD,DLP | 244 x 153 x 163 | 120 | 2.449 | 5,5 |
| **LD-6** | ALF,AWA,AWC | 318 / 407 × 153 × 163 | 230 | 3.175 | 9,0 |
| **LD-8** | DQF,ALE,MQP | 244 / 318 × 153 × 163 | 127 | 2.450 | 7,0 |
| **LD-9** | AAP | 318 x 224 x 163 | 215 | 6.000 | 10,8 |
| **LD-9 Reefer** | RAP | 318 x 224 x 163 | 400 | 6.000 | 9,6 |
| **LD-11** | ALP,AW2,DLP | 318 × 153 × 163 | 185 | 3.176 | 7,3 |
| **LD-26** | AAF | 318 / 406 x 224 x 163 | 250 | 6.033 | 13.3 |
| **LD-29** | AAU | 318 / 472 x 224 x 163 | 265-450 | 6.033 | 14,4 |
| **M-1** | AMA,AQA | 318 x 244 x 244 | 350 | 6.804 | 17,6 |
| **M-2** | AGA,ASE | 606 x 244 x 244 | 1.000 | 11.340 | 33,7 |
| **Pallets** | | | | | |
| **Half pallet** | PLA,FLA,P9A | 318 x 153 x 163 | 91 | 3.175 | 7,1 |
| **LD-7** | P1P,PAA | 318 x 224 x 163 | 105 | 4.626 | 10,5 |
| **P6P** | P6P | 318 x 244 x 163 / 300 | 120 | - | 11-21 |
| **MDP** | PRA,P4A,PZA | 498 x 244 x 244 | 410 | 11.300 | 27,6 |

## 2.6 The Airports

The infrastructure necessary for realizing and servicing air transport related operations are known as airports or aerodromes. According to ICAO, the definition of an aerodrome is given as "*A defined area on land or water (including any buildings, installations, and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft*" (ICAO, 1999). The term includes the total of any kind of structures and installations serving the air transportation of people and goods. From a purely transportation perspective, it is a hub where the air transport network is connected to the surface transport networks.

The airport, in the case of cargo transport, is tasked with the service of the following needs. In relation to the aircraft these include take-off and landing, parking, refuelling and maintenance. In relation to the air cargo, they consist of pickup and delivery, validation and packaging, recording, weighting and classification, preparation for loading/unloading and handling to and from the aircraft.

Although most airports can handle certain amounts of goods, the size and shape of the air cargo terminal varies greatly and is affected by factors such as the characteristics of the goods, the types of aircraft, communication systems etc. Furthermore, the various air freight business model discussed previously produce different volumes of freight and have different needs leading as a result to a range of cargo handling airports from very basic to extremely sophisticated. In any case, the main functions of a cargo terminal remain the same and include conversion (aggregation and unitization), sorting, storage and facilitation and documentation (Ashford, et al., 2011).

The reasons that enable the development and evolving of business into a cargo airport are associated with the wider economic development of the region or the country in which the airport is located, the ability and ease of access to and from the airport and the type of products and how well these can justify the requirement of an air transport operator. As a result, major air cargo hubs are usually found in regions with strong industrial production, where there is the need to import raw materials for the production process, and then export those products, that usually have either high value, a short life or urgency to be delivered, making the cost of transport a secondary matter.

That is evident if one takes a look at the world airport traffic rankings, as published by Airports Council International and shown in Table 22. At first, it is easy to see that a lot of the airports that are featured in the top-30 list for passenger traffic are also in the same list for cargo traffic. In fact, 60% of them are on both lists showing an important correlation between passenger and cargo traffic. Airports that service a high number of passengers are located usually close to large urban centres with millions of inhabitants, have already developed and invested in infrastructure in order to accommodate that traffic and enjoy a healthy revenue stream that allows them to incorporate with greater ease any further equipment and infrastructure needs that cargo handling operations demand. On the other hand, the list of busiest cargo airports contains some exceptions that fall out of this norm and are not included in the passenger list, which are airports that operate as main cargo hubs for specific companies, mostly Integrators. For example Memphis is a main hub for FedEx, Louisville for UPS, Anchorage for both FedEx and UPS and Leipzig is the central hub of DHL.

As far as the geography of the cargo busy airports is concerned, it follows closely the size of the market and in general the status of the economy in that area. Consequently, almost half of the top thirty airports are located either in the United States or in Europe. The consumers that inhabit these two geographic regions have a healthy spending power thus attract products of high value that use air transport services. The other half is completed by airports that are located either also in wealthy areas, such as the Middle East or production oriented areas such as China, Korea and Thailand where raw materials necessary for the production process are expensive and time-sensitive hence are transported by air. The airports of Japan, in Osaka and Tokyo, fit in both situations as the country's economy is one of the top worldwide in purchasing power parity and also has a highly developed consumer electronics manufacturing industry, one of the most common clients of air transport service providers.

**Table 22: List of the top 30 airports by passenger and cargo traffic, adapted from ACI web site (ACI, 2014)**

| Airport | Passengers | Airport | Cargo (m. tonnes) |
|---|---|---|---|
| ATLANTA GA, US (ATL) | 94431224 | HONG KONG, HK (HKG) | 4161718 |
| BEIJING, CN (PEK) | 83712355 | MEMPHIS TN, US (MEM) | 4137801 |
| LONDON, GB (LHR) | 72368061 | SHANGHAI, CN (PVG) | 2928527 |
| TOKYO, JP (HND) | 68906509 | INCHEON, KR (ICN) | 2464384 |
| CHICAGO IL, US (ORD) | 66777161 | DUBAI, AE (DXB) | 2435567 |
| LOS ANGELES CA, US (LAX) | 66667619 | ANCHORAGE AK, US (ANC) | 2421145 |
| DUBAI, AE (DXB) | 66431533 | LOUISVILLE KY, US (SDF) | 2216079 |
| PARIS, FR (CDG) | 62052917 | FRANKFURT, DE (FRA) | 2094453 |
| DALLAS, TX, US (DFW) | 60470507 | PARIS, FR (CDG) | 2069200 |
| JAKARTA, ID (CGK) | 60137347 | TOKYO, JP (NRT) | 2019844 |
| HONG KONG, HK (HKG) | 59594290 | MIAMI FL, US (MIA) | 1945012 |
| FRANKFURT, DE (FRA) | 58036948 | SINGAPORE, SG (SIN) | 1885978 |
| SINGAPORE, SG (SIN) | 53726087 | BEIJING, CN (PEK) | 1843681 |
| AMSTERDAM, NL (AMS) | 52569200 | LOS ANGELES CA, US (LAX) | 1747284 |
| DENVER CO, US (DEN) | 52556359 | TAIPEI, TW (TPE) | 1571814 |
| GUANGZHOU, CN (CAN) | 52450262 | AMSTERDAM, NL (AMS) | 1565961 |
| BANGKOK, TH (BKK) | 51363451 | LONDON, GB (LHR) | 1515056 |
| ISTANBUL, TR (IST) | 51172626 | GUANGZHOU, CN (CAN) | 1309746 |
| NEW YORK NY, US (JFK) | 50423765 | NEW YORK NY, US (JFK) | 1295473 |
| KUALA LUMPUR, MY (KUL) | 47498127 | BANGKOK, TH (BKK) | 1236223 |
| SHANGHAI, CN (PVG) | 47189849 | CHICAGO IL, US (ORD) | 1228791 |
| SAN FRANCISCO CA, US (SFO) | 44945760 | INDIANAPOLIS IN, US (IND) | 991953 |
| CHARLOTTE NC, US (CLT) | 43457471 | TOKYO, JP (HND) | 954446 |
| INCHEON, KR (ICN) | 41679758 | SHENZHEN, CN (SZX) | 913472 |
| LAS VEGAS NV, US (LAS) | 40933037 | DOHA, QA (DOH) | 883264 |
| MIAMI FL, US (MIA) | 40562948 | LEIPZIG, DE (LEJ) | 878024 |
| PHOENIX AZ, US (PHX) | 40341614 | COLOGNE, DE (CGN) | 717146 |
| HOUSTON TX, US (IAH) | 39799414 | KUALA LUMPUR, MY (KUL) | 713254 |
| MADRID, ES (MAD) | 39717850 | ABU DHABI, AE (AUH) | 712488 |
| MUNICH, DE (MUC) | 38672644 | OSAKA, JP (KIX) | 682338 |

## 2.7 Costs and pricing

The costs involved in air cargo transport have many components and are very complex to determine especially as they can be heavily influenced by external factors, completely outside the actual transport operations. Costs can be generally divided in two categories namely capital and direct operating costs. The first includes costs such as aircraft depreciation and fees for leasing equipment or aircraft while the latter has to do with airport fees and fuel, crew, maintenance and insurance related costs (The World Bank Group, 2009). Some of these costs are partly controlled by the airline, for example crew costs and others are completely external, like fuel costs. Other costs components such as airport fees, and equipment maintenance can vary between different aircraft and geographical regions, nevertheless these variations have low impact on the final costs of air freight.

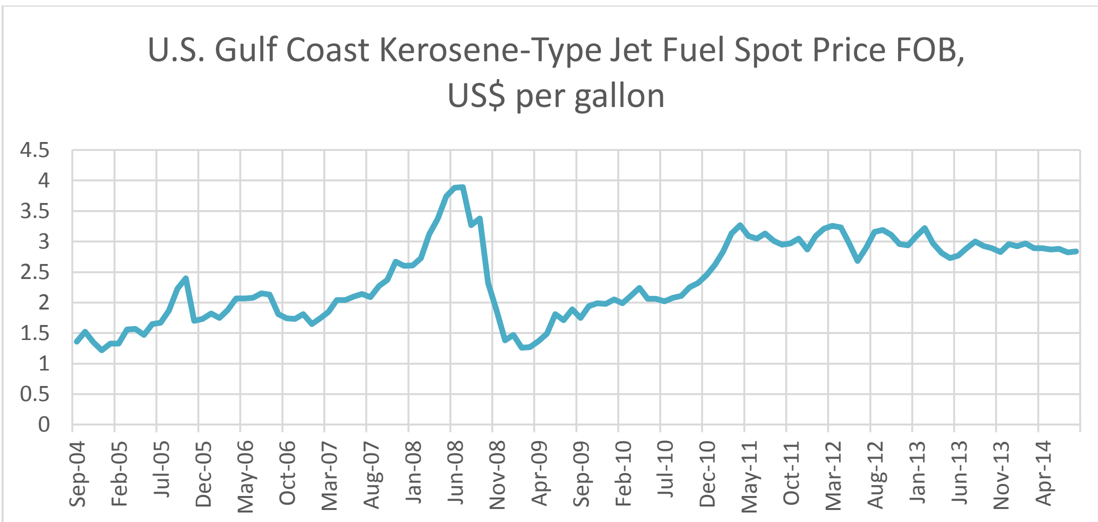



**Figure 8: Historical Jet fuel prices, Source: US Energy Information Administration**

As the common practice in the air freight industry is to use second hand passenger aircraft that were converted to freighters, the capital costs are less significant because of the depreciation that has taken place. Therefore, fuel remains as the main and most important cost component of air transport operations, not only as an absolute percentage of total costs but also because of its price volatility, influenced by geopolitical and other factors. These fluctuations can be clearly seen in the historical jet fuel prices as demonstrated in Figure 8, for the past 10 years. Furthermore, fuel costs can vary from region to region. The pattern there is that fuel can be purchased in a lower price in the Middle East region, whereas prices in other parts of the world can be higher by 2% to 8%, as shown in Table 23.

**Table 23: Current (October 2014) jet fuel prices per region, $cents/gallon (IATA, 2014)**

| Region | Jet fuel price |
|---|---|
| **Asia & Oceania** | 254.8 |
| **Europe & CIS** | 257.6 |
| **Middle East & Africa** | 249.8 |
| **North America** | 256.9 |
| **Latin & Central America** | 268.2 |

Fuel costs can also be affected by the type of service. Pure cargo flights that are long haul have less fuel costs because the aircraft spend more time in cruising altitude, avoiding having to perform energy-intensive operations, such as taxiing, climbing and descending, many times. This leads to a declining fuel consumption per distance unit as the trip distance becomes bigger, reaching an asymptote at around 4 to 6 thousand kilometres (The World Bank Group, 2009). On the other hand, larger flying distances have the disadvantage of having to carry larger quantities of fuel on board, thus decreasing the available payload and burning fuel to carry fuel. The significance of the fuel costs is evident when one takes a look at the operational expenses of major airlines. The Research and Innovative Technology Administration (RITA) of the U.S. Department of Transportation gathers aviation and, more specifically, monthly financial data in their Form 41, Schedule P-12(a) tables that show the extend of the fuel expenses. Although the carriers that participate are mainly U.S. based passenger airlines, their fleet is quite common with other carriers around the world thus provide a good indication of the costs. Figure 9 and Figure 10 below were derived with RITA data for the year of 2014 and show the relationship between fuel costs and total operational costs per aircraft type and per block hour.

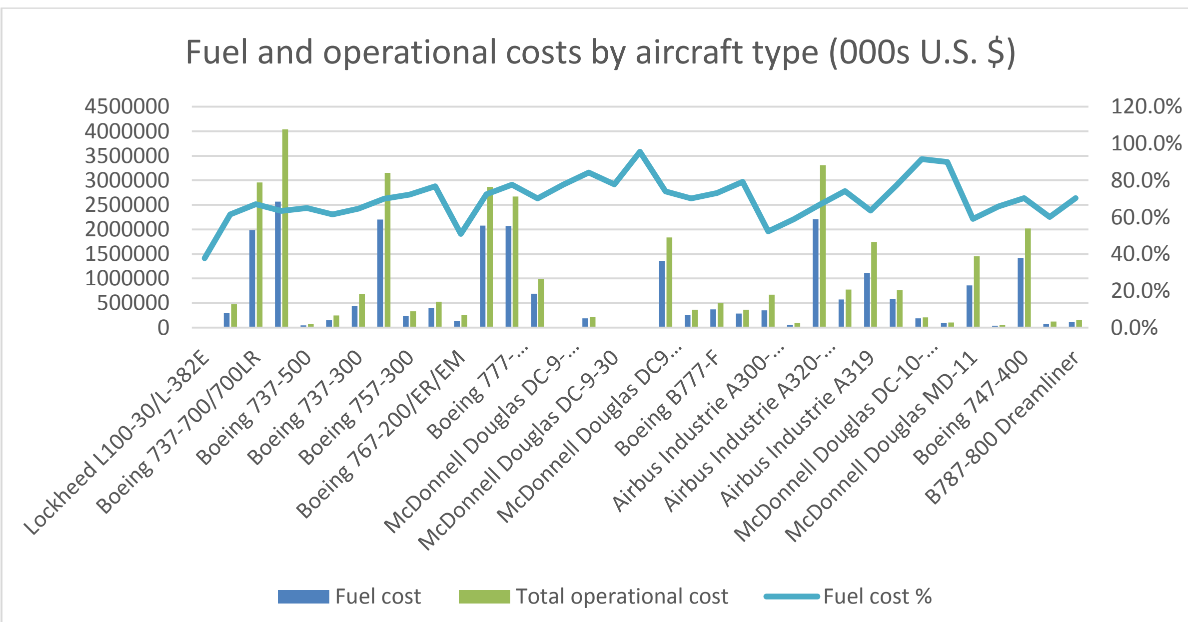



**Figure 9: Fuel and operational costs by aircraft type** (RITA, 2014)

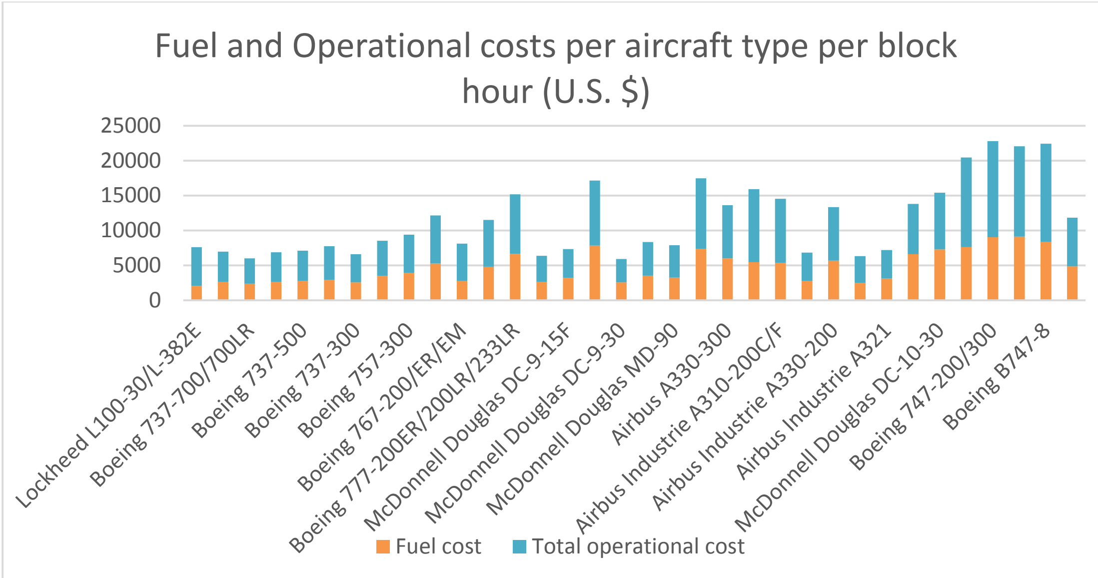



**Figure 10: Fuel and Operational costs per aircraft type per block hour** (RITA, 2014)

Even though the data includes values for a wide range of aircraft, which vary significantly in weight, power, dimensions and capacity, the percentage of fuel costs in the total operational costs stays high and does not differ much. For all the aircraft shown above, which cover a large share of the aviation market, fuel costs account for more than half of operational costs. The percentage values range between 50% and 90% with an average value of 70% and 73% in the case of the B-777 freighter. Additionally, Figure 10 gives the costs per block hour again of a wide variety of aircraft. There the values range from $3500 to $14000 for the total operational costs/block hour and from $2600 to more than $9000 for the fuel costs/block hour with an average of $4700 for the latter. The sheer importance of the fuel costs becomes clear when the impact of 1% change in fuel price in total operational costs is considered as an example. To be more specific, a change of 2 to 3 dollar cents in fuel price per gallon translates in almost 50 dollars cost difference per block hour.

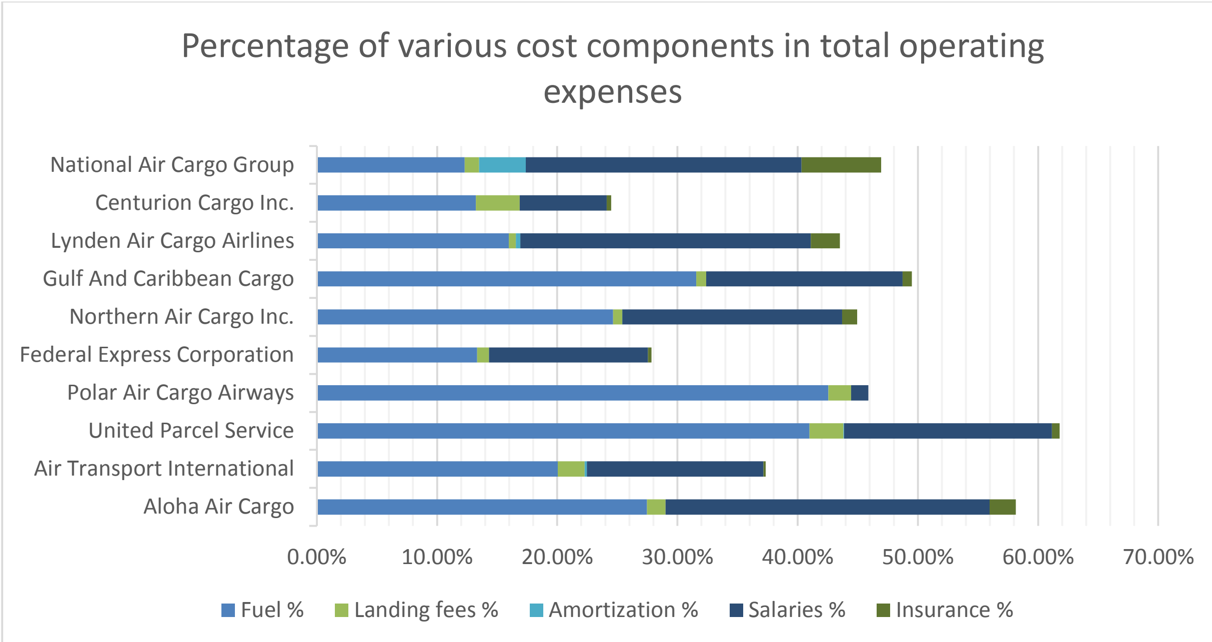



**Figure 11: Percentage of fuel, landing fees, amortization, salaries and insurance costs in total operating expenses for a variety of cargo transporting airlines (RITA, 2014)**

In terms of total operating costs, including salaries, benefits, materials and services purchased, landing fees, amortization, fuel and insurance, Figure 11 gives an indication of how much some of these components contribute to the total expenses. The data, also taken from RITA, under Form 41, Schedule P-6 contain entries for U.S. airlines but for the purposes of this research, only the cargo airlines are shown in the above figure. Again, fuel remains the highest cost contributor, followed by salaries and insurance costs. Landing fees and amortization do not play a significant role, even though the airlines taken into account operate fleet that vary greatly between one another and land in different airports.

The structure of air cargo tariffs is proved to be a quite complex issue, determined mainly by market conditions (The World Bank Group, 2009). In the same pattern as the passengers' tariffs, international air cargo rates are a product of the agreement between the airlines through IATA and consequently accepted by governments (Doganis, 2010). More specifically, IATA publishes the quarterly updated "The Air Cargo Tariff and Rules" (TACT) where industry as well as carrier specific rates and surcharges can be found, given also per country and even city pair (IATA, 2014). In general, several characteristics and conditions define the level of tariffs; including weight, dimensions, volume and density of the shipment, the type of the commodities, routes, distance, season, priority and speed of delivery, to name but a few (Kiso & Deljanin, 2009) (Belay, 2009). Discount policies are applied based on transported volume and business connection with the customer in order to attract new customers and maintain the existing ones, while some markets are developed through specific commodities tariffs (The World Bank Group, 2009) (Kiso & Deljanin, 2009). This discriminatory pricing is based also on the level of service that companies provide. Fluctuation on prices exists according to a guaranteed delivery time or the speed of the distribution. For instance, slower deliveries go with lower tariffs as they allow airlines to optimize their capacity by scheduling accordingly their routes (The World Bank Group, 2009). All in all, in a world where integrators are constantly gaining market share, rates will reflect three variables, namely speed of the delivery, whether cargo is transported in a unit load device or not and whether the commodities require special handling (Doganis, 2010). Table 24 illustrates the common airfreight tariffs for major trade routes as they appeared in 2008, without fuel surcharges.

**Table 24: Air Freight tariffs, 2008 (The World Bank Group, 2009)**

| Routes | $/kg |
|---|---|
| **S. China - W. Europe** | 4,39 |
| **S. China - WCUS** | 4,62 |
| **S. China - Middle East** | 6,54 |
| **W. Europe - Middle East** | 2,01 |
| **ECUS - Middle East** | 2,00 |
| **W. Europe - E. Africa** | 3,45 |
| **W. Europe - W. Africa** | 6,44 |
| **China - C. Europe** | 8,85 |

The air cargo transport rates are mainly determined by the weight and dimensions of the shipment and, of course, the distance flown. Besides these, any needs for special handling and different service offers by the airline will affect the final amount. The final air fare includes the basic rate, the security surcharge, the fuel surcharge (FSC) and, for international shipments, the screening surcharge.

The basic fare, as stated previously, is determined through agreements and market conditions. The common practice in air cargo for that matter is to calculate it based on the dimensional weight of the shipment and apply rates accordingly. The reasoning behind this is that, due to the limited capacities of aircraft, airlines try to achieve the best possible utilization of their fleet by matching the density of the shipments to that of the cargo hold, as close as possible. In paragraph 2.5 The Fleet, the characteristics of the most commonly used aircraft were presented and it can be seen that freighter aircraft have very similar optimal densities, meaning the cargo density that would result in the cargo hold being completely full both in weight and volume capacity. The B777F has an optimal density of 164 kg/$m^3$, the MD-11F 150 kg/$m^3$, the B747F 145 kg/$m^3$ and the A330-200F 137 kg/$m^3$. Consequently, airlines use similar values to determine whether a shipment will be charged based on its actual or dimensional weight. The values used throughout the industry are three, namely 5000 $cm^3$/kg (=200 kg/$m^3$), 6000 $cm^3$/kg (=166.67 kg/$m^3$) and 7000 $cm^3$/kg (=142.86 kg/$m^3$) with the second being the most common. Therefore, the dimensions of a shipment in centimetres are multiplied and then divided by one of the previously mentioned factors, to determine the volumetric weight. If the result is lower than the actual weight, then the fees will be calculated based on the actual weight and vice versa. It is important to mention here that the dimension calculations are done based on the volume of the smallest possible rectangular cuboid in which the shipment could fit completely. After the final chargeable weight is determined, the rate is applied based on the weight classes set by the carrier. Sometimes, it might be more economical for the shipper that his shipment is classified at a higher weight class. In that case, shippers can indicate a weight value that is higher than the actual weight and be charged accordingly.

The security surcharge is usually a fixed fee, especially for international shipments, regardless of transport distance and is charged based on the actual weight. Usually the fee is around 0.15€/kg and might differentiate depending on country of origin (AF-KLM, 2013) (Delta Cargo, 2014) (UPS, 2013) (American Airlines Cargo, 2013). The fuel surcharge is a fee that is used by airlines to counterbalance the volatility of jet fuel prices. The calculation of that fee is based upon the current prices on major fuel stock markets (jet/diesel and crude oil). Airlines determine fuel price categories and based on which category the current price falls, apply a fuel surcharge (in the form of a percentage of the chargeable weight) accordingly. As of October 2014, that percentage was set around 16.5% (DHL, 2014) (BRT, 2014) The FSC can also be a fixed value. That practice is more common with combination and full service carriers that make use of fuel hedging, meaning maintaining fuel purchase contracts in order to have a fixed price. Typical example of this is Air France-KLM-Martinair Cargo which applies a fixed fuel surcharge for specific zones, categorized by flight time. For trips below 4 block hours, it is 1.03€/kg, between 4 and 9 0.83€/kg and more than 9 block hours 0.52€/kg (AF-KLM, 2012).

# Chapter 3: Modelling Transport

This chapter has two purposes. First it helps to introduce the reader, even the unfamiliar one, to the topic of transport modelling and the basic concepts that go with it. Secondly, it attempts to review and analyse the existing methodologies and techniques used, with a focus on freight transport modelling. In that sense, it serves as the second pillar of the structure of this study that, later, will be the basis of developing an air freight modelling methodology and achieving the objective of this thesis.

## 3.1 Introduction

The very first task before attempting any type of modelling is to understand the underlying concept and pinpoint the existing methods and tools. Eykhoff (1974) gave the definition for a model as "a representation of the essential aspects of an existing system (or a system to be constructed) which presents knowledge of that system in a usable form". In mathematical models, these representations take the form of mathematical formulations used to construct an analysis method that would be the model.

Models can be very useful for the reason that they provide a suitable way analysing a system when, as it is often the case, it is impossible or too costly to carry out experiments in real-life situations. In general, the purpose of modelling can be summarised as:

- A way to understand the reality of a system by recreating, as close as possible, the desired conditions in order to deepen over the system as much as possible.
- A helpful tool for choosing the best alternative solution concerning the operation of a system, as it provides the ability to produce a variety of results by changing components of the model and uncover the optimum situation.
- A means of understanding how a system functions through interpreting the valuable information that comes from the results of the model, provided that it is realistic enough.
- A method of grasping the underlying characteristics of system because building a model brings forward the need to think about what to include and what to exclude, which parameters can be ignored and which should be used to build upon. The knowledge that comes out of constructing a model can be sufficient to make decisions concerning a proposed system but even when that is not the case, a non-optimal model can be regarded as a basis for negotiations on how the system should be developed and modelled.

Summarizing it can be said that modelling is necessary to understand how systems work, to predict parameters and outcomes in real situations and to improve models that are already in use.

## 3.2 Modelling freight transport

Freight transport modelling attempts have surfaced since the early 1960s (Tavasszy & de Jong, 2014) and they were developed following passenger transport modelling methodologies. This is quite understandable as at the time freight transport generated a minor percentage of the, compared with today, smaller total flows resulting in simplistic solutions that satisfied the need of public policy makers. Furthermore, there was a lack of freight transport specific data, a problem that in many cases still troubles researchers, and appropriate theory that could facilitate the distinguishing of freight with passengers was missing. Although there are many shared characteristics between freight and passenger transport, there are also major differences that, before moving any further, it is imperative to pinpoint.

The users of freight transport systems are mostly interested in a reliable and on-time delivery of the goods in question so that production can move to the next stage, when the goods are part of a production supply chain, or so that retail can take place, when finalised end products are transported. On the other hand, time is also important in passenger transport but not so decisively. Travellers are also concerned about their comfort, the offered services and, very importantly, the waiting time and number of transfers. Furthermore, the value of life is considered higher than any goods thus safety plays also a major role in passenger transport. Such characteristics as well as other psychological factors and personal preferences can have a substantial impact in passenger transport but are not relevant for freight transport.

Moreover, the attributes of the shipment can have great influence and differentiate even further freight with passengers. A great example is the paper by de Jong et al. (2001) where the importance of attributes such as value density and whether a shipment is part of a round-trip or in parcels is highlighted. Unlike passenger transport, here there is a truly wide range of goods to be transported from raw material to manufactured goods and perishables. Different types of commodities can have their own specific transport needs and the stakeholders involved make decisions based on these characteristics and needs. Holguin Veras et al. (2010) identified the following fundamental differences between passenger and freight transport:

- Identity and number of decision makers
- Autonomy of units in transport
- Interactions between decision makers
- Correspondence between demand and trips
- Structure of a trip from origin to destination
- Heterogeneity in trips

Naturally, there are factors that are common in modelling both types of transport such as trip purpose, mode of transport or the time of transport, but are considered on a different level and play different roles in freight transport than in passenger. That fact is evident in the criteria for best practice freight modelling as identified by Donelly (2006) which include a link to economic forecasting preferably in the global scale, multimodal options, commodity flows and their conversion in modal flow units, the ability to perform sensitivity analysis and evaluate relevant policies and finally data requirements that should be minimal.

## 3.3 Categorization of models

As the researchers dove deeper into the subject of freight transport modelling, the aforementioned differences and their importance became more and more evident. Freight-specific practices that were developed gained momentum and modelling efforts became more focused. For example, the role of 3PL companies (Selviaridis & Spring, 2007) and Just-in-time strategies (Hensher & Figliozzi, 2007) were researched in extend, showing the need to incorporate the quickly changing nature of supply chains and logistics. Behavioural models that identify the decision makers and how they reach to their decisions try to do just that (Gray, 1982). The focal points became many, to the point where the categorization of models became a problem of its own.

A variety of criteria have been used in the literature to categorize modelling attempts with the most common differentiation being between vehicle-based and commodity-based models (Holguín-Veras & Thorson, 2000). Commodity-based models focus on the number of commodities to be transported, usually by weight as this is the most important measurement unit. This type of models have five steps, unless OD patterns and modal split are taken as input in which case there are three steps as depicted in Figure 12.

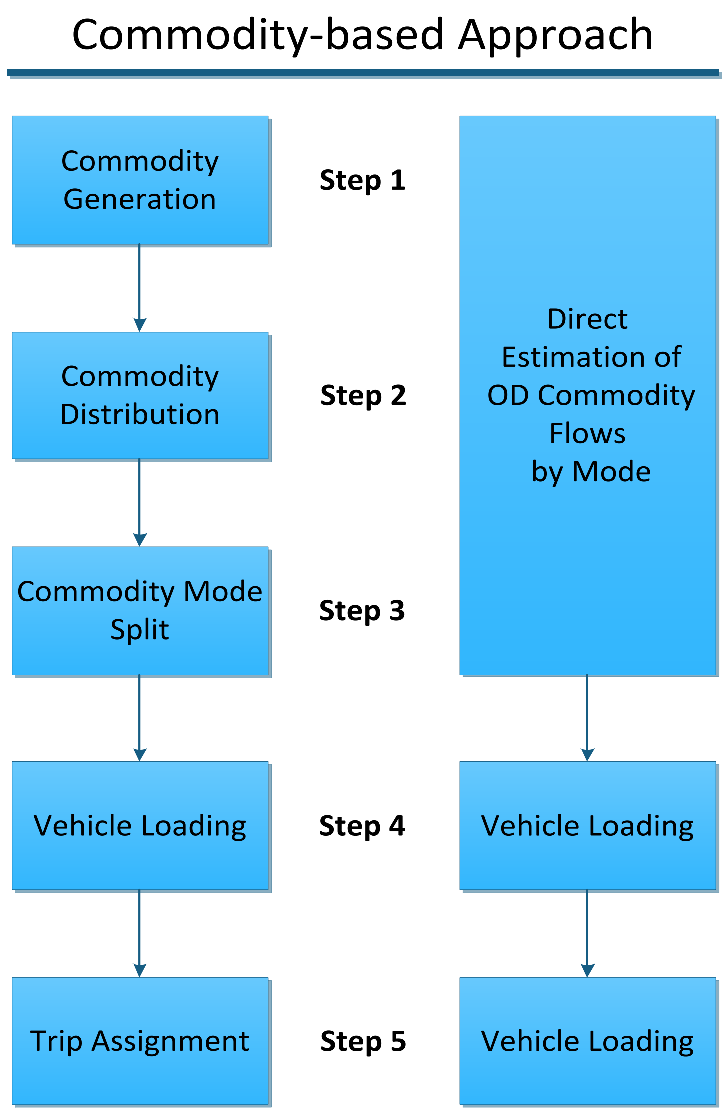



Figure 12: Typical structure of commodity-based modelling approach (Holguín-Veras & Thorson, 2000) (Gunyoung, et al., 2003)

The first step of commodity generation includes splitting the concerned area into traffic analysis zones and attempting to calculate the weight of the commodities that are produced in each of the zones. In the second step, commodities are distributed from origin to destination using a spatial interaction model. Modal split takes place in the third step where, usually with the help of discrete choice or logit models, the amount of commodities transported per type of mode are calculated. Step four continues with translating the volumes of step three into number of vehicles (of each mode). This is done by taking into account the vehicle characteristics and load factors. Finally, the vehicle trips calculated previously are assigned into the respective network in step five.

Using the modelling criteria of Donelly (2006) in order to evaluate commodity-based modelling it can be concluded that this type of models are strongly related to the economy as they use economic data as input. Furthermore, they can have a global scope if input-output commodity data are used and, as seen in Holguin-Veras & Thorson (2001), they can also have multi-modal capabilities. The main shortcomings of commodity-based modelling can be located in their inability to incorporate behavioural factors and the fact that they present a need for detailed data that are usually hard to come across.

Vehicle-trip based models deal with the vehicle flows and have a three-step structure with sometimes a fourth step in between as shown in Figure 13**.**

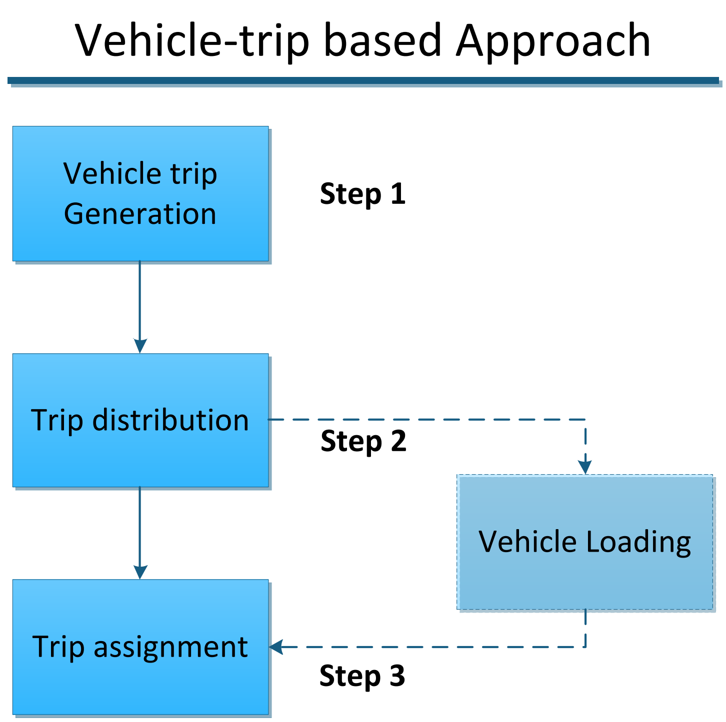



Figure 13: Typical structure of vehicle-trip based modelling approach (Gunyoung, et al., 2003)

This type of models start with trip generation, where the amount of trips per vehicle type in each of the traffic analysis zones is calculated with, most commonly the use of regression models. Next comes the step of trip distribution, which makes use of spatial interaction models followed sometimes by a vehicle loading step with the help of logit models. Finally, the calculated trips are assigned to the network.

Holguin-Veras & Thorson (2001) discussed that type of modelling approach and concluded that although the vehicle-trip approach provides the ability to take into account also empty trips, there are many significant shortcomings. For example, the lack of a direct link to the economy can lead to missing out on important factors that play a big role in vehicle selection and routing. Moreover, they pinpoint that the structure of the model and its focus on vehicle trips include a predetermined mode choice process, a fact that make it inappropriate for multimodal freight operations.

Another category is micro simulation freight models which are usually developed at urban or local level, as they incorporate behavioural characteristics of freight transport. Here, trip purpose and start time are assigned per trip per vehicle. These assignments are calculated with the use of discrete choice models. Following that is a repetitive procedure during which the previous and next stop, the trip length and duration are taken into account. A general overview of the steps included in such models is given in Figure 14.

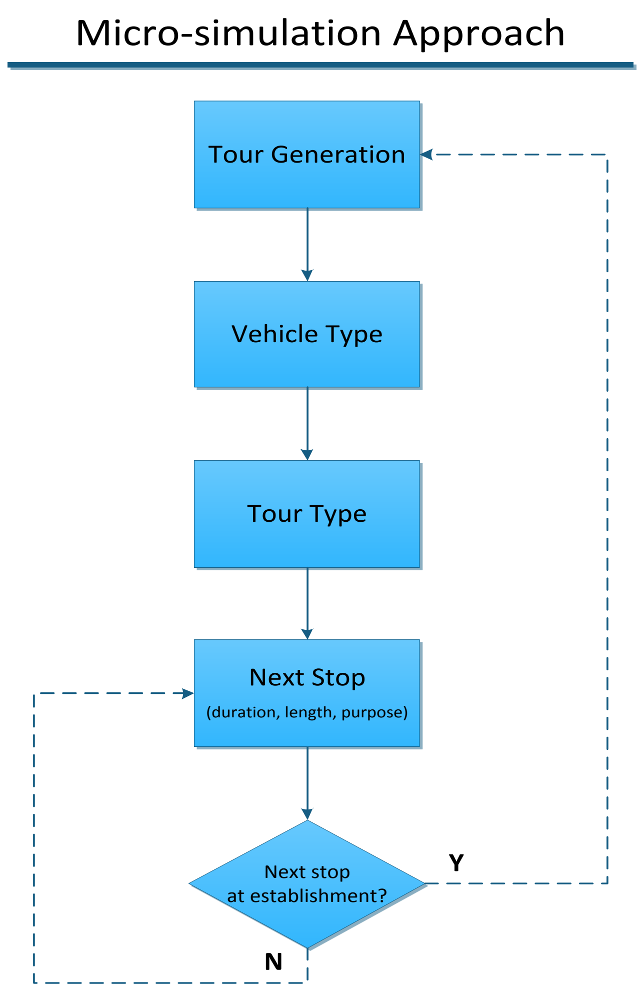



**Figure 14: Typical structure of a micro-simulation modelling approach (Stefan, et al., 2006)**

The main advantage of such approaches is the high level of detail regarding the vehicle trip and the reasons behind them. They are also successful in representing policy changes because a small alteration in a step of the process results in changes at the other steps. On the other hand, micro simulation models are not sufficiently linked to the economy and need a large volume of very detailed data which not only is hard to accumulate, verify and validate but also makes it impossible to use such models on a global scale.

Additionally, models were categorized into seven classes by Yang et al. (2009), similarly to previous works performed by Regan & Garrido (2001) but critical to these efforts, as indicated in the literature, was the work of Winston (1983) where freight transport models were split, based on the type of data used, into two general categories, Aggregate data based models and Disaggregate data based models, a level of categorization that is still used. Besides that and depending on the perspective under which a model is examined there can be a number of categorizations based on:

- The level of spatial detail: Depending on the spatial scope of the model there can be four distinguishable categories namely international, national, regional and urban.
- The modelling techniques used: This criterion implies the mathematical and statistical background used to formulate the underlying formulations that structure the model. According to Wigan & Southworth (2005) some of these techniques are: regression models (linear or non-linear), zone to zone spatial interaction models, commodity based inter-regional input-output models, micro-simulation and network-based spatial price equilibrium models.
- The time horizon: transport systems can be examined in a long or short term basis. Again Wigan & Southworth (2005) present us with five such categories. These include models that predict the present, models used for pivot point analysis, demand variation models, present and recent past predictions models and forecasting models.

## 3.4 The four step methodology

As described previously, in the early 60's, when the first attempts to model transport were made, the goal was to identify and describe all the stages of passenger transport. The result was the development of a modelling framework known as the four step model. This includes the following steps:

1. Trip Generation
2. Traffic Distribution
3. Modal split
4. Traffic Assignment

That framework provided the researchers with the ability to analyse, simulate, evaluate and forecast passenger transport in any spatial level. The four step framework proved very successful in incorporating with great detail and ease mathematical models, making it easy to understand and use. For that reason, the same framework was sequentially applied for freight transport modelling. Of course, the necessary adjustments have been made to accommodate freight transport needs. For example, the flows are now created by the interaction between the production and consumption of goods instead of the various trip purposes (work, leisure, shopping etc.) used in passenger modelling. Figure 15 illustrates the four steps in freight transport modelling.

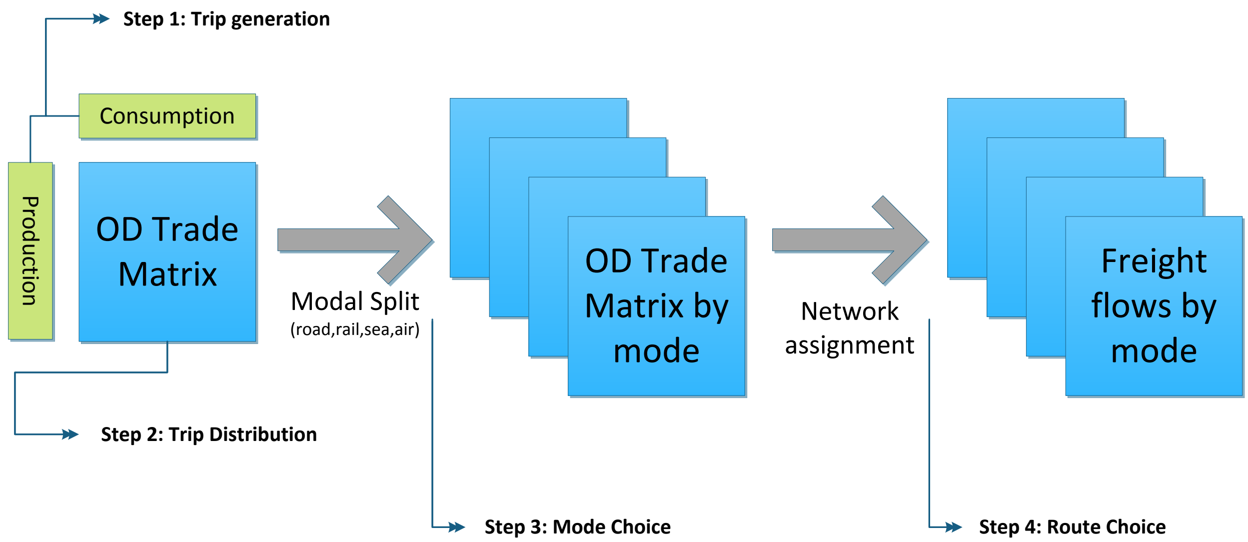



Figure 15: The basic four-step modelling approach for freight transport

## Trip Generation

The first step of trip generation deals with the genesis of freight volumes. In other words it focuses in freight demand that generates when consumption and production are linked. Cambridge systematics Inc. (1996) produced a thorough research study that pinpointed 21 factors that affect, directly and indirectly, demand for freight transport. Some of these factors are listed in the following paragraphs, accompanied with a short discussion for each one of them.

### *Economy*

It is easily understandable that the demand for freight is directly linked to the volume of produced and consumed goods. The development and growth of the economy, at national and global level, brings higher demand for goods and services because people in that economy find themselves having higher purchasing power and thus develop the need to fulfil more and more needs. At national level, the size and well-being of the economy is measured with the help of mainly two indicators, gross national product (GNP), which signifies the market value of all the yearly produced products and services by means supplied by the citizens of a country, and gross domestic product (GDP), the market value of all final goods and services produced, usually in a yearly basis within a country. Although these indexes are a good way to measure the state of an economy, when the attempt is made to link them with freight transport volumes there is the disadvantage that they are measured in monetary values and not in volume or weight, making necessary a form of conversion between the two which can lead to inconsistencies and errors. An example of the clear relationship between GDP and freight transport is given in Figure 16 where it can be observed that the curves of GDP and freight transport volumes follow an almost identical path through the years.

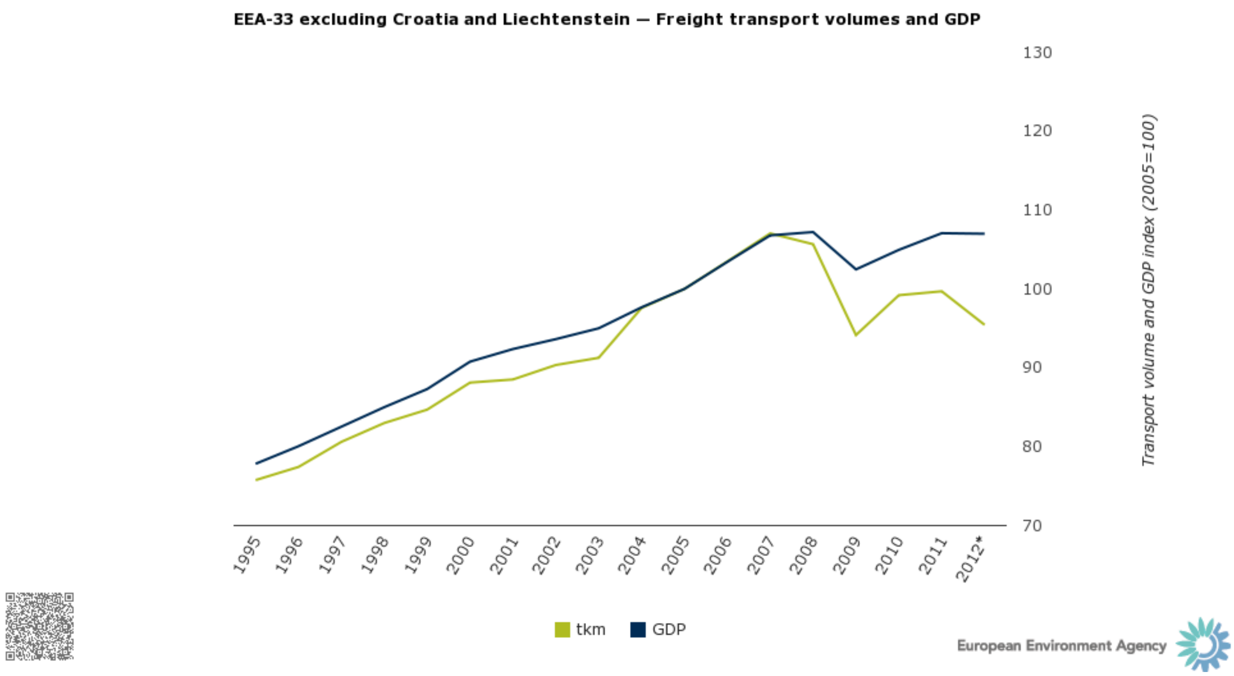



**Figure 16: The Relationship between freight transport volumes and GDP in Europe (European Environment Agency, 2014)**

### *Industrial location patterns*

The location of production, regardless the product produced, plays a rather significant role in the demand for freight transport services and its characteristics. These location patterns dictate the form of the freight flows and shape the distances between origins and destinations. For freight transport, distances lie in the heart of the decision making as they affect total costs, the type of mode to be chosen, the total transport time, available capacities etc.

### *Globalization of Business*

Nowadays, many businesses have placed their production facilities in different countries than the one they are based in. The reason behind that is the competitive advantage they gain by operating in areas with lower labour and production costs. Consequently this leads to higher demands and creates global supply chains that become more efficient by taking advantage economies of scale, having a direct effect on freight flows and freight mode choice.

### *International trade agreements*

Such agreements have been signed amongst a variety of countries around the world and were prompted by the high growth in international trade. Typical examples of trade organizations that were created out of that process are the European Union and the Free Trade Area of the Americas. The goal of such agreements is to simplify and facilitate trade between regions and, by doing that, has a major impact in freight flows.

### *International transportation agreements*

Transportation agreements can be quite complex as each country that takes part ultimately has the goal of protecting its own interests and take advantage of any opportunity for further development. A typical example of such agreements can be found in the air transport industry, in the form of bilateral agreements between served countries that regulate and control the routes, the tariffs, the number of carriers, even the aircraft type that might be operated hence affecting freight transport significantly.

### *Just-in-Time (JIT) inventory strategies*

Just-in-time logistics systems emphasize in keeping a minimum level inventory by coordinating the supply of materials with the production schedule. The result is higher transport frequencies and lower freight volumes per trip, so that flows match the demand at any given time. The use of JIT systems originated in Japan during the 1950s and has since then spread in businesses all over the globe. As a result, this can lead to a preference in different modes and routes since the focus shifts from available capacity to reliability and punctuality.

### *Carrier-Shipper alliances*

Alliances between carriers and shippers is another important factor that affects freight transport. Such alliances are created so that the carrier can achieve better capacity utilization while the shipper enjoys better as well as easier and cheaper services by creating a stable business relationship and having to deal with only one party, regarding the transport of their products. Even though these agreements do not have a significant effect on the total freight transport volumes, they can explain though the behaviour of shippers and their decisions. Furthermore, different carriers use different networks and these alliances have the potential to move freight volumes onto specific networks thus changing freight flows.

### *Centralized warehousing*

The betterment of transport systems has led to fewer warehousing needs in order to reduce inventory costs. Centralized warehousing is the result, where businesses satisfy the needs of their, sometimes global, network through one central warehouse. This on the one hand reduces inventory costs and on the other increases hauling distance and demands for more reliable, efficient and fast transportation. A typical example of that trend are the integrators in the air freight industry that operate such warehouses in their hub-airports, providing transport services of, usually, high-value products.

### *Economic regulation and deregulation*

Deregulation with respect to the transport sector started in the 1970's and 1980's and had the purpose of encouraging competition and drive transports costs down and offered service levels up. Typical examples are the Air Deregulation Act in 1978, the Motor Carrier Act in 1980 and the Shipping Act in 1984. These acts paved the way for transport related businesses to expand their networks and adopt multi-modal solutions.

### *Oil and Fuel Prices*

In freight transport, fuel price is a major component of the final transport costs. Higher fuel prices will result in higher transport costs, especially for energy-intensive modes such as aircraft, driving the demand for transport down or causing a mode shift to other less energy-intensive modes of transport. Furthermore, when the oil price moves higher, production costs become greater and, consequently, the final products absorb that difference in their final price, decreasing demand for goods in the first place and thus demand for transport services.

### *Environmental and safety policies and restrictions*

Various policies that focus on environmental issues and safety have a major impact on transportation. In the majority of regions around the world, emissions and fuel quality are regulated by law in order to ensure a viable and sustainable future. Most characteristics examples are truck transport regulations regarding emissions and weight per axle and air transport regulations, covering the aircraft age, noise pollution, emissions and other. These policies affect the cost of transport as well as the routes chosen by the carriers. Furthermore, safety policies impact insurance costs, a factor that can play a key role in choosing mode of transport.

Included in the four-step methodology and the step of trip generation is demand modelling. A variety of modelling approaches are used for that matter with the most commonly found being trend and time series models, systems dynamics models, zonal trip rate models and input-output models.

Trend and time series models try to extrapolate trends and correlations between variables by making use of data from previous years, in order to forecast the future situation. Although such techniques are relatively simple to use and can produce quick results, they do have a need for a significant amount of data as input and they do not give a sufficient explanation regarding the reasons behind the correlations between different variables. That makes it a tool that is useful mostly for the short term and in stable economic environments.

Systems dynamics modelling approaches examine the various changes on transported freight volumes over time as well as the impact on the form of the flows to and from the economy that these changes will have. The advantages of this type of approach is the minimal need for input data and the ability to incorporate exogenous variables. As a drawback it can be noted that there is a lack of statistical checks as far as the variables used are concerned.

Zonal trip rate models are mainly used for road transport and apply rates derived from the classification of transport volume data between zones into a number of homogenous types of zones (Wang, 2012). Such models demand a very small amount of data to operate but on the other hand provide little or no insight on the reasons behind the various changes.

Input-output models are at their core a macro-economic models starting from given data tables of input and output flows to and from industry sectors. Of course, these tables might also include imports and exports, hence the trade between countries. In any case, the volumes are measured in monetary values. The major asset of this approach is the direct link it has to the economy. That enables researchers to identify the interactions with the economy, land use and the various policies that are in play. The need for an existing data table to feed the model is the basic drawback as well as the fact that at some point, the monetary values must be translated into freight volumes and that can lead to inconsistencies.

## Trip Distribution

The second step in the four step methodology is trip distribution. At this stage, a form of transport resistance is used, in order to transform the previously calculated generated trips into trade flows between origins and destinations. Modelling approaches at this stage are based in aggregate data. The transport resistance is usually defined as the transport costs or generalized transport costs (Samar Ali, 2011). The most popular method for trip distribution is the gravity model, where the freight flows between two zones is a function of the product of production and consumption of these zones (possibly also other criteria of attractiveness) divided by the friction between them, which is the transport resistance. Although the input-output modelling approach can work for both trip generation and trip distribution, the gravity model has the advantage of simplicity, minimal input data needs and it can also portray the impact of various policies, through the (generalized) transport costs.

## Modal Split

The third step of the traditional modelling methodology is mode choice or modal split. Here with the help of various models an attempt is made to allocate the freight transport demand in the predetermined area, calculated in the previous steps or taken as input in the form of an OD matrix, over the available transport modes (de Jong, 2014). In freight transport the availability of modes enables road (truck), rail (train), pipeline, water (ship) and air (aircraft) transport. Which modes will or will not be included in a specific research depend on the spatial scale and commodities that are taken into account. Figure 17 shows the development of freight transport modal split within the EU.

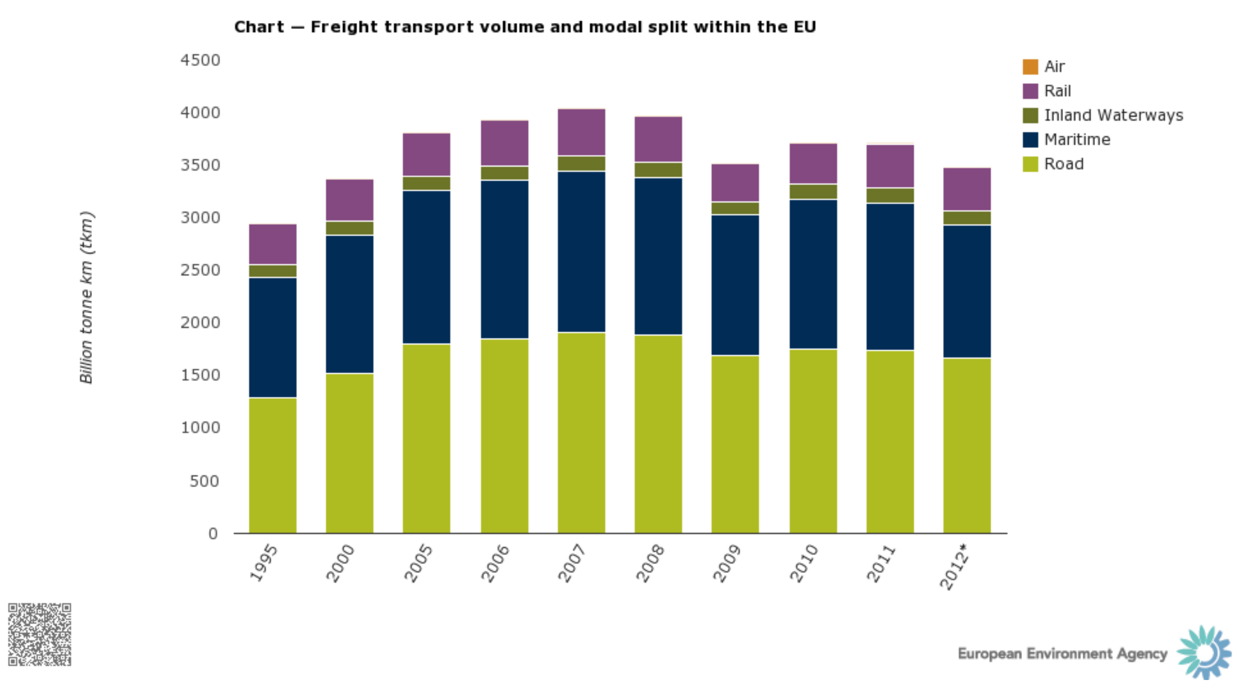



**Figure 17: Freight transport volume and modal split within the EU (European Environment Agency, 2011)**

### *Available freight transport modes*

There is a wide variety of transport modes that can be used in today's operations. When international/global scale is considered though, the available modes are limited to truck, aircraft, rail, sea vessel and pipeline with each one having various configurations depending on what is to be transported. Besides that, there is also the ability to combine more than one modes in a multimodal transport chain. Figure 18 shows the available modes and their variations.

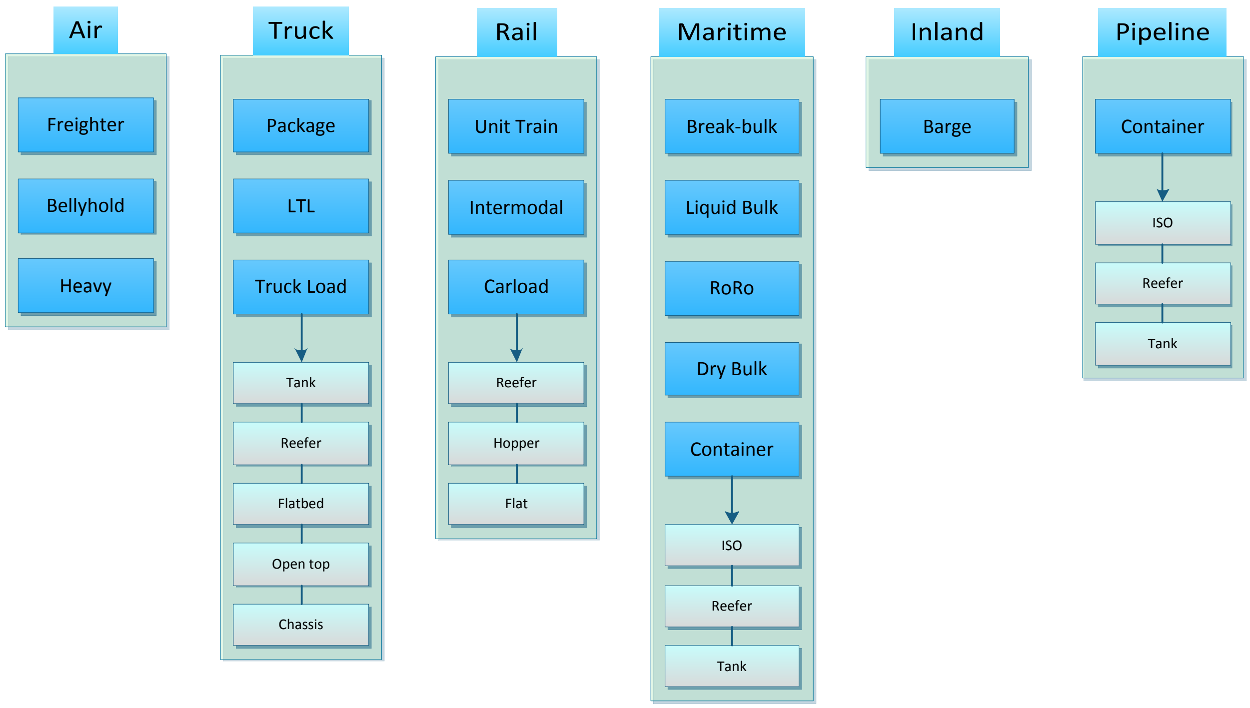



**Figure 18: Main freight modal options, adapted from (Rodrigue, et al., 2013)**

Road transport has been and still is the dominant mode of transport not only in Europe, as shown in the previous figure, but also worldwide. Although it requires the existence of a road bed to travel on, that network is considered a public good and thus offered by the government. Furthermore, besides freight there is a wide variety of road users which makes it possible to allocate the, otherwise high, costs onto a wide base. That has led to a very extended and sophisticated road network, giving that mode a major advantage over the other, that of flexible route choice and the ability to provide door to door service. Other advantages are low capital costs, which makes it easy for new users to enter, and relatively high speed (Rodrigue, et al., 2006). On the other hand, due to size and technical constraints as well as environmental policies set by governments, it is difficult to achieve scale economies using road transport modes, a major disadvantage compared with other modes.

Rail transport requires mode-specific infrastructure (rail tracks) to operate, a fact that, along with the procurement of rolling stock, produces high initial capital costs and sets entry barriers difficult to overcome by potential new players. Moreover, rail cars do not have the ability to easily adapt to any type of topography, making route choice inflexible and door to door service nearly impossible. Additionally, railways have not yet been completely standardized for example in track width and most importantly signalling systems posing a problem in continuity of operations between different regions making rail transport not a viable option in some cases. However, rail transport has the ability to haul large quantities over great distances with high speed and reliability and that gives it its main advantage. Scale economies can be achieved leading to lower costs and better energy efficiency. Technological advancements in the field have resulted in faster trains and coupled with a higher degree of standardization show a prominent future for rail transport.

Pipelines are extremely important for the transport of liquid and gaseous products. Although there is a very large network of pipelines in existence, it is not given much thought as a transport mode by most people, due to the fact that pipes are usually buried underground and they transport a very limited range of commodities that the general public does not purchase directly. The main advantage here is the low operating costs and the main disadvantage is the inherent inflexibility of the mode (Rodrigue, et al., 2006). Typical examples of large pipeline projects are the Eastern Siberia-Pacific Ocean oil pipeline that moves crude oil from Russia to the Asian Pacific and the Trans-Mediterranean, a 2475km-long natural gas from Algeria to Italy.

Maritime transport makes use of the rather extensive, mainly physical, network of water routes over oceans, rivers and lakes and, given the existing global port infrastructure, provides the ability to link origins and destinations worldwide. Ships have the advantage of combining very large volumes of freight with very low operating costs, offering the lowest rates in comparison with the rest of the modes. Additionally, many oceanic routes are in international water, hence can be utilized with no cost, and the shipping industry operates under a very business-friendly regime, for example allowing for the use of flags of convenience, resulting in very low costs for the operators. On top of that, the huge capacity of today's mega-vessels offers the opportunity to take advantage of scale economies, further lowering the costs. But there are two disadvantages. First, water transport is slow with speeds that range around 21 to 25 knots (38-45 kilometres per hour) (McNicholas, 2008) and is subject to delays due to weather or hindrances at ports. Although the latter has seen great improvement along the years with new technologies applied, it can still pose a significant threat especially for time-sensitive supply chains.

Air transport is mostly associated with high value and time sensitive commodities (Brogan, et al., 2013) because that type of goods can utilize the great advantage of this mode, being speed. Doing so, it is possible to offset the many shortcomings compared to the rest, such as high operating costs and limited capacities. In terms of route choice, one might think that airspace gives total flexibility and freedom but in reality that is not the case. At first, routes are limited by the fact that there is a need for airport infrastructure at both ends of a trip. Additionally, aircraft try to take advantage or avoid upper atmospheric winds in order to reduce fuel consumption and enhance speed (Rodrigue, et al., 2006). Besides that, routes are also limited by specific corridors that are established by airspace control authorities and, sometimes, political factors can make some routes unavailable to some carriers. Aircraft acquisition can be very costly, further highlighting the capital intensive nature of the air transport industry but that does not take away from its importance as a key component to just-in-time and flexible production chains around the world. A further analysis of the air transport sector will be given in following chapter.

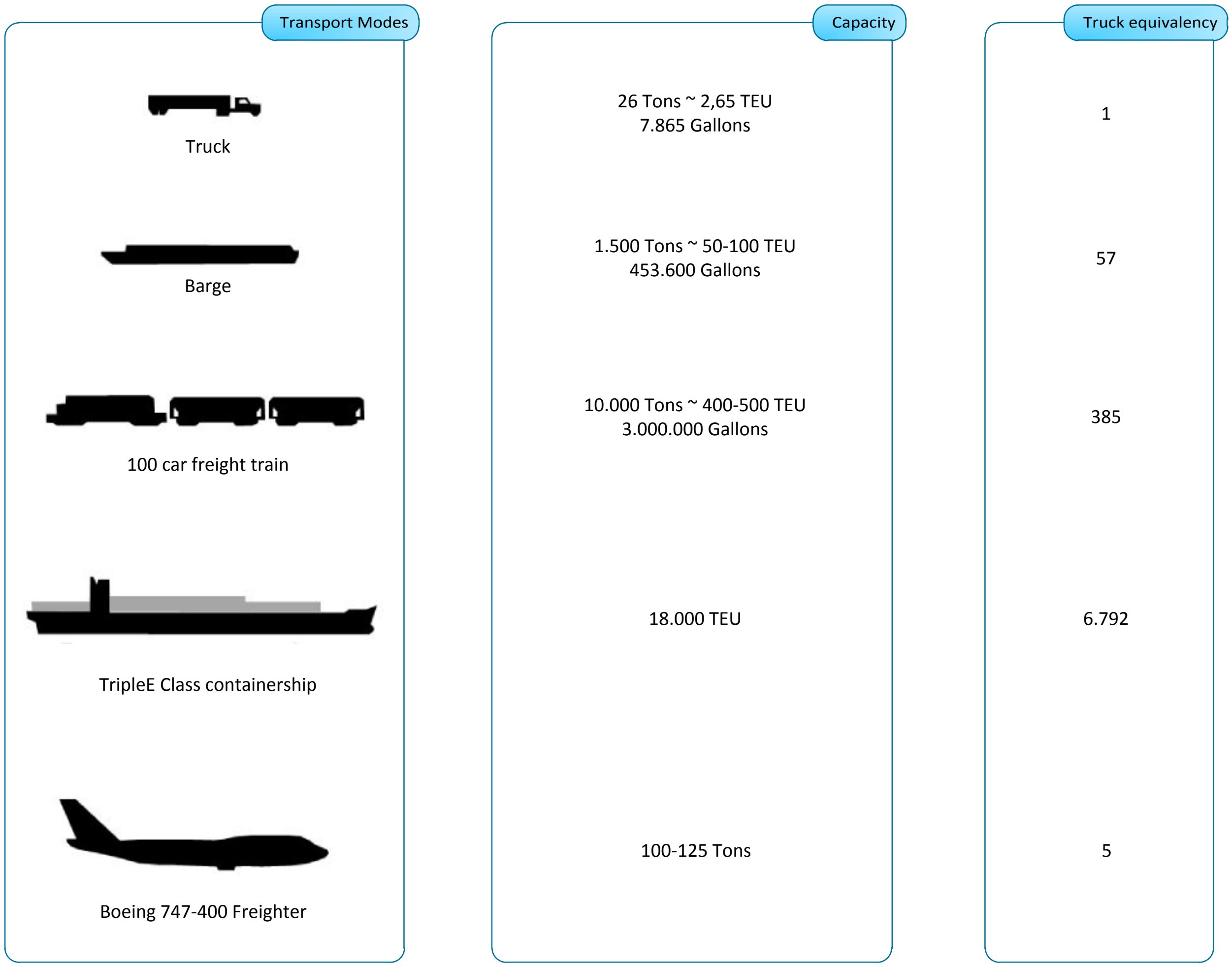



**Figure 19: Example of capacities of different freight modes of transport and their truck equivalency, adapted from (Rodrigue, et al., 2006)**

All available modes have their specific characteristics, advantages and limitations that make them suitable or not for a certain type of transport operation. A nice example of their diversity is given in Figure 19, where capacities of freight transport modes are compared. The modes sometimes compete with each other and other times can complement each other and form multimodal transport chains. Modal choice is a crucial step in modelling freight transport and it is important to understand the factors that affect mode choice before reviewing the available modelling tools.

### *Factors affecting mode choice*

Services regarding freight transport are acquired by shippers hence the relevant decisions are made based on a multitude of factors so that in the end the interests of them and their third-party logistics partners. Although the factors themselves do not differentiate much, as the costs are most of the time the main concern, this means that the importance of such factors in the decision making process is heavily dependent on the individuals making those decisions. Several researchers have made attempts to identify these factors and quantify their importance with Cullinane & Toy (2000) reviewing 75 related papers, concluding in the five most influencing of them, and Grosso (2011) giving a more up to date literature review on the subject. Combining the existing literature on freight modal choice yields the following main factors, which can be divided in five categories namely modal characteristics, commodity characteristics, shipper and receiver characteristics, logistics costs and other additional factors, as seen in Table 25 below.

**Table 25: Factors affecting freight modal choice, compiled from (Cullinane & Toy, 2000) (Grosso, 2011) (Brogan, et al., 2013) (Cambridge Systematics Inc., 1996)**

| Categories | Factor |
|---|---|
| **Modal Characteristics** | Capacity |
| | Transit time/Speed |
| | Reliability |
| | Loading availability |
| | Weight and volume limits |
| **Commodity Characteristics** | Shipment size |
| | Package characteristics |
| | Shipment shelf life |
| | Shipment value |
| | Shipment density |
| | Perishability |
| **Shipper and Receiver Characteristics** | Access to modes |
| | Influence of the customers |
| | Company policy |
| **Logistics Costs** | Order and handling costs |
| | Transport charges |
| | Capital carrying cost in transit |
| | Service costs |
| | Inventory costs |
| | Loss and damage costs |
| **Additional Factors** | Length of haul |
| | Shipment frequency |
| | Environmental and sustainability |
| | Security requirements |

These factors play a very important role in forming the criteria used to shape various mathematical cost functions for mode choice modelling. They are the backbone of modelling methodologies used within this step, methodologies that will be reviewed in the coming paragraphs.

### *Modal split modelling methodologies*

Again here the main distinction between models splits them in aggregate and disaggregate. The distinction, as de Jong (2014) explains, is made at the observation unit which, in disaggregate modelling approaches is the individual actor (traveller or firm) and in aggregate approached is the combination of actors at a certain spatial level. Although both types have been developed for freight transport mode choice modelling, the latter is much more commonly used. Besides these two categories, Ali (2011) distinguishes further into elasticity-based as well as neoclassical and direct demand models. A brief overview of these model categories will follow.

- Elasticity-based models catch variations in individual variables, using elasticities that are derivatives of expert knowledge or taken from other models. They have limited data needs and are mainly used for rough strategic evaluations.
- Aggregate models make use of primarily binomial or multinomial logit models that give the market share percentage of a specific mode rather than absolute transport volumes. It is a relatively easy and pragmatic approach that produces decent result without much effort, especially in terms of data gathering.
- Neoclassical and direct demand models are based on the economic theory of the firm. Given a transport cost function they can directly produce a demand function for a specific mode. Although they have very limited data requirements, it is not easy to incorporate with the four-step methodology.
- Disaggregate models are mostly multinomial logit models (MNL) and make use of detailed data coming from a variety of surveys. Besides MNL, other model variations can be found here, such as nested logit, probit, cross nested logit etc. (de Jong, 2014). For disaggregate observations, utility maximization theory is used as the base for these models (Samar Ali, 2011). Disaggregate models can incorporate a great variety of variables but they have a great need for data, which in freight transport modelling can prove quite a large deficit.

### Network Assignment

This constitutes the fourth step of the methodology and has to do with assigning the flows determined in the previous steps onto the respective transport network. These networks are composed of links that together make up routes that a transport mode can use. A distinction that can be made here is whether the assignment step is done separately or in combination with mode choice. The former allows for a disaggregate mode choice model but can lead to unreal results while the latter can handle multimodal chains on the same route but lacks in control over the optimization process (Samar Ali, 2011).

## 3.5 Modelling for air freight

In this chapter, a complete overview of the modelling methodologies and techniques for freight transport has been given. The way these methods were developed, originating from passenger transport and then adapted to the needs of that of freight, produced solutions that address satisfyingly the needs of general freight transport. Moreover, as capacity limitation is a bigger issue for road and sea transport than other modes, the focus has been always there resulting in extensive research being undertaken for these specific markets. On the other hand, air freight transport has been neglected in that sense, because this mode is still very strongly linked to passenger transport, transports a small volume of freight and there is still enough capacity left unused. As a result, modelling attempts for this mode have been limited and usually tackle very specific issues. For example, airline route optimization, airport slot allocation, fuel consumption minimization or personnel allocation optimization are some of the topics that one might find in modelling literature regarding air transport. In a strategic level, there is limited work done and even that has a different focus that the transport itself.

Such examples, from a financial management perspective, are the research done by Pak (2005), who investigates the modelling of airline revenue management both for cargo and passengers as well as its relationship with capacity. More focused on the link between air cargo revenue and capacity management is Popescu (2006), examining the cargo bidding and booking process next to revenue management. From a transport modelling perspective, the recent work of Scholz (2012) covers the subject of the network structuring of cargo airlines with the use of a simulation model. Other than that, the existing air cargo related literature contains many examples of works tackling very specific problems such as dynamic routing for time-sensitive cargo (Azadian, et al., 2011) and delay estimation modelling (Tu, et al., 2008).

On a strategic global level, the most relevant and recent work is a modelling tool developed by Martinez et al. (2014) aiming to forecast international freight and the related $CO_2$ emissions. Using Eurostat exports data that includes value, weight and mode, they calibrate a multinomial logit model to perform mode choice and produce value shares. In this case, air transport is taken in whole as one type of mode of transport, which, if forecasting emissions at a global level is the goal, makes sense. Air transport here is not further analysed as the market share of service types and the volumes on each route are irrelevant. That level of detail would be necessary once the goal is to model the freight volumes transported by air, internationally between world regions. Furthermore, such an addition to this modelling approach would allow approaching environmental issues that occur at a more microscopic level, such as noise pollution.

Incorporating the structure of air freight in a more detailed level is necessary to create a modelling approach applicable to air freight. As seen in the previous chapter, in air transport, there is a direct link between service type, costs, routes and network types. These elements are essential for a valid transport model, calling for a new approach as discussed in the chapter that follows.

# Chapter 4: Synthesis and Methodology

In this chapter the findings of the previous chapters are synthesized in order to form a suitable methodology for a large scale air freight model. More specifically, the generic guidelines of freight modelling that were described in Chapter 3: Modelling Transport are combined with the detailed analysis of the air transport industry in Chapter 2: The Air Freight Industry, in order to produce a result that will be tailored to the needs and characteristics of air freight transport.

## 4.1 Introduction

As described in previous chapters, freight transport modelling developed as a by-product of passenger transportation modelling. Nevertheless, the relevant tools evolved through time and gave us better methodologies that are better equipped to describe freight transport. Still, the main focus has been consistently given on more mainstream transport modes leaving air transport out, except for recent modelling efforts that are focused on emissions and only include air on the initial general mode choice (Martinez, et al., 2014). Therefore, to begin this chapter is a brief point-by-point comparison of the aircraft as a mode of transport, in a modelling perspective, which leads to formulating a conceptual framework. At first that conceptual framework for a strategic air freight modelling approach is presented with the remaining of this chapter following the logic of the freight modelling methodology, being divided according to the steps necessary. First comes the demand for freight transport, followed by mode choice between air and sea transport. The third step is additional to the generic framework and it has to do with service choice between different types of air transport services offered according to the specific transport needs of each commodity. Next is the route choice step and finally comes the assignment of flows to the network of each type of service.

## 4.2 Conceptual framework

The combination of the first two chapters leads to revealing the substantial differences between the air transport and the rest of the modes. At the demand level, the variance lies in the type of commodities that are transported via air. Here, only a small percentage, weight-wise, is served, leaving commodities that have higher value and/or time sensitivity. As most of the econometric and such models aiming to describe and forecast global trade are based in general economic and physical indicators on a country or region level (such as GDP, distance, population), they are made to capture total trade and not just the high-end, expensive goods. Knowing that air freight accounts for roughly 2% of the total transported weight, it is likely that the contribution of this mode can very well be within the error margins of such a trade model and therefore constitutes them insufficient to describe air freight related trade. Since the development of new methods to describe this part of the trade falls out of objective of this study, production and consumption in the form of global observed trade flows will be taken as input.

As far as mode choice is concerned, the thinking has to remain more or less the same. Each commodity has a specific utility for being transported with a specific mode. The differences here are found firstly in the number of modes available to choose from and secondly on how to express this utility. Obviously, here we are looking at modes that can cover transport of any type of goods globally, which leaves us with two choices, sea and air transport. Consequently, the utility of being transported with these modes cannot be judged alone on the difference in costs between them. The major attribute that separates them, being speed, must also be taken into account in the form of time savings. Therefore, in an air freight transport model, mode choice must be performed with the integration of commodity-specific time savings, expressed in terms of commodity unit value. Furthermore, this means that the trade input has to contain, next to weight, also value data.

Up to this point, the traditional modelling methodology, albeit the differences mentioned above, seems to cover the subject satisfyingly. At this point though, there is a gap. In the four-step methodology route choice would normally be following but, in air freight transport, at this stage there is not enough information to perform the route choice step. This is because, contrary to other modes, in air transport there is limited, if any, freedom in choosing a route. Every flight leg has to start and end at an airport. Adding this to the fact that refuelling en route is out of the question makes it clear that whatever limited possible deviations from the planned route are saved only for emergencies. Additionally, not all airports can serve all types of aircraft (due to minimum runway length requirements, guidance systems etc.) and neither at all times (due to environmental and noise restrictions). Also, airport slots is a scarce good with limited availability and high demand. For these reasons, airlines form agreements between them and with airports and plan their slots months ahead. Therefore, routes have already been decided beforehand and cannot be changed at will. This makes for an important difference with other modes, for example trucks where there is the ability to freely choose practically any available route or ships where there is the possibility to change routing and ports with relatively short notice. There is at this point the need for an intercalary step which can then provide a clear link to the routes.

In the five step freight modelling methodology, this step is described as logistics services (Tavasszy, 2006) and contains inventory location and further considerations related to supply chain management. The thinking behind this step is to identify and incorporate elements that influence and shape the route choice and the same can be applied for air transport. The decisive logistics element here though is not inventory location, as we are dealing with fast moving commodities where lack of inventory is the objective. The decisive element is the type of air freight service as that is the reason behind the differences in fleet composition and airport choice, hence route choice. Therefore, the third step should contain the air freight service choice, between the three available types, (belly, cargo-only and integrator) as discussed in chapter 2. A utility based choice between services can be performed here, similarly to the step of mode choice, based on cost differences and the value of the commodities.

Having transformed the raw trade flows into air freight flows per service type, we have the necessary information to proceed with route choice. To achieve that, it is necessary to map the available links between airports of each region in a service type specific way. Air freight volumes can then be allocated to the routes that are used by the service type chosen. A critical assumption here is that once a service type is chosen, it cannot change meaning that multi-air-freight-service-type transport solutions are not considered. Finally, the air freight volumes per route and service can be transformed in number of aircraft using commodity specific densities and combining them with the cargo transporting volume capacity of design aircraft, calculated for each service type based on their fleet composition.

Figure 20 shows in a concise diagram the methodology described here and followed in the making of this modelling attempt where the inputs, processes, steps and outputs of the model can be clearly seen.

Following that is an in-depth description of all the model components and inputs used, presented in a five step logic, in accordance to that of the model itself.

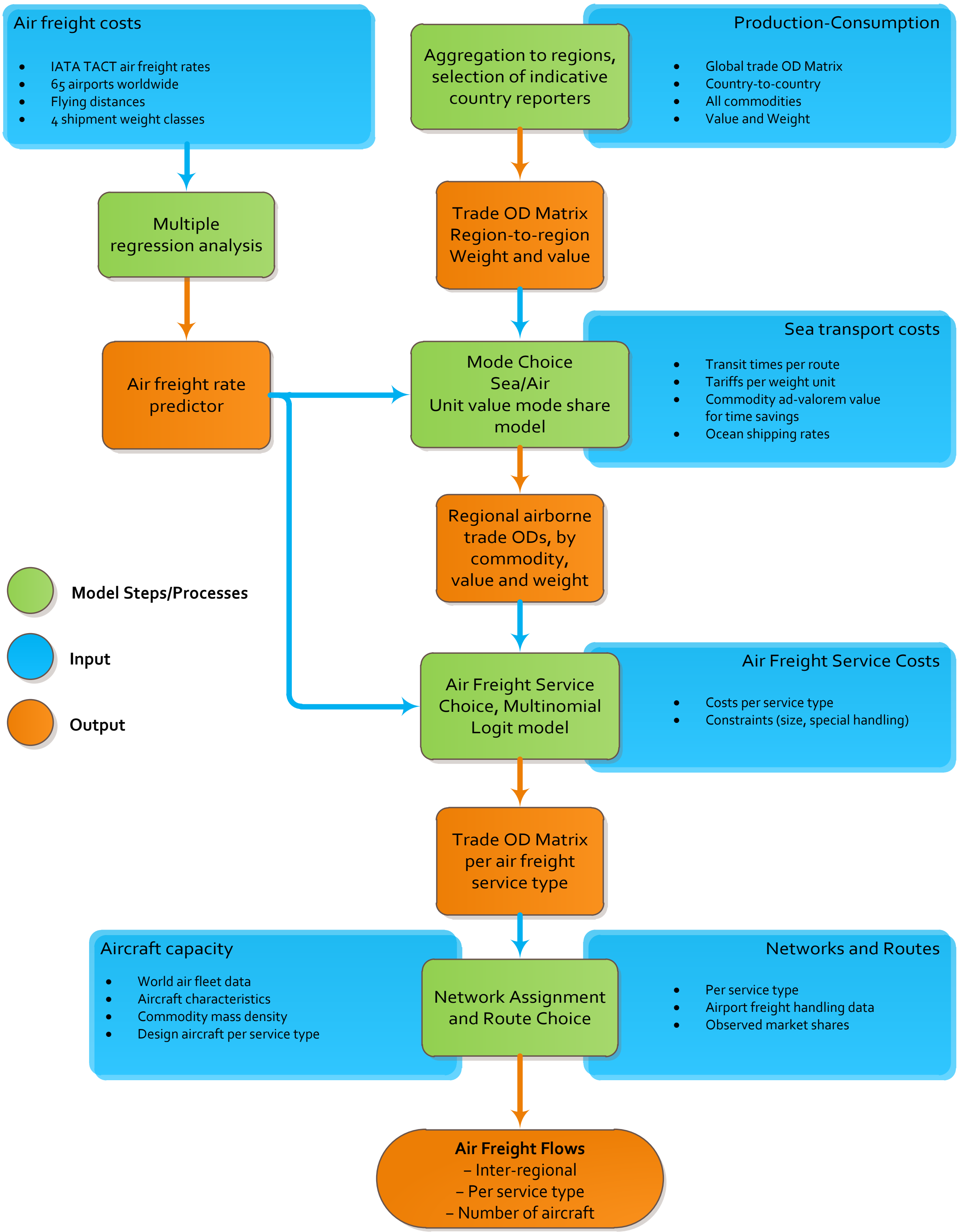



**Figure 20: Schematic description of the model**

## 4.3 Step 1: Economic inter-activity - Trade flows OD matrix

As explained previously, the demand for air freight consists mostly of high value and time-sensitive goods that are transported internationally. Therefore it is common to see air freight demand linked to global economic indicators such as GDP. Kupfer et al. (2009) investigated the relationship between world air freight, measured in tonne-kilometres, merchandise exports and the share of manufactures in them. Their model showed an elasticity of 1 between demand and both indicators, meaning a 1% change in them will result, in the long run, in 1% change in air freight demand. Albeit such a relationship being correct, the global economic environment has proven quite volatile in the past decade and can be affected by a variety of developments, irrespective of where in the world they take place.

For that reason, and for the purposes of this study, observed trade data will be used as a demand starting point. At first all the commodity classes will be used, as defined by the Standard International Trade Classification (SITC) Revision 4. There are 10 general commodity groups (sections) in SITC Rev.4, further split in 67 divisions, 262 groups and 1023 subgroups. The general commodity sections can be seen in Table 26.

**Table 26: Commodity sections according to the SITC Rev.4 (United Nations, 2006)**

| Commodity section code | Description |
|---|---|
| **0** | Food and live animals |
| **1** | Beverages and tobacco |
| **2** | Crude materials, inedible, except fuels |
| **3** | Mineral fuels, lubricants and related materials |
| **4** | Animal and vegetable oils, fats and waxes |
| **5** | Chemicals and related products |
| **6** | Manufactured goods classified chiefly by material |
| **7** | Machinery and transport equipment |
| **8** | Miscellaneous manufactured articles |
| **9** | Commodities and transactions not classified elsewhere in the SITC |

The trade datasets were taken from the UNComtrade website where they are publicly available. The trade data for the year 2012 were used as this is the most recent year with complete data for all countries. The reason for choosing that particular data source is that these databases give the total trade flows at a country to country level for all commodities (SITC Rev.4 Classification) and, most importantly, they contain both value and weight for each of them. For manageability reasons and taking into account that the database has a limit of maximum 50000 entries per download request, the world has been divided in 7 large regions (based on the observed air freight routes), and for each region a number of indicative countries were chosen as representatives based on air freight affecting factors (GDP, availability of source materials, area covered, population, production areas, location of major cargo hubs). These regions and the respective indicative countries are:

- EU27 and Russia
- North America (Canada, USA, Mexico)
- Latin America (Colombia, Brazil, Argentina, Peru, Bolivia)
- Asia (China-all regions, Japan, India, Thailand, Singapore, Bangladesh)
- Middle East (Qatar, Brunei, Kuwait, Bahrain, United Arab Emirates, Saudi Arabia)
- Africa (South Africa, Nigeria, Algeria, Morocco, Botswana, Egypt, Namibia)
- Oceania (Australia, Fiji, Indonesia, New Zealand, Papua New Guinea)

Figure 21 shows the GDP per capita of all countries in the world, based on purchasing power parity, according to data from the World Bank for the years 2011 to 2013. The map shows clearly the areas with high purchasing power, which create much of the demand for business-to-customer air freight transport. Developing areas, where a big part of the world's manufacturing of goods takes place create also such demand, but business-to-business.

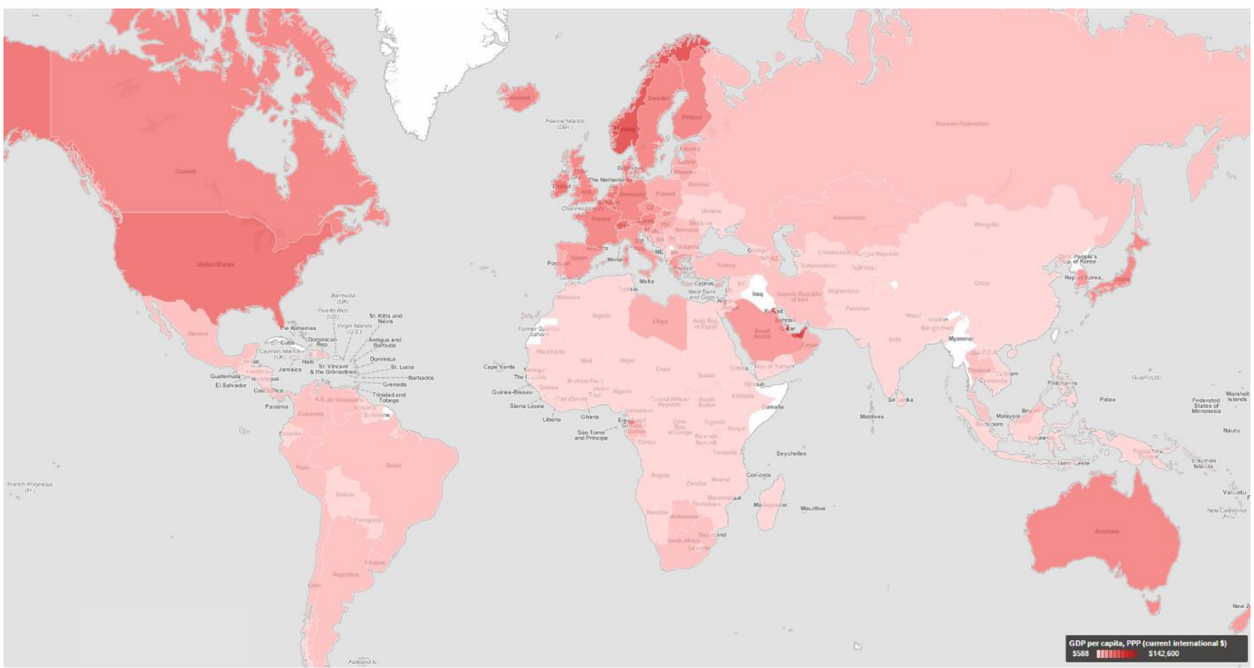


**Figure 21: Map of the world coloured according to the GDP per capita in 2013 US dollars (The World Bank, 2014a)**

## 4.4 Step 2: Mode choice (air/sea)

Since wide regions are taken into consideration with large distances separating them, for the purposes of this study it can be assumed that there are only two viable options to transport goods from one to another, namely by air and by sea.

Modal split between air and sea can be done by calculating the difference in depreciation of the commodities between sea and air transport. Having the value of a commodity and assuming a yearly depreciation (interest) rate it is possible to see which commodities are best served by air, as the savings in depreciation of their value due to less travel time balances the higher transport costs of air freight transport. Other assumptions for that matter could be that the access and egress costs (door to port/airport and port/airport to door) are the same or differ insignificantly as those segments are usually performed by truck transport. Furthermore it can also be assumed that the costs involved with customs are the same between the same two countries and for the same commodity regardless the mode of transport. With that said, the conclusive difference that leads to mode choice is the balance between transport costs and commodity value depreciation.

Tables that can be used for that matter can be trade matrices between countries that include the value of the commodities. The direction of the flow will be shown by whether trade volumes are imports or exports. As the model has a low level of detail and a global scope, in the case where trade flows are found at country level, they will be aggregated to region level.

As discussed in the previous step, the UNComtrade data provide value and weight per commodity type hence the mode choice at this stage can be executed with the use of value density (value per unit weight). Besides transportation costs, the depreciation in value of a certain commodity can be regarded as inventory costs during transit and must be considered as well. When that is also taken into account, the weight and cost of an item can justify centralized stocking with air shipments, meaning that the more expensive an item is, the higher the inventory carrying costs will be. Comparing the total costs, transportation and inventory for air and sea shipments, should give the mode of transportation that results in lower total costs and is therefore selected.

As a decision variable the cost (or price) of an item can be derived. In order to calculate this, for each destination the freight cost by air and by sea and the corresponding transportation times are needed. Hence for an item to be transported by air the following must hold:

*AirFreightCost − SeaFreightCost < SeaInvCost – AirInvCost*

$$\Delta FreightCost < \frac{UnitValue \cdot ICC \cdot Tsea}{365} - \frac{UnitValue \cdot ICC \cdot Tair}{365}$$

$$\Delta FreightCost < UnitValue \cdot \frac{ICC}{365}(Tsea - Tair)$$

$$UnitValue > \frac{365 \cdot \Delta FreightCost}{ICC \cdot \Delta T}$$

With the above formula the unit cost (or the price) of an item becomes the decision variable for choosing air-freight services, where:

- AirFreightCost: The base cost to transport a unit by air for a specific route
- SeaFreightCost: The base cost to transport a unit by sea for a specific route
- UnitValue: The value per unit of a specific commodity
- ICC: Annual inventory carrying cost percentage for a specific commodity
- Tair: The total transit time by air transport for a specific route in days
- Tsea: The total transit time by sea transport for a specific route in days

At this stage general freight transport cost values per route per weight unit can be used to perform the air-sea mode choice. For sea transport, values are derived from the latest Review of Maritime Transport (UNCTAD, 2013) publication and for air transport, base values per route found in literature can be used. Transit times can be calculated with the use of flight distances and speeds. To calculate the flight distance, the great circle distance (GCD) is computed, having the latitude and longitude of each airport, and then multiplied by a region specific factor k, in order to increase the distance due to flight inefficiencies, as shown in the detailed analysis by Reynolds (2009). The formula for the GCD between two airports A and B as well as the values for k are the following:

$$GDC = R \cdot k \cdot \cos^{-1}(\sin LAT_A \cdot \sin LAT_B + \cos LAT_A \cdot \cos LAT_B \cdot \cos \Delta L)$$

Where:

- GDC: The great circle distance between A and B in kilometres
- R: The Earth radius, taken equal to 6371 km
- $LAT_i$: The latitude of point i in degrees
- ΔL: The absolute difference between the longitudes of A and B
- k: A flight path inefficiencies factor, the values of which can be seen in Table 27

**Table 27: Values for the flight path inefficiency factor k, Reynolds (2008) (2009)**

| Flight Region | Value for k |
|---|---|
| Domestic Europe | 1,14 |
| Domestic US | 1,12 |
| Domestic Africa | 1,08 |
| Europe - US | 1,05 |
| Europe - Asia | 1,07 |

For routes between regions that are not covered by the values of the previous table but the respective regions are recorder, the value for factor k is taken as the average values of the k values of those regions. For regions that are not covered whatsoever, the value for k has been taken as the average of all values for all regions. Table 28 shows the average flying distances between the world regions taken into account in this study.

Table 28: Average flying distances between world regions (in kilometres)

| Average flying distances | Africa | Asia | Europe | L. America | M. East | N. America | Oceania |
|---|---|---|---|---|---|---|---|
| Africa | - | 11529 | 5863 | 9384 | 5474 | 12369 | 15238 |
| Asia | 11529 | - | 9786 | 18750 | 7588 | 12539 | 7820 |
| Europe | 5863 | 9786 | - | 10742 | 4989 | 8144 | 17176 |
| Latin America | 9384 | 18750 | 10742 | - | 13591 | 8987 | 14582 |
| Middle East | 5474 | 7588 | 4989 | 13591 | - | 13109 | 12994 |
| North America | 12369 | 12539 | 8144 | 8987 | 13109 | - | 15113 |
| Oceania | 15238 | 7820 | 17176 | 14582 | 12994 | 15113 | - |

At this stage, it is necessary to translate these flying distances into flying times in order to compare with ocean shipping and use as input in the mode choice equation described previously. To achieve that, a fictitious design aircraft is used, the characteristics of which are the result of a weighted mean of the characteristics of the aircraft that comprise the world airliner fleet. Figure 6 shows the percentages of the world fleet that each type of aircraft is accountable for. Using these percentages as weights while incorporating the numbers of freighter aircraft that are operational, yielded a design aircraft with the following main characteristics.

Table 29: Main characteristics of the design aircraft

| | Design Aircraft |
|---|---|
| Cargohold volume ($m^3$) | 122 |
| Payload (t) | 35 |
| Operational speed (km/h) | 829 |
| Range (km) | 6.633 |

With these values in mind, Table 28 can be transformed to show the average flying times between regions of the world as shown below.

Table 30: Average flying times between world regions, in hours

| Average flying times | Africa | Asia | Europe | L. America | M. East | N. America | Oceania |
|---|---|---|---|---|---|---|---|
| Africa | - | 14 | 8 | 12 | 7 | 15 | 19 |
| Asia | 14 | - | 12 | 23 | 10 | 16 | 10 |
| Europe | 8 | 12 | - | 13 | 7 | 10 | 21 |
| Latin America | 12 | 23 | 13 | - | 17 | 11 | 18 |
| Middle East | 7 | 10 | 7 | 17 | - | 16 | 16 |
| North America | 15 | 16 | 10 | 11 | 16 | - | 19 |
| Oceania | 19 | 10 | 21 | 18 | 16 | 19 | - |

At his point, it has to be noted that air freight consists mostly of night operations. As a matter of fact, 82% of cargo departures at the main European airports take place between midnight and 05:00 in the morning

(EUROCONTROL, 2009). On top of that, airlines try to consolidate shipments to achieve a better load factor and cargo has to go through time consuming security checks and customs procedures. This means that it takes some time for a shipment to actually be loaded in an aircraft and start flying. Additionally, cargo airlines operate a multi-hub network structure (EUROCONTROL, 2009) which, in combination with aircraft range limitations, means that there will be stops in hub airports along the way, especially for long haul flights, also for refuelling purposes. All these reasons lead to the conclusion that taking into account only the actual flying times is not representative of the reality. In order to resemble actual operations more closely, an extra amount of time (12 hours) was added to the values of the previous table and then they were rounded up to the closest half day. These final values can be better compared to the ocean transport transit times that already incorporate such delays to some extent. This yields the following table:

**Table 31: Average flying transit times between world regions, in days**

| *Average flying times* | *Africa* | *Asia* | *Europe* | *L. America* | *M. East* | *N. America* | *Oceania* |
|---|---|---|---|---|---|---|---|
| ***Africa*** | - | 2 | 0.5 | 1.5 | 0.5 | 2 | 2 |
| ***Asia*** | 2 | - | 1.5 | 2.5 | 1 | 2 | 0.5 |
| ***Europe*** | 0.5 | 1.5 | - | 2 | 0.5 | 1 | 2.5 |
| ***Latin America*** | 1.5 | 2.5 | 2 | - | 2 | 0.5 | 2 |
| ***Middle East*** | 0.5 | 1 | 0.5 | 2 | - | 2 | 2 |
| ***North America*** | 2 | 2 | 1 | 0.5 | 2 | - | 2 |
| ***Oceania*** | 2 | 0.5 | 2.5 | 2 | 2 | 2 | - |

The next key component to deciding the mode choice between air and sea transport is the transit times between world regions with ocean transport. To determine this, the top 50 container ports of the world in throughput were considered, covering all the regions (UNCTAD, 2013) (Port of Hamburg, 2014) (World Shipping Council, 2014) and the transit times between them were determined based on publicly available schedules from various shipping lines. Ports were then grouped by region and the averages between ports of regions were used to yield a general transit time value between them, which can be seen in Table 32.

**Table 32: Average shipping transit times between world regions, in days**

| *Average shipping transit times* | *Africa* | *Asia* | *Europe* | *L. America* | *M. East* | *N. America* | *Oceania* |
|---|---|---|---|---|---|---|---|
| ***Africa*** | - | 21.1 | 8.6 | 14.8 | 8.8 | 21.2 | 20.9 |
| ***Asia*** | 21.1 | - | 29.5 | 29.9 | 14.1 | 25.2 | 9.1 |
| ***Europe*** | 8.6 | 29.5 | - | 15.7 | 15.5 | 17.9 | 28.5 |
| ***Latin America*** | 14.8 | 29.9 | 15.7 | - | 22.3 | 12.9 | 25.3 |
| ***Middle East*** | 8.8 | 14.1 | 15.5 | 22.3 | - | 25.6 | 33.8 |
| ***North America*** | 21.2 | 25.2 | 17.9 | 12.9 | 25.6 | - | 26.4 |
| ***Oceania*** | 20.9 | 9.1 | 28.5 | 25.3 | 33.8 | 26.4 | - |

As far as the transportation costs per mode are concerned, prices here can fluctuate depending on market conditions. For maritime transport many sources provide general cost data per TEU or FEU for transport through the main shipping routes. As Rodrigue (2012) mentions in his research, shipping rates can vary with distance, trade patterns, market conditions and whether it is export or import flow among other. Furthermore, he provides some cost values between American ports and Shanghai, values that are in accordance with the ones published for the same routes by the UNCTAD (2013). These values are general and include all commodities moved with maritime transport, ranging between 1000$ and 2000$ which, assuming a TEU contains an average of 12.5 tons, translates to a range of 7 to 17 US dollar cents per kg. On the other hand, when more commodity-specific data are taken into account, the values are different. The Organisation of Economic Co-operation and Development provides such data on their online database, where the maritime transport costs between two countries can be found per weight unit, specifically for containerized manufacturing commodities. The data reach as far as 2007 and vary quite a lot, compared to the general values. For flows from China to Europe and the USA, average values are some 4 to 6 times higher (0.65$ and 0.37$ per kg respectively) and 1.5 to 2.5 times (0.24$ and 0.17$ per kg respectively) for the reverse flow (OECD, 2014). Diving further into the ocean shipping costs, Korinek & Sourdin (2009) provide indicative costs per TEU for a selection of main routes between Asia, Asia-pacific, EU, US and Africa. Although these values come from data for the first half of 2008 and naturally have changed since then, the differentiations observed between them can be assumed to have remained stable as they have to do with the costs at specific ports and countries as well as with the trade characteristics between them.

In order to reach to a matrix of ocean shipping cost values that reasonably resembles the actual costs, a combination of all the previously mentioned sources is necessary. More specifically, using as basis the values obtained from OECD (2014) for the average cost of shipping a kg of containerised manufacturing commodities from Europe to Asia, as this is the most established set of data available, it is possible to apply weight factors on this value and determine the respective cost for other routes. These weight factors can be derived by dividing the costs of various routes, as given by Korinek & Sourdin (2009), by the cost value they provide for the Europe to Asia route. The resulting ocean shipping costs can be seen in Table 33.

**Table 33: Ocean shipping costs between world regions, in US$ per kg**

| *Ocean shipping costs* | *Africa* | *Asia* | *Europe* | *L. America* | *M. East* | *N. America* | *Oceania* |
|---|---|---|---|---|---|---|---|
| ***Africa*** | - | 0.30 | 0.13 | 0.38 | 0.20 | 0.58 | 0.40 |
| ***Asia*** | 0.45 | - | 0.50 | 0.68 | 0.33 | 0.50 | 0.08 |
| ***Europe*** | 0.25 | 0.25 | - | 0.25 | 0.28 | 0.46 | 0.23 |
| ***Latin America*** | 0.58 | 0.58 | 0.50 | - | 0.65 | 0.70 | 0.08 |
| ***Middle East*** | 0.33 | 0.20 | 0.38 | 0.50 | - | 0.70 | 0.33 |
| ***North America*** | 0.75 | 0.25 | 0.28 | 0.35 | 0.45 | - | 0.28 |
| ***Oceania*** | 0.55 | 0.10 | 0.45 | 0.15 | 0.58 | 0.53 | - |

In the case of air shipping costs, the available data are very scarce. The air freight market deals with a very small percentage of the total demand for transport, at least volume and weight-wise, making such data very valuable in the fight of carriers to keep their market share against other competitors, not just within the same mode of transport. Nevertheless, at this stage the mode choice between ocean and air transport is performed at a very high level thus it could be argued that the absence of detailed data does not affect the result greatly. Therefore, one way to overcome the obstacle of air freight tariffs is to use found in the report by The World Bank Group (2009), generic as they may be, as seen in Table 24.

Another way is to analyse further the structure of air freight tariffs and produce route specific formulas that can satisfyingly predict the air freight rates. To achieve this, IATA's The Air Cargo Tariff and Rules (TACT) for the year 2008, so as to be comparable with the ocean shipping rates, was made available. TACT includes air freight rates in a worldwide airport-to-airport base, given by weight classes and sometimes by type of service, commodity and/or carrier. The latter though, is an information that is not present in the majority of airport sets and thus cannot be used with confidence. Combining the data from TACT with the flying distances calculated previously, a dataset that contains air freight rates, flying distances and weight classes is produced. This dataset is then used to perform a multiple regression analysis with air freight rate as the predicted variable while flying distance and shipment weight class being the two independent variables, as in:

$$AirFreightRate_{ij} = b_{0,ij} + b_{1,ij} \cdot WeightClass + b_{2,ij} \cdot FlyDistance_{ij}$$

In order to use the available data as efficiently as possible and produce formulas that can predict the air freight rates as close as possible, different regression analyses have been made for each dataset of each of the region pair flows, from region i to region j. The regression weights $b_0$, $b_1$ and $b_2$ that were computed for each pair can be seen in Table 34.

The shipment weight classes given in the TACT are four, namely up to 100 kgs, from 100 to 300 kgs, from 300 to 500 kgs and finally higher than 500 kgs. For the regression dataset needs, the average of each class has been used and paired with the respective flight distance and air freight rate. The regression weights reveal an expected outcome with two main conclusions. The first is that higher shipment weight classes result in lower rates which is rather reasonable as larger shipments make it easier for the carrier to fill up their aircraft, achieving higher fleet utilization and thus lowering their operation costs. The second is that flying distance is directly proportional with the freight rates. This is also expected, as the further the destination is, the more fuel have to be used and, as discussed in previous chapter, fuel is a large part of the carriers' total cost structure. There are of course other hidden variables within these results such as airport agreements and the variability in airport costs for landing, handling etc. Although, with the available data, it is impossible to extract such variables, the use of a number of different airports for each region should help in offsetting the gravity of their influence on the final result.

Table 34: Directional regression weights per region pair

| From/To | | Africa | Asia | Europe | Latin America | Middle East | North America | Oceania |
|---|---|---|---|---|---|---|---|---|
| Africa | ***b0*** | — | -5.9948 | 2.0359 | 8.1826 | 0.7905 | 4.2164 | 4.4104 |
| | ***b1*** | — | -0.0096 | -0.0046 | -0.0138 | -0.0078 | -0.0081 | -0.0119 |
| | ***b2*** | — | 0.0015 | 0.0005 | 0.0006 | 0.0011 | 0.0005 | 0.0006 |
| Asia | ***b0*** | 4.5070 | — | -8.9756 | 7.5204 | 2.9132 | 10.2482 | 5.2800 |
| | ***b1*** | -0.0144 | — | -0.0104 | -0.0152 | -0.0099 | -0.0103 | -0.0065 |
| | ***b2*** | 0.0008 | — | 0.0019 | 0.0005 | 0.0009 | 0.0001 | 0.0002 |
| Europe | ***b0*** | 6.1541 | 5.3970 | — | 13.2197 | 3.4869 | 7.4326 | -8.0901 |
| | ***b1*** | -0.0153 | -0.0129 | — | -0.0142 | -0.0104 | -0.0086 | -0.0320 |
| | ***b2*** | 0.0010 | 0.0005 | — | 0.0000 | 0.0012 | 0.0001 | 0.0019 |
| Latin America | ***b0*** | 4.8102 | 30.1519 | 4.1496 | — | 17.9343 | 3.2331 | 11.0247 |
| | ***b1*** | -0.0230 | -0.0132 | -0.0175 | — | -0.0251 | -0.0045 | -0.0077 |
| | ***b2*** | 0.0015 | -0.0008 | 0.0010 | — | 0.0004 | 0.0003 | 0.0003 |
| Middle East | ***b0*** | 1.3346 | 21.4371 | -0.8485 | -27.7314 | — | 10.5612 | 31.7216 |
| | ***b1*** | -0.0136 | -0.0157 | -0.0083 | -0.0213 | — | -0.0145 | -0.0243 |
| | ***b2*** | 0.0016 | -0.0013 | 0.0016 | 0.0033 | — | 0.0004 | -0.0009 |
| North America | ***b0*** | 10.7239 | 10.7421 | 5.5523 | 4.8175 | 7.9339 | — | 5.9720 |
| | ***b1*** | -0.0172 | -0.0188 | -0.0116 | -0.0081 | -0.0146 | — | -0.0085 |
| | ***b2*** | 0.0008 | 0.0003 | 0.0005 | 0.0005 | 0.0006 | — | 0.0005 |
| Oceania | ***b0*** | 4.0093 | -13.0551 | -34.2710 | 19.2057 | -5.4585 | 12.5752 | — |
| | ***b1*** | -0.0120 | -0.0084 | -0.0134 | -0.0181 | -0.0110 | -0.0179 | — |
| | ***b2*** | 0.0005 | 0.0025 | 0.0025 | -0.0002 | 0.0011 | 0.0001 | — |

The time savings component of the mode choice, expressed as annual carrying cost percentage, although as a concept fits the purpose of this study, is also problematic. At first, finding commodity specific rates is a difficult task and these available vary from country to country. Secondly, not all commodities are depreciable or have a useful life that exceeds one year, rendering this method inappropriate as it would result in excluding such goods. For that reason, this component is substituted by values reflecting the daily time savings from choosing a faster mode of transport, in other words the firm's willingness to pay for time savings. Hummels et al. (2007) give such commodity-specific values as percentages of the value of each commodity. Therefore, the final form of the mode choice decision variable for a commodity k between regions i and j would be:

$$UnitValue_k > \frac{\Delta FreightCost_{ij}}{VT_k \cdot UnitValue_k \cdot \Delta T_{ij}} \Leftrightarrow UnitValue_k > \sqrt{\frac{\Delta FreightCost_{ij}}{VT_k \cdot \Delta T_{ij}}}$$

Where VT depicts the value of time savings per day, as a percentage of the unit value of the commodity. These values range from 0.2% for footwear to 2% for road vehicles (Hummels, et al., 2007).

## 4.5 Step 3: Service choice

After step 2, only the goods that are better served by air transport will remain. Next comes the choice between the available air freight transport services, namely pure cargo airlines, combination carriers and integrators. In order to achieve this, the split of the demand between services will be made based on the commodities' time-sensitivity and value density as well as the different transport costs between services and the availability thereof. Furthermore, the differences in rates between the available services will be a decisive factor in said choice especially for commodities that are not highly time-sensitive.

Regarding the time sensitivity of the various commodities, Djankov et al. (2006) give an indication of time-sensitive and insensitive industries under the SITC categorization system. As insensitive, industries revolving around materials such as various fabrics, glass and various construction materials are found while industries of electrical equipment, machines and the parts thereof are found to be time-sensitive. Furthermore, the authors categorize agricultural products according to their time-sensitivity, based on their minimum storage life (Djankov, et al., 2006). These indications can be used at this point to determine which commodities can be regarded as time-sensitive and therefore will be candidates for higher end air transport services.

Similarly to step two, shippers are assumed to choose an air transport service based on the characteristics of the commodity they wish to ship, the price of the service and the availability thereof. Determining the price differentiations between the air transport services is not an easy task, as the actual prices are usually customer-specific and the data are not available publicly. Nevertheless, the TACT data, where service-specific values are available, suggest a rate step of around 30% between the air transport services, with belly transport being the cheapest, pure cargo in the middle and integrators the most expensive. However, allowing the differences in utility between the alternatives to remain only in terms of a fixed cost difference would result in constant probabilities amongst them, no matter the commodity. This is clearly misleading.

At this point, an assumption is necessary to clear this out. That assumption is that the transport needs of a commodity are directly linked to its value. The most expensive of goods are more likely to be susceptible to damage or theft and therefore have a greater need for a better, more secure transport service that also has the ability to offer special handling along the transport chain. Furthermore, these commodities, having higher value, are expected to enjoy higher benefits from a faster service hence would be expected to choose freight-oriented air transport services, cargo-only or integrators. It is clear then that the value of the goods must be integrated in the service choice.

Having so far obtained equations that predict air freight costs between the world regions, a Multinomial logit model is applied. The air freight rate equations are differentiated by service type firstly in terms of cost, by applying the multiplication steps discussed above. Secondly, an alternative specific constant (ASC) is applied to one of these, in this case belly transport. Now, this ASC needs to have the ability to shape the choice probabilities in a commodity value specific manner and be easy to calibrate. Following the key assumption, the actual value of the commodity is not a good enough measure. Instead, the difference between the commodity's value and the pivot point value between choosing air or sea transport shows the "worthiness to fly" of a certain commodity and is comparable throughout the total commodity group range. Multiplying this component by a scale parameter allows for later calibration. Using the mode choice pivoting value as expressed in the previous step, the utilities of commodity k for transport with each air freight service type between regions i and j and the corresponding probabilities per alternative are the following:

$$PPV_{ij}^{k} = \sqrt{\frac{\Delta FreightCost_{ij}}{VT_k \cdot \Delta T_{ij}}}$$

$$U_{ij,k}^{B} = \lambda \cdot \left(V_k - PPV_{ij}^{k}\right) + V_k \cdot VT_k \cdot \Delta T_{ij}^{B} - AirFreightRate_{ij}$$

$$U_{ij,k}^{C} = V_k \cdot VT_k \cdot \Delta T_{ij}^{C} - \varphi \cdot AirFreightRate_{ij}$$

$$U_{ij,k}^{I} = V_k \cdot VT_k \cdot \Delta T_{ij}^{I} - \varphi^2 \cdot AirFreightRate_{ij}$$

$$P_S^{k,ij} = \frac{e^{\beta \cdot U_{ij,k}^{S}}}{e^{\beta \cdot U_{ij,k}^{B}} + e^{\beta \cdot U_{ij,k}^{C}} + e^{\beta \cdot U_{ij,k}^{I}}} \quad , S = B, C, I$$

Where:

$PPV_{ij}^{k}$: The mode choice pivot point value for commodity k between regions i and j

$U_{ij,k}^{B}$, $U_{ij,k}^{C}$, $U_{ij,k}^{I}$ : The utility for commodity k choosing a specific service (B: belly, C: cargo only, I: integrator) between regions i and j

$V_k$ : The value per unit weight of commodity k

$\Delta T_{ij}^{B}$, $\Delta T_{ij}^{C}$, $\Delta T_{ij}^{I}$: The time savings of each air freight service over ocean transport between regions i and j

$P_S^{k,ij}$: Probability of commodity k being transported with air freight service S between regions i and j

$\lambda$: Air freight service choice calibration parameter

β: MNL scale parameter

ϕ: Air freight service cost parameter, equal to 1.3

## 4.6 Step 4: Route choice

The Route choice step depends heavily on the available infrastructure and cost/revenue strategies of each carrier. This step has to be kept as simple as possible in order not to increase the complexity to unmanageable levels. Shortest flying distances and/or transit times can be used in combination with available airport freight handling capacity. Moreover, one very important factor regarding route choice is the frequency of the offered services. Services with high frequency are more preferred by shippers as they allow for more flexibility in their supply chain. Unfortunately, such information is not available and therefore a frequency component cannot be incorporated in this step.

To remain within the boundaries of this study, a selection of indicative airports has been made for each region based on the intensity of their cargo related activities. Publicly available data from IATA and other sources, such as airline and airport websites, have been used to make this distinction. Furthermore, the available connections of each airport of every region have been identified, regarding the service type-specific routes that are available. This will help create the air networks for each type of air freight service, necessary for the last step of network assignment that follows. The chosen airports per region are shown in Table 35.

**Table 35: The chosen airports for each of the world regions**

| Middle East | Asia |
|---|---|
| Dubai International Airport (DXB) | Hong Kong Int. Airport (HKG) |
| Doha International Airport (DOH) | Narita International Airport (NRT) |
| Abu Dhabi International Airport (AUH) | Incheon International Airport (ICN) |
| Sharjah International Airport (SHJ) | Shanghai Pudong Int. Airport (PVG) |
| Bahrain International Airport (BAH) | Singapore Changi International Airport (SIN) |
| King Khaled International Airport (RUH) | Taiwan Taoyuan International Airport (TPE) |
| King Abdulaziz International Airport (JED) | Suvarnabhumi Airport (BKK) |
| Kuwait International Airport (KWI) | Kansai International Airport (KIX) |
| Queen Alia International Airport (AMM) | Beijing Capital International Airport (PEK) |
| | Guangzhou Baiyun International Airport (CAN) |
| **Europe** | **Africa** |
| Amsterdam Schiphol Airport (AMS) | OR Tambo Int. Airport (JNB) |
| Brussels Airport (BRU) | Mohammed V Int. Airport (CMN) |
| Charles de Gaulle International Airport (CDG) | Murtala Muhammed Int. Airport (LOS) |
| Cologne Bonn Airport (CGN) | Jomo Kenyatta Int. Airport (NBO) |
| Copenhagen Kastrup Airport (CPH) | Bole Int. Airport (ADD) |
| Düsseldorf International Airport (DUS) | King Shaka International Airport (DUR) |
| Frankfurt am Main International Airport (FRA) | Houari Boumediene Airport (ALG) |
| Leipzig Halle Airport (LEJ) | Nnamdi Azikiwe Int. Airport (ABV) |
| Liège Airport (LGG) | Menara Airport (RAK) |
| London Heathrow Airport (LHR) | Léopold Sédar Senghor Int. Airport (DKR) |
| London Stansted Airport (STN) | Mwalimu Julius K. Nyerere Int. Airport (DAR) |
| Luxembourg-Findel International Airport (LUX) | Kotoka International Airport (ACC) |
| **North America** | **Latin America** |
| Memphis International Airport (MEM) | El Dorado International Airport (BOG) |
| Ted Stevens Anchorage Int. Airport (ANC) | Guarulhos André Franco Montoro Int. Airport (GRU) |
| Los Angeles International Airport (LAX) | Comodoro Arturo Merino Benítez Int. Airport (SCL) |
| Louisville Int. Standiford Field Airport (SDF) | Viracopos International Airport (VCP) |
| Miami International Airport (MIA) | Ministro Pistarini International Airport (EZE) |
| Indianapolis International Airport (IND) | Galeão - Antônio Carlos Jobim Int. Airport (GIG) |
| Newark Liberty International Airport (EWR) | **Oceania** |
| Hartsfield Jackson Atlanta Int. Airport (ATL) | Sydney Kingsford Smith Intl. Airport (SYD) |
| Dallas Fort Worth International Airport (DFW) | Melbourne International Airport (MEL) |
| Metropolitan Oakland International Airport (OAK) | Brisbane International Airport (BNE) |
| Licenciado Benito Juarez Int. Airport (MEX) | Auckland International Airport (AKL) |
| | Soekarno-Hatta International Airport (CGK) |

The types of service that are considered in this study include the following three, cargo, belly and integrator. The links between airports that serve each type of service are of course not constant, as airlines change their schedules and form different alliances through time that can affect greatly their routes and networks. At this time, the research performed for each airport and airline served thereat, revealed specific links between the world regions, as these are perceived for the purposes of this study. The available service links and, consequently, the networks that they form can be seen in Tables Table 36 to Table 42, where the ✓ symbol depicts the existence of a direct flight from at least one carrier of each service type, C for cargo only B for belly and I for integrator.

Table 36: Availability of Links from African airports to the world regions

| Origin Airport Location: Africa | Availability of Links | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Europe | | | Asia | | | Middle East | | | North America | | | Latin America | | | Oceania | | |
| (IATA Code) | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I |
| *(JNB)* | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | ✓ | — | — | ✓ | — | — | ✓ | — |
| *(CMN)* | ✓ | ✓ | ✓ | ✓ | — | — | ✓ | ✓ | — | ✓ | — | — | — | — | — | — | — | — |
| *(LOS)* | ✓ | ✓ | ✓ | ✓ | — | — | ✓ | ✓ | — | — | ✓ | — | — | — | — | — | — | — |
| *(NBO)* | ✓ | ✓ | — | — | ✓ | — | ✓ | ✓ | — | — | — | — | — | — | — | — | — | — |
| *(ADD)* | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | — | — | — | — | — | — | — | — |
| *(DUR)* | — | — | — | — | — | — | — | ✓ | — | — | — | — | — | — | — | — | — | — |
| *(ALG)* | ✓ | ✓ | — | — | ✓ | — | ✓ | ✓ | — | — | ✓ | — | — | — | — | — | — | — |
| *(ABV)* | ✓ | ✓ | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *(RAK)* | — | ✓ | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *(DKR)* | ✓ | ✓ | — | — | — | — | ✓ | ✓ | — | — | ✓ | — | ✓ | — | — | — | — | — |
| *(DAR)* | ✓ | ✓ | — | — | — | — | — | ✓ | — | — | — | — | — | — | — | — | — | — |
| *(ACC)* | ✓ | ✓ | — | — | — | — | ✓ | ✓ | — | — | ✓ | — | — | — | — | — | — | — |

Table 37: Availability of Links from Asian airports to the world regions

| Origin Airport Location: Asia | Availability of Links | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Europe | | | Africa | | | Middle East | | | North America | | | Latin America | | | Oceania | | |
| (IATA Code) | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I |
| *(HKG)* | ✓ | ✓ | ✓ | ✓ | ✓ | — | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | — | — | — | ✓ | ✓ | ✓ |
| *(NRT)* | ✓ | ✓ | — | — | — | — | ✓ | ✓ | — | ✓ | ✓ | ✓ | — | — | — | ✓ | ✓ | — |
| *(ICN)* | ✓ | ✓ | — | — | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | ✓ | — | — | — | ✓ | ✓ | — |
| *(PVG)* | ✓ | ✓ | ✓ | — | — | — | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | — | — | — | ✓ | ✓ | — |
| *(SIN)* | ✓ | ✓ | ✓ | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | ✓ | — | — | — | ✓ | ✓ | ✓ |
| *(TPE)* | ✓ | ✓ | ✓ | — | — | — | ✓ | — | — | ✓ | ✓ | ✓ | — | — | — | ✓ | ✓ | — |
| *(BKK)* | ✓ | ✓ | ✓ | — | ✓ | — | ✓ | ✓ | ✓ | — | — | — | — | — | — | ✓ | ✓ | — |
| *(KIX)* | ✓ | ✓ | — | — | — | — | ✓ | ✓ | — | ✓ | ✓ | ✓ | — | — | — | — | ✓ | — |
| *(PEK)* | ✓ | ✓ | — | — | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | — | — | — | ✓ | — |
| *(CAN)* | ✓ | ✓ | ✓ | — | ✓ | — | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | — | — | — | — | ✓ | ✓ |

Table 38: Availability of Links from Oceania airports to the world regions

| Origin Airport Location: Oceania | Availability of Links | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Asia | | | Africa | | | Middle East | | | Latin America | | | Europe | | | North America | | |
| (IATA Code) | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I |
| *(SYD)* | ✓ | ✓ | — | — | ✓ | — | ✓ | ✓ | — | — | ✓ | — | — | — | — | — | ✓ | ✓ |
| *(MEL)* | ✓ | ✓ | — | — | — | — | ✓ | ✓ | — | — | — | — | — | — | — | ✓ | ✓ | — |
| *(BNE)* | — | ✓ | — | — | — | — | — | ✓ | — | — | — | — | — | — | — | — | — | — |
| *(AKL)* | — | ✓ | — | — | — | — | — | — | — | — | ✓ | — | — | — | — | — | ✓ | ✓ |
| *(CGK)* | ✓ | ✓ | ✓ | — | — | — | ✓ | ✓ | — | — | — | — | ✓ | — | — | — | — | — |

Table 39: Availability of Links from European airports to the world regions

| Origin Airport Location: Europe | Availability of Links | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Asia | | | Africa | | | Middle East | | | North America | | | Latin America | | | Oceania | | |
| (IATA Code) | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I |
| *(AMS)* | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | — | — |
| *(BRU)* | ✓ | ✓ | — | ✓ | ✓ | ✓ | ✓ | ✓ | — | ✓ | ✓ | — | — | — | — | — | — | — |
| *(CDG)* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | — | ✓ | — | — |
| *(CGN)* | — | — | ✓ | — | ✓ | — | ✓ | ✓ | ✓ | ✓ | — | ✓ | — | — | — | — | — | — |
| *(CPH)* | ✓ | ✓ | — | — | ✓ | — | — | ✓ | — | ✓ | ✓ | — | — | — | — | — | — | — |
| *(DUS)* | — | ✓ | — | — | ✓ | — | ✓ | ✓ | — | — | ✓ | — | — | ✓ | — | — | — | — |
| *(FRA)* | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | — | ✓ | — | — |
| *(LEJ)* | ✓ | — | ✓ | — | — | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | — | — | — | — | — | — |
| *(LGG)* | — | — | ✓ | ✓ | — | — | ✓ | — | ✓ | ✓ | — | ✓ | — | — | — | — | — | — |
| *(LHR)* | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | ✓ | — | — | ✓ | — | — | — | — |
| *(STN)* | ✓ | — | — | — | — | — | ✓ | — | — | ✓ | — | ✓ | — | — | — | — | — | — |
| *(LUX)* | ✓ | — | — | ✓ | — | — | ✓ | — | — | ✓ | — | — | ✓ | — | — | ✓ | — | — |

Table 40: Availability of Links from Latin American airports to the world regions

| Origin Airport Location: Latin America | Availability of Links | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Asia | | | Africa | | | Middle East | | | North America | | | Europe | | | Oceania | | |
| (IATA Code) | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I |
| *(BOG)* | — | — | — | — | — | — | — | — | — | ✓ | ✓ | ✓ | ✓ | ✓ | — | — | — | — |
| *(GRU)* | — | ✓ | — | — | ✓ | — | — | ✓ | — | — | ✓ | — | — | ✓ | — | — | — | — |
| *(SCL)* | — | — | — | — | — | — | ✓ | — | — | ✓ | ✓ | — | ✓ | ✓ | — | — | ✓ | — |
| *(VCP)* | — | — | — | — | — | — | ✓ | — | — | ✓ | — | ✓ | ✓ | — | — | — | — | — |
| *(EZE)* | — | — | — | — | ✓ | — | — | — | — | ✓ | ✓ | — | ✓ | ✓ | — | — | ✓ | — |
| *(GIG)* | — | — | — | — | ✓ | — | — | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | — | — |

Table 41: Availability of Links from Middle East airports to the world regions

| Origin Airport Location: Middle East | Availability of Links | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Europe | | | Asia | | | Africa | | | North America | | | Latin America | | | Oceania | | |
| (IATA Code) | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I |
| *(DXB)* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | ✓ | ✓ |
| *(DOH)* | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | ✓ | — |
| *(AUH)* | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | ✓ | — |
| *(SHJ)* | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | — | — | — | — | — | — | — | — |
| *(BAH)* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | — | ✓ | — | ✓ | — | — | — | — | — | — | — | — |
| *(RUH)* | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | — | — | — | — | — |
| *(JED)* | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | ✓ | — | — | — | — | — | — | — |
| *(KWI)* | ✓ | ✓ | — | ✓ | ✓ | — | — | ✓ | — | — | ✓ | — | — | — | — | — | — | — |
| *(AMM)* | ✓ | ✓ | — | — | ✓ | — | — | ✓ | — | ✓ | ✓ | — | — | — | — | — | — | — |

Table 42: Availability of Links from North American airports to the world regions

| Origin Airport Location: North America | Availability of Links | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Asia | | | Africa | | | Middle East | | | Latin America | | | Europe | | | Oceania | | |
| (IATA Code) | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I | C | B | I |
| *(MEM)* | — | — | ✓ | — | — | — | — | — | ✓ | — | — | ✓ | — | — | ✓ | — | — | — |
| *(ANC)* | ✓ | — | ✓ | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *(LAX)* | ✓ | ✓ | — | — | — | — | ✓ | ✓ | — | ✓ | ✓ | — | ✓ | ✓ | — | — | ✓ | ✓ |
| *(SDF)* | — | — | ✓ | — | — | ✓ | — | — | — | — | — | ✓ | ✓ | — | ✓ | — | — | — |
| *(MIA)* | ✓ | — | — | — | — | — | — | — | — | ✓ | — | ✓ | ✓ | — | — | — | — | — |
| *(IND)* | — | — | ✓ | — | — | — | — | — | — | — | — | — | ✓ | — | ✓ | — | — | — |
| *(EWR)* | — | ✓ | — | — | — | — | — | ✓ | — | — | ✓ | — | — | ✓ | ✓ | — | — | — |
| *(ATL)* | — | — | — | — | — | — | ✓ | — | — | — | ✓ | — | ✓ | — | — | — | — | — |
| *(DFW)* | ✓ | ✓ | — | — | — | — | — | ✓ | — | — | ✓ | — | ✓ | ✓ | — | — | ✓ | — |
| *(OAK)* | — | — | ✓ | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| *(MEX)* | ✓ | — | — | — | — | — | ✓ | — | — | ✓ | ✓ | — | ✓ | ✓ | — | — | — | — |

At this point, it has to be mentioned that, in reality, the three types of service can be and are combined, in an effort to achieve the best service at the lowest possible cost. Especially integrators, they operate their own forwarder businesses and, through them, make use of other carriers of different business models to complement their already established network and serve customers even when their do not have available capacity. Furthermore, some passenger airlines operate under the same corporate umbrella with pure cargo and/or integrators, resulting in cooperation between them for the purposes of freight transport. As the nature and specifics of such techniques are not visible to the outside observer, for this study the assumption has to be made that the various types of service cannot be combined. Route choice remains within the specific type of service with the purpose of offering the best available route (fastest), having in mind the characteristics of the commodity and assuming there is always available capacity.

## 4.7 Step 5: Network assignment and flows

This step is also highly linked to service choice at step 3, as each type of air freight service makes use of different types of networks. This is because of both geographical/practical reasons as well as logistical. So far, the flight times and distances between the aforementioned airports have been calculated, the selection of commodities that use air transport has been made and the type of service chosen has been established. In this step, the volume of goods that are to be transported by air for each type of service using the corresponding network will be translated into number or aircraft. The trade data obtained give the commodities in terms of value and also weight units. In order to make transform the weight data to number of aircraft, an intermediary step is necessary where the density of each commodity will be used to transform weight into volume and then into number of ULDs or number of aircraft. For that purpose, density values for a variety of commodities that make use of air freight services are taken from the Air Cargo Density Research, a TU Delft Master thesis by Van de Reyd & Wouters (2005), in cooperation with Jan de Rijk Logistics Company. Their research makes use of a shipment database with more than half a million entries, giving statistical data regarding their densities, categorized per commodity type the main findings of which can be seen in Table 43.

**Table 43: Weighted mean density of various air cargo commodities, compiled with data from Van de Reyd & Wouters (2005)**

| Commodity Description | SITC 4 Class | Weighted mean density (kg/m$^3$) |
|---|---|---|
| **Aerospace cargo** | 7 | 142.23 |
| **Apparel and footwear** | 8 | 144.74 |
| **Art, music goods, handcrafts** | 8 | 175.86 |
| **Audio/Video media** | 7 | 271.86 |
| **Automotive cargo** | 7 | 194.34 |
| **Chemicals** | 5 | 312.9 |
| **Computers and peripherals** | 8 | 165.41 |
| **Consumer housewares** | 7 | 143.2 |
| **Jewellery** | 8 | 207.95 |
| **Cosmetics** | 5 | 211.6 |
| **Express freight** | 9 | 161.69 |
| **Electrical goods** | 7 | 179.57 |
| **Live animals** | 0 | 101.57 |
| **Machine parts** | 7 | 263.29 |
| **Metal products** | 6 | 457.29 |
| **Perishables** | 0 | 212.54 |
| **Pharmaceuticals** | 5 | 163.81 |
| **Plastic products** | 5 | 215.41 |
| **Precision instruments** | 8 | 161.47 |
| **Printing and publishing** | 2 | 322.59 |
| **Processed food** | 0 | 261.46 |
| **Telecom equipment** | 7 | 170.91 |
| **Textiles** | 6 | 183.11 |
| **Tobacco products** | 1 | 204.65 |
| **Complete database** | - | 187.44 |

The commodities found in their research include a wide range of typical air cargo goods, including apparel and footwear, automotive cargo, pharmaceuticals, computers and electronics, perishables, food, textiles etc. Knowing the weight of the trade goods to be transported by air, it can be divided by the commodity-specific density value and give the physical volume of the total trade in each commodity section. Using the characteristics of the design aircraft, as they were shown previously, these volume figures can be translated into aircraft flows.

Moreover, in order to specialize the results even further, there can be three design aircraft, one per air freight service type, resulting in flows that better describe each air freight business model. Combining the information described previously over the world air fleet, the characteristics of all types of aircraft and the respective fleet of the most known examples of each service type, the following table was created, containing the three design aircraft and their attributes. Also, it includes the average cargo load factors observed in passenger aircraft and freighters, as reported by CAPA centre for aviation and IATA.

**Table 44: Design aircraft characteristics per service type (Flightglobal, 2013) (Cargolux, 2012) (Airfleets.net, 2015) (CAPA, 2014)**

| Characteristics | Design Aircraft | | |
|---|---|---|---|
| | Belly | Cargo | Integrator |
| Cargohold (m3) | 72 | 678 | 510 |
| Payload (t) | 32 | 106 | 74 |
| Speed (km/h) | 878 | 890 | 855 |
| Range (km) | 7508 | 7691 | 7770 |
| Load Factor | 0.37 | 0.68 | 0.68 |

Dividing the payload figures by the cargohold volume for each design aircraft yields 444, 156 and 145 kg/m$^3$ respectively for belly, cargo and integrator services. Comparing these values with the average commodity density, it can be concluded that freight transport in passenger aircraft tends to cube out while in freighter aircraft of cargo-only and integrator services tends to weight-out. This will be used in the conversion of weight flows to number of aircraft which in the case of belly services will be performed based on volume and for the remaining two service types, based on weight. The traffic will be assigned using the shortest path available, based on the flying distances and the range of the aircraft.

Furthermore, if an individual shipment size is assumed, then the respective volume value can be compared with the ULD and/or aircraft cargo hold volume and yield utilization factors and their relationship with commodity shipment size as well as the opportunity to further develop this part towards optimal aircraft type selection on a commodity-specific basis.

# Chapter 5: Results of the model and validation

In this chapter, the results of the model described previously are presented. More specifically, the outcome of the model is given so as to cover the subject of global air freight transport geographically (region-to-region as well as per region), economically (commodity-specific analysis with weight and value figures) and mode-wise (mode split, air freight service choice, aircraft flows). The findings are presented in eight paragraphs, covering each of the seven world regions and one that sums them all in a global scale.

## 5.1 Introduction

The starting point to transforming the conceptual framework presented in Figure 20 is obtaining the trade data and treat it in such a way that can be used in the following steps. The data from UNCTAD contained all commodities with a small portion of them being measured in units other than weight (cubic meters, units, pairs, dozens, carats, number of packs etc.) and had to be removed from the dataset. Nevertheless, the final trade matrix compiled contains 465.700 commodity entries between the countries taken into account in this study. Another interesting point here is the inequality observed between exports from country A to country B and imports of country B from country A. This is a common fact in such datasets and the reasons behind it are usually different recording methods between exports and imports as well as data quality levels between countries. Nevertheless, for the purposes of this study, it is assumed that import data are more reliable and accurate, since imports generate tariff revenues, and tend to be more carefully recorded. Therefore, import data were used throughout the study, except a small number of countries were imports were not available.

Besides trade data, not much else information regarding air freight transport is openly available. This posed a threat regarding the accuracy and validity of the model and was addressed the only way possible, by using general values widely accepted in the industry, to calibrate the model at two key points. First, the global observed mode choice in terms of value and weight was used to calibrate the mode choice between sea and air in the model. Global freight data over the recent years as well as industry reports by Boeing and Airbus show that air freight accounts for around 2 to 3% of total trade in weight units and around 40 to 45% of total trade in terms of value. These key values were used to calibrate the mode choice through iterating around the value of time savings of the commodities, while remaining within the boundaries found in literature. The second calibration point is at the air freight service choice. Again, public data at the air freight service type level are not available but there are industry reports that reveal that around 50% of air freight is transported in the belly of passenger aircraft (Centre for Asia Pacific Aviation, 2014) (Boeing, 2013). With that in mind, the multinomial logit scale factor as well as the belly transport utility formula were calibrated. Assuming a mean shipment size of 100 kgs throughout the global airborne trade, the final values for the model parameters are shown in Table 45 and Table 46.

**Table 45: Model parameters after calibration**

| Parameter | Description | Value |
|---|---|---|
| **$\lambda$** | Air freight service choice calibration parameter | **-0.333** |
| **$\beta$** | Multinomial logit calibration parameter | **0.5** |
| **-** | Average air freight shipment size (kgs) | **100** |

Table 46: Ad-valorem value of time savings after calibration

| SITC Classes | Description | Ad-valorem value of time savings |
|---|---|---|
| 0 | Food and live animals | 1.7 |
| 1 | Beverages and tobacco | 0.8 |
| 2 | Crude materials, inedible, except fuels | 0.2 |
| 3 | Mineral fuels, lubricants and related materials | 0.2 |
| 4 | Animal and vegetable oils, fats and waxes | 1.2 |
| 5 | Chemicals and related products | 0.7 |
| 6 | Manufactured goods classified chiefly by material | 0.8 |
| 7 | Machinery and transport equipment | 1.5 |
| 8 | Miscellaneous manufactured articles | 1.2 |
| 9 | Commodities not classified elsewhere in the SITC | 0.1 |

In the following paragraphs the results of the model will be presented both per region as well as aggregated to a global level. The findings include mode choice, air freight service choice, weight and value of freight per mode, service type, origin, destination and commodity group and finally, flows between regions in weight, value, and tonkilometers next to number of aircraft.

## 5.2 Global level

On a global scale, the model shows that, in terms of mode choice, there is an almost equal split for the trade entries taken into account. Out of the total number of observations, 45.8 % are transported via air and the remaining 54.2 % by sea. Translating this in terms of weight and value, the model reveals a more recognisable relationship, with airborne trade accounting for 2.9 % in weight and 42.5 % in value.

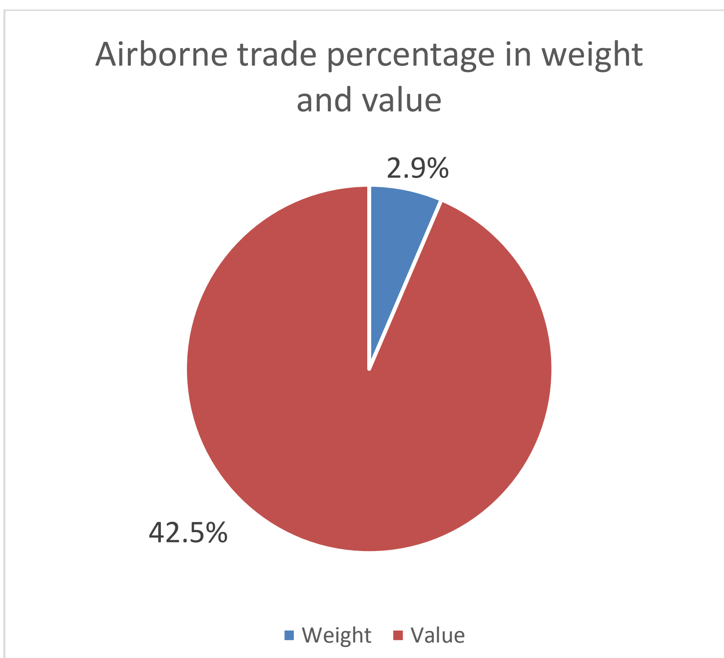



Figure 22: Modal split of airborne trade

Diving further into the global air freight market, the tonkilometers were calculated. Historical data as well as industry reports, as depicted earlier in Chapter 2: The Air Freight Industry, show that the major air freight markets of the world revolve around three regions, Asia, North America and Europe with the first being the largest. The same conclusion can be made from the model results. The model demonstrates that slightly more than 85 % of total air freight tonkilometers are produced in these three regions with Africa and Latin America being the regions with the least values, as can be seen in Figure 23.

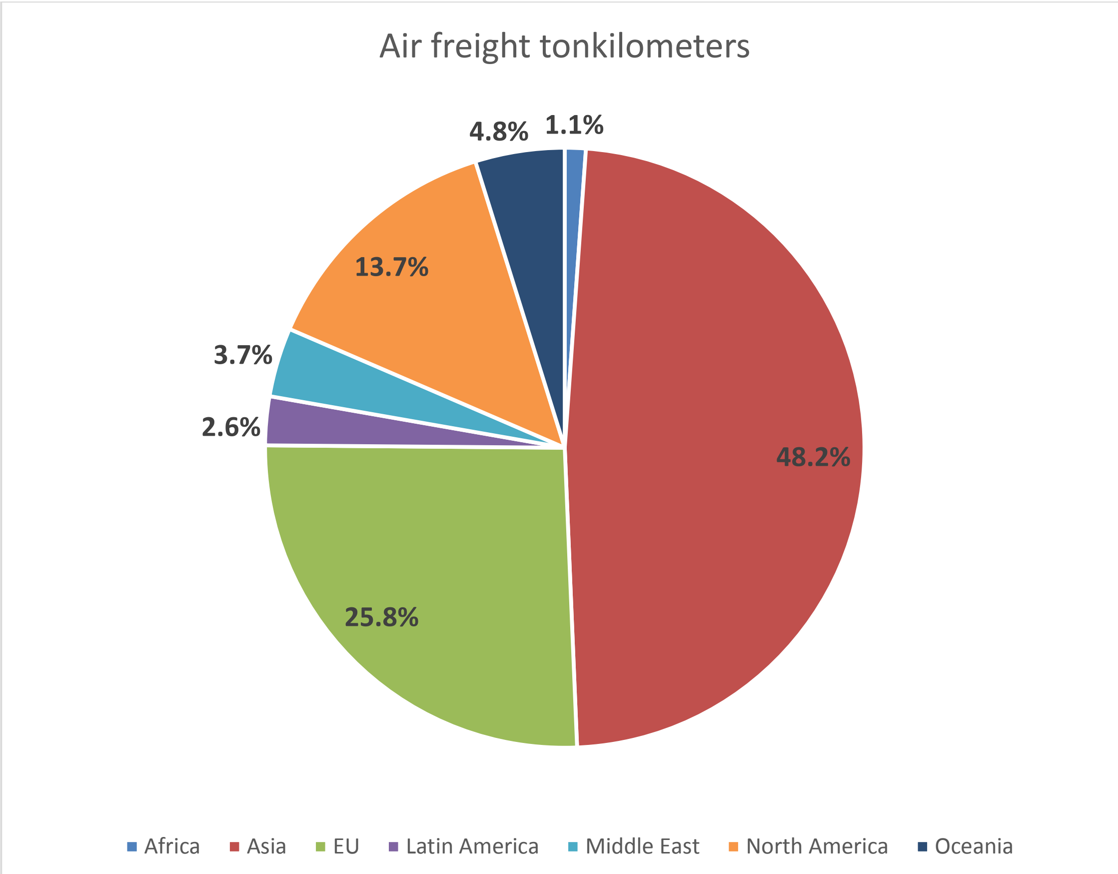



Figure 23: Air freight tonkilometers percentages per origin region

Another significant characteristic of the airborne trade is imbalance. Again, a variety of sources in the literature point out the imbalance between in-and-outgoing flows especially in production oriented market like Asia, where the consumers have not yet developed a significant spending power, resulting in air freight flows toward Asia being hectic, compared to the outgoing ones. This model produces relevant information by combining the respective results per region in terms of origin and destination. The outcome does not fall far from what was expected. Looking at the three big markets, Asia and North America show the greatest imbalance with exports being 6 times larger than imports in terms of weight for Asia. North America shows the opposite, with imports being 3 times larger weight-wise than exports. Europe, on the other hand, shows more balanced airborne trade. This can be explained by the fact that many of the high value brands in the air freight relevant commodities (e.g. fashion, cars and precision instruments) are produced there. Another interesting result is that in terms of value, not much of an imbalance is noticed in the results. Combined with the weight asymmetry, a possible explanation for this is that much trade volume of raw material is imported in production oriented regions, the manufacturing process takes place and then the finalized products are exported to the consuming markets, explaining the large drop in weight and smaller increase in value. The characteristics of airborne trade as they were computed by the model can be seen in Figure 24 and Figure 25.

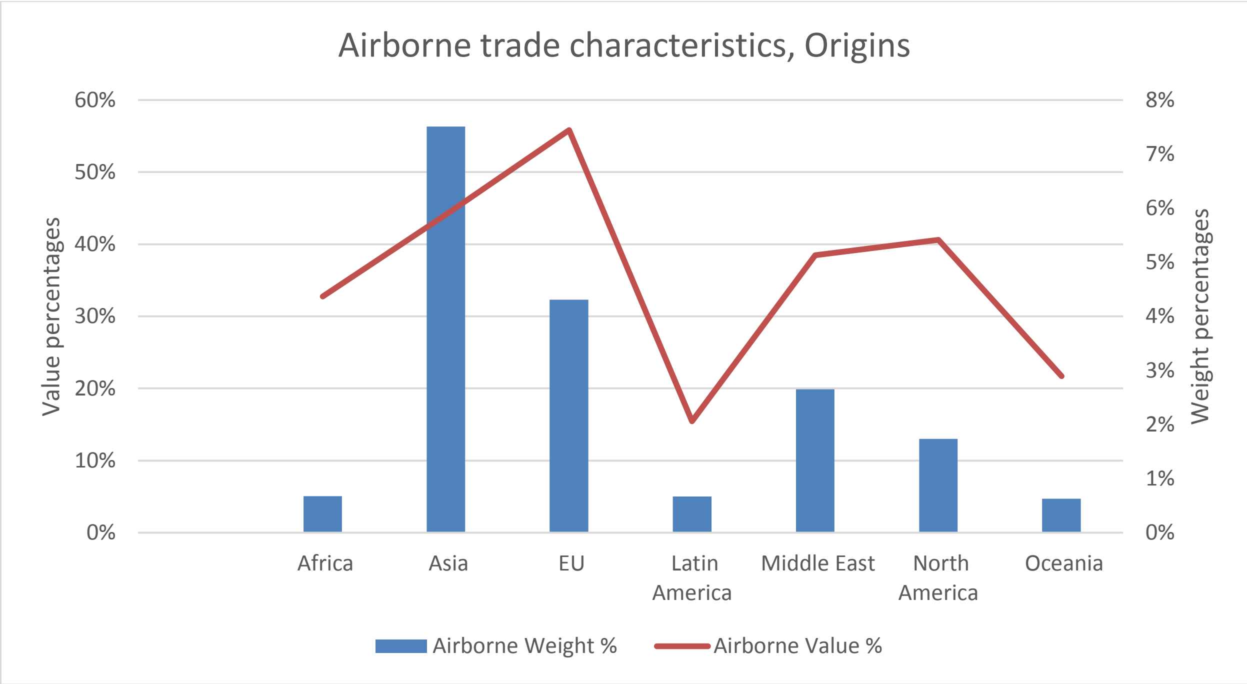



**Figure 24: Characteristics of airborne trade outgoing flows**

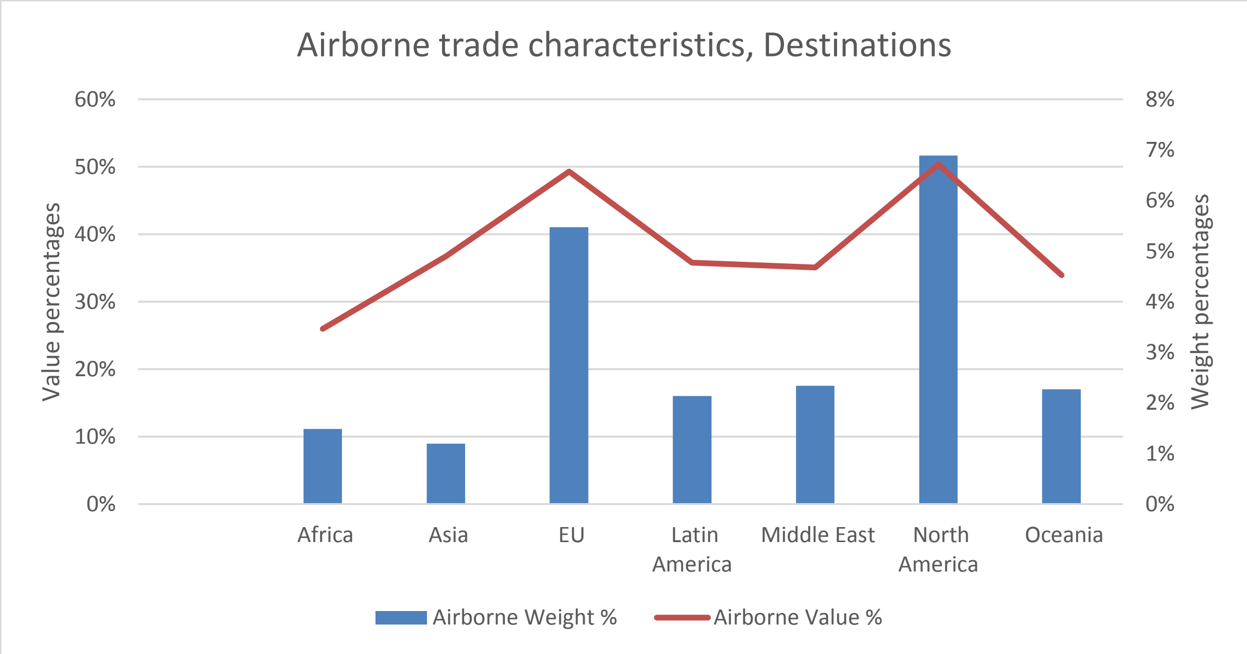



**Figure 25: Characteristics of airborne trade incoming flows**

Proceeding a level deeper into the airborne trade are the commodity types. The unit value mode share model results reveal that air freight has strong market presence in commodity classes 5, 6, 7 and 8 which combined are responsible for 97% of air freight weight and 95% of the value, as can be seen in Figure 26.

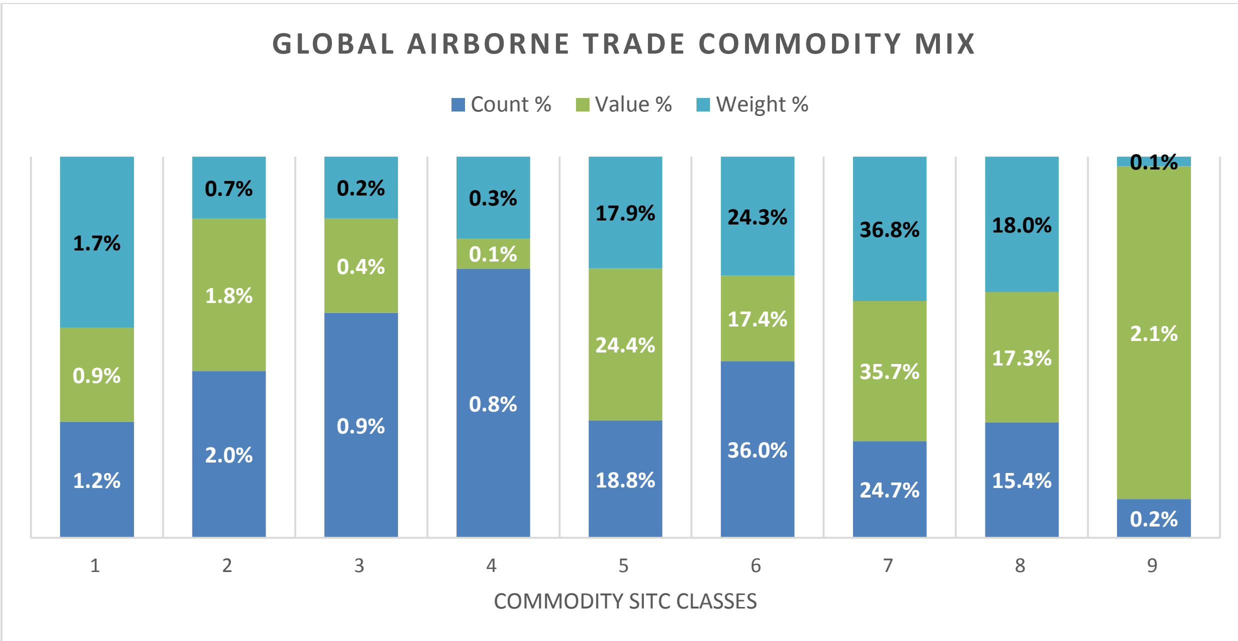



Figure 26: Airborne trade characteristics by commodity class

Analysing the result a little further, SITC class 7 commodities (machinery and transport equipment) has the largest share in both weight and value, responsible for roughly 36% of each. In terms of value per weight unit, besides class 9 (coins and non-monetary gold) which is somewhat extreme, classes 2, 3 and 5 are the most valuable with 1% of weight being translated in roughly 2% of weight. The average value density of each commodity class in the airborne trade can be seen in Table 47.

Table 47: Average value density per commodity class in airborne trade

| Commodities | Average Value Density (US$/kg) |
|---|---|
| **1** | 11.91 |
| **2** | 52.91 |
| **3** | 33.21 |
| **4** | 7.92 |
| **5** | 29.49 |
| **6** | 15.47 |
| **7** | 20.97 |
| **8** | 20.73 |
| **9** | 753.26 |
| **Average** | 21.63 |

So far, the results provide a clear image of what air freight consists of and brings us to the question of how these flows are distributed within the three air freight service types. The air freight service choice module of the model, after calibration as discussed previously, allocates the largest portion of weight to belly transport, the largest value portion to cargo-only services and the smaller but with high value to weight ratio portion to the integrators. Figure 27 shows the exact breakdown of the air freight flows per service type in terms of weigh and value.

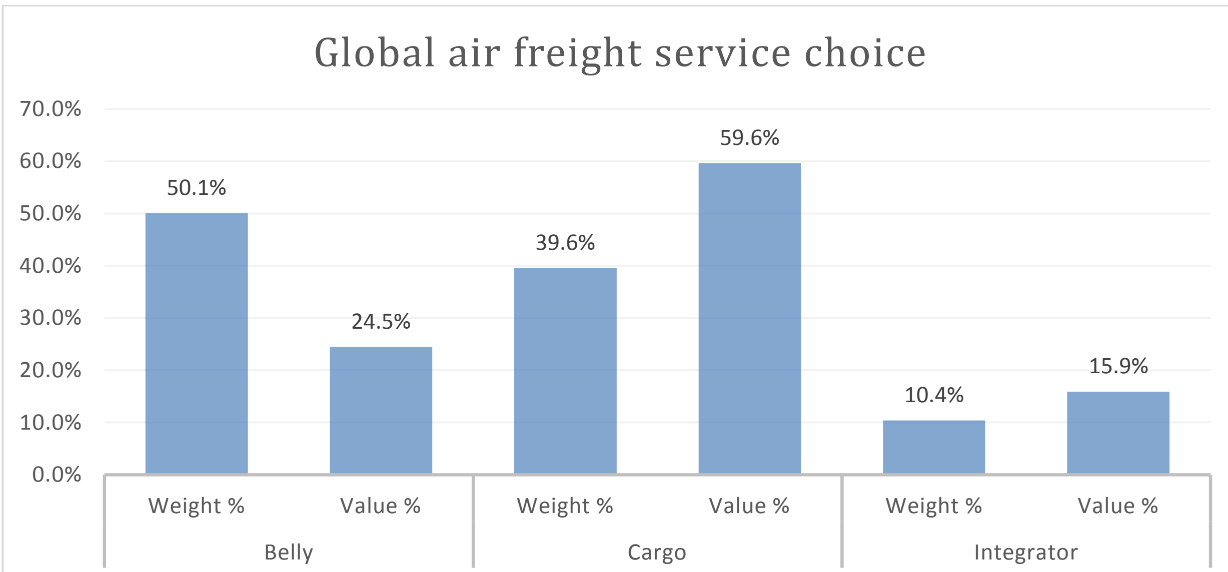



**Figure 27: Air freight service choice in value and weight**

The flows are also further analysed by commodity type. Cargo only services seem to gather most of the value of their transport share through class 5 and 7 commodities. These two classes are also responsible for most of the weight transported with this service. Nevertheless, cargo only services show a strong presence throughout the air transported commodities. In the case of belly transport, the highest value and weight share comes from class 6 and 7 commodities with the presence in other classes being quite lower. Integrators on the other hand, have a rather low but stable presence in all classes. The model shows that integrators make their business by handling the most expensive part of all commodities throughout the trade. Key characteristic here is that the value percentage always surpasses that of the weight. These conclusions are evident in Figure 28.

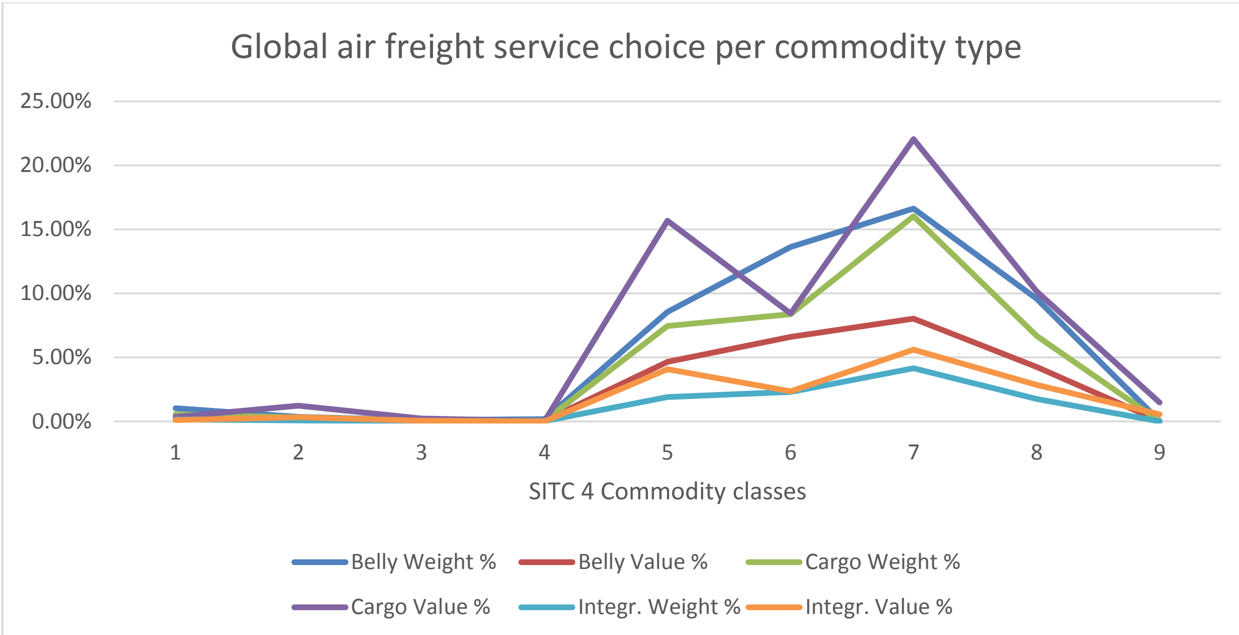



**Figure 28: Air freight service choice per commodity type**

The total flows in weight and value, as a percentage of the world total, in the form of an origin-destination matrix are shown in Table 48 and Table 49.

**Table 48: Air freight transport global weight flows percentages on total airborne trade**

| Total weight | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Africa** | **Asia** | **EU** | **Latin America** | **Middle East** | **North America** | **Oceania** |
| **Africa** | - | 0.21% | 0.92% | 0.01% | 0.01% | 0.25% | 0.02% |
| **Asia** | 1.04% | - | 21.02% | 2.21% | 2.11% | 16.27% | 1.07% |
| **EU** | 1.41% | 10.99% | - | 2.11% | 3.34% | 10.10% | 1.36% |
| **Latin America** | 0.03% | 0.40% | 0.56% | - | 0.01% | 1.35% | 0.02% |
| **Middle East** | 0.02% | 0.79% | 4.56% | 0.01% | - | 0.62% | 0.04% |
| **North America** | 0.21% | 4.02% | 6.15% | 1.36% | 0.69% | - | 0.93% |
| **Oceania** | 0.05% | 1.36% | 1.27% | 0.05% | 0.30% | 0.72% | - |

**Table 49: Air freight transport global value flows percentages on total airborne trade**

| Total value | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Africa** | **Asia** | **EU** | **Latin America** | **Middle East** | **North America** | **Oceania** |
| **Africa** | - | 0.56% | 1.16% | 0.01% | 0.02% | 0.37% | 0.02% |
| **Asia** | 0.73% | - | 14.93% | 1.60% | 1.58% | 13.18% | 1.17% |
| **EU** | 1.71% | 13.20% | - | 2.79% | 4.22% | 11.75% | 1.75% |
| **Latin America** | 0.03% | 0.33% | 0.72% | - | 0.01% | 1.15% | 0.03% |
| **Middle East** | 0.04% | 0.61% | 4.82% | 0.01% | - | 0.82% | 0.03% |
| **North America** | 0.25% | 4.93% | 8.65% | 1.38% | 0.81% | - | 0.84% |
| **Oceania** | 0.09% | 1.86% | 0.96% | 0.05% | 0.14% | 0.68% | - |

Comparing the values in these two tables, a very significant conclusion can be reached. Even though air freight, in terms of goods carried, seems very imbalanced (carries 42.5% of the value and only 2.9% of the weight) from an outside perspective, when it is observed closely, removing all other modes, the flows are almost perfectly balanced. For each origin destination pair, the weight to value percentages ratio is very close to one.

Additionally, these flows were further analysed per service type. The result, shown in the following tables, represent the percentage of each service's traffic that corresponds to each OD pair, per weight and value accordingly.

**Table 50: Air freight flows percentages per OD pair, Belly (W: weight, V: value)**

| | Africa | | Asia | | Europe | | Latin America | | Middle East | | North America | | Oceania | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W% | V% | W% | V% | W% | V% | W% | V% | W% | V% | W% | V% | W% | V% |
| Africa | - | - | 0.20 | 0.22 | 0.32 | 0.45 | 0.01 | 0.02 | 0.01 | 0.01 | 0.24 | 0.24 | 0.03 | 0.03 |
| Asia | 1.43 | 1.43 | - | - | 22.67 | 17.82 | 3.17 | 3.33 | 2.40 | 2.37 | 18.40 | 17.99 | 0.89 | 0.99 |
| EU | 1.26 | 1.88 | 9.54 | 9.61 | - | - | 2.28 | 2.93 | 2.70 | 2.87 | 8.27 | 8.42 | 1.91 | 2.79 |
| Latin America | 0.05 | 0.06 | 0.55 | 0.67 | 0.76 | 0.96 | - | - | 0.02 | 0.03 | 1.10 | 0.87 | 0.03 | 0.04 |
| Middle East | 0.02 | 0.02 | 0.86 | 0.98 | 3.38 | 3.09 | 0.01 | 0.02 | - | - | 0.64 | 0.85 | 0.07 | 0.08 |
| North America | 0.31 | 0.40 | 4.65 | 5.46 | 5.03 | 5.85 | 1.22 | 1.37 | 0.84 | 1.06 | - | - | 1.18 | 1.31 |
| Oceania | 0.05 | 0.06 | 0.91 | 1.09 | 1.29 | 1.12 | 0.07 | 0.08 | 0.33 | 0.26 | 0.92 | 0.91 | - | - |

**Table 51: Air freight flows percentages per OD pair, Cargo-only (W: weight, V: value)**

| | Africa | | Asia | | Europe | | Latin America | | Middle East | | North America | | Oceania | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W% | V% | W% | V% | W% | V% | W% | V% | W% | V% | W% | V% | W% | V% |
| Africa | - | - | 0.23 | 0.62 | 1.27 | 1.20 | 0.01 | 0.01 | 0.01 | 0.01 | 0.27 | 0.42 | 0.02 | 0.01 |
| Asia | 0.71 | 0.55 | - | - | 19.22 | 13.88 | 1.45 | 1.22 | 1.82 | 1.32 | 14.80 | 12.13 | 1.16 | 1.15 |
| EU | 1.62 | 1.74 | 12.56 | 14.46 | - | - | 2.10 | 2.98 | 3.90 | 4.54 | 11.43 | 12.28 | 0.97 | 1.71 |
| Latin America | 0.01 | 0.02 | 0.28 | 0.24 | 0.42 | 0.67 | - | - | 0.01 | 0.01 | 1.38 | 1.08 | 0.02 | 0.03 |
| Middle East | 0.02 | 0.04 | 0.74 | 0.51 | 5.18 | 4.86 | 0.01 | 0.01 | - | - | 0.68 | 0.93 | 0.02 | 0.02 |
| North America | 0.13 | 0.23 | 3.73 | 5.13 | 7.22 | 9.45 | 1.47 | 1.35 | 0.62 | 0.79 | - | - | 0.76 | 0.75 |
| Oceania | 0.05 | 0.10 | 1.61 | 1.88 | 1.21 | 0.89 | 0.05 | 0.04 | 0.25 | 0.10 | 0.57 | 0.65 | - | - |

**Table 52: Air freight flows percentages per OD pair, Integrators (W: weight, V: value)**

| | Africa | | Asia | | Europe | | Latin America | | Middle East | | North America | | Oceania | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W% | V% | W% | V% | W% | V% | W% | V% | W% | V% | W% | V% | W% | V% |
| Africa | - | - | 0.17 | 0.86 | 2.45 | 2.10 | 0.00 | 0.00 | 0.02 | 0.02 | 0.26 | 0.40 | 0.01 | 0.01 |
| Asia | 0.41 | 0.34 | - | - | 19.88 | 14.45 | 0.48 | 0.40 | 1.86 | 1.35 | 11.56 | 9.73 | 1.66 | 1.52 |
| EU | 1.30 | 1.36 | 11.97 | 13.95 | - | - | 1.31 | 1.87 | 4.25 | 5.12 | 13.87 | 14.88 | 0.16 | 0.34 |
| Latin America | 0.00 | 0.02 | 0.12 | 0.13 | 0.21 | 0.53 | - | - | 0.00 | 0.01 | 2.46 | 1.84 | 0.01 | 0.01 |
| Middle East | 0.02 | 0.05 | 0.65 | 0.44 | 7.91 | 7.35 | 0.00 | 0.00 | - | - | 0.30 | 0.41 | 0.01 | 0.00 |
| North America | 0.03 | 0.10 | 2.16 | 3.40 | 7.52 | 9.93 | 1.66 | 1.52 | 0.26 | 0.48 | - | - | 0.40 | 0.44 |
| Oceania | 0.03 | 0.11 | 2.58 | 2.96 | 1.38 | 0.99 | 0.02 | 0.02 | 0.29 | 0.12 | 0.35 | 0.44 | - | - |

Finally, the flows shown above where assigned to the air freight networks of each service type, using the links as they were previously shown in paragraph 4.6. Where there are OD pairs with a flying distance larger than the design aircraft range, the traffic was assigned to the shortest path available that can connect them, while using links within that range. The results for each type of service are illustrated at the maps below, for value and weight respectively, as percentages of the total air freight demand of each service type.

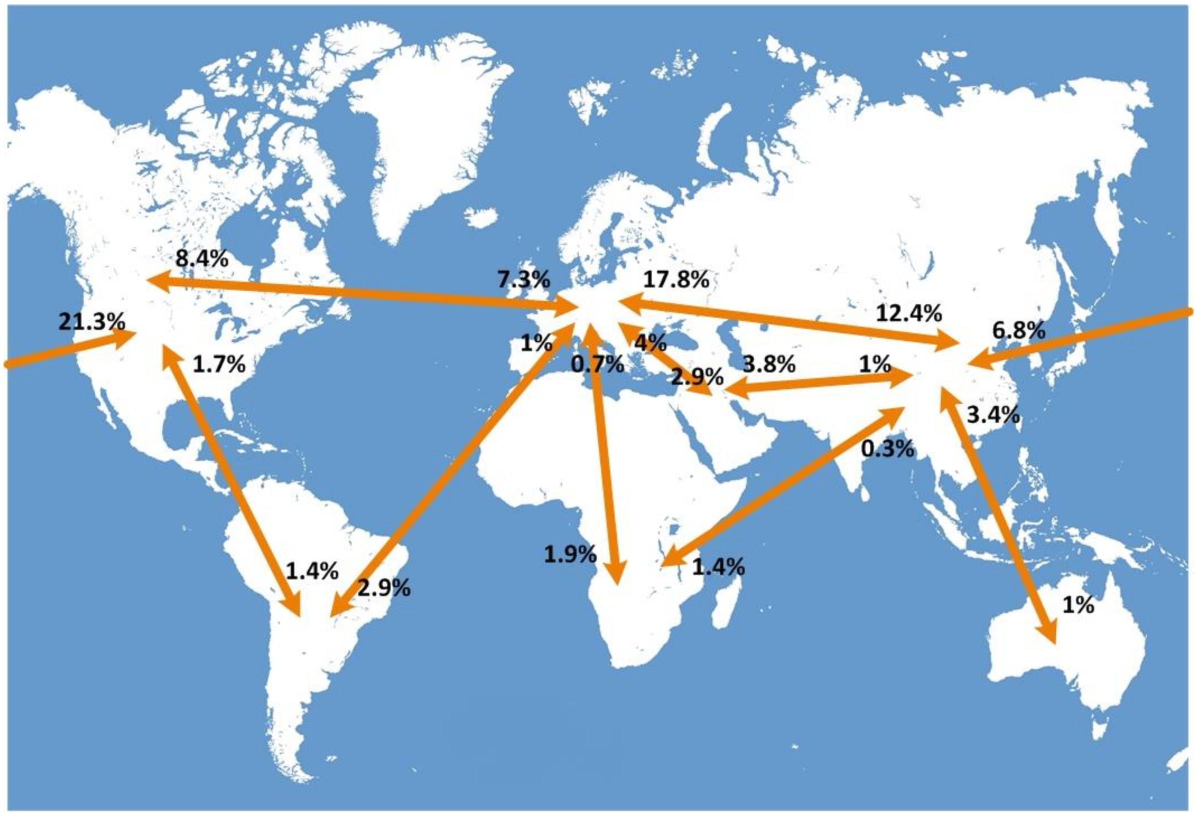



**Figure 29: Value flows percentages, type of service: Belly**

Examining first the results for the air freight transport in the belly of passenger aircraft, Figure 29 and Figure 30 show the value and weight flows respectively. The highest air freight value share is found on the Asian export flow to North America, while the OD pair with the highest share both ends combined is this between Europe and Asia. On the other hand with weight considered, the flow between Asia and Europe holds the highest shares and, at the same time, contains the flow with the largest weight share. The two largest market partners of Asia, North America and Europe, although they generate roughly the same air freight weight demand, they differ in terms of value. Flows to Europe seem to consist of commodities with less value.

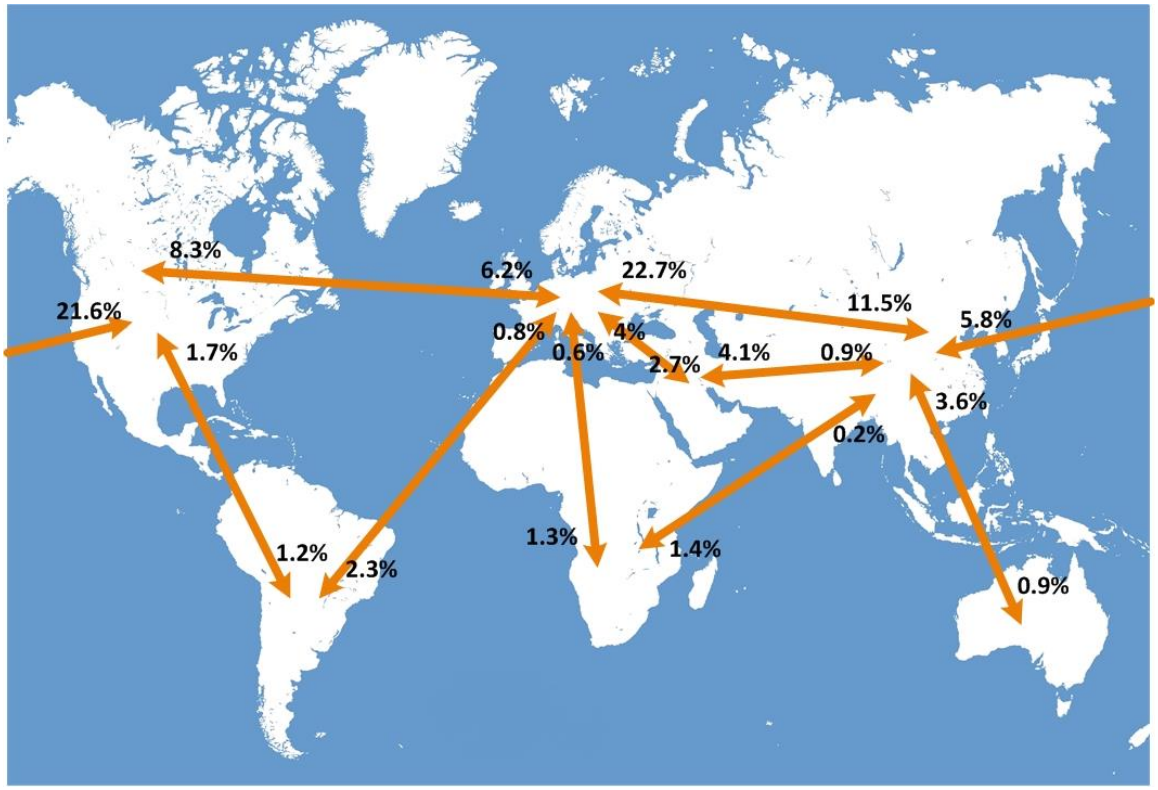



Figure 30: Weight flows percentages, type of service: Belly

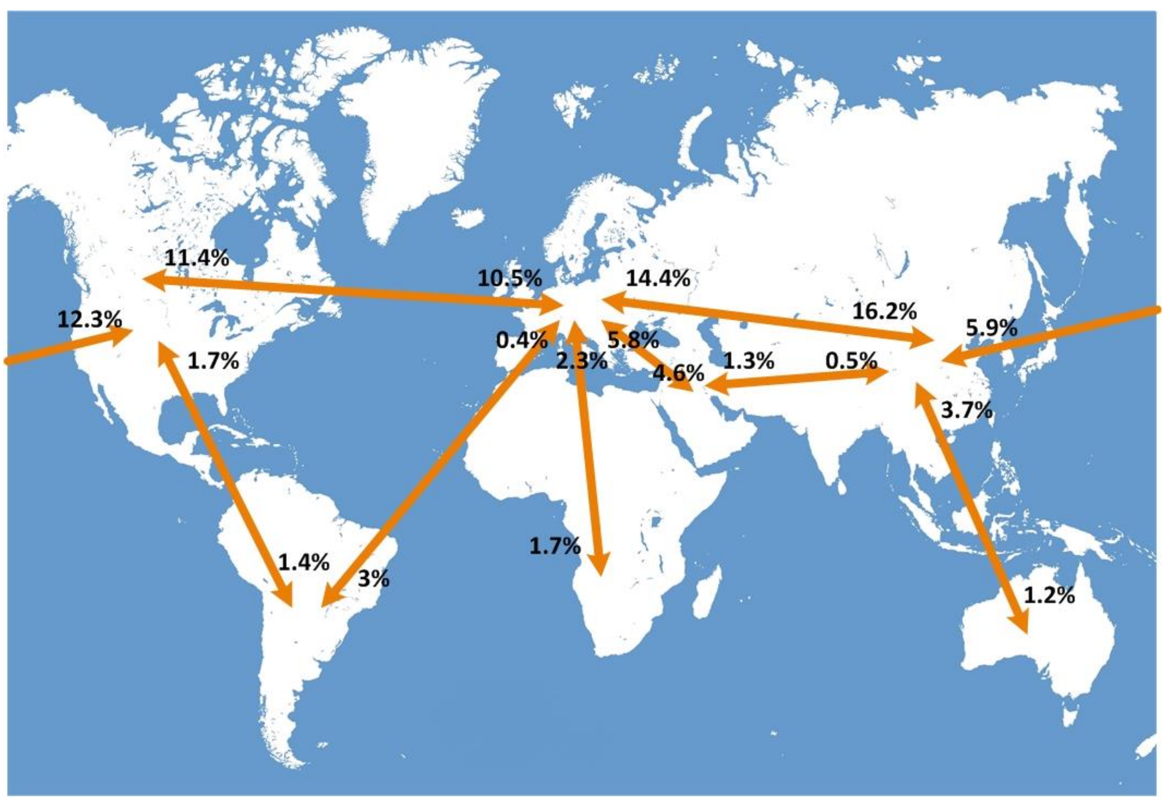



Figure 31: Value flows percentages, type of service: Cargo

With cargo-only services, flows are found to be more balanced in terms of value than weight, as shown in Figure 31 and Figure 32. Again, the main air freight markets hold the lion share in both perspectives, with the main difference being the highest shares of the Middle East region. This is because for this type of service, some links, compared to belly, are not available and this region serves as a middle point between Asia-Pacific and Europe, consolidating the demand.

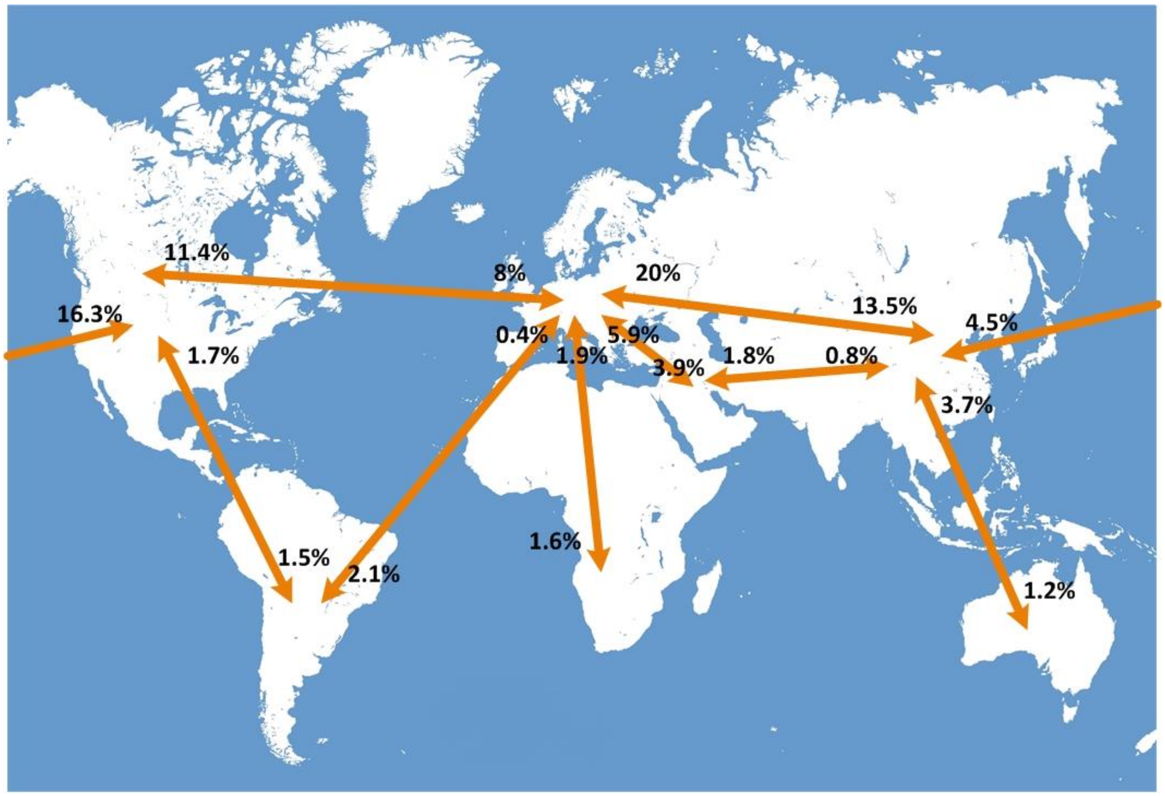



**Figure 32: Weight flows percentages, type of service: Cargo**

Finally, integrators operate through main hubs that are located in North America, Europe, Middle East and Asia. Therefore all air freight demand for that service is channelled through these regions. The busiest route here is by far the one between Europe and Asia, both in terms of weight and value. Weight flows imbalance becomes very high with this type of service, with some of the major market routes having a ratio of 5:1 such as this between North America and Asia. The region of Middle East seems to play an important role here, where consolidation and achieving economies of scale is a key objective. Being strategically located between two of the largest air freight markets, it shows elevated shares in both categories.

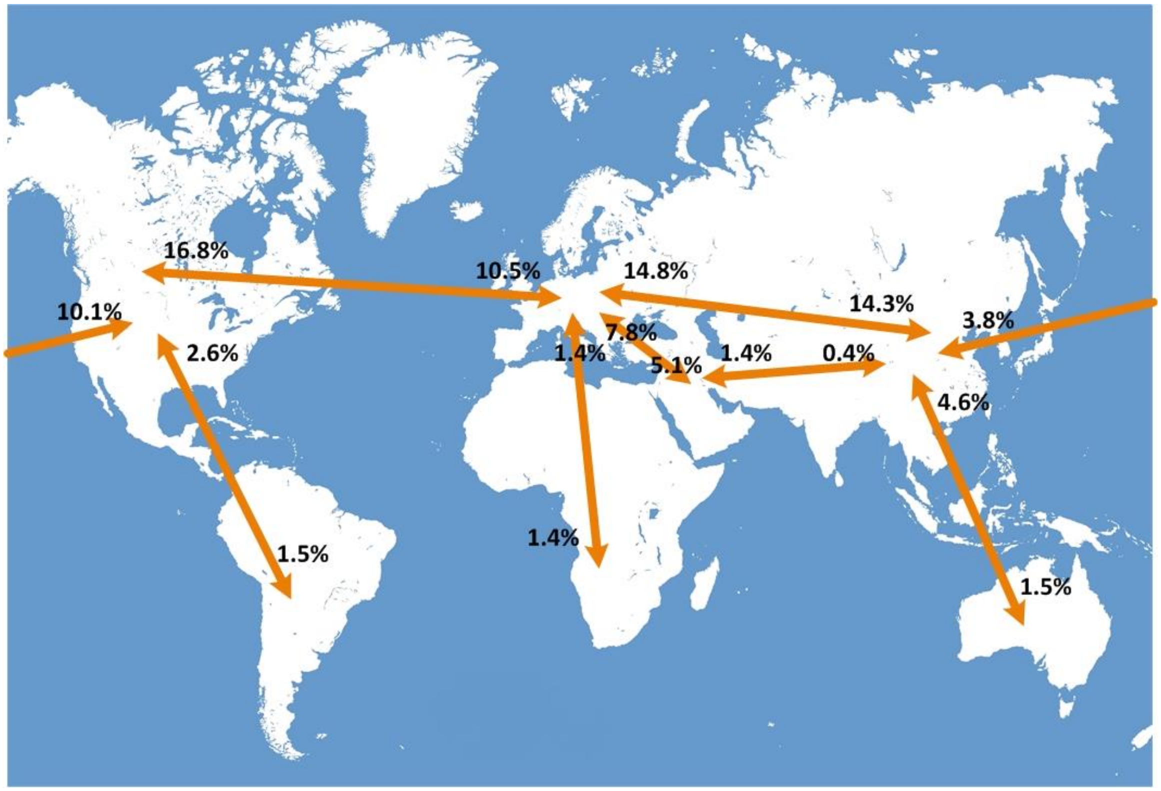



**Figure 33: Value flows percentages, type of service: Integrators**

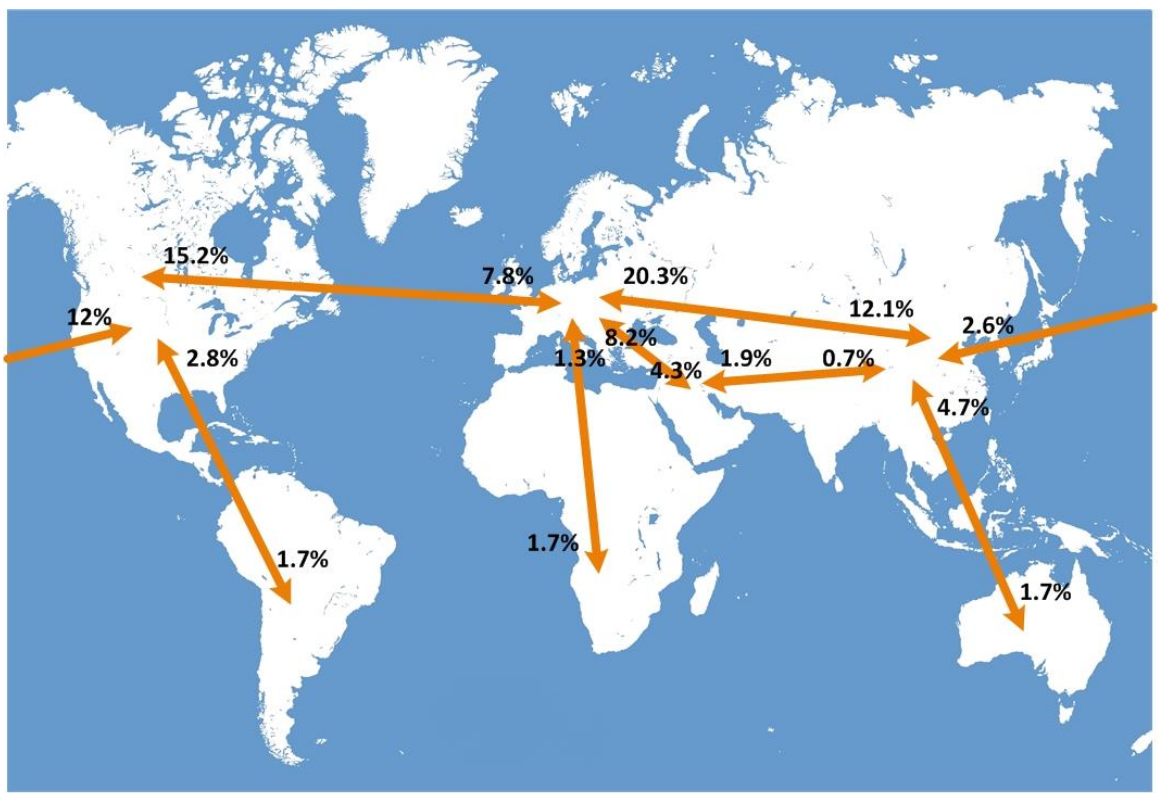



**Figure 34: Weight flows percentages, type of service: Integrators**

## 5.3 Regional level: Africa

The airborne trade volumes produced in the region of Africa are the lowest in absolute values, compared to the rest of the seven regions of the model. Nevertheless, even here the general norm associated with air freight trade value versus weight holds. More specifically, just 0.7% of the total weight of African exports are transported by air, corresponding to 32.8% of the value. Africa is a region that very rich in mineral wealth, and that shows in the airborne commodities breakdown of Figure 35.

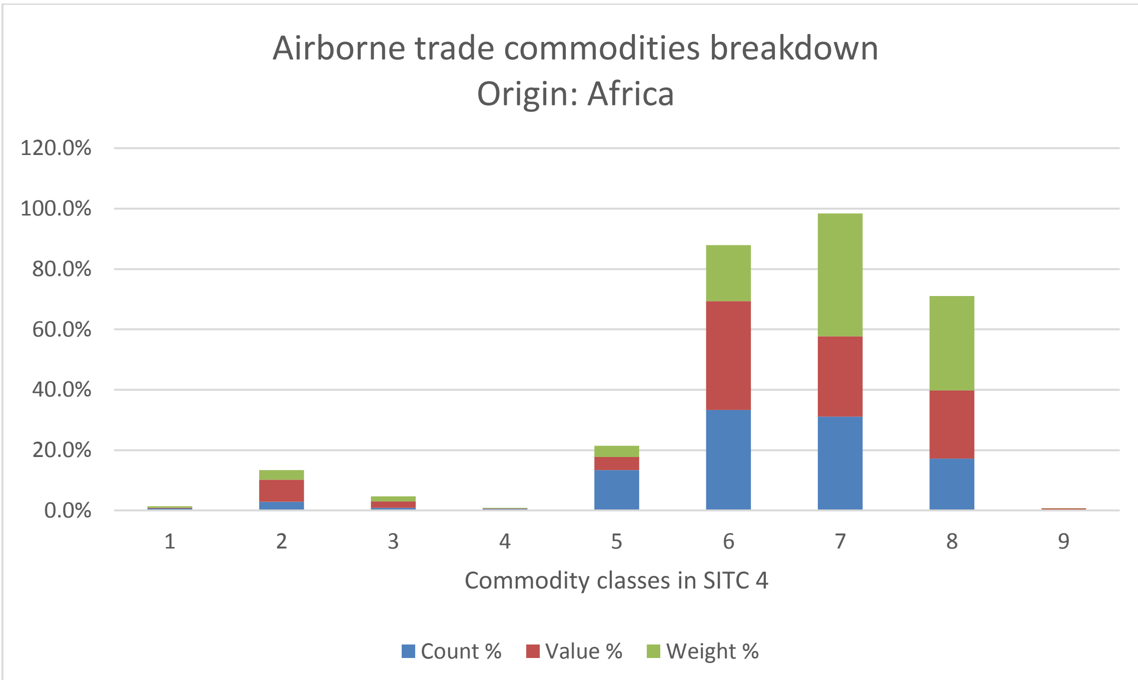



Figure 35: Breakdown of airborne trade commodities in Africa

Most part of the value comes from such commodities, grouped in class 6, while the combination of classes 6, 7 and 8 accounts for almost 80% of total value and 90% of weight. What stands out from the general picture of the global air freight trade is that the unit value mode choice model identifies also as air freight cargo a small part in class 2 commodities (beverages and tobacco) which can be justified by some high end products that source their materials in Africa. Market-wise, the model shows a very strong air freight relationship with Europe, as more than half of the value and weight are heading there. Asia and North America follow in distance, with a combined value percentage of 32% and the almost the same in terms of weight. It is worth to note here that Asia is the only region where the air freight volumes with Africa show higher shares in value than in weight. The rest of the world regions show only fragments of the total Africa airborne trade, as it can be seen in Figure 36.

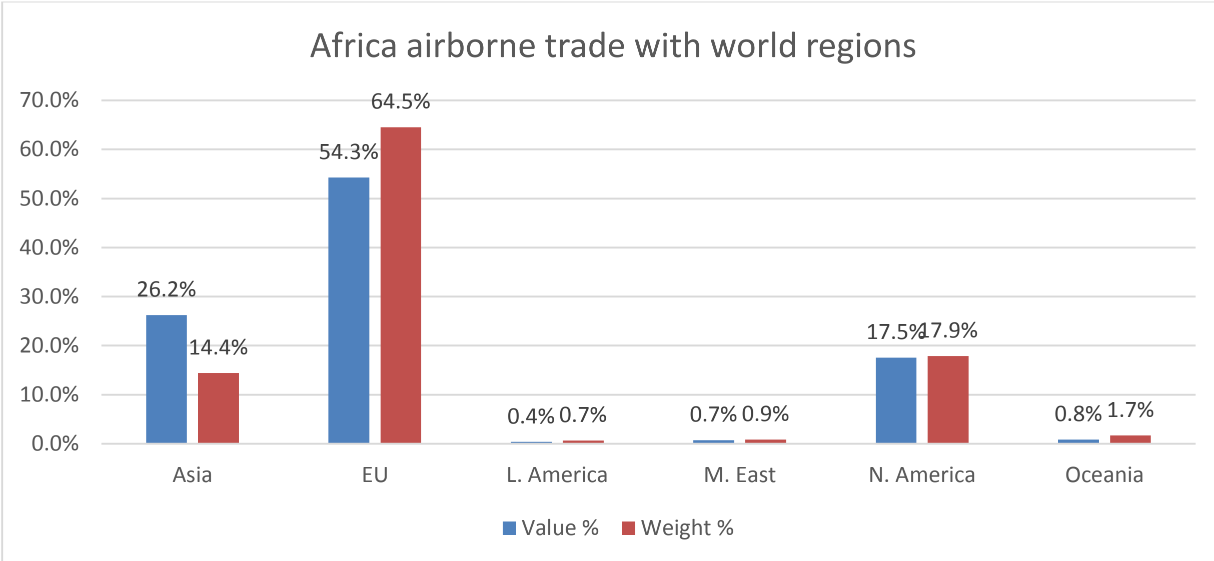



**Figure 36: Airborne trade of Africa with world regions in weight and value percentages**

The same story is told when the tonkilometers are considered, with almost half of the tonkilometers being recorded in the flow with Europe. This makes sense as Africa has the strongest air transport links with that region and it is possible that some volumes heading towards production areas (Asia) have to pass from Europe first either because of lack of air transport links or for consolidation purposes. The next strong markets are with North America and Asia which together practically match the air freight transport between Africa and Europe. The rest of the world regions only have a small percentage reaching 5% combined. The shares with all regions can be seen in Figure 37.

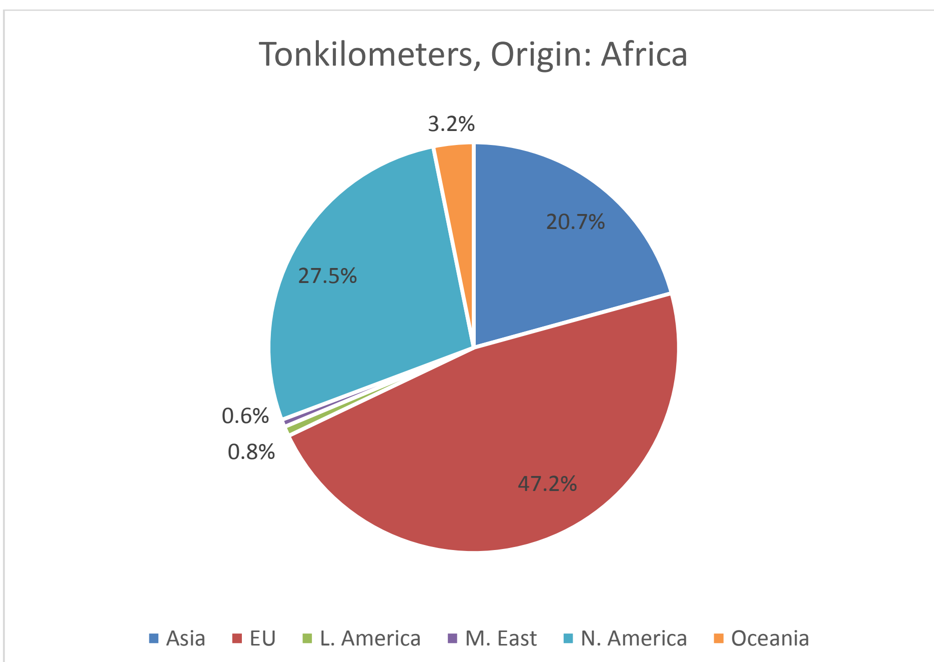



**Figure 37: Ton kilometre shares between Africa and the world regions**

In the case of Africa, the air freight service choice module allocates the largest share of air freight traffic, in terms of both weight and value, to cargo-only services with 50.3% and 63.7% respectively. A little more than one fifth of the value is transported in the belly of passenger aircraft while integrators handle one fourth of the value and just a tenth of the weight. The precise results for air freight service choice for Africa can be seen in Figure 38.

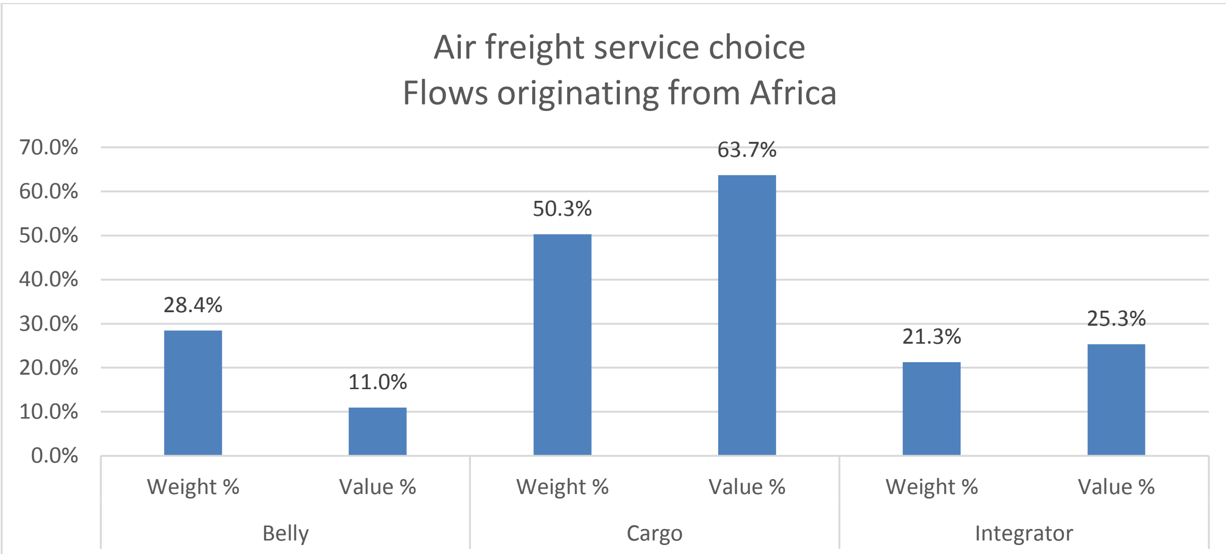



Figure 38: Air freight service choice split, flows originating from Africa

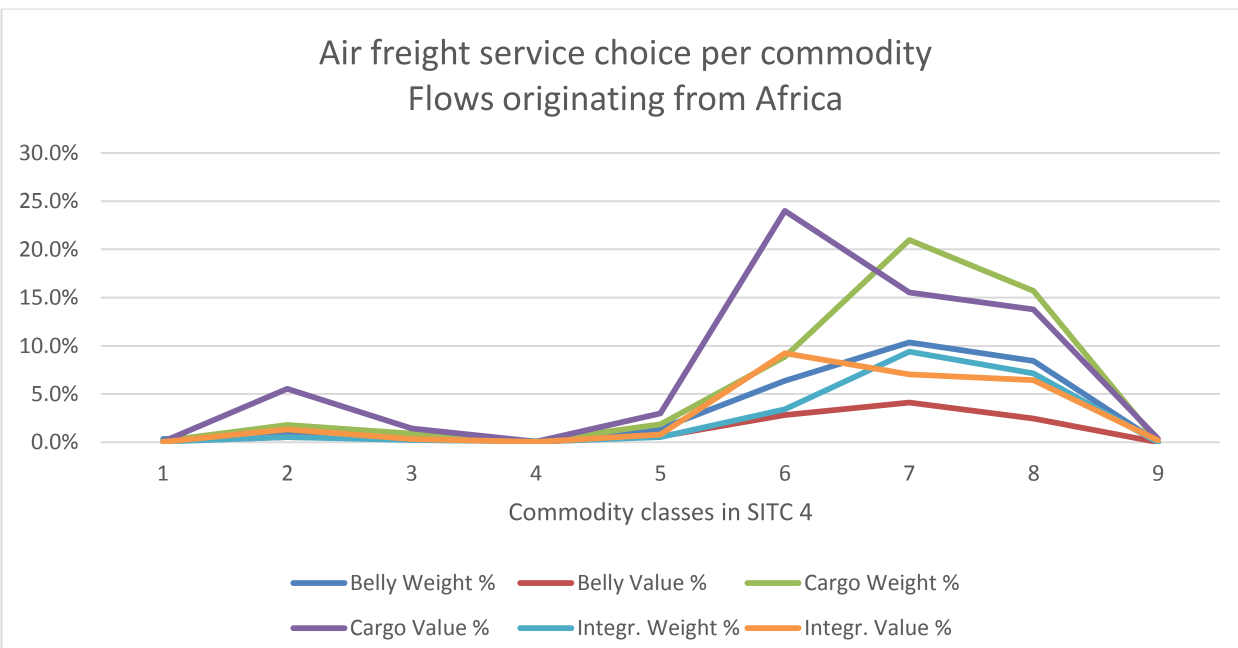



Figure 39: Air freight service choice per commodity type, Africa

Figure 39 shows the air freight service choice analysed by commodity class. There, it can be seen that cargo only services have the strongest presence throughout the range in both weight and value with the highest shares being recorder in class 6. On the other hand class 7 commodities are shown to have the highest preference for belly transport and integrators have increased share in handling commodities of classes 6 and 8.

## 5.4 Regional level: Asia

Asia trade is by far the most populated, in terms of observations, within the trade data of this study. It also concentrates a big part of the total world trade both in weight and value. This of course is expected given the position of Asian countries in the global manufacturing chain. Compared to the global values, the model shows increased values regarding air freight transport which here is 44.1% of total Asia airborne trade in terms of value and 7.5% in terms of weight. It is mostly consisting of commodities in classes 5 to 8, with class 7 showing the most value and class 6 commodities the most weight percentage. Figure 40 shows the percentages of each commodity class in weight, value and number thereof.

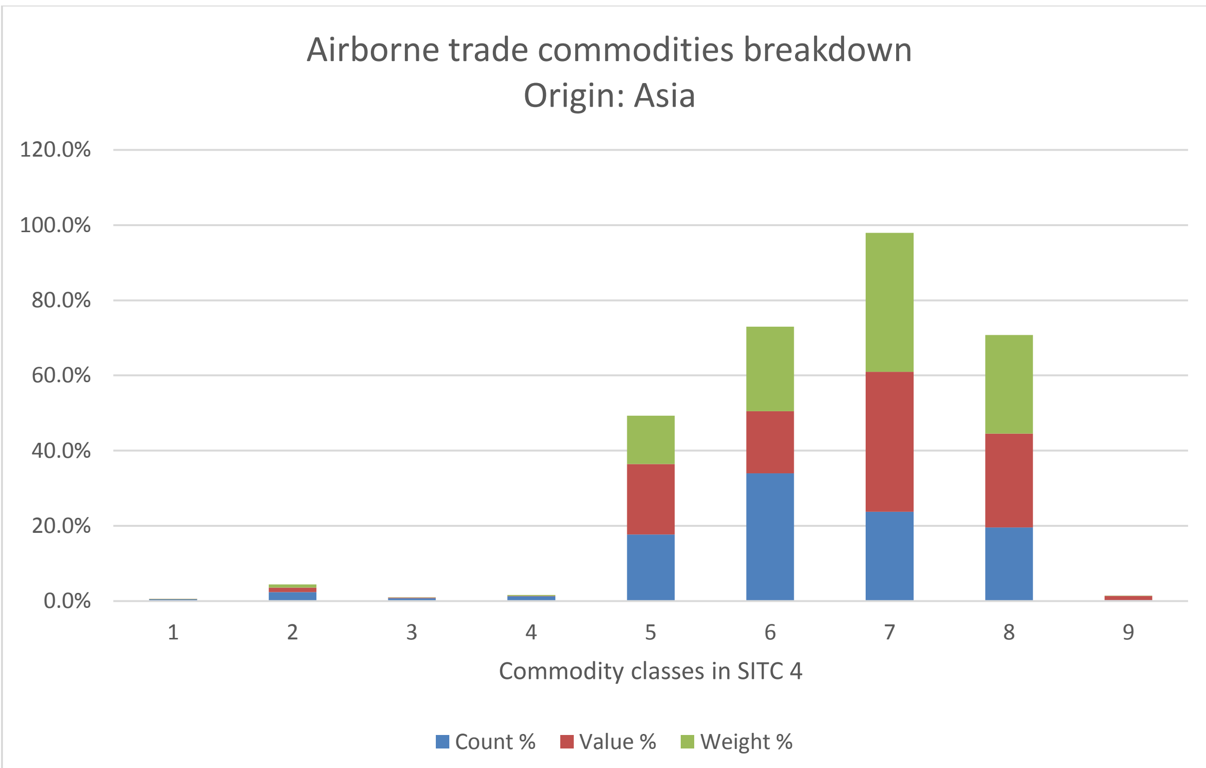



**Figure 40: Breakdown of airborne trade commodities in Asia**

When it comes to air freight volume flows, the region of Asia is in business mostly with the two other big markets, North America and Europe. Analysing the results of the mode choice component of the model in an Asia-to-region level reveals the same relationships, with the highest weight and value flows being concentrated around Europe and North America. The former absorbs 45% or the Asia airborne trade in value and 48% in weight while the latter shows percentages of 39.7% and 37.2% respectively. The full picture of the airborne trade with the rest of the regions is shown in Figure 41.

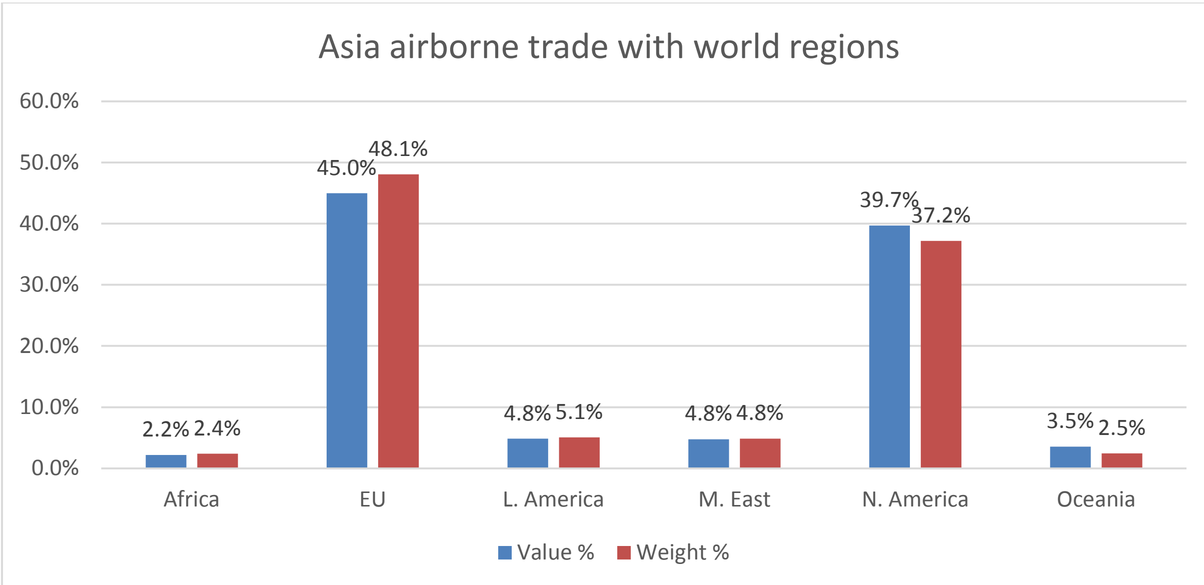



**Figure 41: Airborne trade of Asia with world regions in weight and value percentages**

The model supports this with airfreight tonkilometers being allocated almost equally to the two regions with percentages of around 42% each. The rest of the world regions have small contributions with Latin America showing a slightly elevated percentage of total tonkilometers of 8.5%. Figure 42 contains a pie chart with the relevant shares.

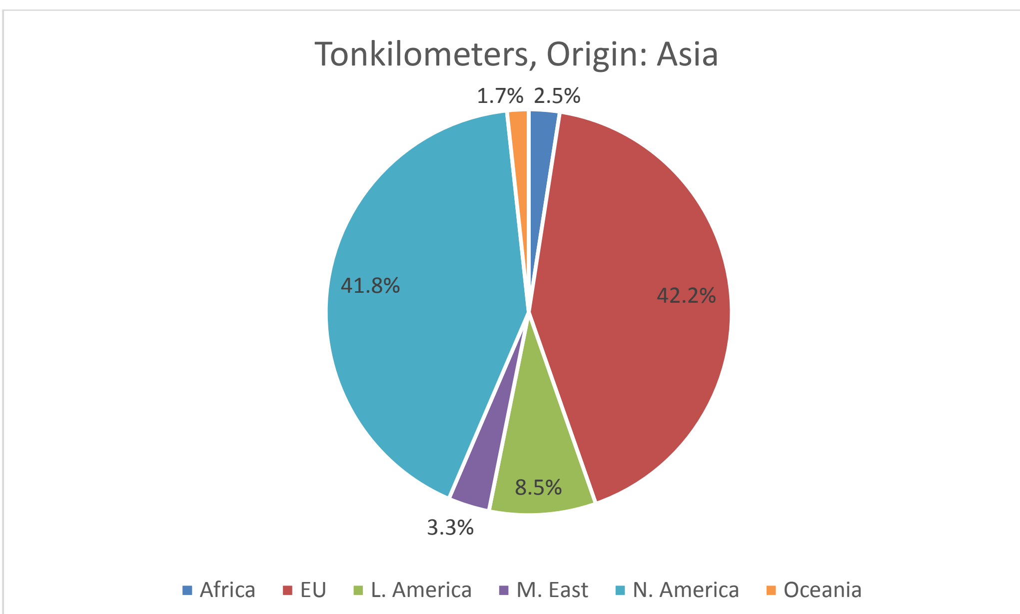



**Figure 42: Ton kilometre shares between Asia and the world regions**

Furthermore, the model shows that, weight-wise, more than half of the air freight originating from Asia, specifically 56%, is transported in the belly of passenger aircraft. The ample availability of direct and frequent connections that link Asia with Europe and North America support this result. Cargo only services carry less weight but enjoy the bigger piece of the value pie with 54.3%. Once again, the model shows the integrators taking the low in volume but high in value part of the total airborne trade. The exact breakdown can be seen in Figure 43.

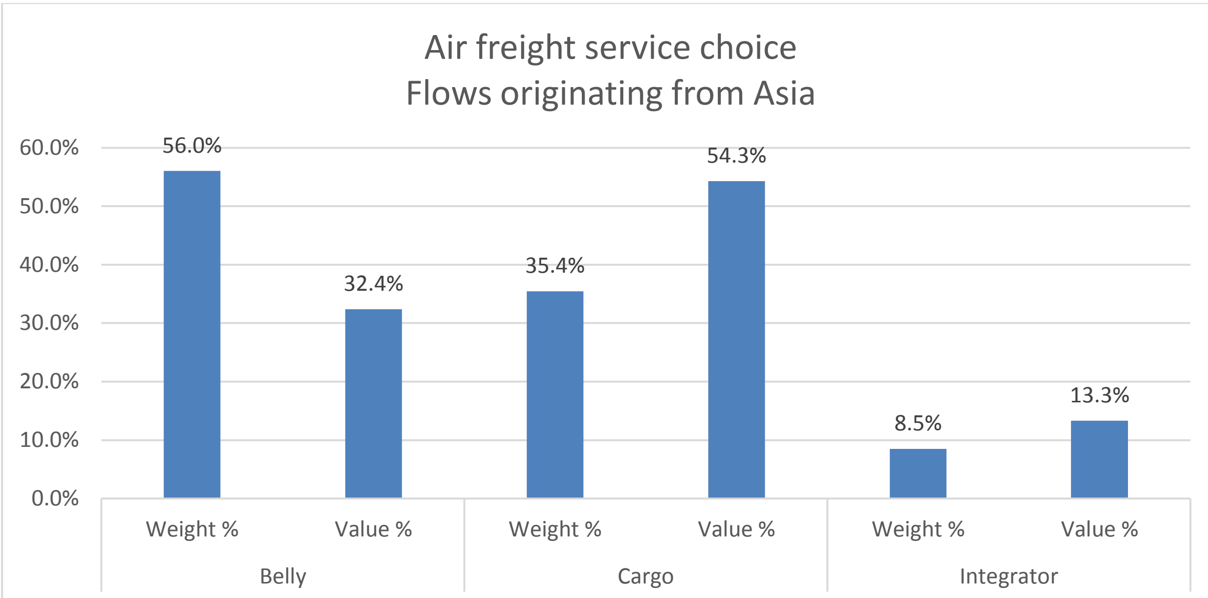



Figure 43: Air freight service choice split, flows originating from Asia

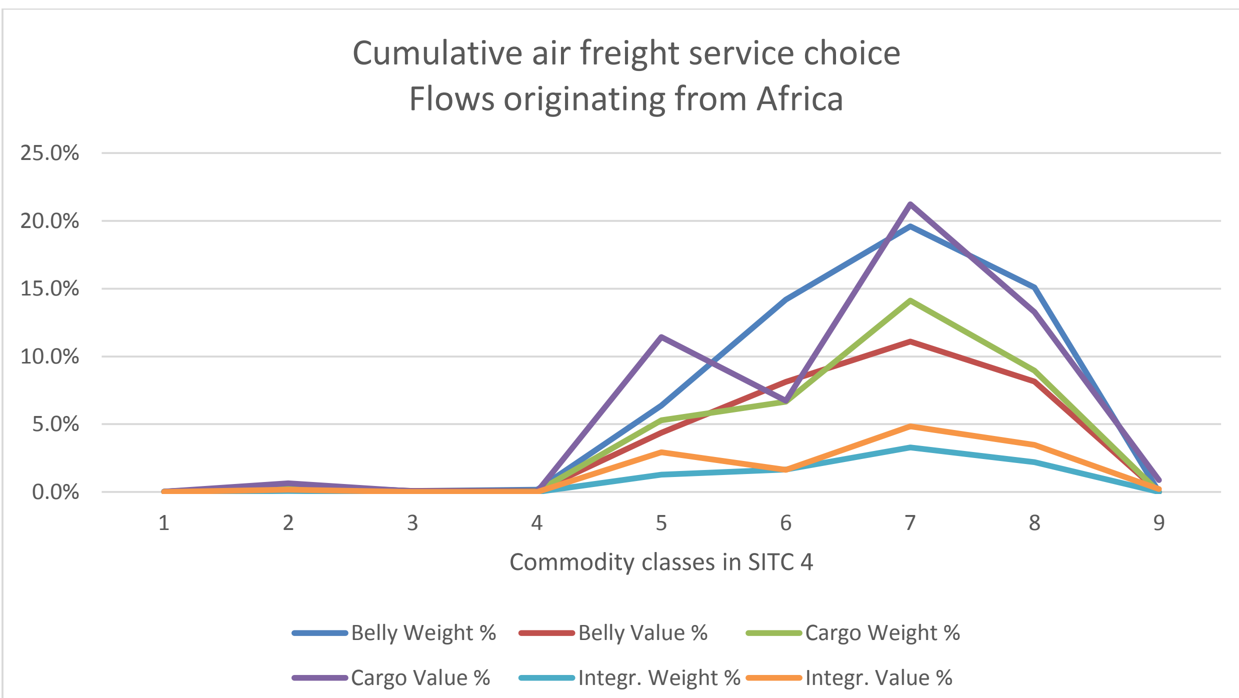



Figure 44: Air freight service choice per commodity type, Asia

Looking deeper in the air freight service choice in regard to commodity class, belly transport has the strongest presence, capturing high shares throughout the commodity range. Cargo only services get most of their value in transporting commodities of classes 5 and 7 while integrators have a rather stable share that doesn't exceed the percentage of 5%. Figure 44 presents the specific percentages in weight and value for each service type per commodity class.

## 5.5 Regional level: Europe

Europe is amongst the most economically developed regions of the world. A great part of European consumers have had increased spending power for many generations and therefore create a large demand for high end products, the core of air freight. Next to that, Europe is the home of many manufacturing businesses that create products with high or even extremely high value density. Well know examples as such are high fashion items and exotic super cars. An increased share of air freight transport is therefore expected and indeed, the model indicates that air freight transport represents 55.8% of the value of trade originating in Europe and 4.3% of the weight, values somewhat increased when compared with the global ones or those of other regions. That volume consists mostly of chemicals, manufactured goods, machinery and transport equipment described by commodity classes 5, 6 and 7 as depicted in Figure 45.

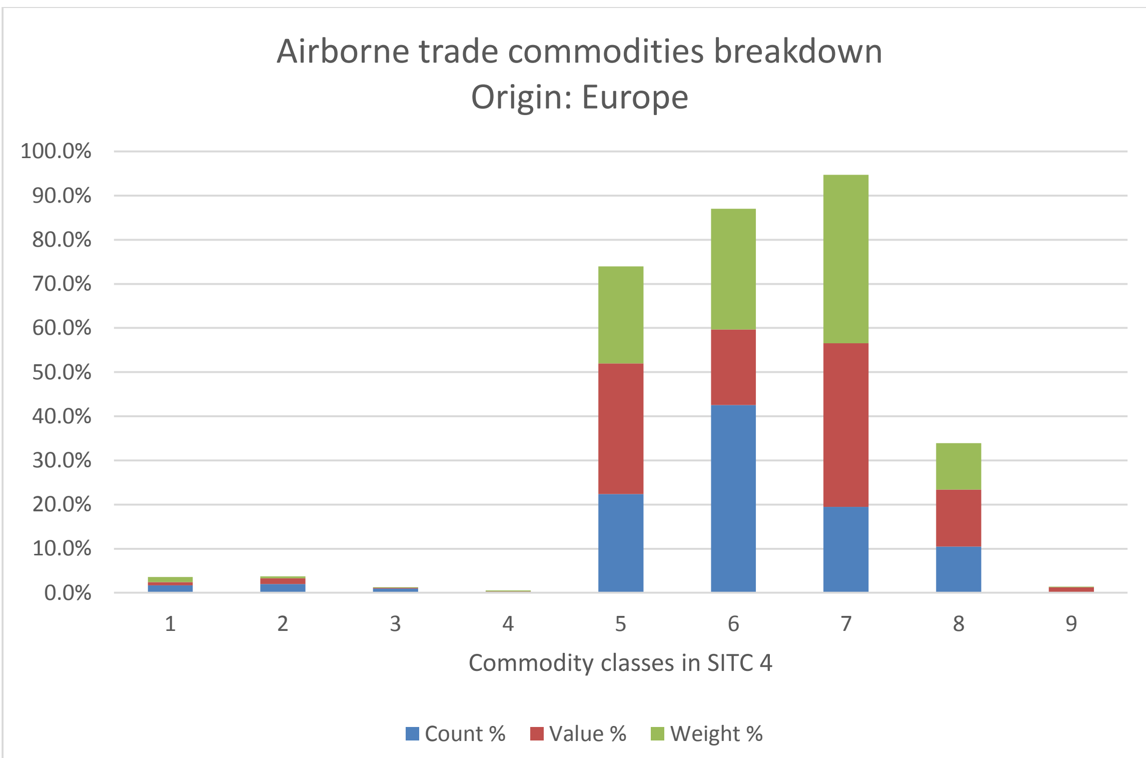



Figure 45: Breakdown of airborne trade commodities in Europe

Europe, being a part of the three big air freight markets, is expected to show strong trade flows with the other two. Continuing with the regional results of the model for Europe, the market shares in terms of tonkilometers are calculated, showing the validity of that assumption. Clearly, Europe's air freight is strongly linked to Asia and North America, with the two regions accumulating 73% of total air freight tonkilometers for this region. The remaining is almost evenly spread between the other destinations, with

Africa having, understandably, the smallest share, as it combines low volumes of trade with small flying distances. Shows the exact the exact shares of air freight tonkilometers between Europe and the world regions, as calculated by the model.

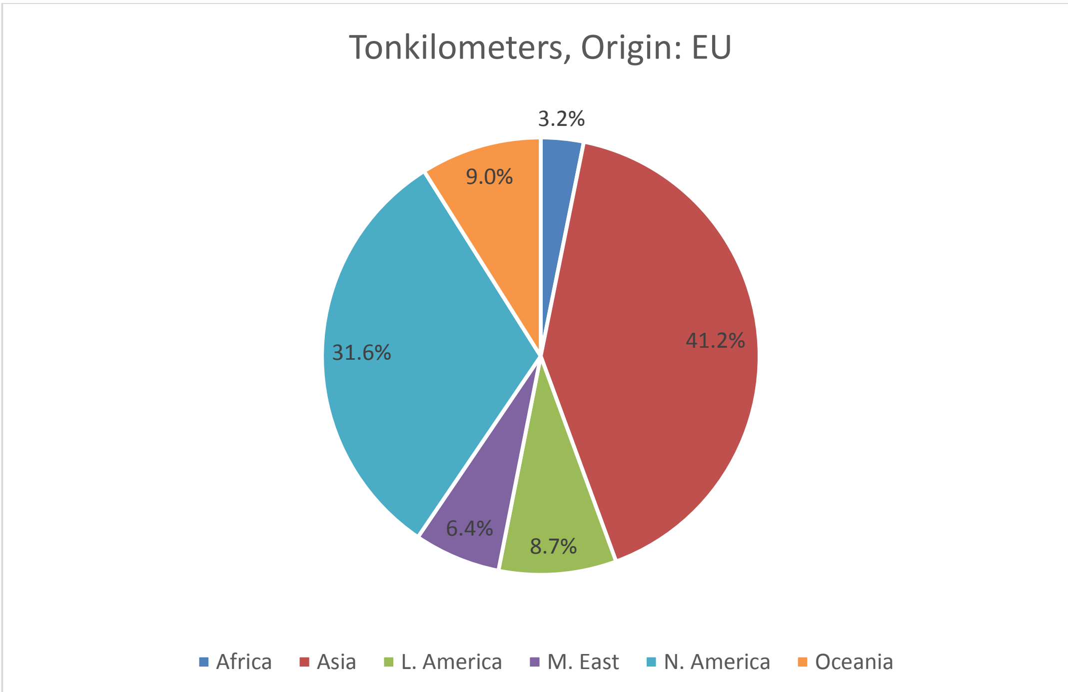



Figure 46: Ton kilometre shares between Europe and the world regions

The same conclusion can be made by looking at the airborne trade split between Europe and the world, in terms of weight and value, as depicted in Figure 47.

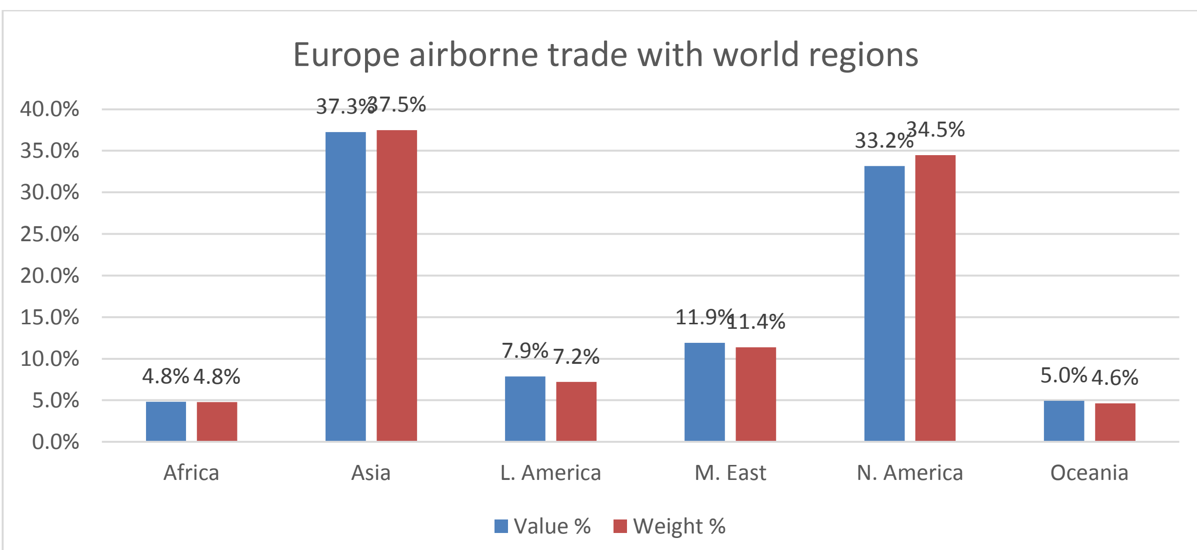



Figure 47: Airborne trade of Europe with world regions in weight and value percentages

The regions of North America and Asia absorb the largest share of European airborne trade with a combined value percentage of 70% and 72% in weight. Combining these figures with the tonkilometers shares it can be shown that between these three regions, there is a strong and almost equal relationship of weight, value and payload-distance of 1:1:1, meaning 1% of airborne weight reflects to 1% of airborne value and 1% of the total transport service.

Considering the air freight service choice that comes next, the air transport volumes from Europe are balanced between belly and cargo-only services in terms of weight, but not in terms of value. The model shows these two services to share around 44% of the weight each, but cargo-only services taking the largest share of value with a percentage of 63.5%. That leaves just 20% of the value being transported in the belly of passenger aircraft and integrators handling a small piece of the market that contains 17% of the value. The split between the air freight services can be seen in Figure 48.

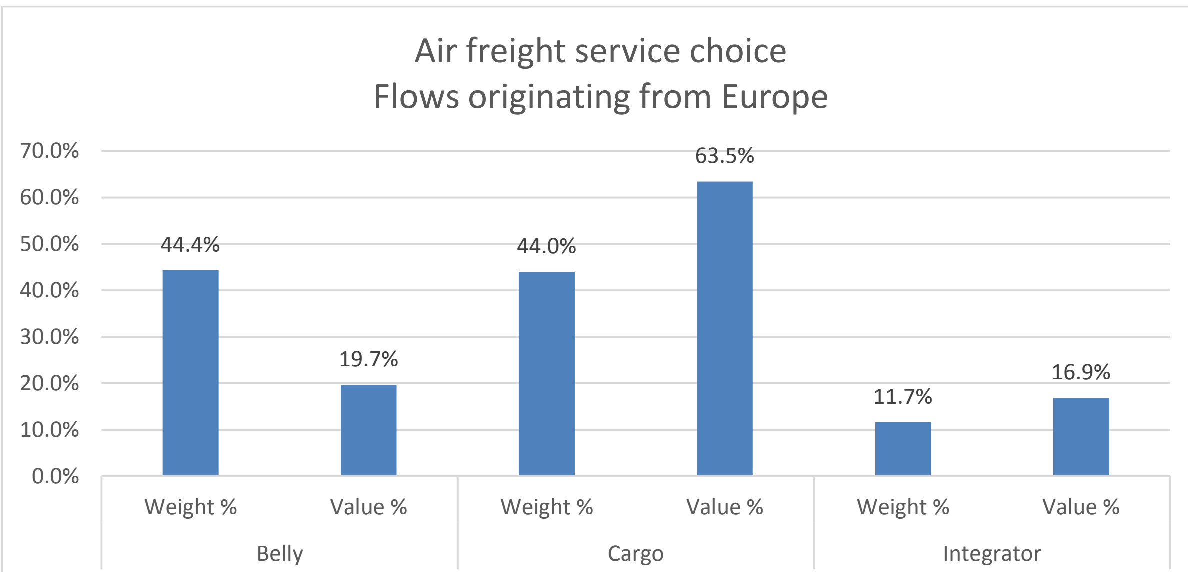



**Figure 48: Air freight service choice split, flows originating from Europe**

In the highest value density commodity classes, cargo-only services seem, according to the model results, to be preferred. More specifically, 20% of the cargo-only freight value comes from chemicals (class 5) and another 25% from machinery and transport equipment (class 7). That result in particular can be characterised as logical, because commodities in these classes often have special handling requirements either due to their nature (chemicals, pharmaceuticals, precision instruments) or to their physical properties (large and heavy equipment, cars etc.). Belly transport services have a steady performance in all air freight commodities, peaking at class 6 where 15% of the belly freight value comes from. Integrators are shown to have a similar steady performance, gaining around the 5% in terms of value and 3% in terms of weight from each class. The specific values can be seen in Figure 49.

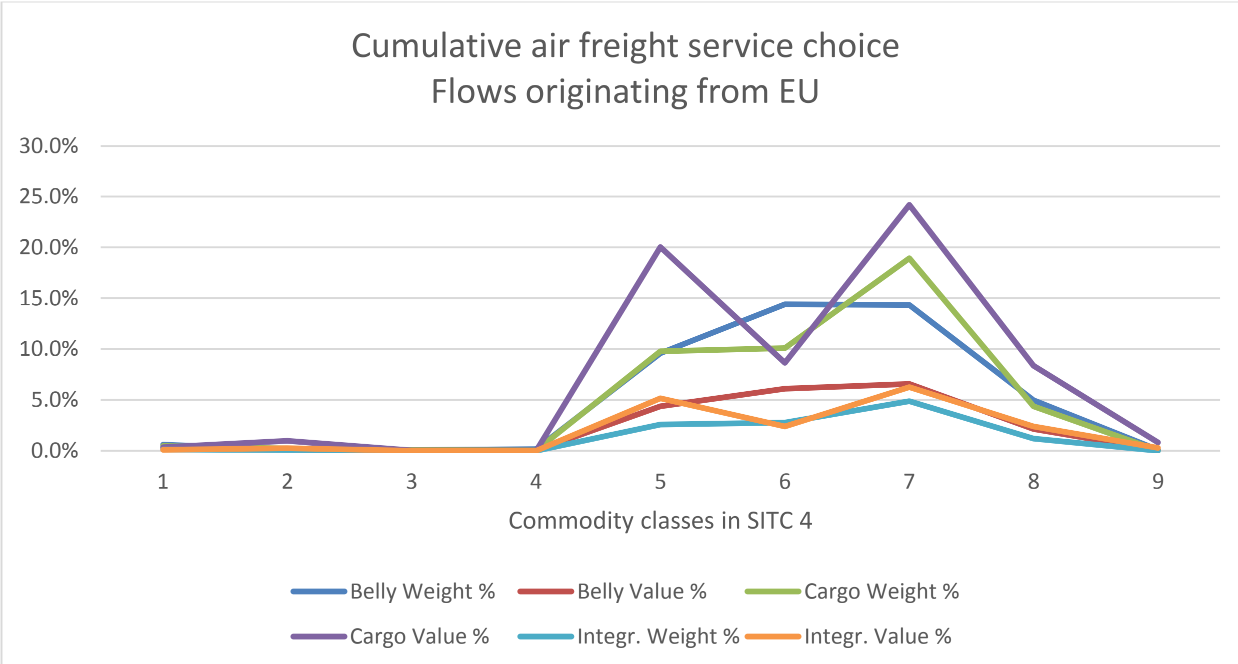



Figure 49: Air freight service choice per commodity type, Europe

## 5.6 Regional level: Latin America

Continuing at the regional level with Latin America, the model shows a thin portion of trade being transported by air. Just 0.7% of the total weight of traded goods falls in the way of air transport, corresponding to 15.4% of the total value. The countries in that region are the source of many types of raw materials, though not chiefly used in the production of high end, air freight relevant, commodities, supporting this finding. Furthermore, distance-wise, it is located quite far from the main production regions making the choice for air transport very costly and therefore less likely. Nevertheless, the airborne commodities breakdown follows the same general pattern, revolving around classes 5, 6 and 7 with one chief distinction in comparison with other regions. Here the mode choice component shows a high value contribution of class 9 commodities to air freight. This is the class that contains coins and gold and, given the fact that 3 out of the 10 biggest gold mines are located in Latin America (Obel, 2011), seeing increased values at this class is expected. The complete picture of the airborne trade from Latin America in terms of weight is shown at Figure 50.

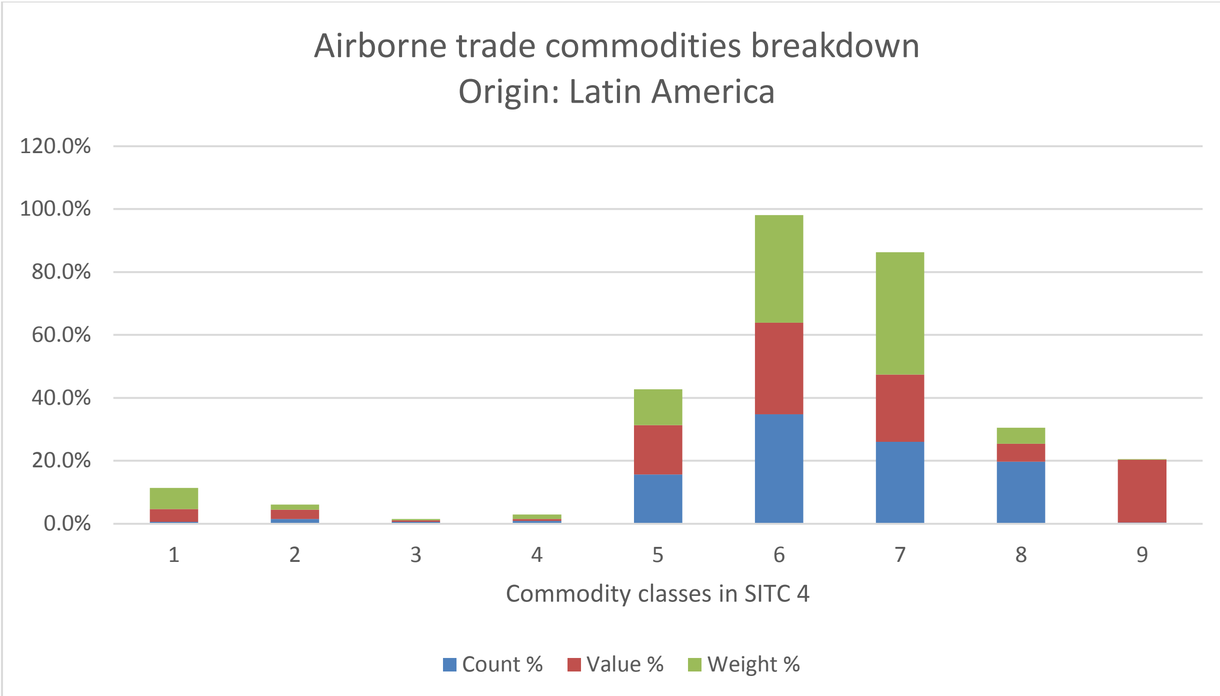



**Figure 50: Breakdown of airborne trade commodities in Latin America**

As seen in the previous chapter, the available air transport links between Latin America and the world regions, especially the ones in different continents, are rather poor. The exception is with North America where larger, better equipped airports are found, next to main integrator hubs with worldwide connections. That abundance of supply is a hint that the largest air freight market for Latin America is to be found with the neighbouring region of the same continent. Undoubtedly, the results of the mode choice component of the model reveal a relationship in the same direction.

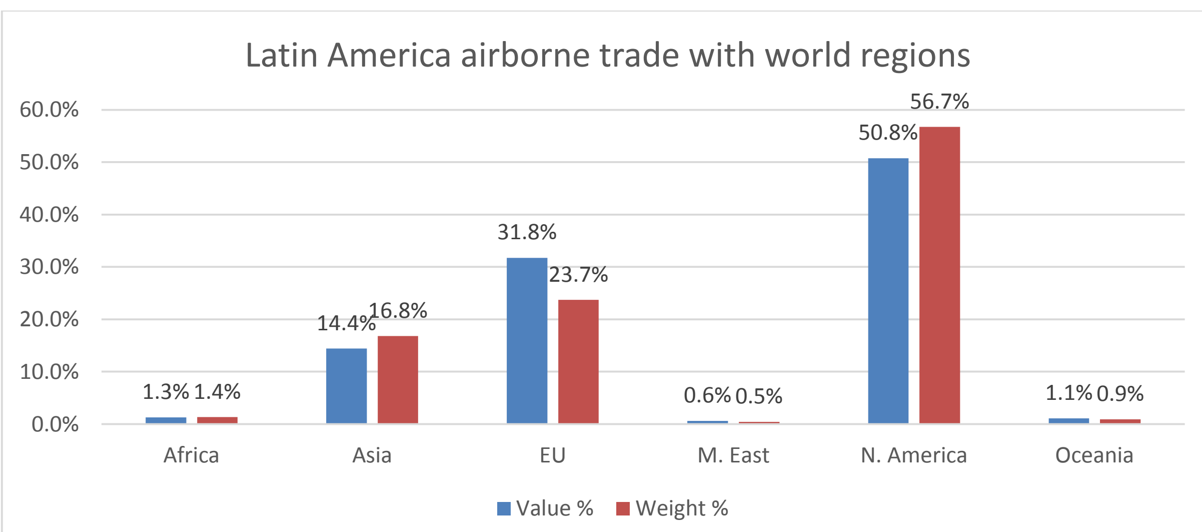



**Figure 51: Airborne trade of Latin America with world regions in weight and value percentages**

Figure 51 shows the value and weight percentages of total Latin America airborne trade flows with the partner regions. Alone the flow with North America contains more than half of the value and 56% of the weight. The other two big markets follow at a distance with value and weight percentages that follow short of those with North America, even when combined.

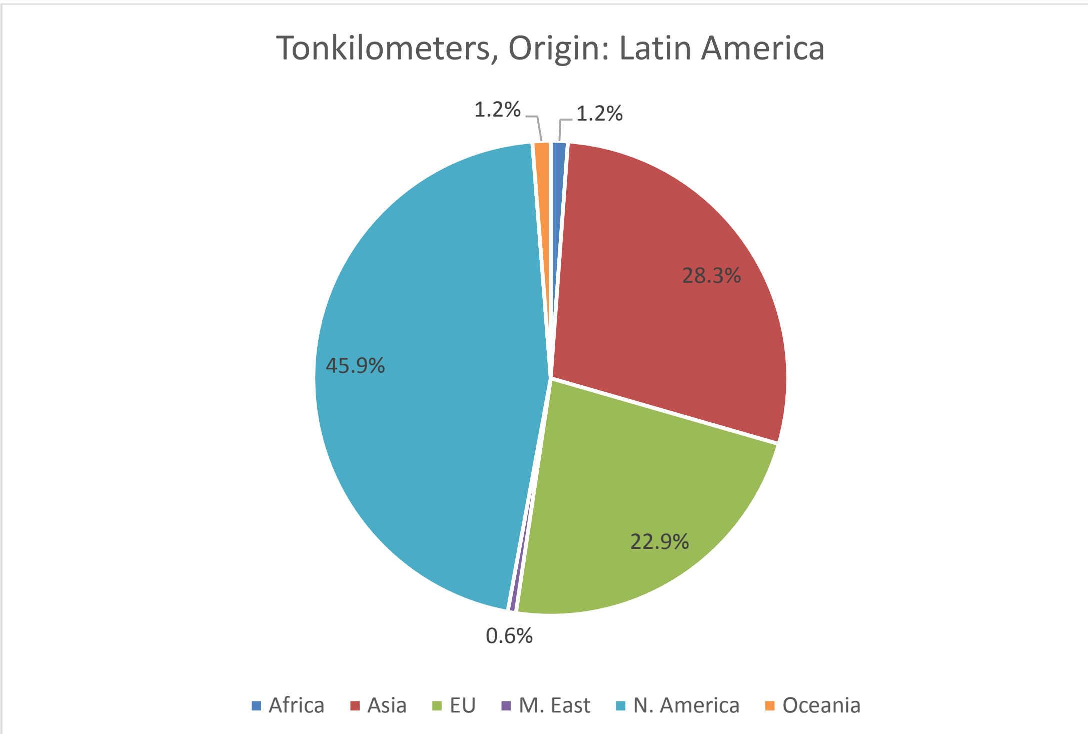



Figure 52: Ton kilometre shares between Latin America and the world regions

The flow with North America is also the largest in terms of transport work, with 46% of the total tonkilometers being performed there, as shown in Figure 52. Flows with Asia and Europe follow next, with each generating around a quarter of the total airborne flows product originating in Latin America.

The air freight service choice component of this model reveals a situation in favour of pure cargo business models. Almost 88% of the airborne weight is divided between cargo only services and belly transport, with the latter getting a larger piece. Practically the same percentages but in the reverse order are found in terms of value, with cargo services transporting 53% of the value leaving 28% filling the belly capacity of passenger aircraft. Integrators, as it can be seen in Figure 53, account for 12% of the weight and a slightly elevated 18% of the value, due to the presence of very high value density commodities in the Latin America airborne trade mix.

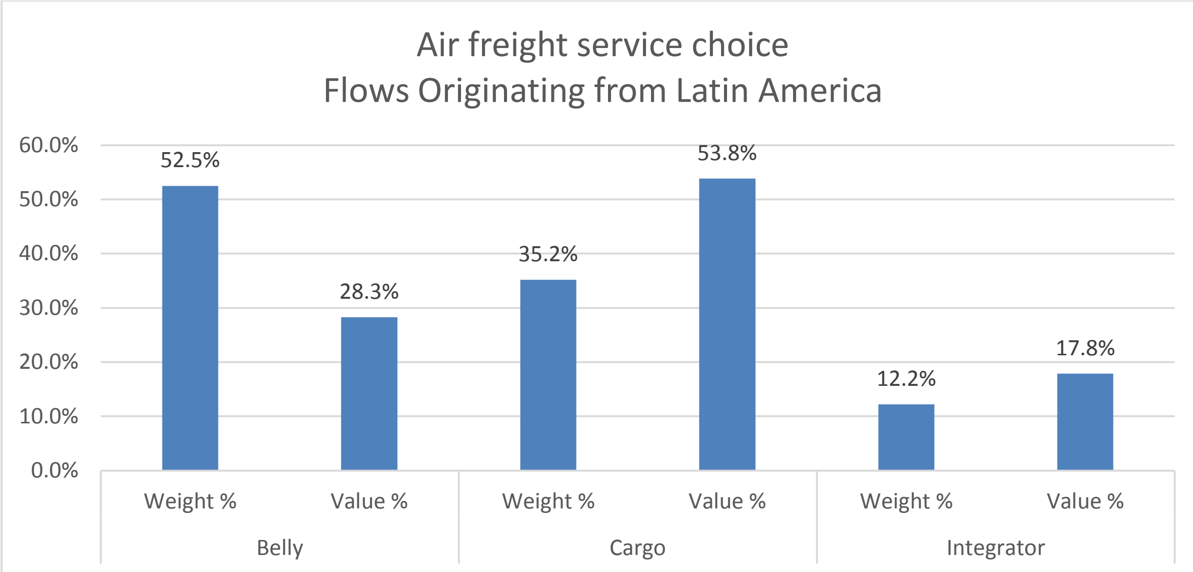



Figure 53: Air freight service choice split, flows originating from Latin America

In particular, commodity class 9 has an increased contribution in terms of value for the services of cargo only air transport and integrators. The former gathers 14% of goods value from that class alone, with the latter having a percentage of 6% for the same, as seen in Figure 54.

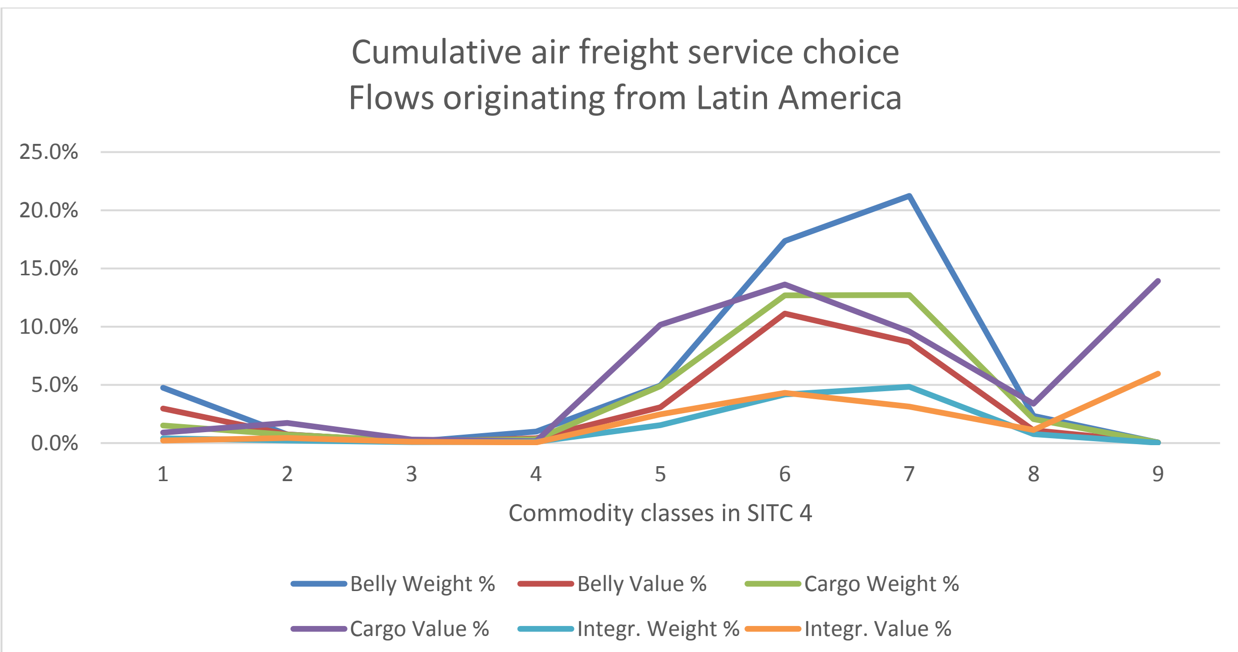



Figure 54: Air freight service choice per commodity type, Latin America

Moreover, class 6 and 7 commodities are the ones that fill up most of the belly and pure cargo capacity, contributing also the largest value portion for these service types. Similar findings are noted for integrators, who, besides having a low but stable performance, seem to acquire most of their business from class 6 commodities.

## 5.7 Regional level: Middle East

The Middle East is comprises of many of the most economically developed countries of the world. Besides the large spending power of the consumers there, which creates high demand for air transported goods, the economy of the region has become rather diversified. It is not so heavily dependent on oil anymore and, after significant privatization efforts from governments such as in Iran, other industries like automotive, mining, telecommunications, chemical etc. are blooming, attracting more air freight services. In the case of Middle East, the model indicates that air freight transport represents 38.5% of the value of trade originating there and 2.7% of the weight. That volume consists mostly of chemicals, manufactured goods, machinery and transport equipment described by commodity classes 5, 6 and 7 as depicted in Figure 55.

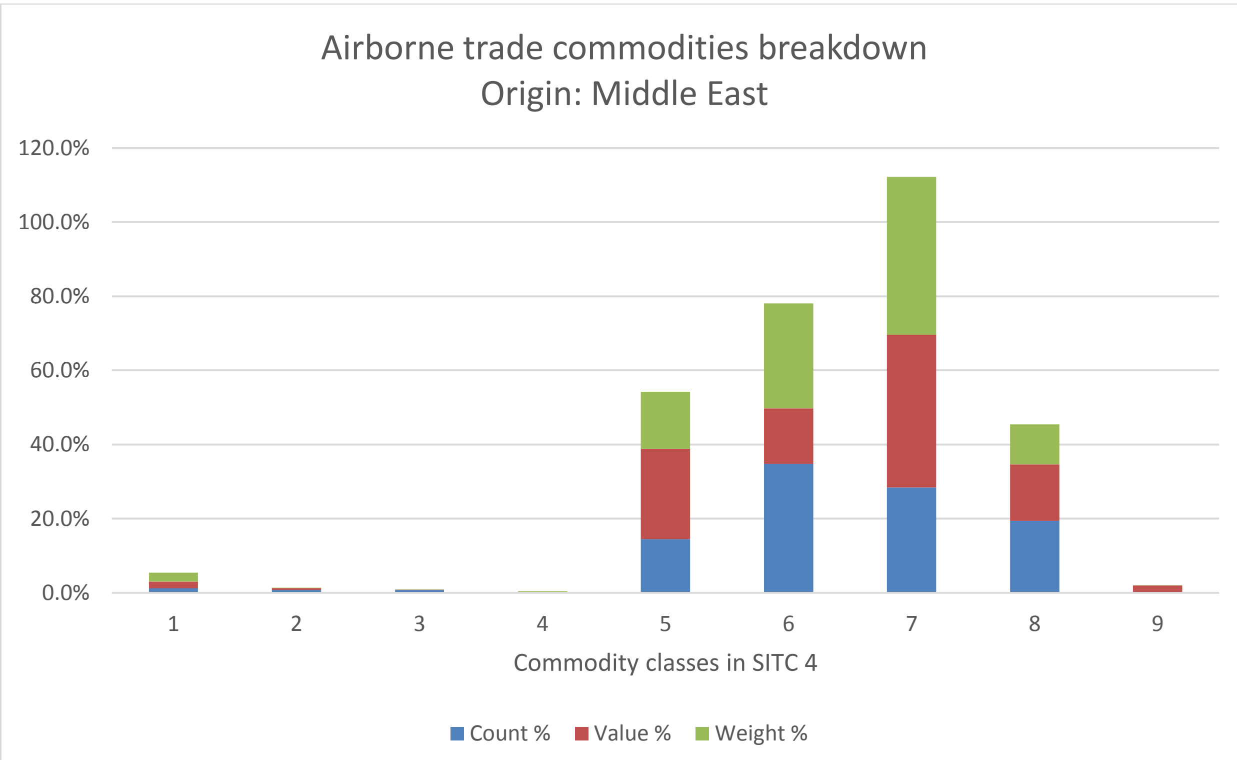



**Figure 55: Breakdown of airborne trade commodities in Middle East**

Machinery and transport equipment trump the rest of commodity classes in terms of their contribution in airborne trade, value and weight wise. More than 40% of the value and weight is generated from that class, with chemicals and raw materials following. As far as the markets that shape the air freight flows from Middle East are concerned, the situation is rather one-sided. According to the results of this model, the major market is the one between Middle East and Europe. An extraordinarily high percentage, 60.4% to be exact, of the total tonkilometers produced are flown between these two regions, keeping in mind the small flying distances between them, it can be concluded that, on the one hand, the European market absorbs a great part of Middle Eastern high end product exports and that, on the other hand, serves as an air freight gateway towards the market of North America, which cannot be reached directly. Figure 56 and Figure 57 show the air freight market shares in terms of tonkilometers, value and weight.

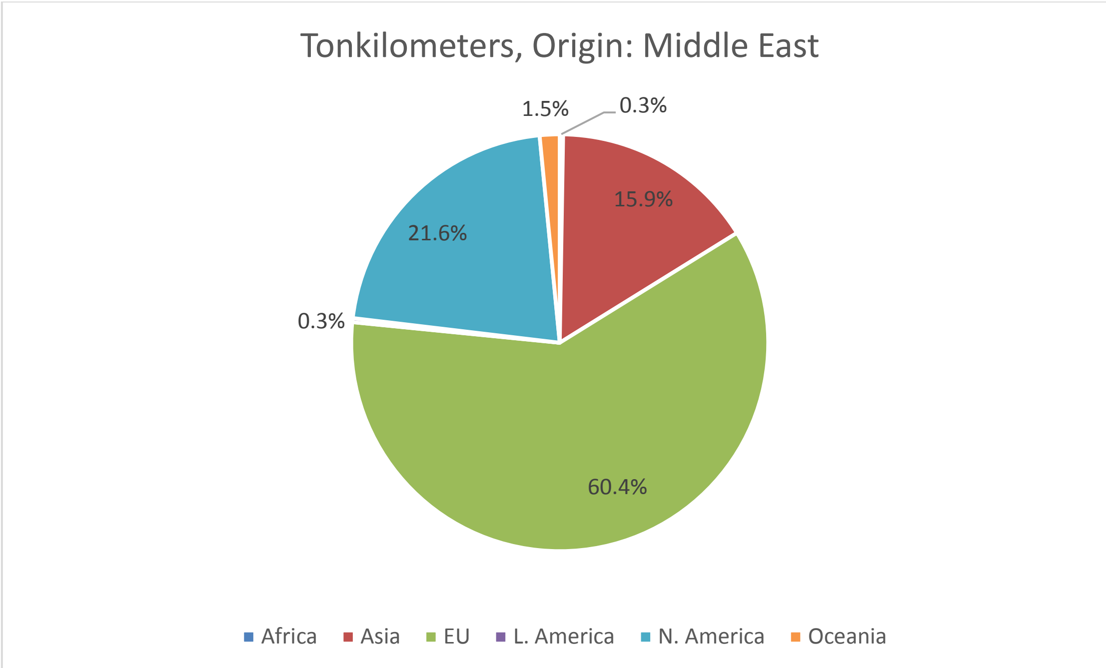



Figure 56: Ton kilometre shares between Middle East and the world regions

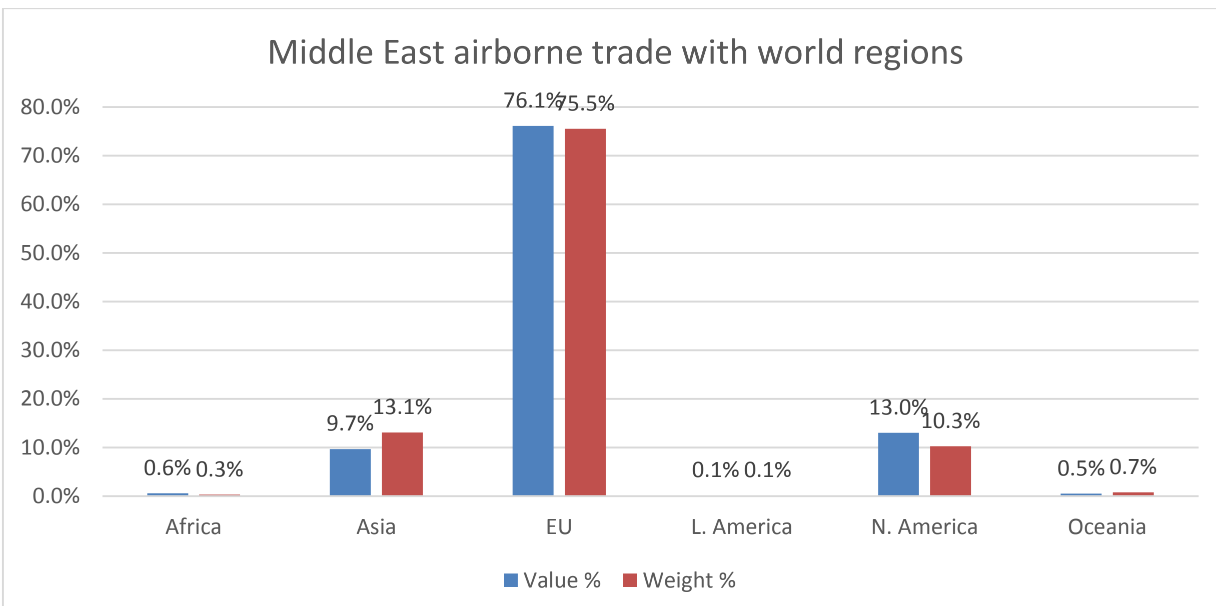



Figure 57: Airborne trade of Middle East with world regions in weight and value percentages

Regarding the air freight transport services that handle all this transport volume, the landscape is rather balanced between pure cargo and combination carriers in terms of weight. Both these service types are found to handle around 40% of the airborne weight each. Products with higher value density prefer the services of cargo only operators, giving 60% of the value to them. Integrators also show an increased performance in value transported, handling a portion of 21%. The full image of the air freight service split for Middle East is shown in Figure 58.

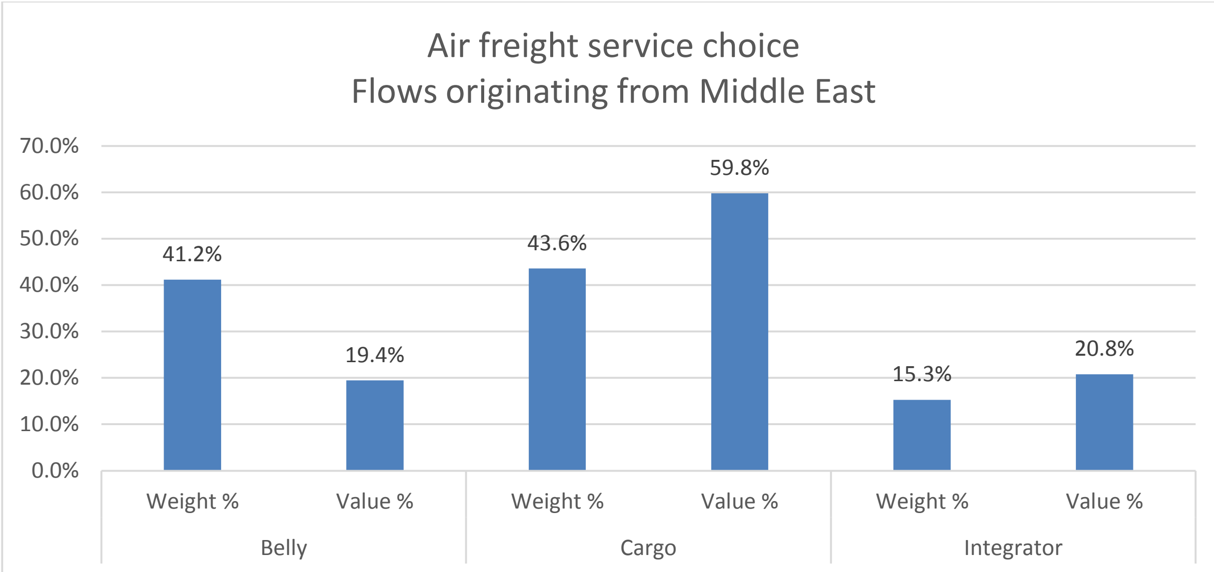



Figure 58: Air freight service choice split, flows originating from Middle East

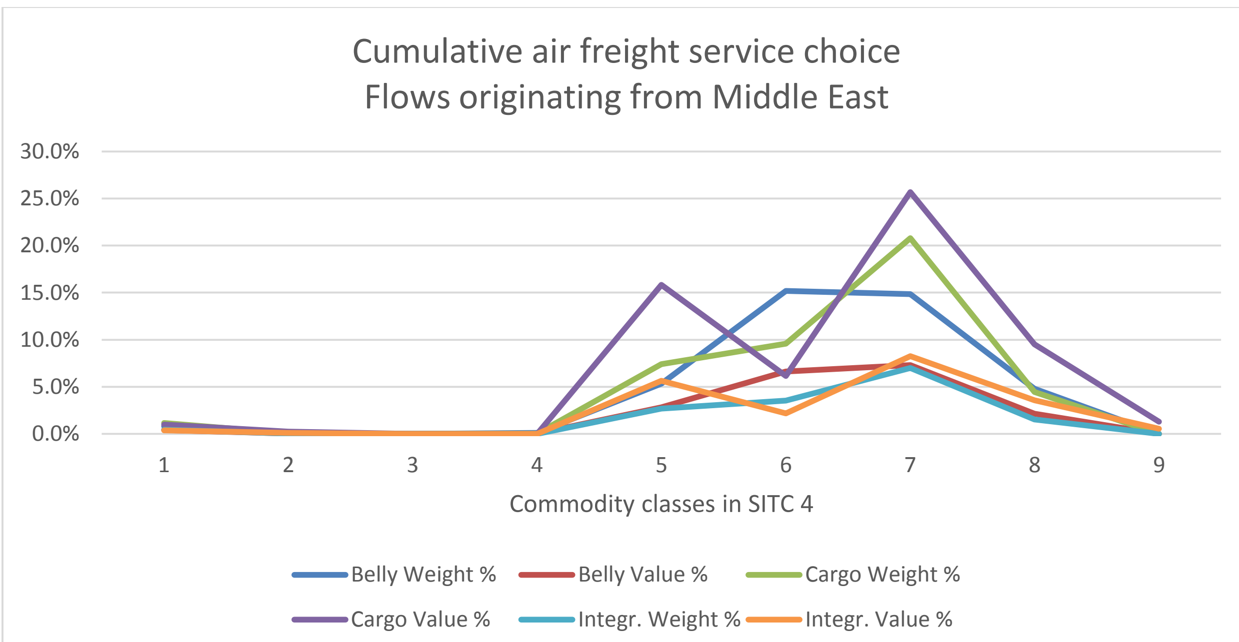



Figure 59: Air freight service choice per commodity type, Middle East

Analysing this further into a commodity-specific service split, commodity classes 5 and 7 are found to contribute most of the value for cargo-only and integrator services, while, weight-wise, classes 6 and 7 are filling up the cargo holds. Combination carriers generate most of their business here with commodity classes 6 and 7, amounting to 15% in weight and half of that in value, as shown in Figure 59.

## 5.8 Regional level: North America

Much like Europe, the region of North America contains highly developed economies that attract and generate air freight volumes. As one of the three big markets, in terms of air freight, it is expected to reveal a mode split that allocates a high value percentage and a low weight percentage to air transport. In this case, the unit value mode choice model produces a result that supports that. According to the findings of the model, airborne trade from North America amounts to 40.6% of value and 1.7% of weight of the total trade with the rest of the world. The commodity mix follows the norm that was seen in previous regional analyses, with classes 5, 6 and 7 creating most of the need for air freight transport. The biggest differentiation here in respect with other regions is the contribution of chemicals and related products (class 5). As it is shown in Figure 60, that class brings 30% of the value and 31% of the weight in the mix.

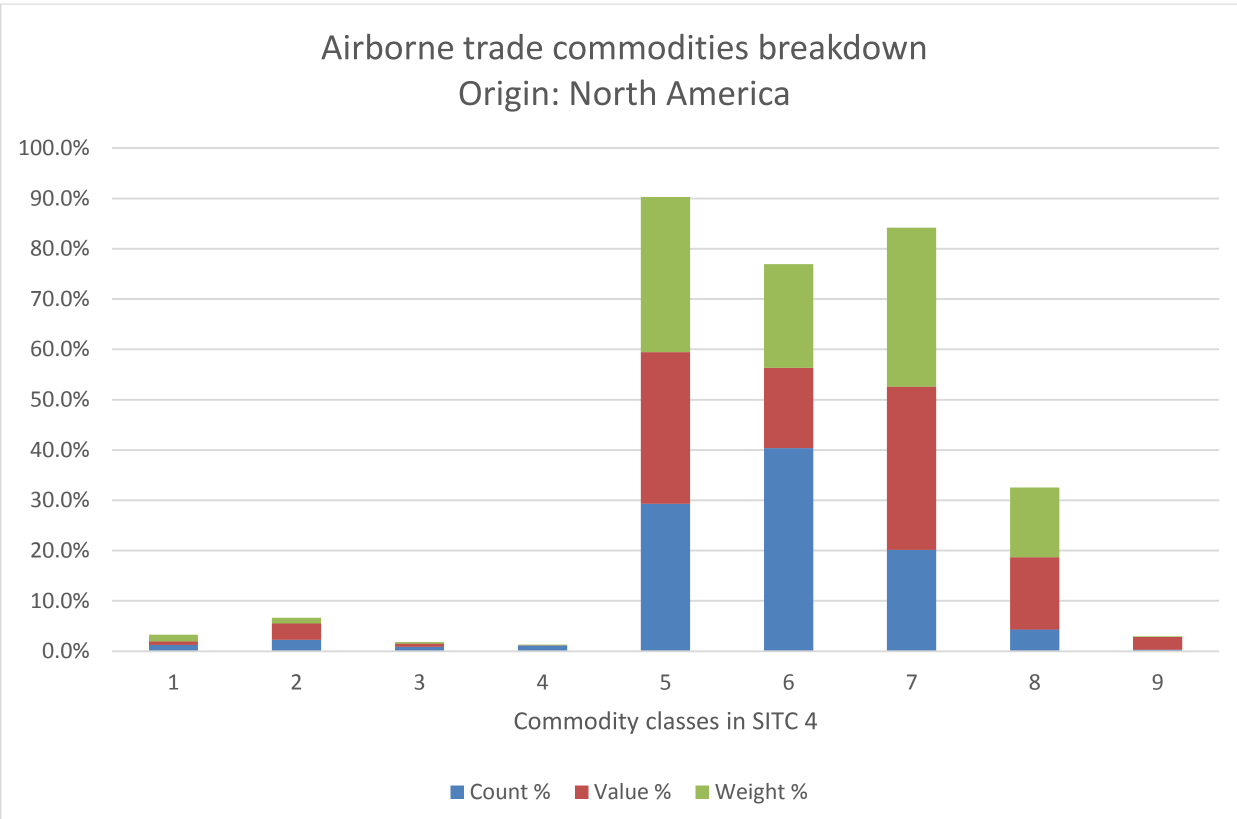



**Figure 60: Breakdown of airborne trade commodities in North America**

Machinery and transport equipment as well as manufactured goods by material (classes 7 and 6) once again show a strong presence in the airborne trade mix, contributing together 48% of the value and 52% of the weight, establishing them as the main air freight clients. Apparel and footwear (class 8) also make a strong contribution, amounting for around 14% of value and weight, even though only 4% of the observations fall under this category.

In line with previous findings in large markets, air freight generated in North America has mainly two destinations, Europe and Asia. The model reveals that the tonkilometers of air transport are almost perfectly balanced between the two, with each absorbing around 36%.

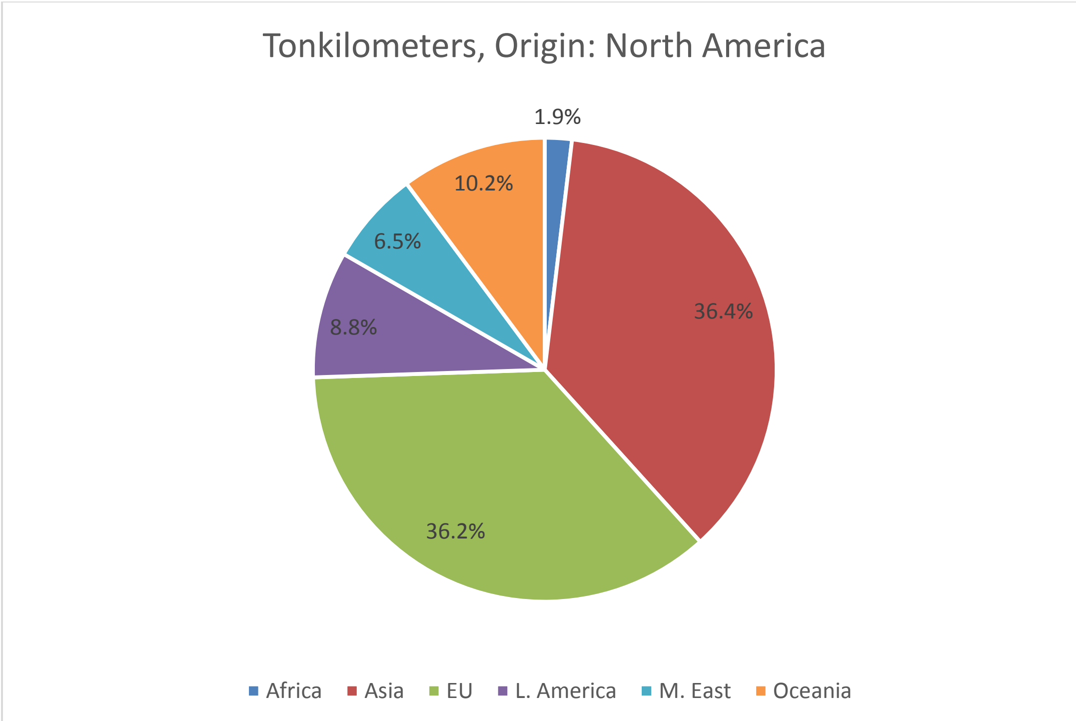



Figure 61: Ton kilometre shares between North America and the world regions

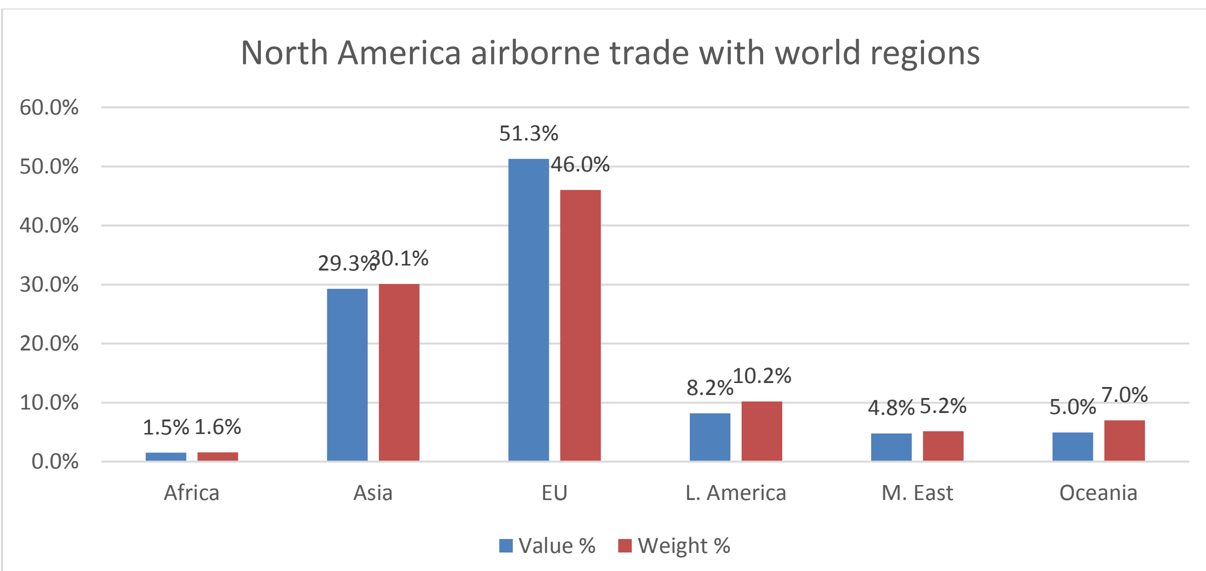



Figure 62: Airborne trade of North America with world regions in weight and value percentages

Figure 61 and Figure 62 further point out the air freight markets between North America and the world. The flow with Europe is found to contain the highest share in value and weight, amounting for almost half of total. Besides, the big markets, elevated figures are spotted for the flows with Latin America as well as Oceania. Moving further, air freight service split follows closely the global figures as seen in paragraph 4.2. Here, the combination carriers (belly) get a slightly smaller weight percentage of 49.5% and 22.4% of the value. This leaves more room for the other services with 41% of the weight handled by cargo-only and 15% of the value by integrators, as seen in Figure 63.

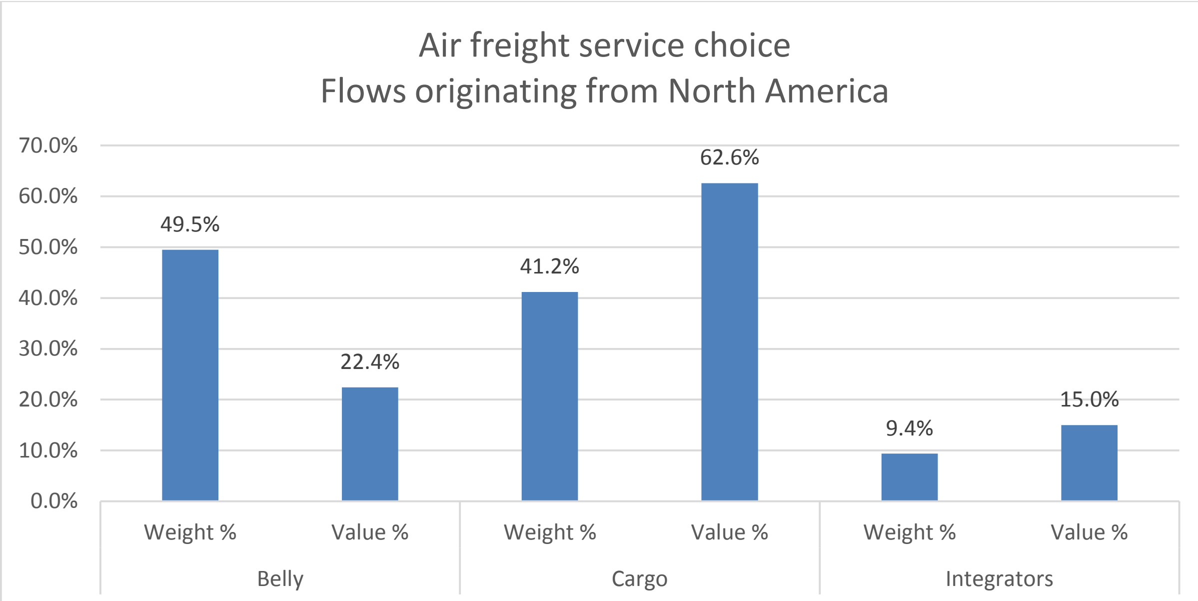



Figure 63: Air freight service choice split, flows originating from North America

Analysing the flows in a commodity type perspective reveals classes 5 and 7 as the largest contributors in weight and value for all the service types, as the peaks in Figure 64 indicate. An interesting finding here is that, for class 5 commodities, the air freight service type percentage lines have similar distances between them, indicating that in this case the cost difference between the service types is what affects mostly the choice and not so much the value of the specific goods.

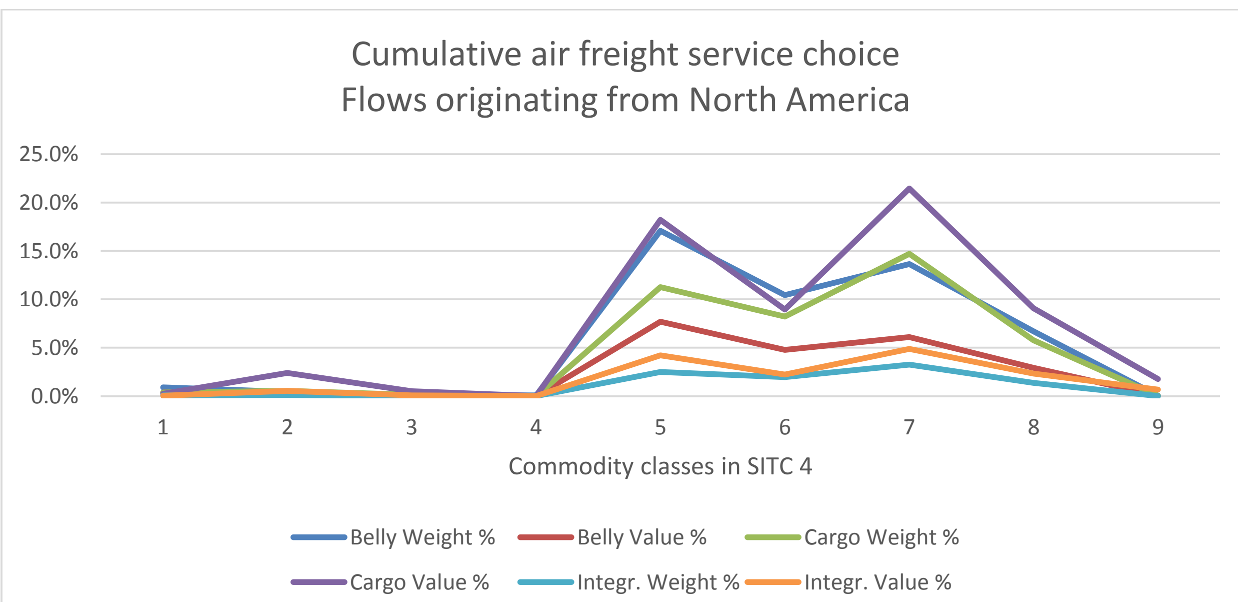



Figure 64: Air freight service choice per commodity type, North America

## 5.9 Regional level: Oceania

Much like the region of Latin America, Oceania does contributes only a small part of the total world trade. That is reflected also in the fact that the trade database for countries in this region is rather small, compared to others and, therefore is doubtful whether it can guarantee the validity of the results. Nevertheless, the model identified some airborne trade flows here as well. More specifically, for the region of Oceania it calculates that 21.7% of the total outgoing trade value, amounting to just 0.6% of the weight is transported via air.

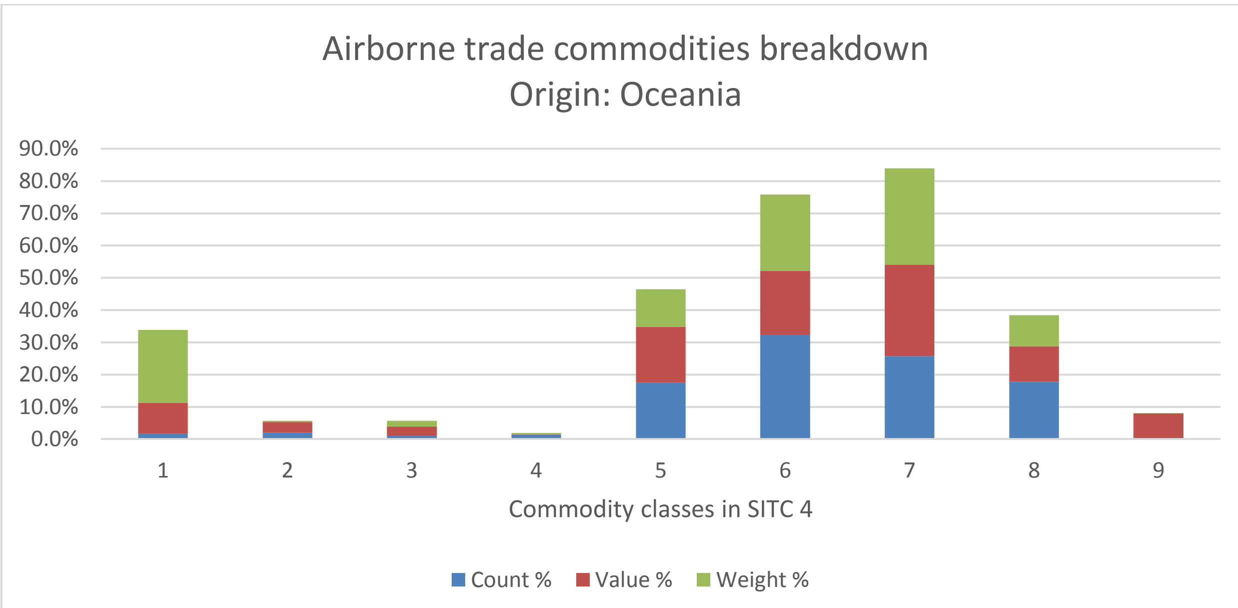



**Figure 65: Breakdown of airborne trade commodities in Oceania**

The airborne goods volumes consist again mostly by commodities of classes 5, 6, 7 and 8 with the exception of a large amount of class 1 (beverages and tobacco) observations that amount to almost 10% of the value. Furthermore, class 9 commodities give some 7% of the value while class 7 commodities remain the most important contributor, as shown in Figure 65. As most important market, the model identifies Europe, the flow towards which contains 45% of the total tonkilometers of airborne trade originating in Oceania. The remaining two large air freight markets take around 22% of the air transport product each, as it can be seen in the pie chart of Figure 66.

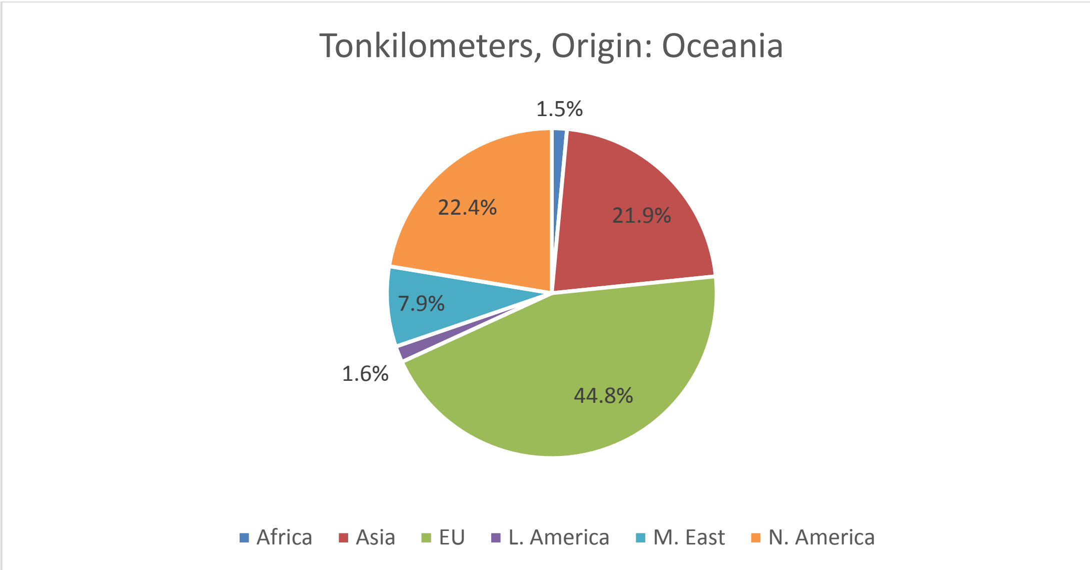



Figure 66: Ton kilometre shares between Oceania and the world regions

Analysing the flows with each market under a weight and value perspective, two major flows are found, one with Europe, with 25.4% of the value and 33.9% of the weight, and the one with Asia with a much higher value percentage of 49.2%, but almost the same weight percentage of 36.4%. Flows towards North America come third, amounting for less than one fifth of the total airborne weight and value, as shown in Figure 67.

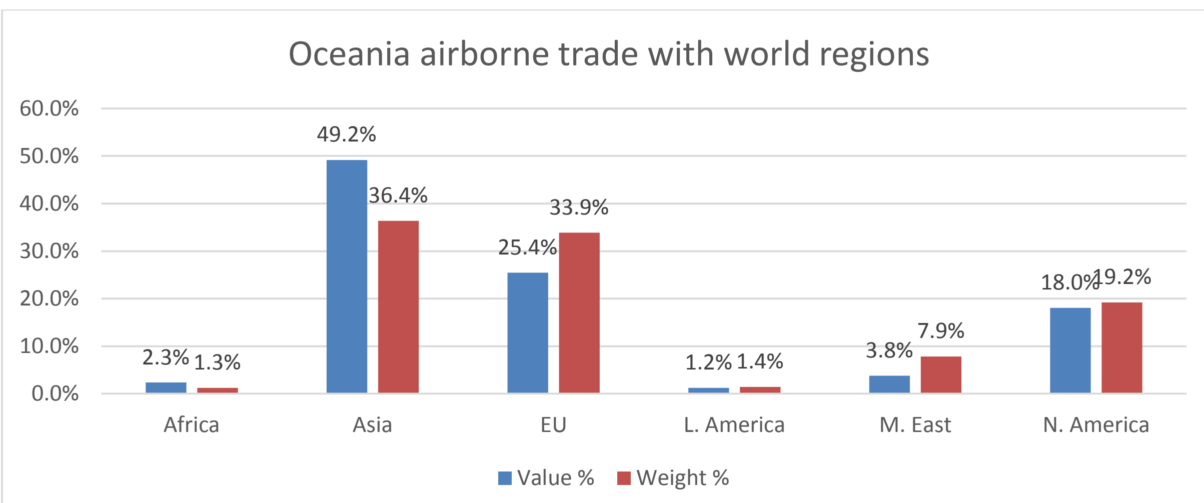



Figure 67: Airborne trade of Oceania with world regions in weight and value percentages

The air freight service choice landscape is shown to be rather balanced for the air freight flows originating in Oceania. Around 85% of the total airborne weight is split between cargo-only and combination carriers with the former transporting almost 60% of the total value. Integrators take a small piece of the weight pie of 13% and, at the same time, 20% of the total value. The exact figures can be seen in Figure 68.

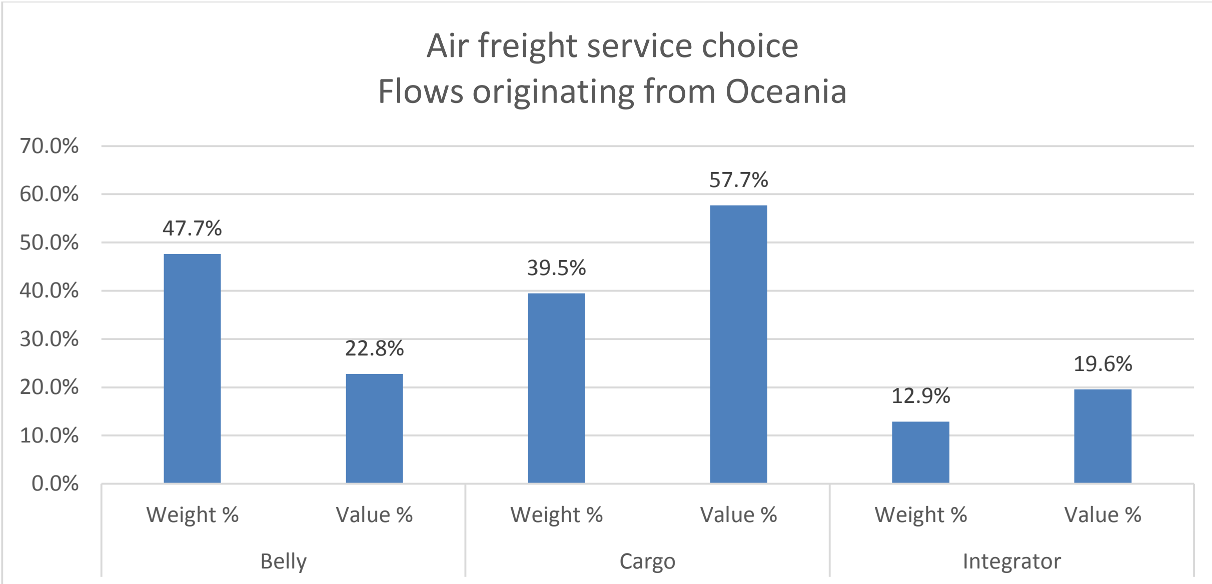



**Figure 68: Air freight service choice split, flows originating from Oceania**

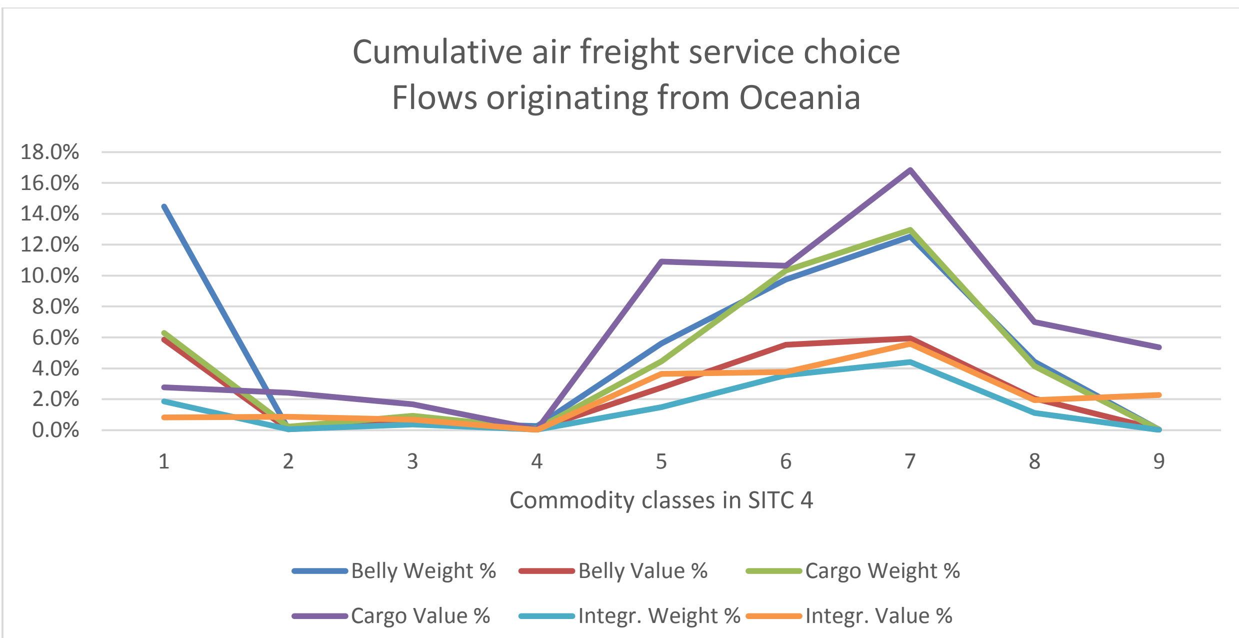



**Figure 69: Air freight service choice per commodity type, Oceania**

Finally, Figure 69 shows the contribution of each type of commodity in each of the air freight services. The increased amount of class 1 commodities identified by the model as air freight are shown to be transported mostly by combination carriers, accompanied with mainly class 6 and 7 commodities. Cargo-only operators get 40% of the value of the goods they transport from classes 5, 6 and 7. Integrators have a steady presence throughout the range, with percentages of 2 to 5%.

## 5.10 Sensitivity analysis

Following the results of the, calibrated as explained previously, model is a sensitivity analysis of key indicators. This is performed in order to see the relationships between different aspects of air freight transport and quantitate the effect that important changes have on the industry. Specifically, the analysis is performed using the one-at-a-time method to reveal the effect of shipment size and ad-valorem value of time savings on the global mode choice in terms of weight and value as well as on air freight service choice.

At first, it is important to mention the extremes of the model results. Keeping the transport costs stable, the values of time savings of the commodities (noted as VTS from this point forward) were given the extreme values of that range (0.1% and 2%) and the resulting air freight shares were recorder. Low VTS percentages mean that commodities do not lose much of their value while they are in transit, therefore the shipper is more reluctant to choose air freight transport solutions. In that case only the very high value commodities are chosen to fly and, consequently, the result represents the lowest point possible, in a sense air freight's worst day. On the other hand, when VTS percentages reach the upper bound, more commodities have more to gain from faster transport thus preferring air transport. Here, the results represent an upper limit for air freight performance, or in other words air freight's best day.

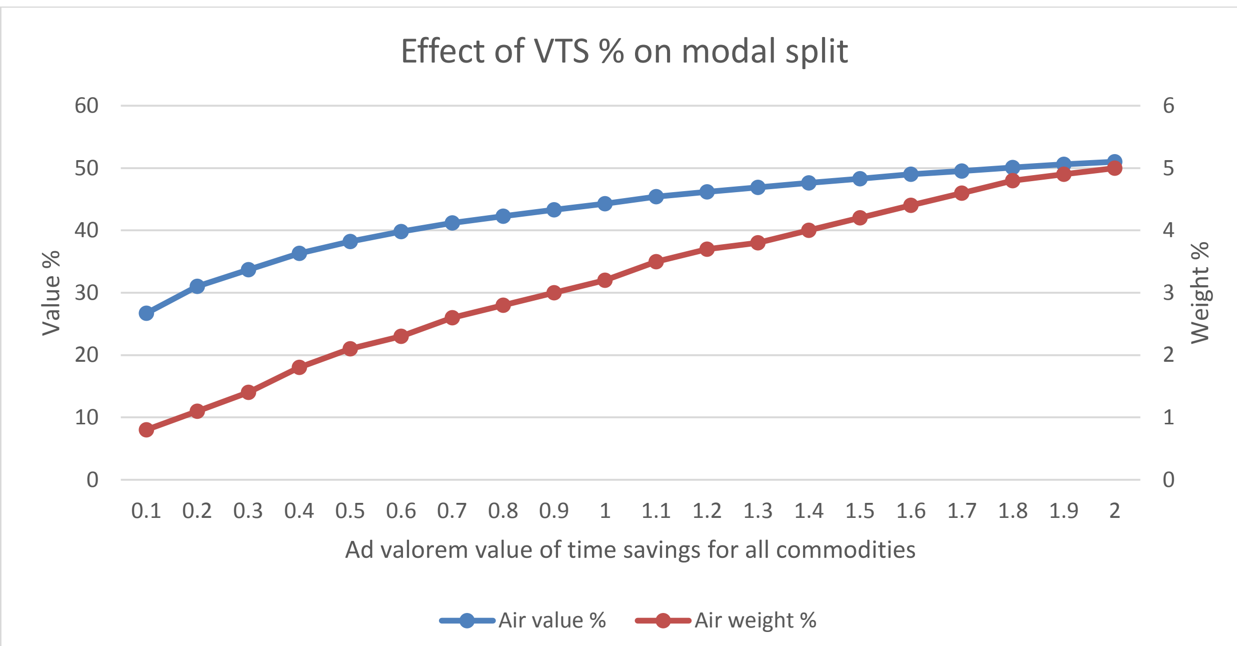



**Figure 70: Effect of commodity value of time savings on air freight performance**

As Figure 70 shows, for the lowest possible VTS figures, air freight accounts for only 0.8% of total traded weight and 26.7% of total value. This shows the importance of air freight transport for the global trade as, according to what the model suggests, irrespective of the market dynamics and how they affect commodity characteristics such as shelf life, air freight will still be the transport mode of choice for more than a quarter of the worlds traded goods in terms of value. As VTS becomes higher, meaning that commodities lose value more quickly, air freight performance becomes better and better, with weight share growing much faster than value share. Moving through the same range of VTS percentages, value share grows almost 2 times while weight share grows more than 6 times. The upper bound values reach 51% for value share and 5% for weight. The effect of VTS can also be seen in more detail in Figure 71, where the relationship with the mode choice pivot values per commodity class is shown.

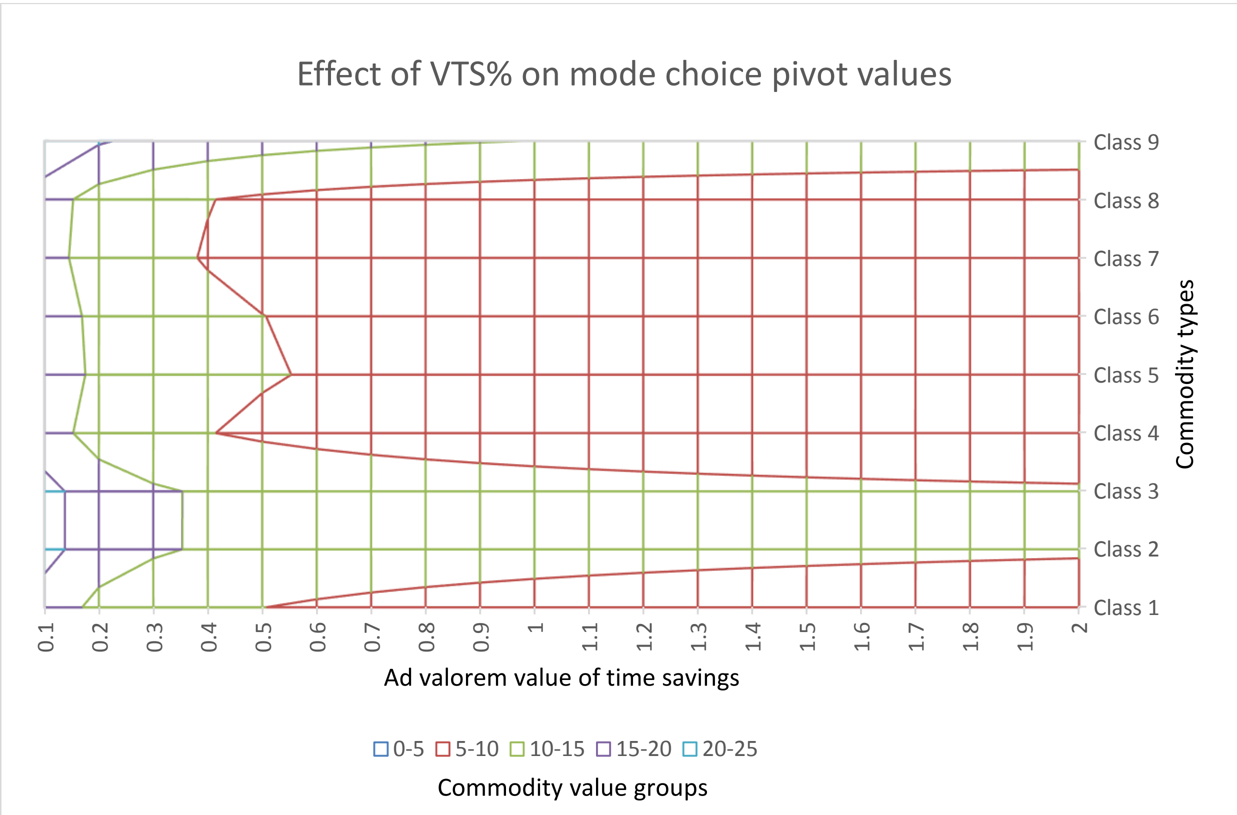



**Figure 71: Effect of commodity value of time savings on mode choice pivot values**

These pivot values represent the commodity value above which air transport is chosen. Naturally, these values are affected by transport costs and therefore transport distance hence they vary between different origin-destination pairs. This surface graph was compiled using the average values per commodity and the border lines between different colours (unit value classes) represent the unit value a commodity must have in order for air transport to be a viable choice. For very low VTS percentages, most commodity classes need a unit value of at least 15 $/kg to be eligible for air freight transport. Pivot point values change very quickly and for percentages between 0.2% and 0.4% the lowest necessary unit value drops to 10 $/kg. After 0.5% VTS, all air freight relevant commodity classes have an average unit value of 5-10 $/kg. The only exceptions to these findings are classes 2 and 3 (beverages, tobacco and crude materials) which, as seen in the regional and global results analysis, are hardly ever air freight cargo candidates. Moreover, it is worth noting that irrespective the commodity class, the model identifies that no goods with a unit value less than 5 $/kg have air transport as a viable choice, a finding that is supported by the air freight tariff examples shown in Table 24.

Moving further with the sensitivity analysis, the shipment size is considered, first regarding air freight shares and secondly air freight service choice. According to the air freight rates regression analysis performed, for practically all routes, rates drop as shipment size becomes larger. This is rather logical because bigger shipments allow carriers to consolidate more efficiently, create larger economies of scale and achieve higher utilization of their fleet resulting in better profit margins. Consequently, they attempt to attract larger shipments by lowering their charges. Similarly to VTS, shipment size has the same effect on global air freight weight and value shares, only in this case it is even stronger.

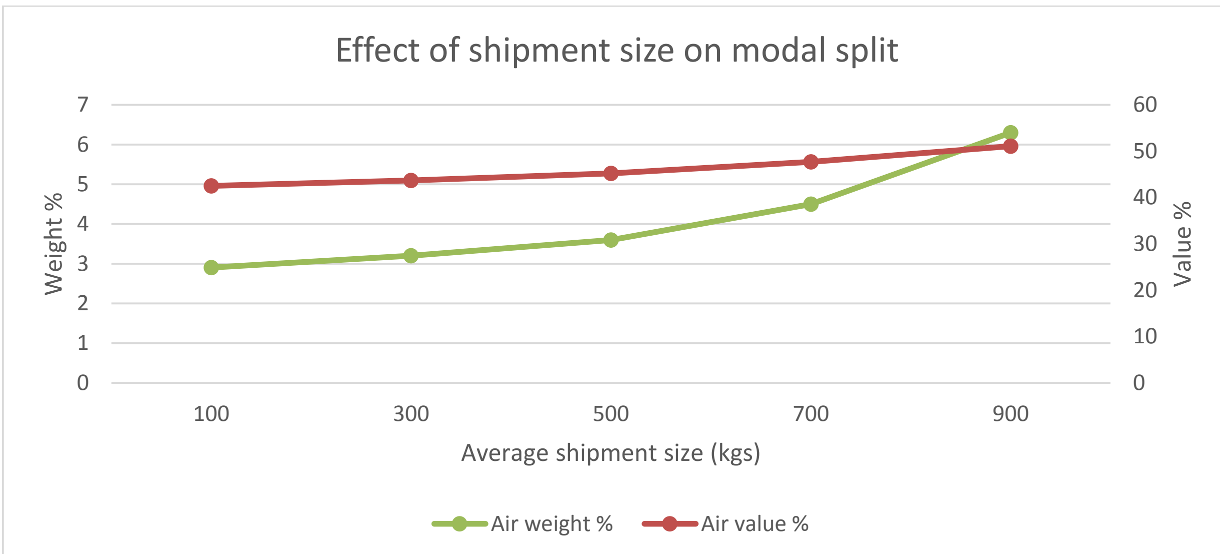



**Figure 72: Effect of shipment size on air freight performance**

As Figure 72 depicts, with growing average shipment size both air transport weight and value shares are growing though not with the same rate. Testing the result for an average shipment size range from 100 kgs to 900 kgs, air freight weight shares grow more than twice the initial value while value shares record a growth of 1.2 times the value calculated for 100 kgs shipment size. Furthermore, as shipments size becomes bigger and air transport costs lower, the difference in utility between the three different air freight transport services becomes smaller, making the more costly but better services of cargo-only and integrator more attractive. Thus, a shift towards these services in expected, something that makes sense in reality. The larger the shipment is, the more likely it is for passenger aircraft to not be able to accommodate it in its cargohold space, leaving only the other two choices. Additionally, shippers and/or forwarders that have such large transport needs are more likely to have transport supply agreements with airlines and operators of cargo-only and integrator services, to ensure that they will always have guaranteed access to enough air transport supply on steady prices. Such agreements are not possible with passenger airlines as, in their case, passengers and their luggage always comes first. For that reason, big shipments drive demand towards cargo-oriented services. Figure 73 shows how this relationship is captured by the model developed for this study.


**Figure 73: Effect of shipment size on air transport service choice**

The graph above shows that the shift in air freight service choice takes place in two steps. For average shipment sizes up to 600 kgs, the highest share of airborne weight is transported in the belly of passenger aircraft with integrators increasing progressively their weight share. Cargo-only operators seem to have a steady performance in terms of weight of around 40% throughout the range. When average shipment size reached 650 kgs, a twofold shift takes place. Firstly, in weight terms, after that point, cargo-only services come on top with belly dropping under 40%. The second shift happens in value shares and it is found between combination carriers (belly) and integrators. For shipment sizes over 650 kgs, integrators outperform them in terms of value carried, though remaining third in weight shares. At the same time, pure cargo carrier show a steady performance in value share, circling around the 60% mark.

Concluding, this shows that, according to the model results, cargo-only operators appear to have a rather fixed presence in the air freight transport market in respect to shipment size. On the other hand, there is competition between belly and integrators that shifts more value and weight share towards the latter, as average shipment size becomes larger.

## 5.11 Validation of the results

Validating the results of a model that was developed to describe interregional air freight transport in a global scale is a hard task. The availability of data on the subject is very scarce and when there is some available, it is either on a completely different scale (usually complete totals including intraregional figures or very specific on a certain route) or is given in terms of indicators that are impossible to compare. Nevertheless, for the purposes of this study, an attempt is made to validate the results of the model against sources that provide comparable units with those the model produces. The purpose is to see whether the model produces logical results

At first, the general air share in terms of weight is considered. As shown in Figure 74, Seabury data for the years 2000 to 2013 reveal that air transport handles a weight share of 3% to 1.7% of the total weight carried by air and ocean transport. If the fact that this graph contains the terrorist attack of September 2011 and the economic recession that became evident worldwide after 2008, one can assume that the values closer to 2013 are somewhat on the low side. Nevertheless, taking a simple average of the two extremes yields an air weight share of 2.35% against the model value for the same metric of 2.9%.

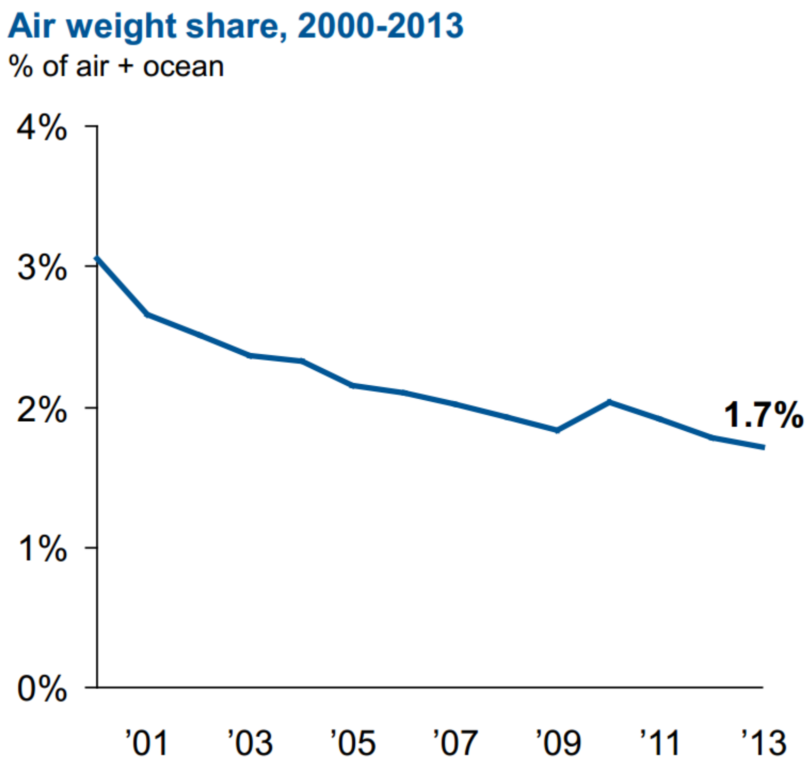



Figure 74: Air weight share for the years 2000 to 2013 (Seabury, 2014)

The values are indeed very close, showing the validity of the method. Taking aside the numerous events that result in changes in freight transport rates regardless of mode, the model result for air freight weight share shows that the unit value mode choice method, albeit simple, is valid. The suggestion that mode choice in the global level is made based on the transport costs and the value for time savings of the commodities seems to hold rather satisfyingly.

Moving further to other figures, the World Bank publishes in a year basis air freight transport volumes in million ton-km. The figures for the past decade, grouped by regions, in million tonkilometers, as given by the organization, can be seen in Figure 75.

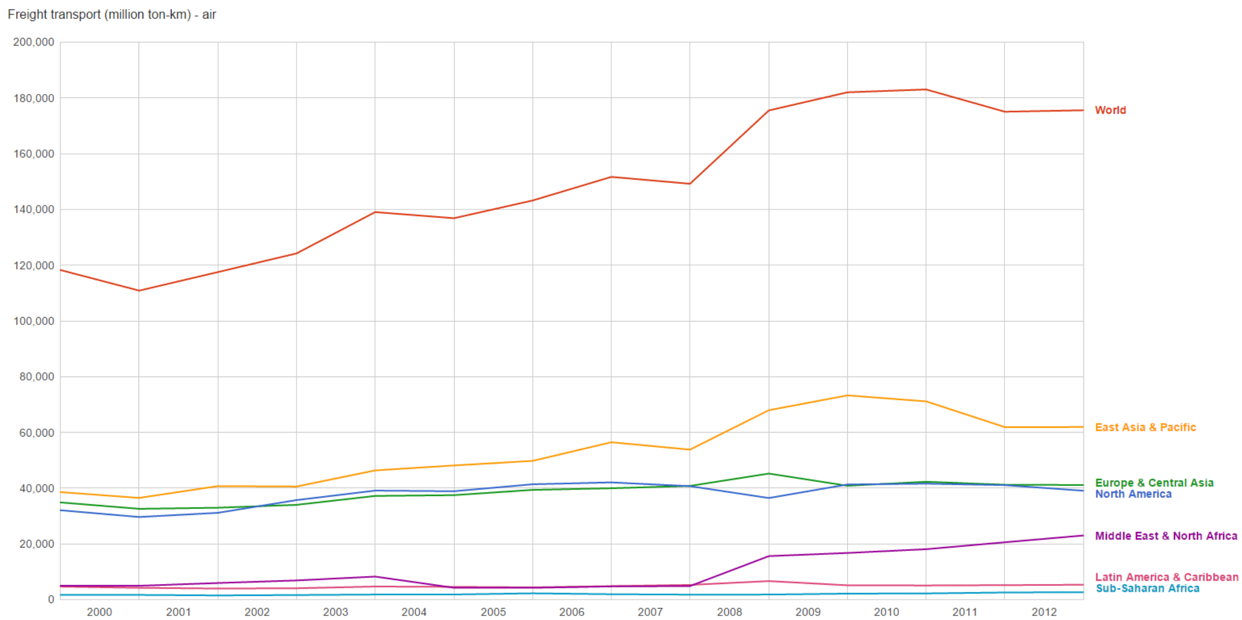



Figure 75: Air freight transport per world region years 2000-2013

Converting the absolute values into percentages of the world air freight tonkilometers allows for comparison with the model values. Table 53 shows the comparison with the model values.

Table 53: Comparison of air freight ton-km per region, percentages of total traffic (The World Bank, 2014)

| | The World Bank | Model Results | Absolute Difference |
|---|---|---|---|
| *Africa* | 1.5% | 1.1% | 0.4% |
| *Asia* | 35.8% | 48.2% | 12.4% |
| *Europe* | 23.8% | 25.8% | 2% |
| *Latin America* | 3.1% | 2.6% | 0.5% |
| *Middle East* | 13.3% | 3.7% | 9.6% |
| *North America* | 22.6% | 13.7% | 8.9% |

Again, the values obtained from the model describe closely the observed data. In fact, in Europe and Africa the values are almost identical with Middle East showing a large variance of around 10%. Besides the fact that, in the model, only a small number of indicative reporting countries was used, the reason behind these differences is that the World Bank data include also intraregional traffic. That could explain that the figures for Asia and North America differ some 10 to 13% while the ones for Europe are so close, as the first two regions have much traffic within their respective area. In the case of Europe, the distances within the region are too small to justify the choice of air transport for freight.

A third validation point is the air freight transport shares per region in terms of weight of air cargo exports. The model results were here compared against values for the year 2013, taken from two different sources, a consulting company and a website with statistical data. The results of the model do not fall far from the two sources. The three big air transport markets are portrayed rather precisely, showing differences in the range of 2% to 4%. The largest variation was noted in smaller markets and especially that of Latin America where the model resulted a 2.4% share in comparison with 7%. Table 54 shows the comparison with the two sources.

**Table 54: Comparison of air freight exports weight shares per region (Seabury, 2014) (Statista.com, 2015)**

| *Air cargo exports* | 2013 Statista.com | Seabury 2013 | Model values |
|---|---|---|---|
| *Africa* | 3.5% | 3% | 1.4% |
| *Asia* | 45.0% | 40% | 43.7% |
| *Europe* | 25.5% | 27% | 29.3% |
| *Latin America* | 7.0% | 7% | 2.4% |
| *Middle East* | 2.0% | 5% | 6.0% |
| *North America* | 17.0% | 18% | 13.4% |

Finally, as far as the air freight service choice is concerned, data at this level is not available or is given grouped by forwarders or airlines that, although represent different business models, are reported together because they belong in the same corporation. That makes it impossible to recognise which market share belongs where. Nevertheless, a small comparison could be made with data found at Statista.com website (2015a) regarding freight ton-km transported by the two biggest integrators, FedEx and UPS, in 2013. Their combined figures represent a 15% market share of the world air freight transport while the model gives integrators a smaller market share of 10.4%. Although the two values are not properly comparable, the fact that both are in the same region number-wise suggests that the concept behind air freight service choice is valid but lacks refinement and is in need of better calibration.

# Chapter 6: Conclusions and recommendations

Following the presentation of the model results and their analysis, this chapter contains the conclusions of this research. The author's reflections on the research undertaken, the model itself, its results, strengths and limitations are discusses in the following paragraphs. Moreover, recommendations on further research on the subject, with the objective of making a better global air freight transport model are given.

At first, it is necessary to reflect on the scientific literature on transport modelling and its lacking in covering this particular mode. It is understandable that air freight transport covers only a small part, weight-wise, of the total world trade volume but that does not excuse us from having the best possible understanding of the industry's dynamics and the underlying forces that shape it. As the global economic environment changes, consumers will obtain higher spending power resulting in more air-captive goods in the trade mix. The largest market of the world, China, has an upper middle class that is expected to grow four times bigger in the next 10 years (McKinsey, 2013), a prospect that has the ability to completely change the existing balance (or rather imbalance) of air freight flows. Being able to model these changes is of paramount importance in many levels, for airport authorities, governments, transport related businesses, airlines, aircraft manufacturers and even regional authorities and municipalities. To achieve that though, there is a need for establishing a comprehensive air freight (and passenger) transport database that can be used by researchers. Similar efforts have been made by other universities, such as the Massachusetts institute of technology global airline industry program (2015), only limited to the passenger sector on a regional level. Before anything, this should be the very first initiative towards air freight transport modelling.

Moving on to the modelling section, some interesting conclusions can be made. From that perspective, the main differences between the aircraft and the other modes are three. The first has to do with were the demand comes from and how can it be modelled. As it has been seen in various literature and as it was concluded by the model in this study, air freight transport demand comes from a narrow range of commodities, namely from classes 5, 6, 7 and 8. The most common methods of forecasting demand include relating it to world GDP growth, population and other inputs such as trade elasticities produced by econometric models (Hilberry & Hummels, 2012). Even though these metrics and parameters are related with air freight demand, there is a lot of room for improvement towards creating demand models that can capture specifically the demand for air freight. Knowing the exact commodity types that constitute that demand, the characteristics of theses specific markets, both on the consumer and on the manufacturing end, can be quantified and inserted in air freight industry specific demand models.

The other main difference is that, here, time is the most important factor in the decision making. Because of that, transport costs become secondary and choices are made not based just on the value of the goods but on the relationship their value has with time. Goods having high value is not enough to choose air transport when that value does not deteriorate with a fast enough rhythm. This is another factor that needs to be incorporated in freight demand models that are developed with the purpose of capturing and predicting air freight transport demand.

The third difference, from a modelling perspective, is the need for a service choice step. With other modes of transport, when different services are chosen, the logistical processes change but the routes and networks can remain exactly the same. The same cannot happen with air transport. Here, when service type changes, the routes and networks change with it. This happens for a number of reasons but mainly because a lot of constraints exist, such as noise restrictions, runway length, competition for the same capacity with passenger operations etc. Therefore each of the air freight business models has created its own network with routes based on long term agreements with airports around the world and is not subject to change unless there are safety reasons. That special characteristic of air transport, demands for the modelling concept to be adapted accordingly, by inserting the service choice step. Furthermore, by having this component in air freight models, it allows for deeper analysis on a financial and environmental level as each service type operates different aircraft types with varying operational costs and emissions.

The model presented in this report is a rather simple modelling approach but, nevertheless, the results show that simple is good enough. As demonstrated in the previous chapter, the model has the ability to capture the air freight transport industry realistically, producing results that do not differ significantly from the observed values. That fact proves that the dimension of time lies at the heart of freight transport mode choice between ocean and air, which seems to be of a deterministic nature and based on commodity value density and how it changes over time. On the other hand, service choice has many more dimensions that were impossible to capture within the scope of this study and more importantly due to the lack of data. There is a lot of room for improvement in this stage and further research is necessary to uncover in detail how this choice is made, how the relationships between shippers/forwarders and airlines affect the costs and when is a combination of different service types possible.

To conclude, the research question of this thesis has been answered, by showing the appropriate adjustments, to the traditional methodology, needed for air freight, and has achieved its objective by developing a model for global air freight transport.

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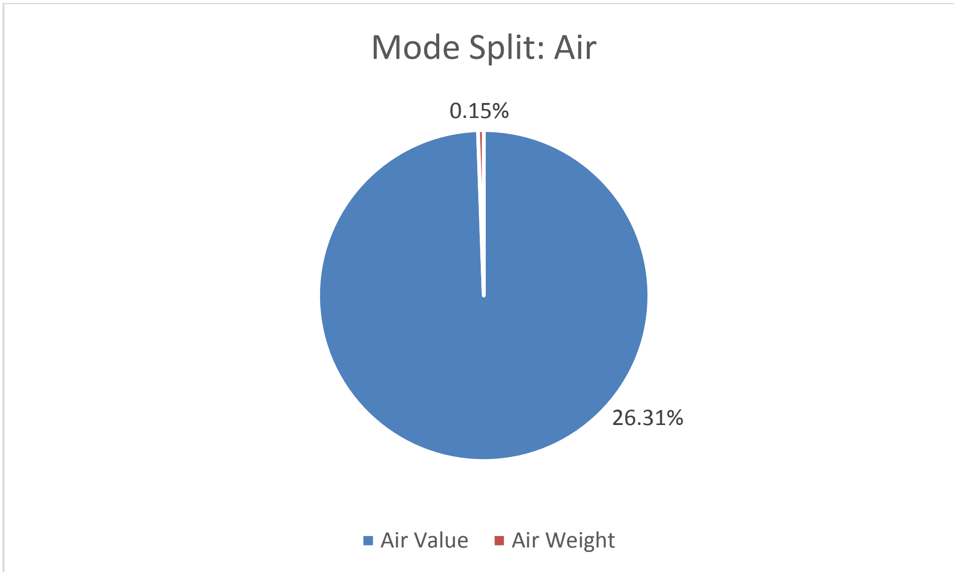
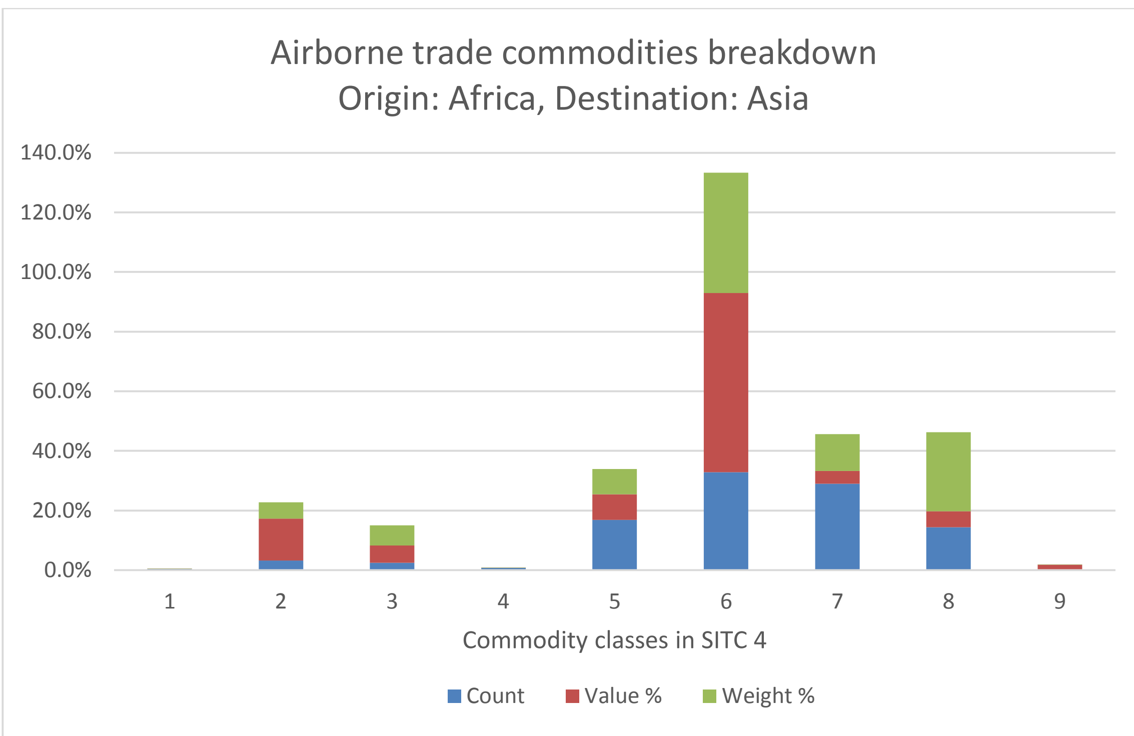
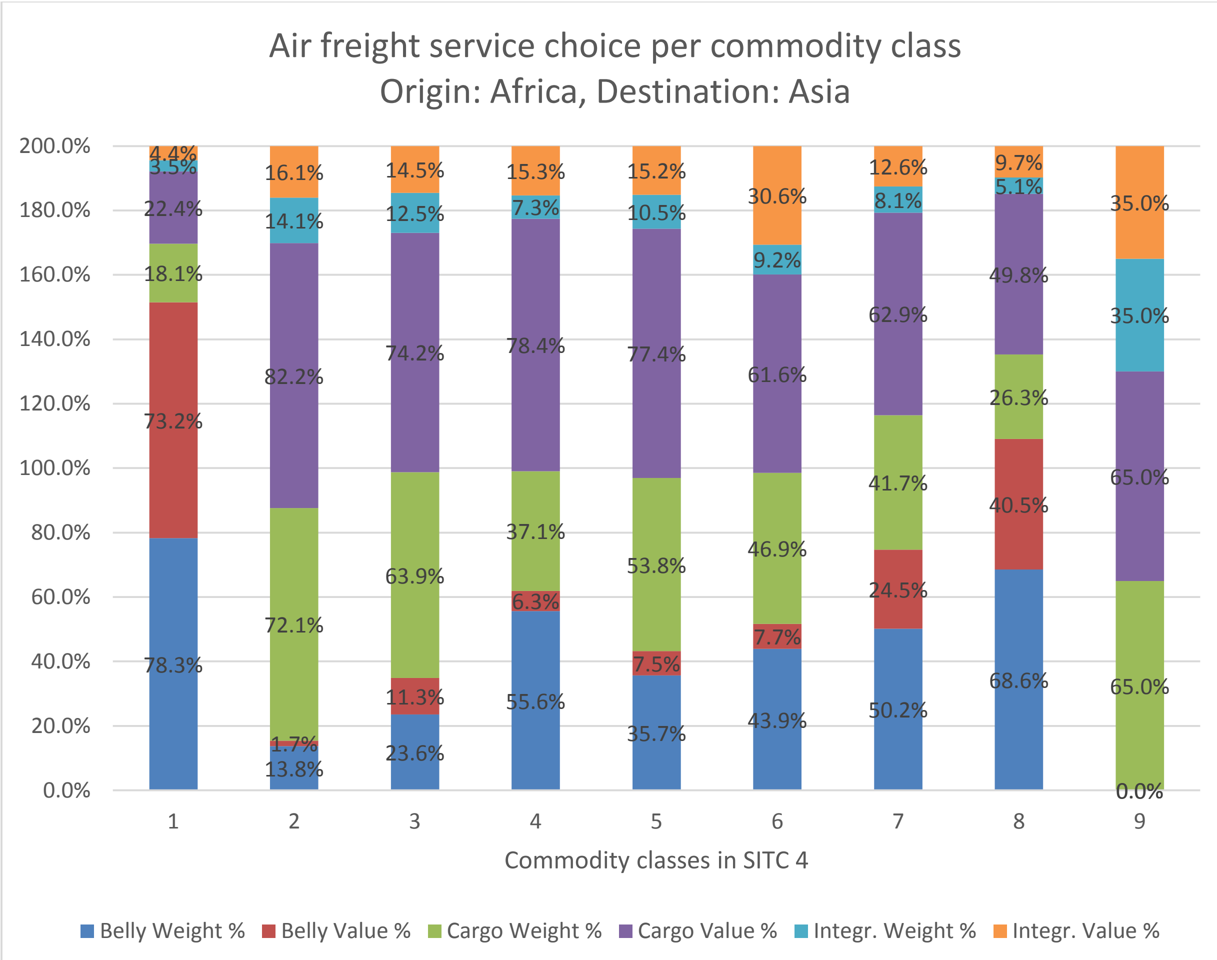
# Appendix A: Model results at an OD level

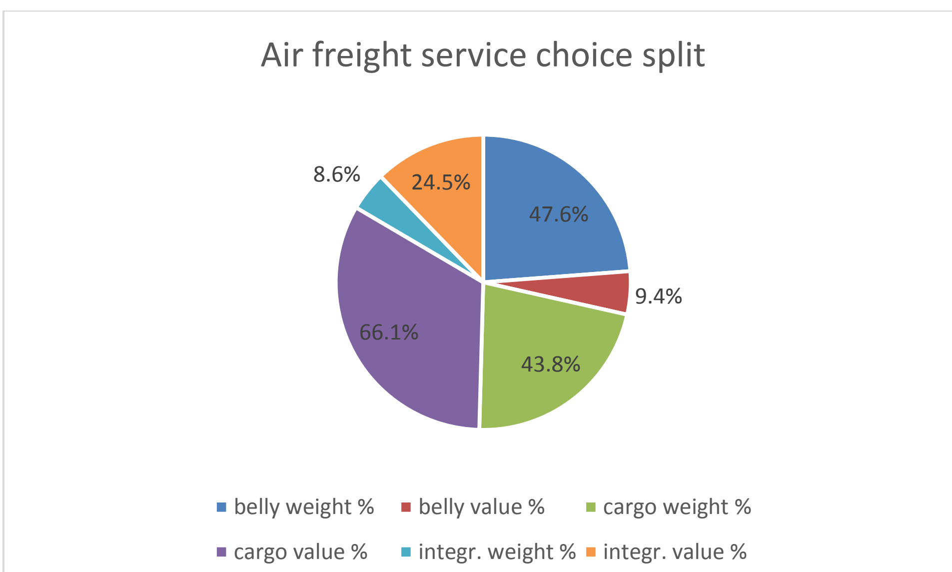
## Africa

### *To Asia*

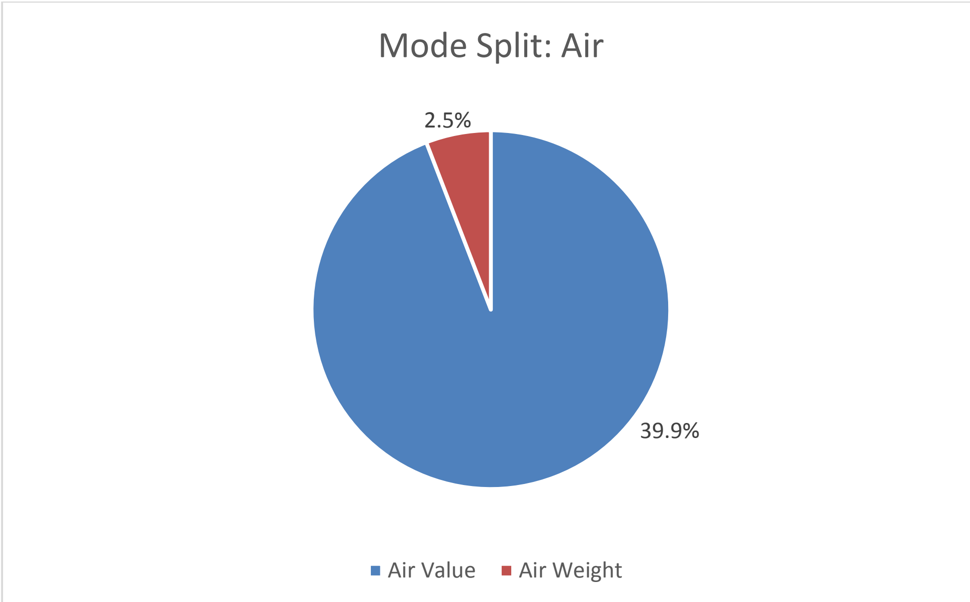


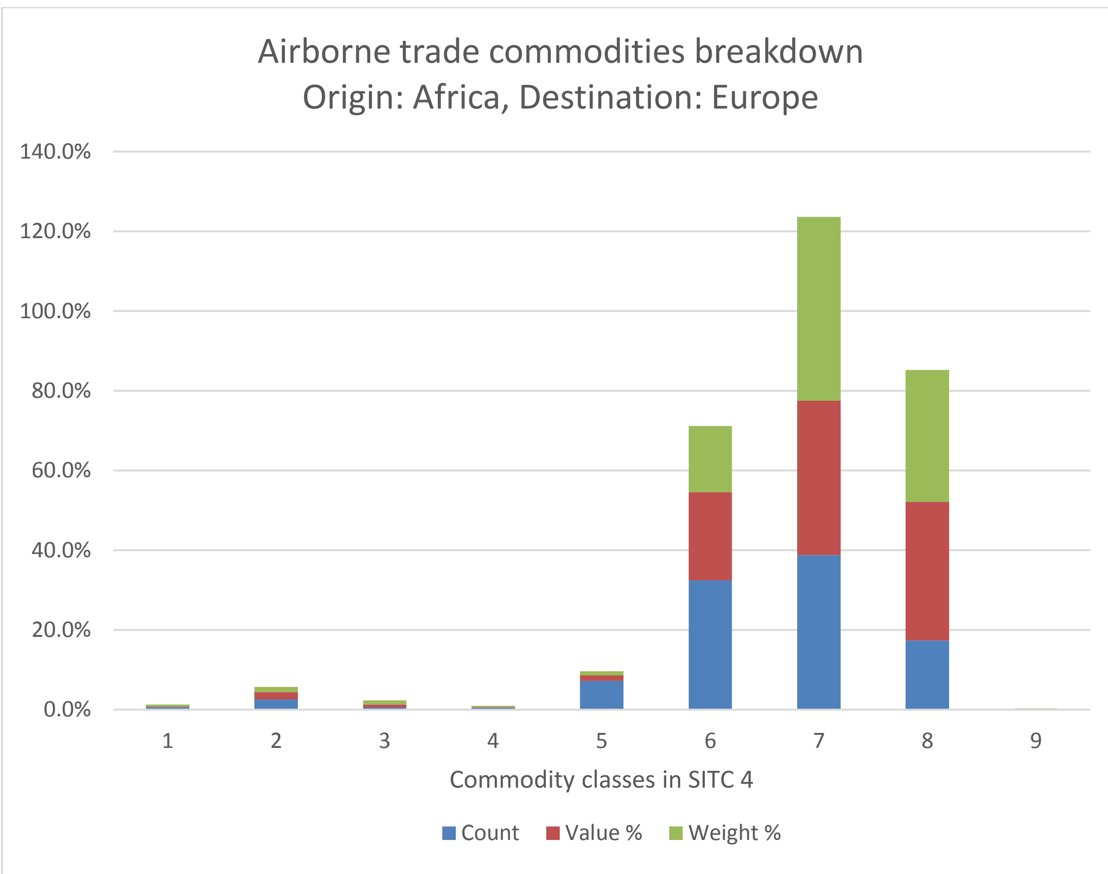

Air freight service choice per commodity class
Origin: Africa, Destination: Asia
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
78.3%
73.2%
18.1%
22.4%
3.5%
4.4%
13.8%
1.7%
72.1%
82.2%
14.1%
16.1%
23.6%
11.3%
63.9%
74.2%
12.5%
14.5%
55.6%
6.3%
37.1%
78.4%
7.3%
15.3%
35.7%
7.5%
53.8%
77.4%
10.5%
15.2%
43.9%
7.7%
46.9%
61.6%
9.2%
30.6%
50.2%
24.5%
41.7%
62.9%
8.1%
12.6%
68.6%
40.5%
26.3%
49.8%
5.1%
9.7%
0.0%
65.0%
65.0%
35.0%
35.0%
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %


Air freight service choice split
47.6%
9.4%
43.8%
66.1%
8.6%
24.5%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

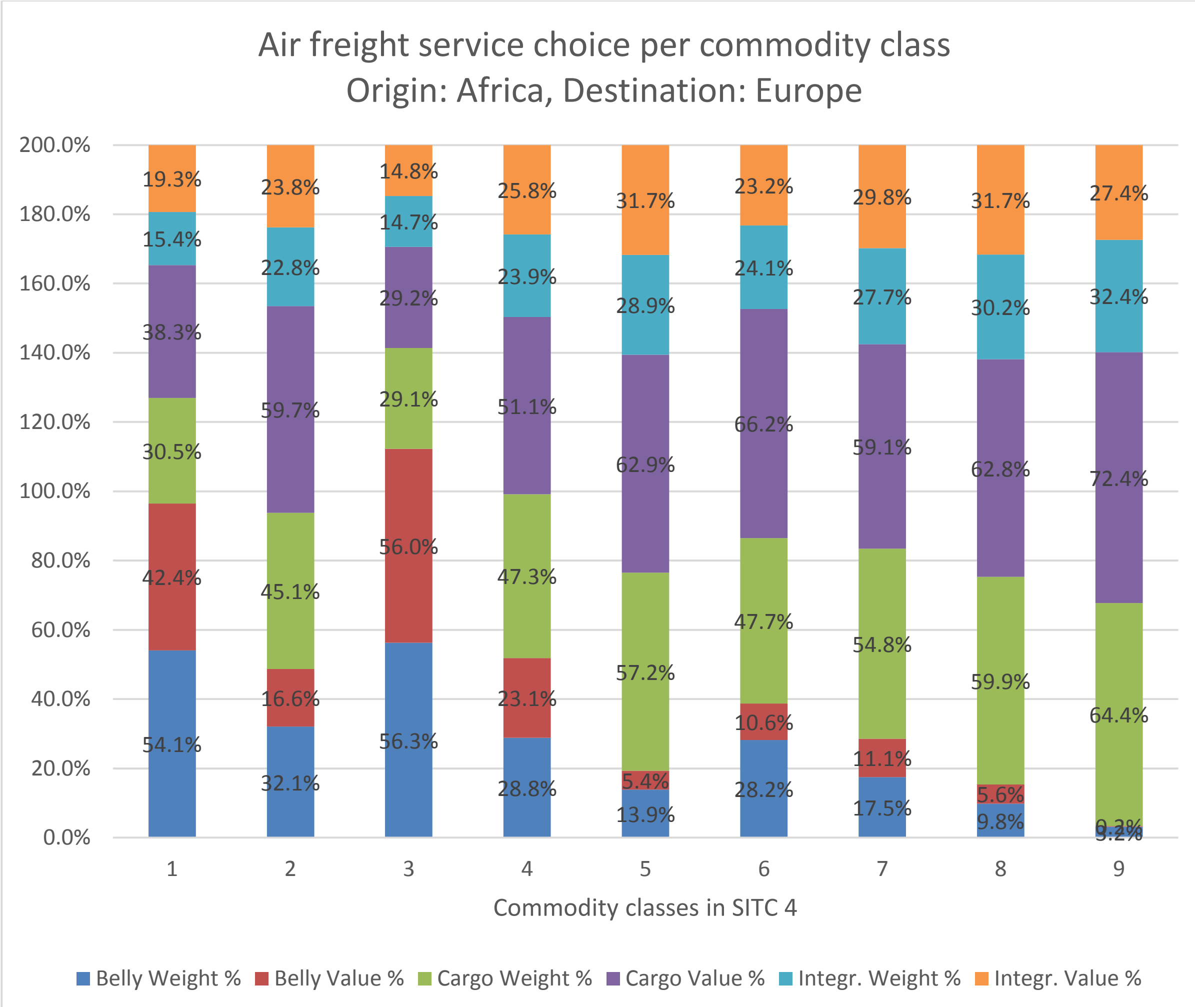
### *To Europe*



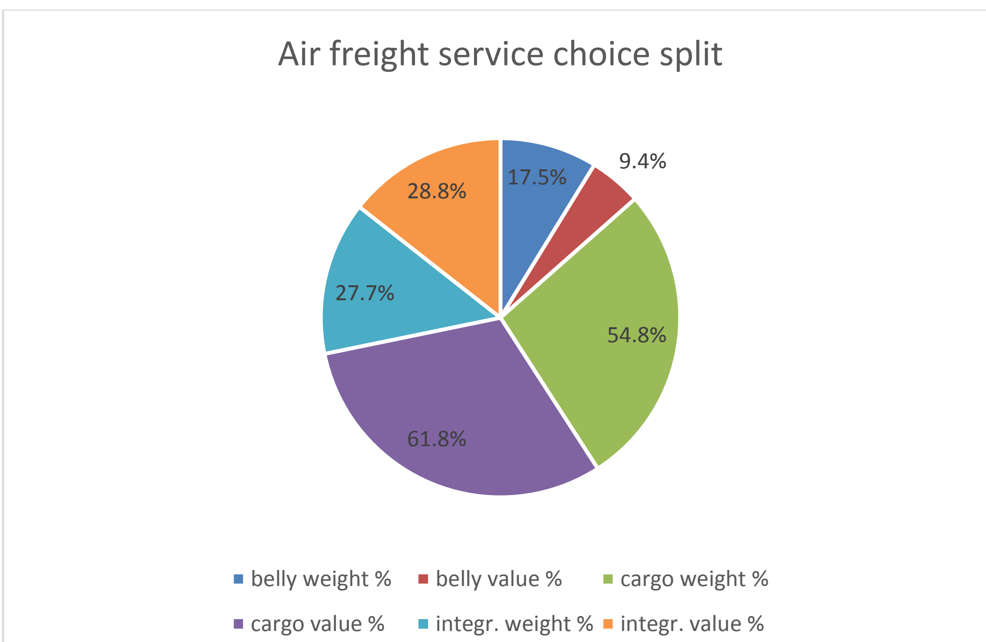
Mode Split: Air
2.5%
39.9%
Air Value
Air Weight

Airborne trade commodities breakdown
Origin: Africa, Destination: Europe
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

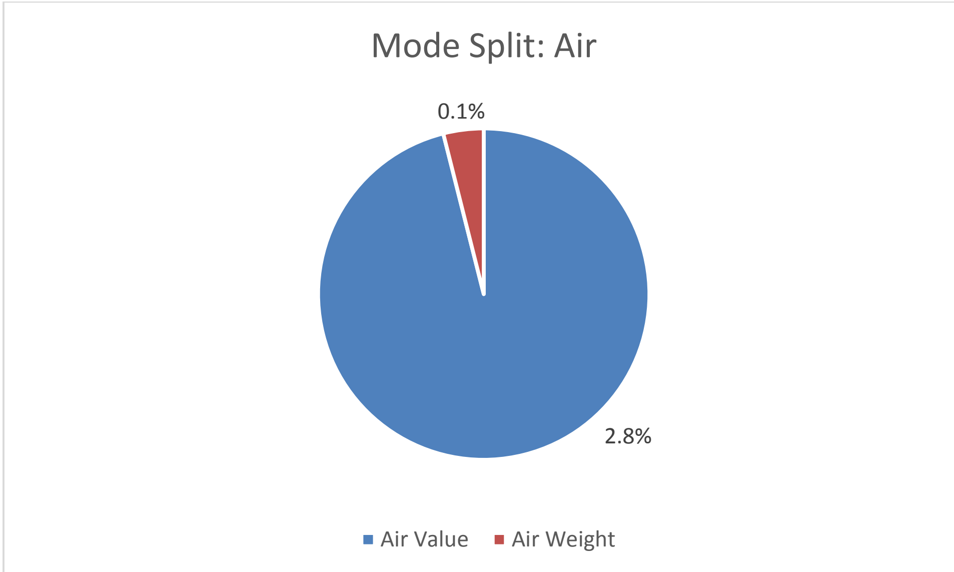


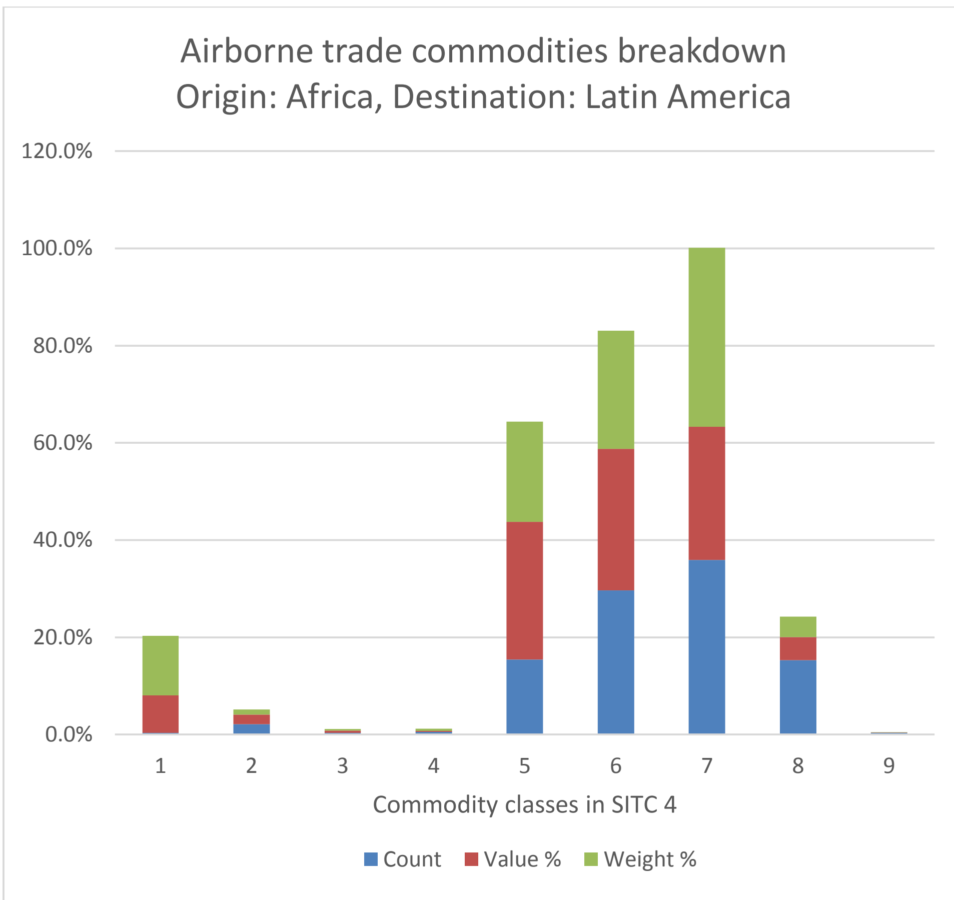
Air freight service choice per commodity class
Origin: Africa, Destination: Europe
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
19.3%
15.4%
38.3%
30.5%
42.4%
54.1%
23.8%
22.8%
59.7%
45.1%
16.6%
32.1%
14.8%
14.7%
29.2%
29.1%
56.0%
56.3%
25.8%
23.9%
51.1%
47.3%
23.1%
28.8%
31.7%
28.9%
62.9%
57.2%
5.4%
13.9%
23.2%
24.1%
66.2%
47.7%
10.6%
28.2%
29.8%
27.7%
59.1%
54.8%
11.1%
17.5%
31.7%
30.2%
62.8%
59.9%
5.6%
9.8%
27.4%
32.4%
72.4%
64.4%
0.2%
3.2%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

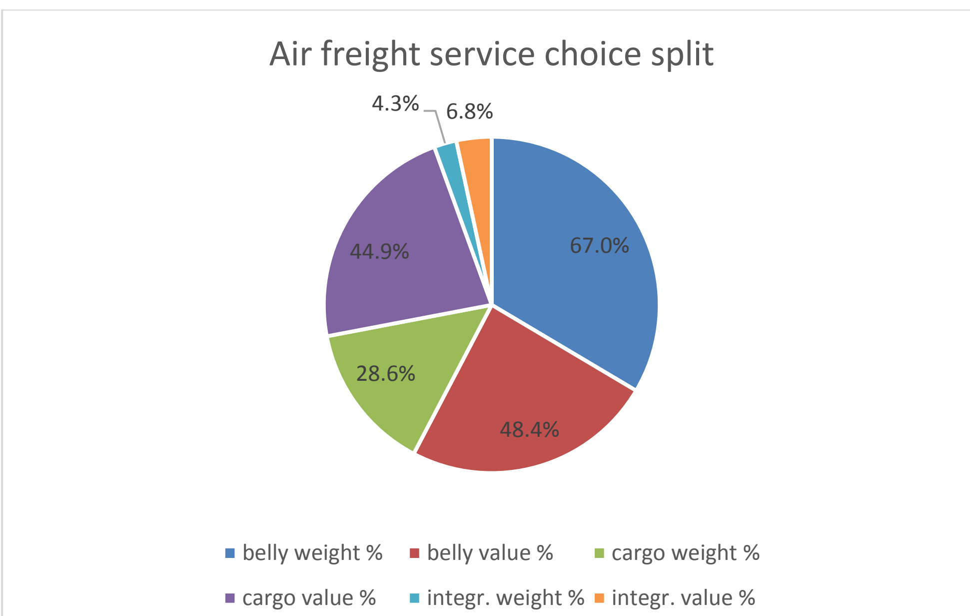
Air freight service choice split
17.5%
9.4%
54.8%
61.8%
27.7%
28.8%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To Latin America*



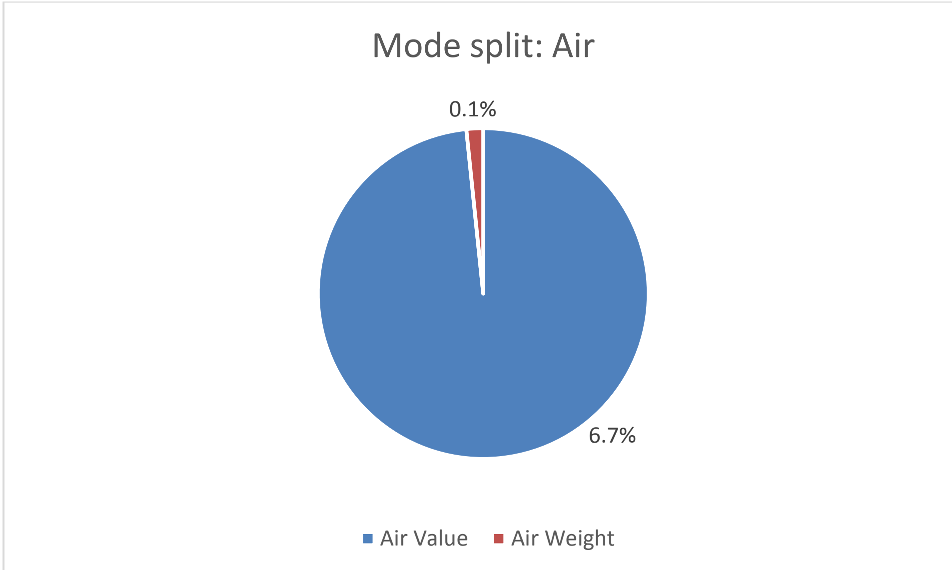



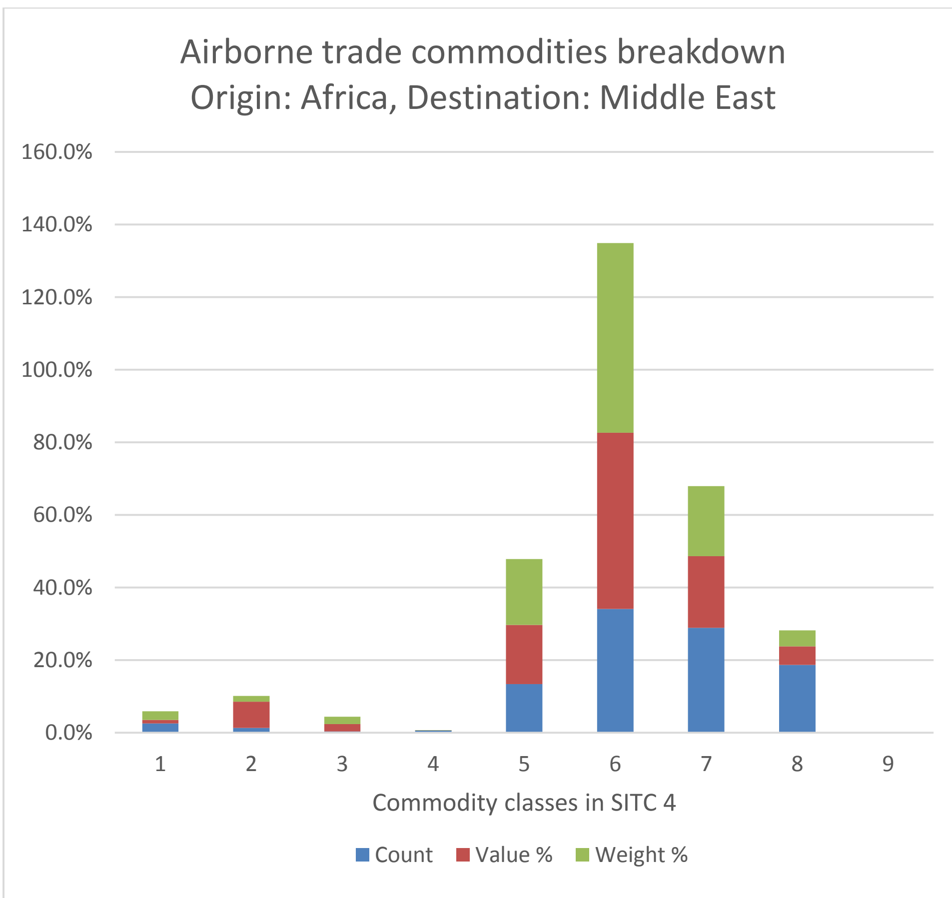
Air freight service choice per commodity class
Origin: Africa, Destination: Latin America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
82.6%
81.9%
15.1%
15.7%
2.3%
2.4%
63.3%
47.1%
31.9%
45.9%
4.8%
6.9%
64.2%
63.4%
31.1%
31.8%
4.7%
4.8%
81.9%
81.2%
15.7%
16.3%
2.4%
2.5%
60.7%
40.3%
34.1%
51.9%
5.2%
7.9%
60.3%
38.4%
34.5%
53.5%
5.2%
8.1%
70.0%
60.7%
26.1%
34.2%
3.9%
5.2%
66.0%
30.7%
29.6%
60.2%
4.5%
9.1%
6.0%
5.7%
81.7%
81.9%
12.4%
12.4%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

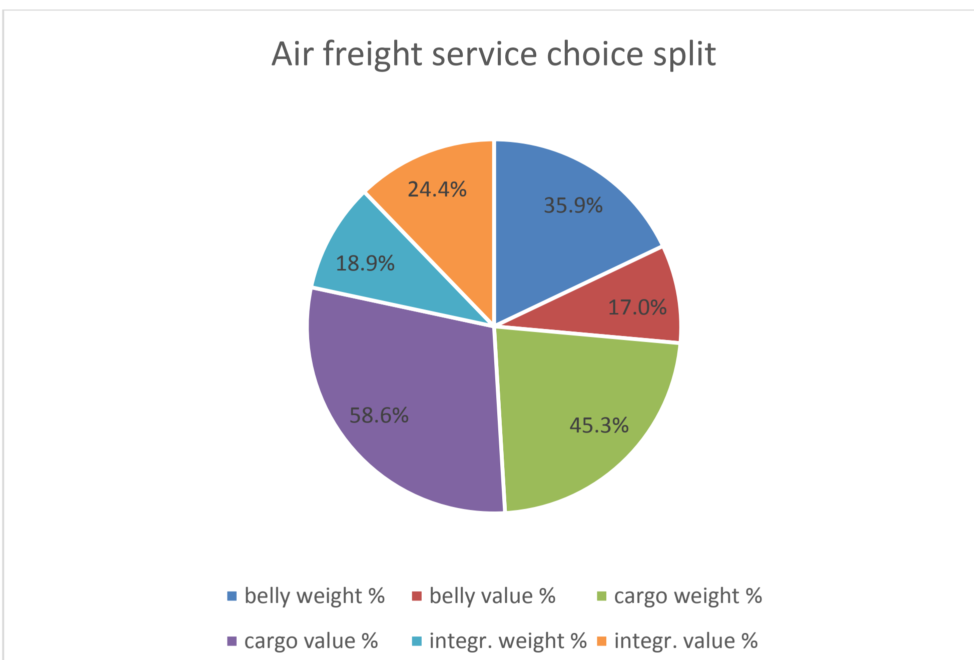
Air freight service choice split
4.3%
6.8%
67.0%
48.4%
28.6%
44.9%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To Middle East*

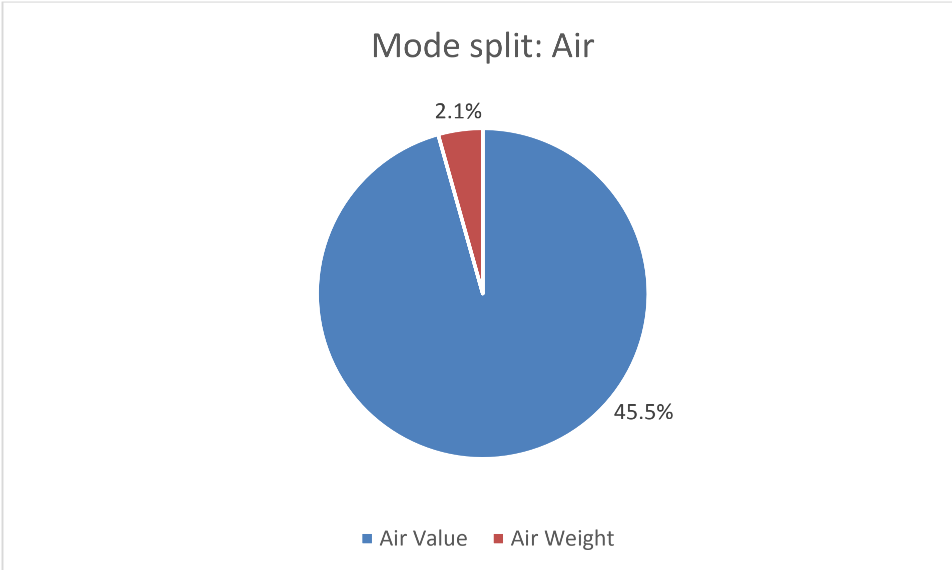


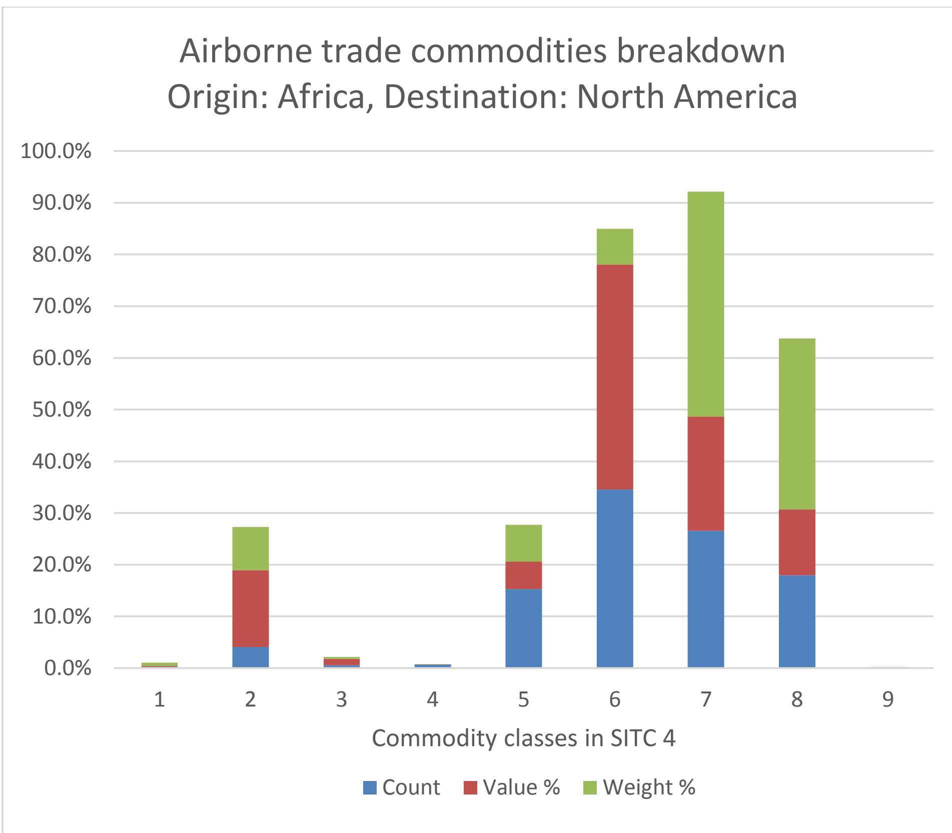




Air freight service choice per commodity class
Origin: Africa, Destination: Middle East
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
14.8%
14.5%
35.4%
34.8%
49.8%
50.7%
27.1%
14.7%
65.1%
35.4%
7.8%
49.9%
18.5%
16.6%
44.4%
39.9%
37.1%
43.5%
25.8%
18.5%
61.8%
44.3%
12.5%
37.2%
24.1%
19.7%
57.8%
47.3%
18.2%
33.0%
24.0%
18.7%
57.5%
45.0%
18.5%
36.3%
25.4%
18.8%
61.0%
45.1%
13.7%
36.0%
26.4%
22.0%
63.3%
52.9%
10.3%
25.1%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

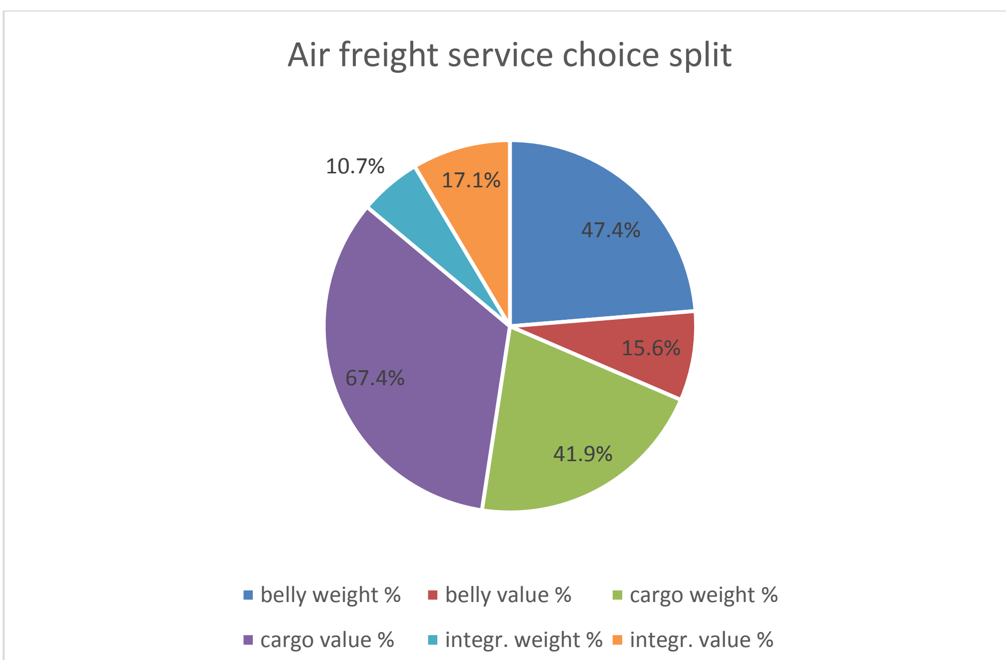

Air freight service choice split
35.9%
17.0%
45.3%
58.6%
18.9%
24.4%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To North America*



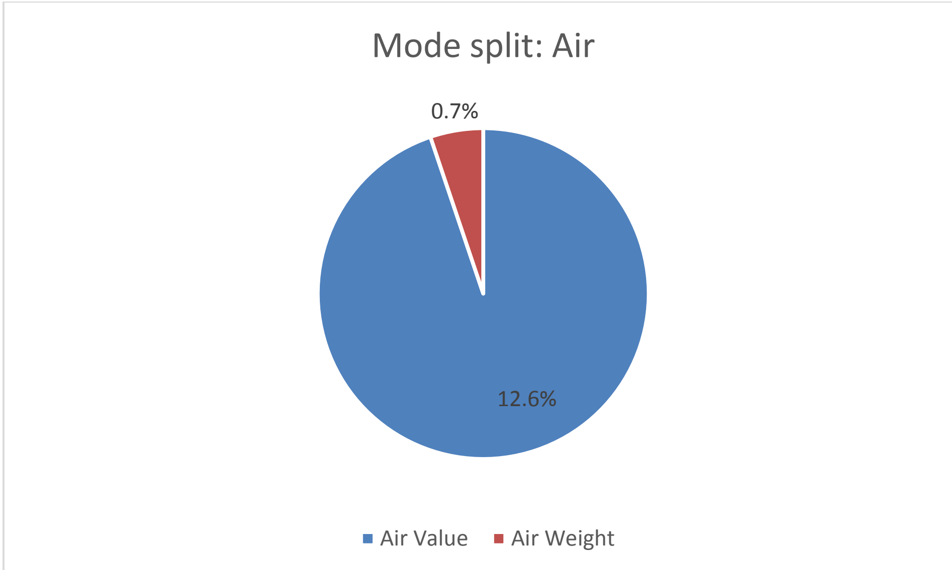



Air freight service choice per commodity class
Origin: Africa, Destination: North America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1 2 3 4 5 6 7 8 9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

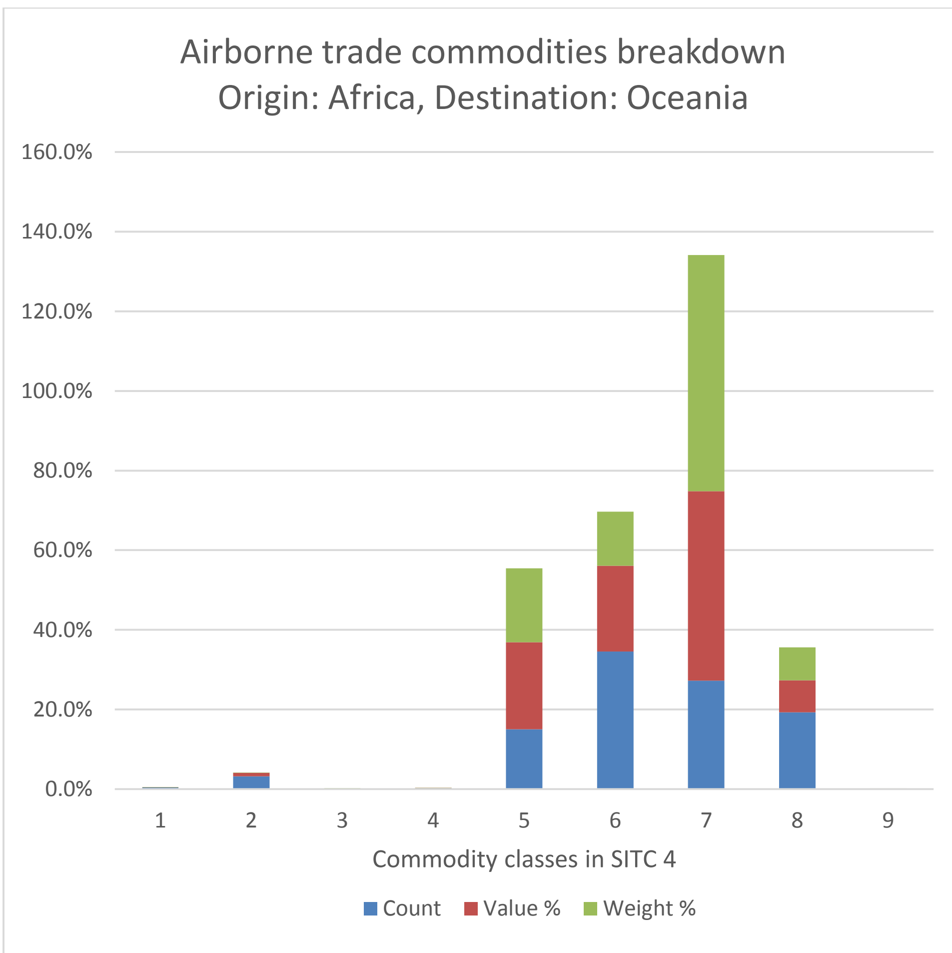



Air freight service choice split
47.4%
15.6%
41.9%
67.4%
10.7%
17.1%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To Oceania*

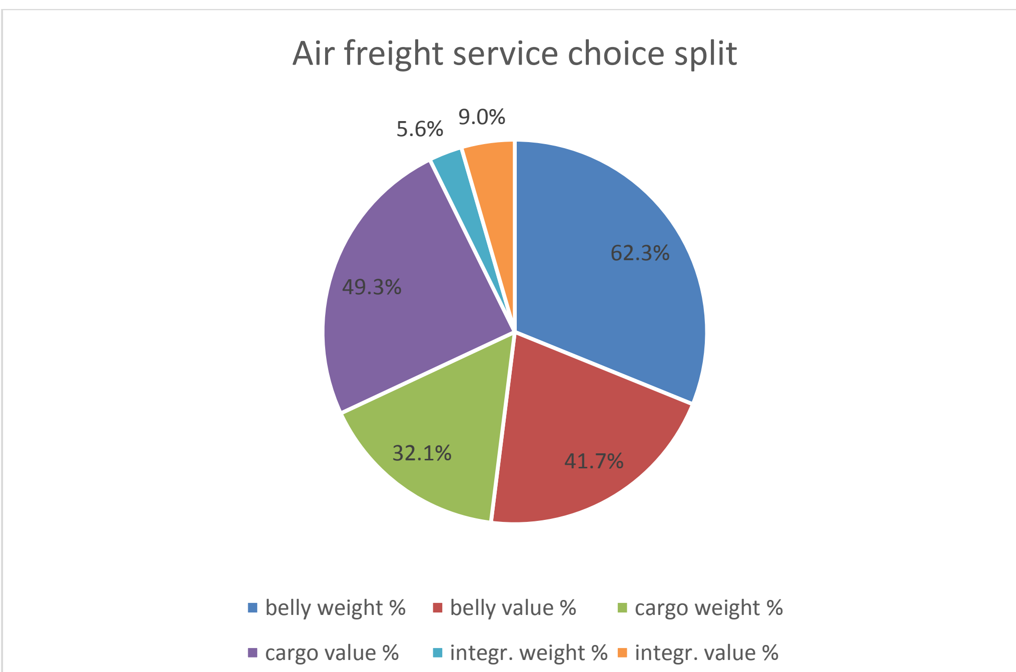


Mode split: Air
0.7%
12.6%
Air Value
Air Weight

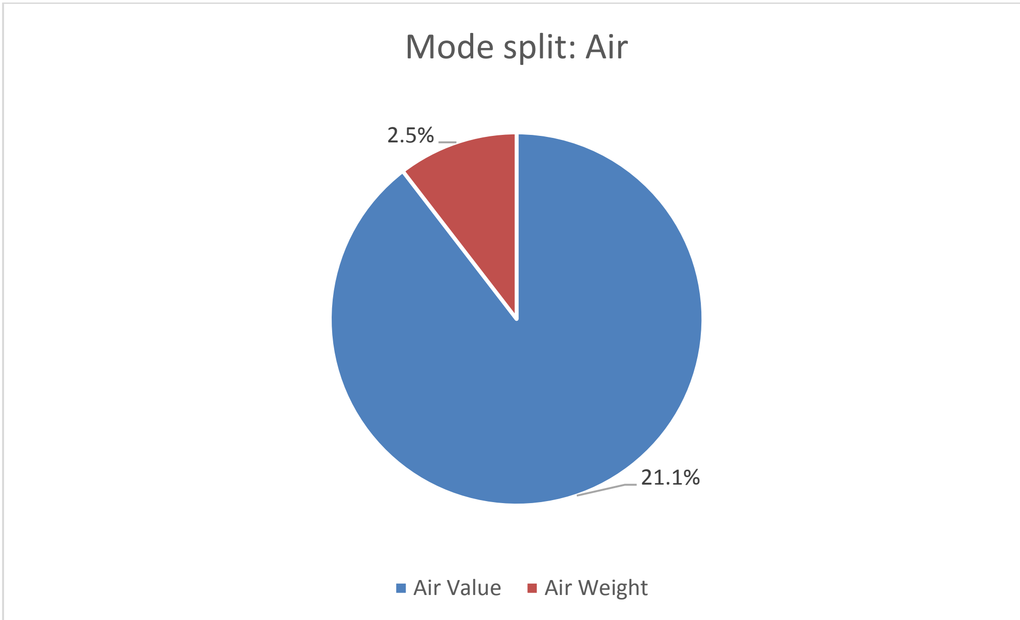
Airborne trade commodities breakdown
Origin: Africa, Destination: Oceania
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

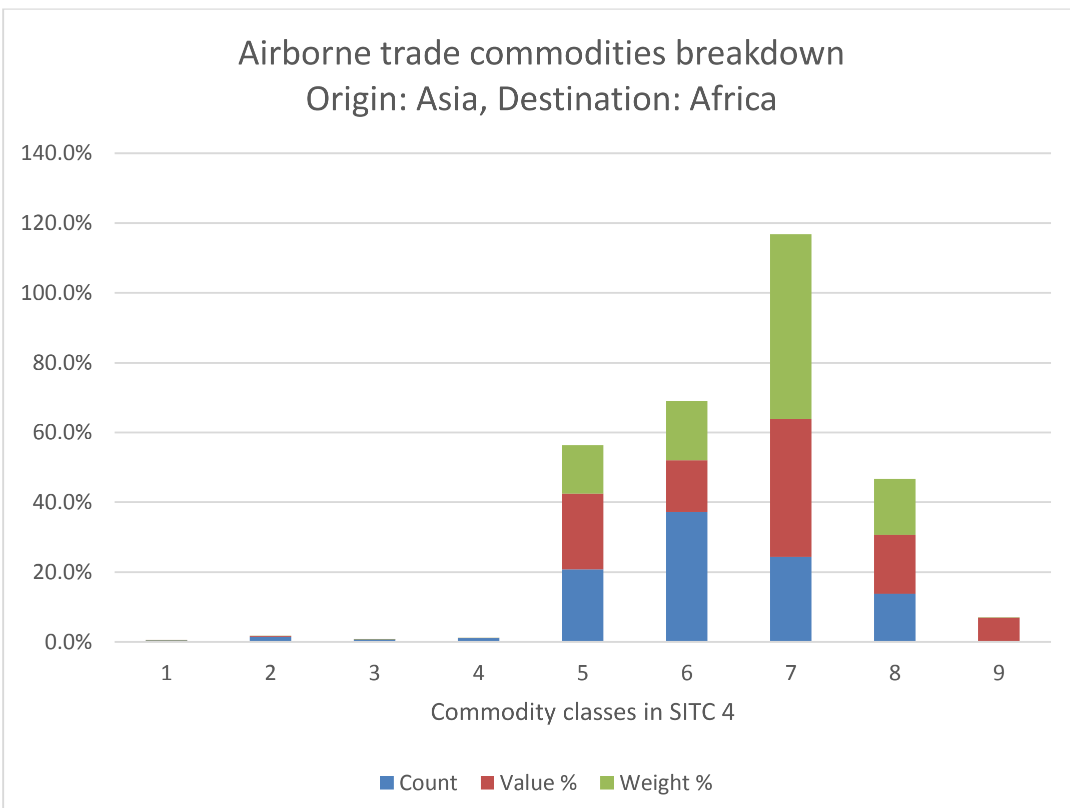

Air freight service choice per commodity class
Origin: Africa, Destination: Oceania
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %
5.4%
4.7%
31.0%
27.2%
63.5%
68.0%
14.2%
12.1%
81.2%
69.2%
4.6%
18.7%
11.1%
11.1%
63.4%
63.4%
25.5%
25.5%
14.4%
13.7%
82.3%
78.3%
3.3%
8.0%
8.7%
6.2%
48.8%
35.6%
42.4%
58.2%
11.9%
6.7%
59.9%
38.7%
28.1%
54.6%
7.7%
5.3%
44.2%
30.3%
48.1%
64.4%
8.6%
4.5%
49.0%
26.0%
42.4%
69.5%
13.6%
13.6%
77.9%
77.9%
8.5%
8.5%


Air freight service choice split
5.6%
9.0%
62.3%
49.3%
32.1%
41.7%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

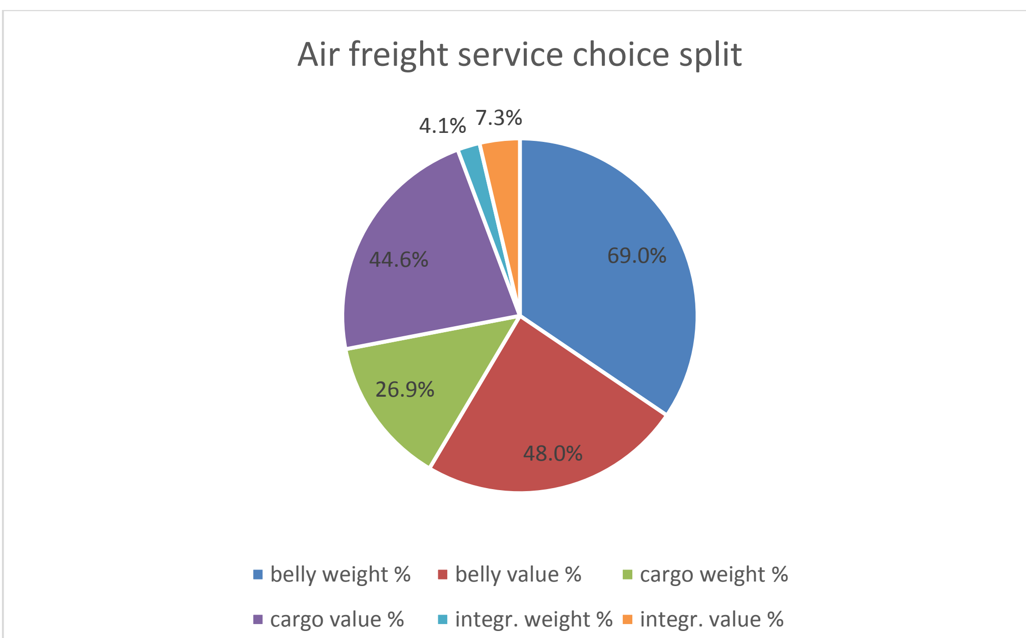
## Asia

### *To Africa*

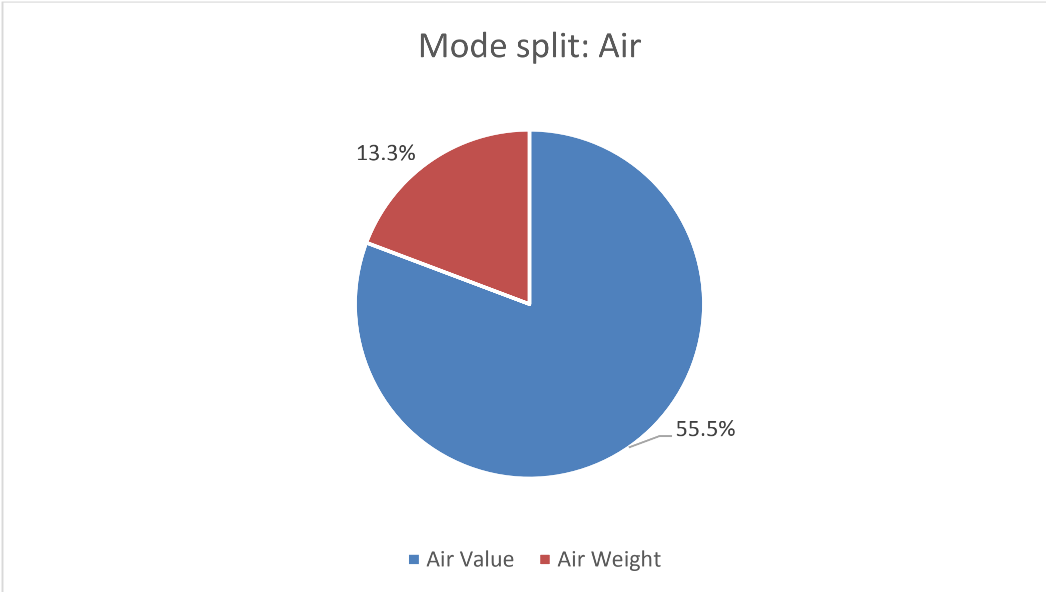


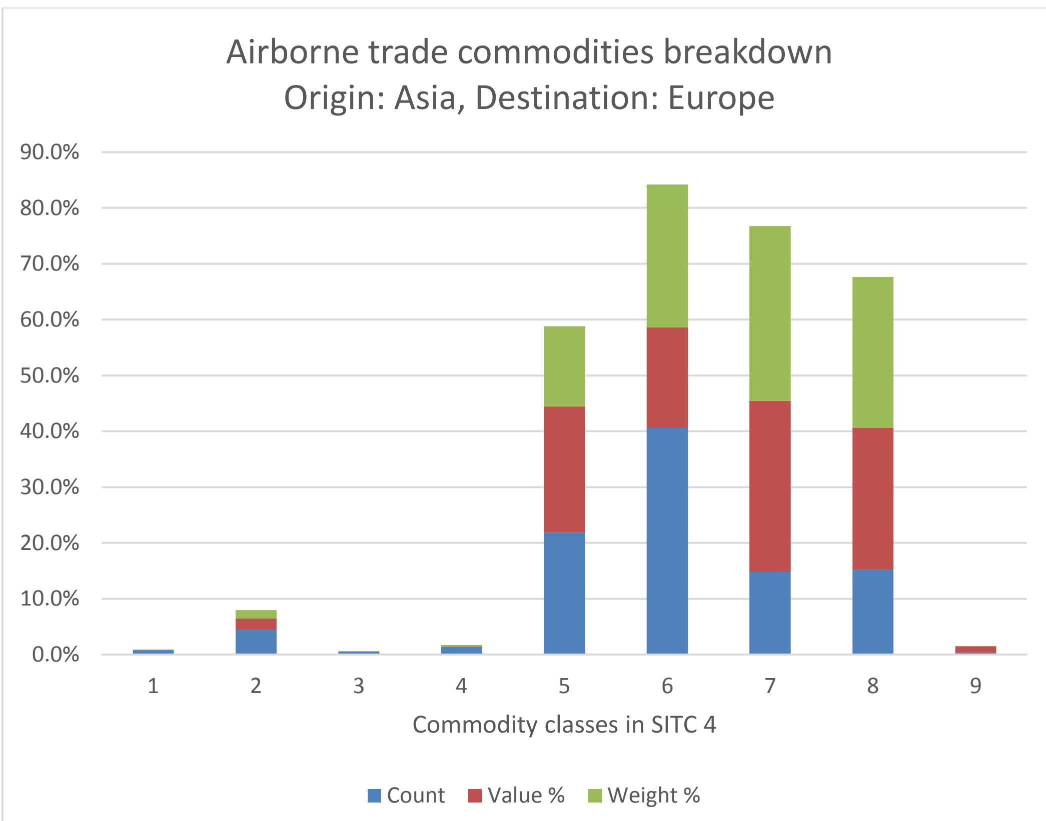




Air freight service choice per commodity class
Origin: Asia, Destination: Africa
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight % Belly Value % Cargo Weight % Cargo Value % Integr. Weight % Integr. Value %
4.8%
3.8%
32.1%
25.4%
63.1%
70.8%
12.3%
11.9%
81.1%
78.9%
6.6%
9.2%
7.7%
5.9%
50.9%
39.1%
41.4%
55.0%
2.8%
2.8%
18.8%
18.3%
78.3%
79.0%
9.0%
6.3%
59.5%
41.5%
31.5%
52.2%
4.6%
3.5%
30.6%
23.3%
64.8%
73.2%
5.3%
3.5%
34.9%
22.9%
59.8%
73.6%
7.2%
4.8%
46.2%
31.4%
46.7%
63.8%
20.0%
18.9%
80.0%
80.0%

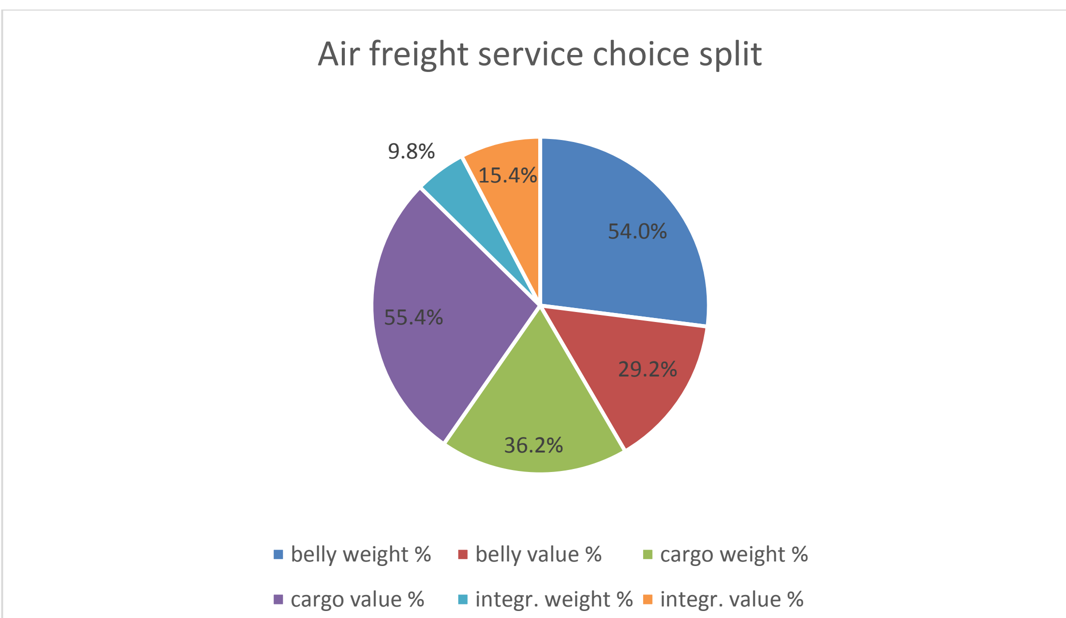

Air freight service choice split
4.1%
7.3%
69.0%
44.6%
26.9%
48.0%
belly weight % belly value % cargo weight %
cargo value % integr. weight % integr. value %

### *To Europe*


Mode split: Air
13.3%
55.5%
Air Value
Air Weight

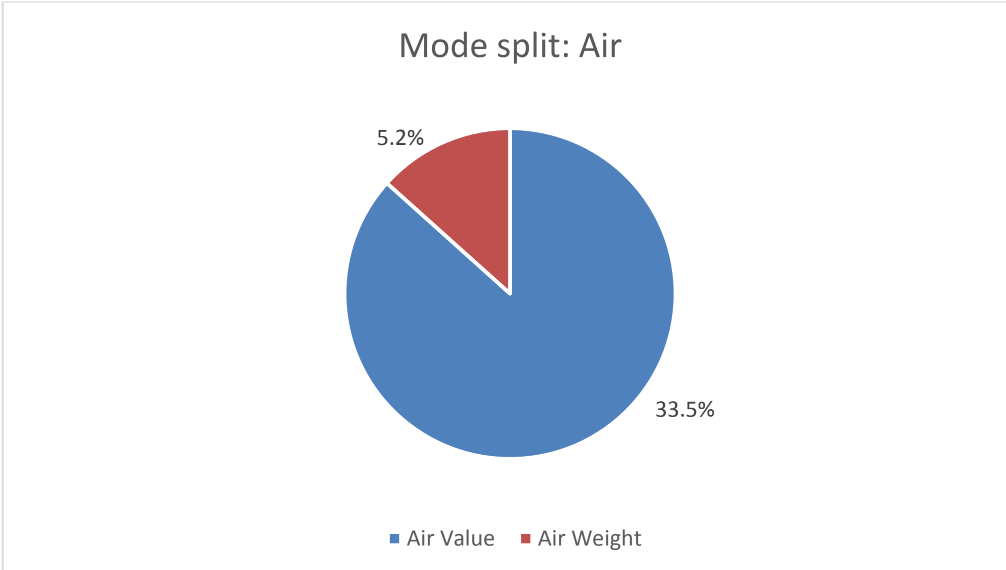

Airborne trade commodities breakdown
Origin: Asia, Destination: Europe
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

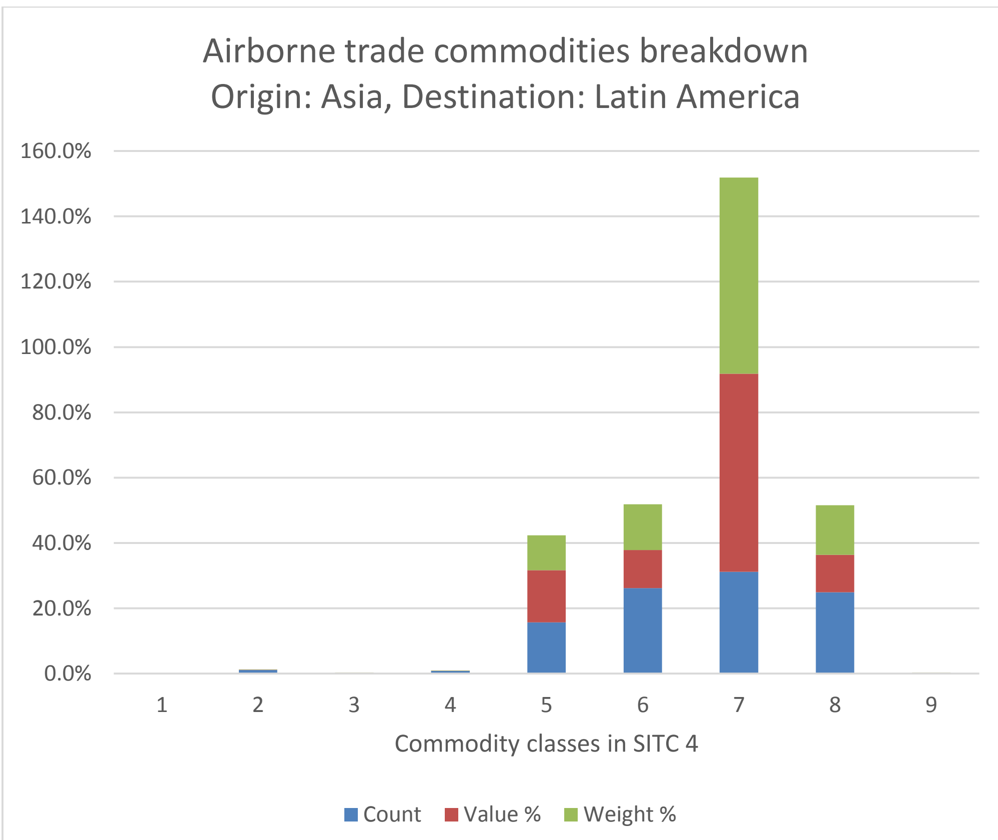
Air freight service choice per commodity class
Origin: Asia, Destination: Europe
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
9.0%
7.1%
33.0%
26.1%
58.1%
66.8%
12.9%
8.2%
47.5%
30.1%
39.6%
61.7%
16.4%
14.8%
60.3%
54.6%
23.4%
30.6%
7.9%
7.2%
28.9%
26.5%
63.2%
66.3%
18.2%
11.3%
62.2%
41.6%
19.5%
47.1%
11.3%
8.1%
41.6%
30.0%
47.1%
61.9%
15.8%
10.5%
58.0%
38.8%
26.2%
50.6%
15.5%
9.9%
55.6%
36.5%
29.0%
53.5%
20.1%
13.1%
79.5%
48.5%
0.4%
38.4%
Belly Weight % Belly Value % Cargo Weight % Cargo Value % Integr. Weight % Integr. Value %

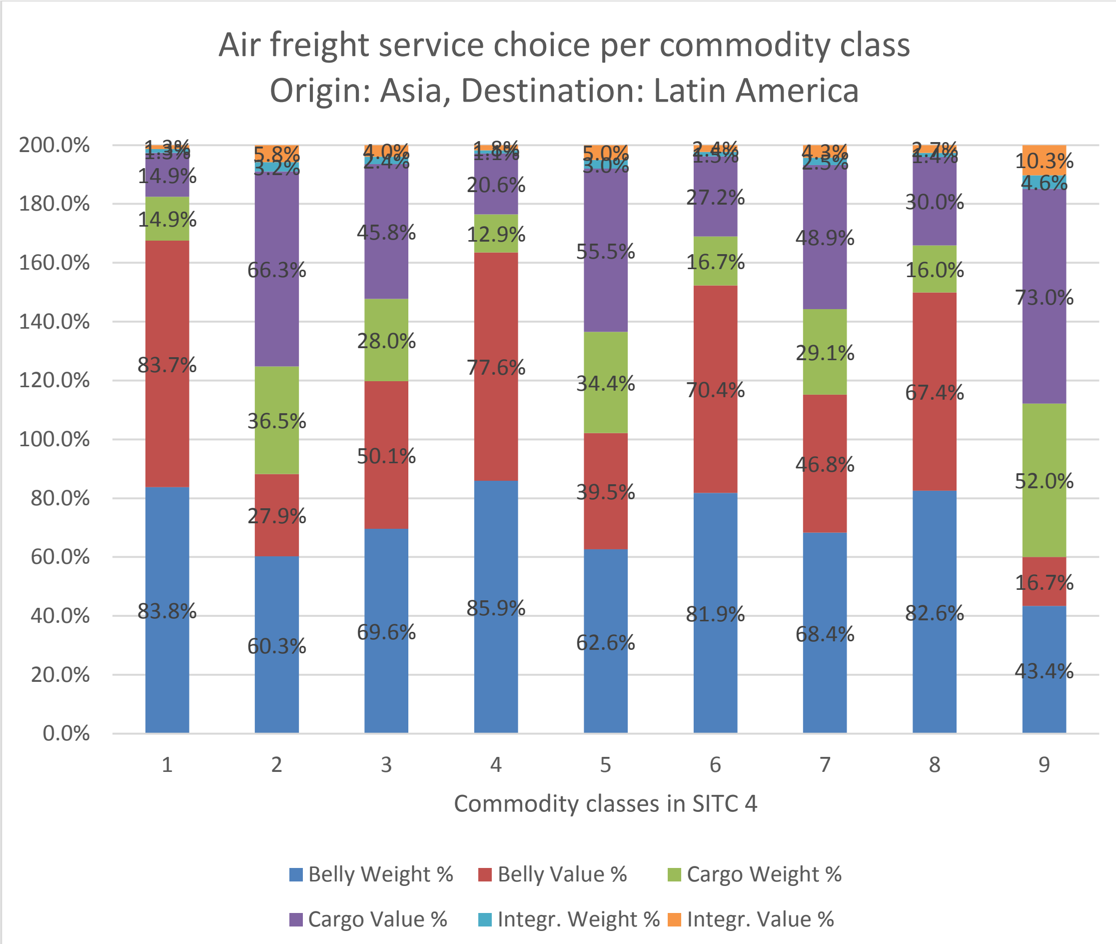



Air freight service choice split
9.8%
15.4%
54.0%
55.4%
29.2%
36.2%
belly weight % belly value % cargo weight %
cargo value % integr. weight % integr. value %

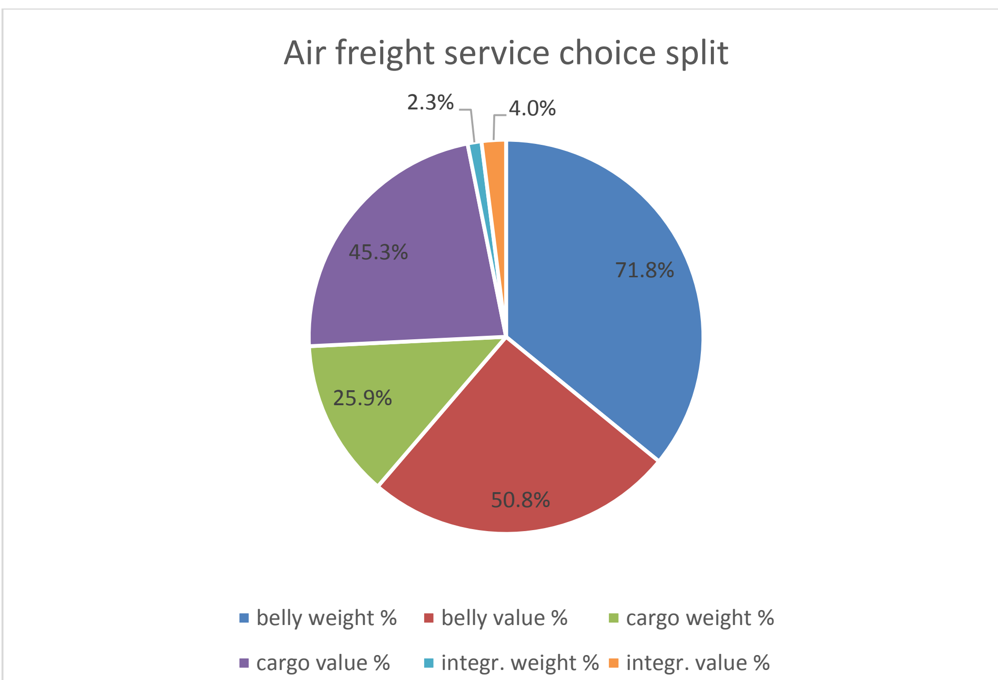
### *To Latin America*



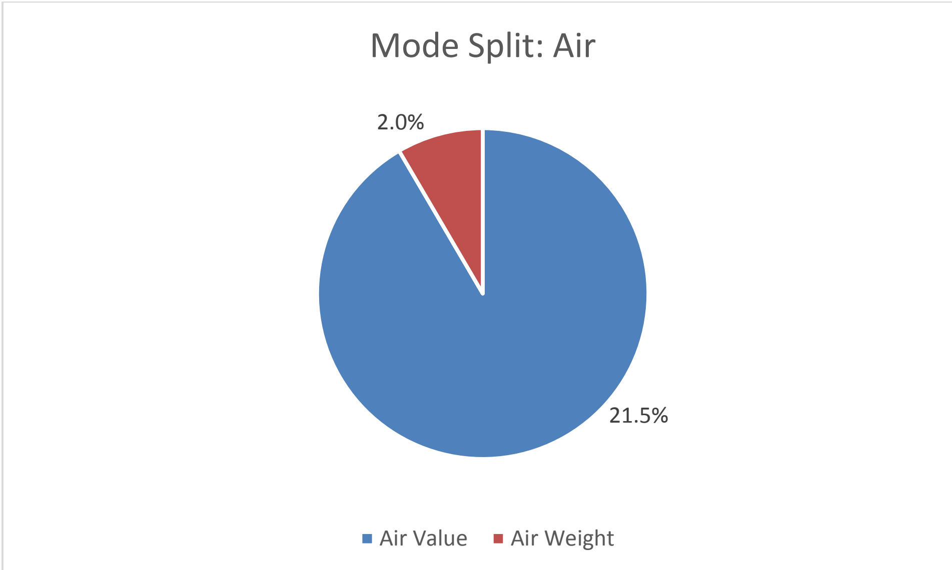


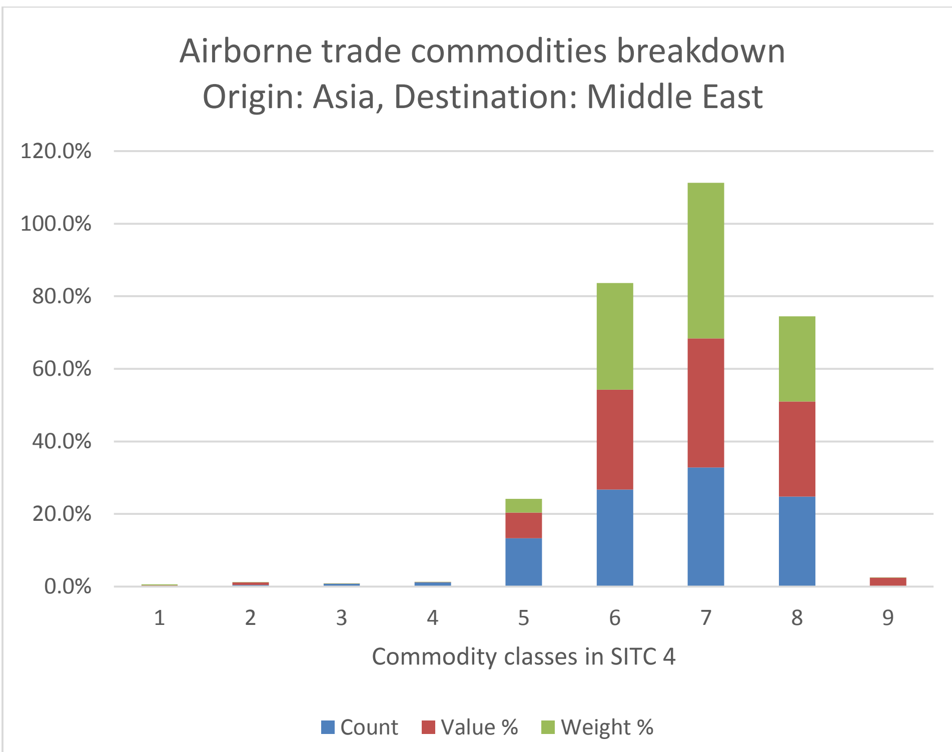
Air freight service choice per commodity class
Origin: Asia, Destination: Latin America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
83.8%
83.7%
14.9%
14.9%
60.3%
27.9%
36.5%
66.3%
5.8%
3.2%
69.6%
50.1%
28.0%
45.8%
4.0%
2.4%
85.9%
77.6%
12.9%
20.6%
62.6%
39.5%
34.4%
55.5%
5.0%
3.0%
81.9%
70.4%
16.7%
27.2%
68.4%
46.8%
29.1%
48.9%
4.3%
2.5%
82.6%
67.4%
16.0%
30.0%
43.4%
16.7%
52.0%
73.0%
4.6%
10.3%
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

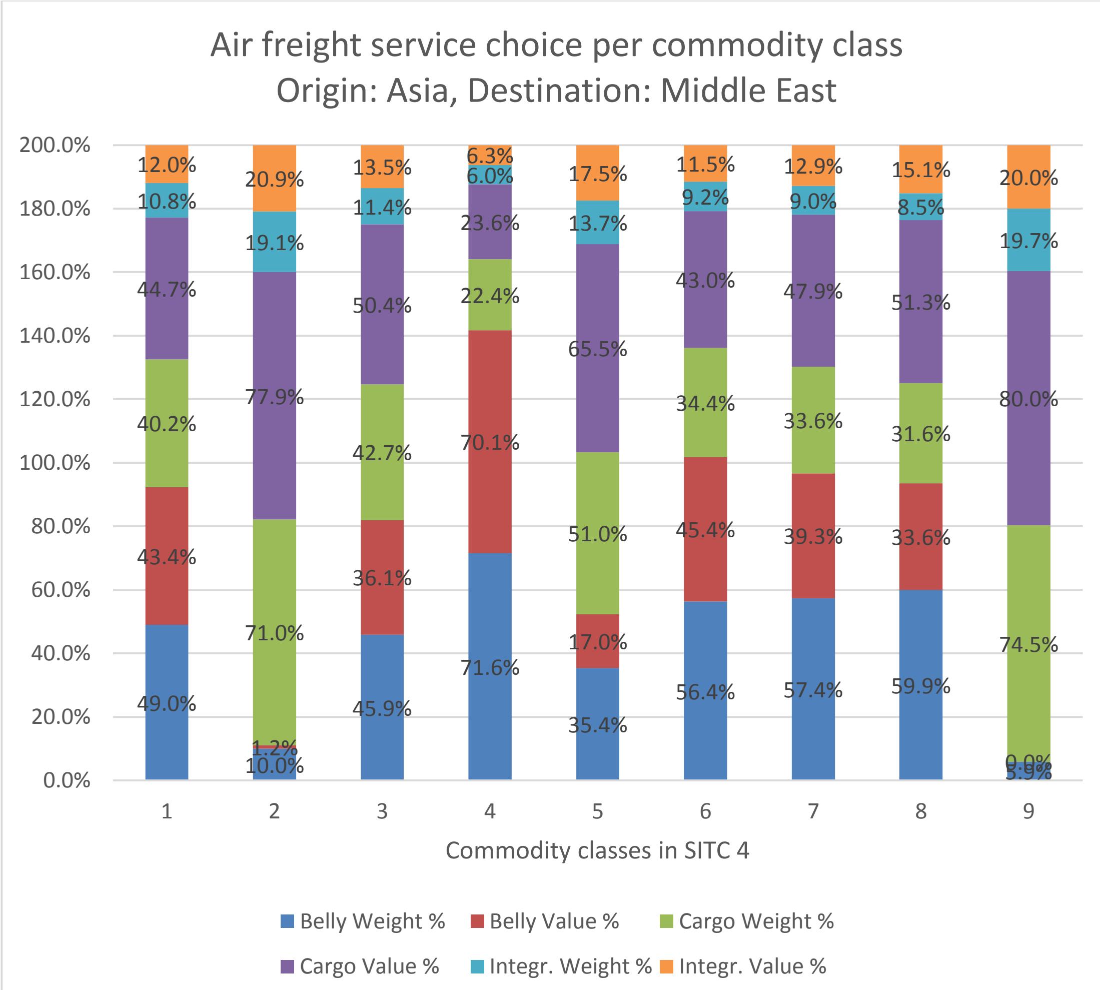



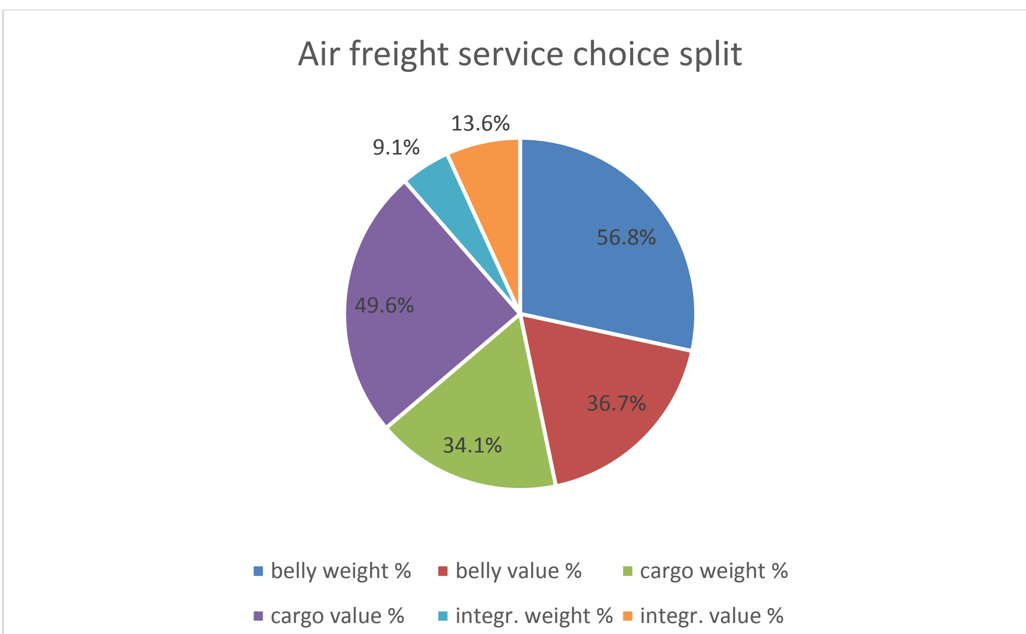
Air freight service choice split
2.3%
4.0%
71.8%
50.8%
25.9%
45.3%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To Middle East*

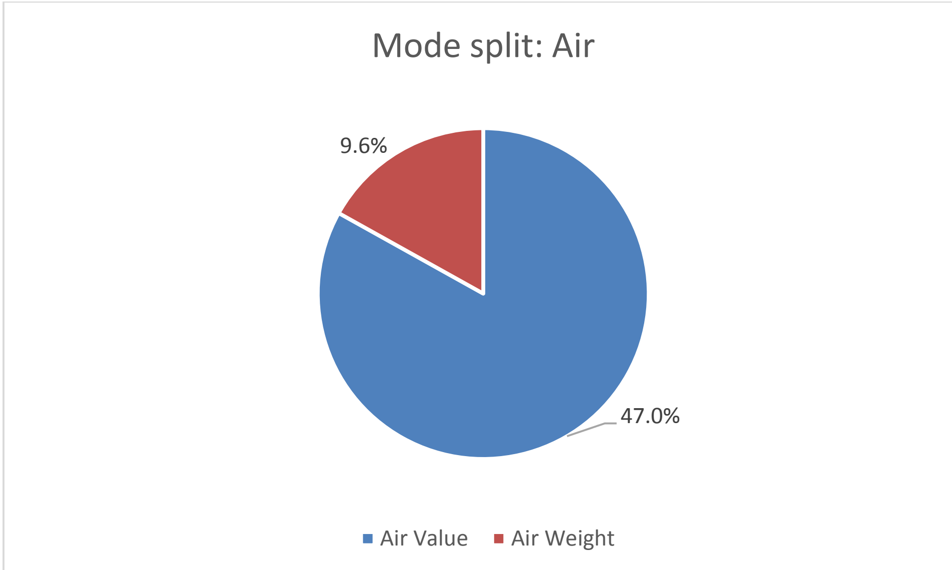


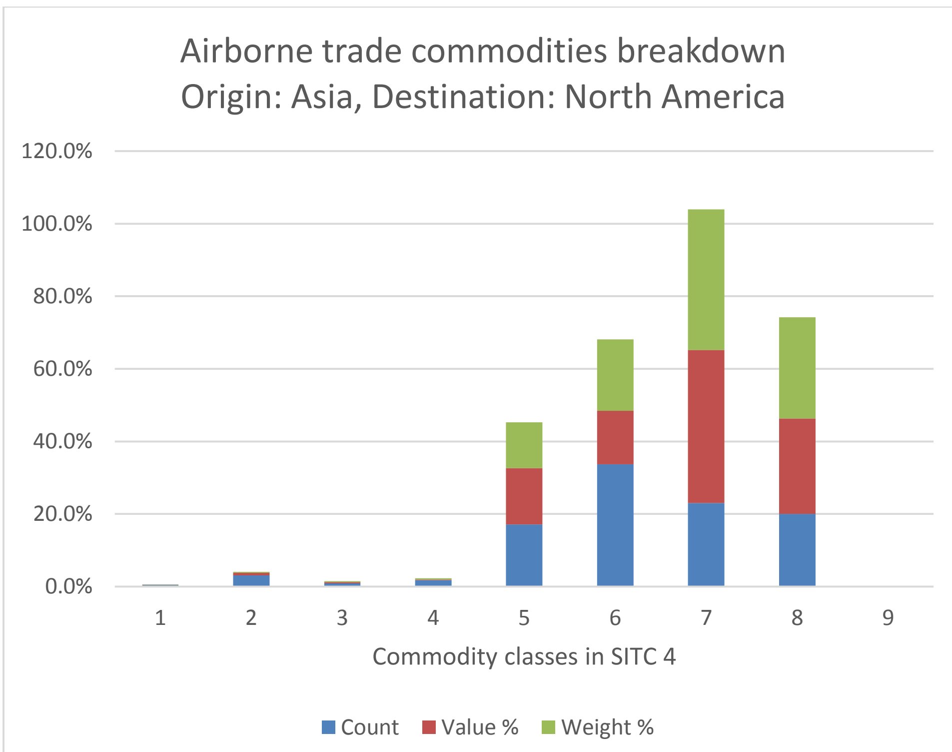




Air freight service choice per commodity class
Origin: Asia, Destination: Middle East
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
12.0%
10.8%
44.7%
40.2%
43.4%
49.0%
20.9%
19.1%
77.9%
71.0%
1.2%
10.0%
13.5%
11.4%
50.4%
42.7%
36.1%
45.9%
6.3%
6.0%
23.6%
22.4%
70.1%
71.6%
17.5%
13.7%
65.5%
51.0%
17.0%
35.4%
11.5%
9.2%
43.0%
34.4%
45.4%
56.4%
12.9%
9.0%
47.9%
33.6%
39.3%
57.4%
15.1%
8.5%
51.3%
31.6%
33.6%
59.9%
20.0%
19.7%
80.0%
74.5%
0.0%
5.9%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

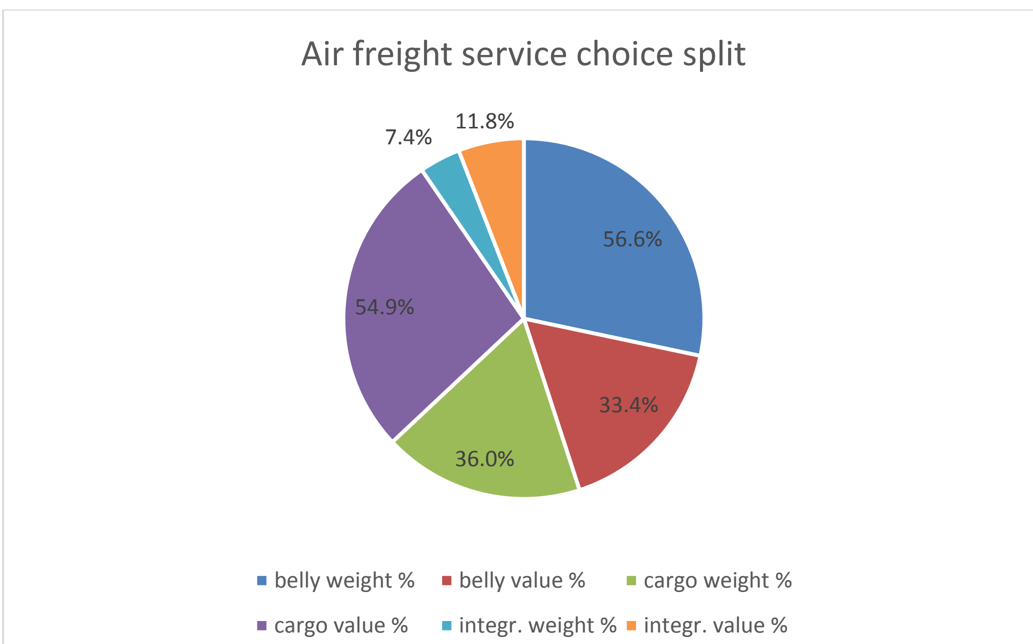

Air freight service choice split
13.6%
9.1%
56.8%
49.6%
36.7%
34.1%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

## *To North America*



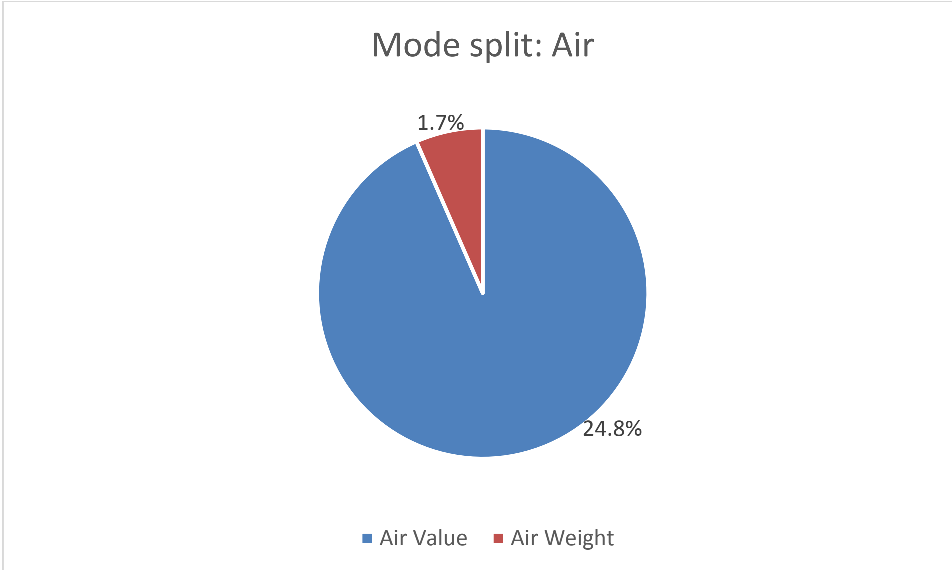



Air freight service choice per commodity class
Origin: Asia, Destination: North America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
9.4%
8.6%
45.6%
41.8%
45.0%
49.7%
12.9%
8.9%
63.0%
43.1%
24.1%
48.0%
5.8%
5.4%
28.2%
26.1%
66.0%
68.5%
5.3%
4.7%
25.8%
23.1%
68.9%
72.2%
12.1%
8.1%
58.7%
39.6%
29.3%
52.3%
8.4%
6.0%
40.8%
29.3%
50.8%
64.7%
12.3%
8.4%
60.2%
40.9%
27.5%
50.7%
12.6%
6.7%
52.2%
32.4%
35.2%
60.9%
18.2%
11.5%
76.6%
55.7%
5.2%
32.9%
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

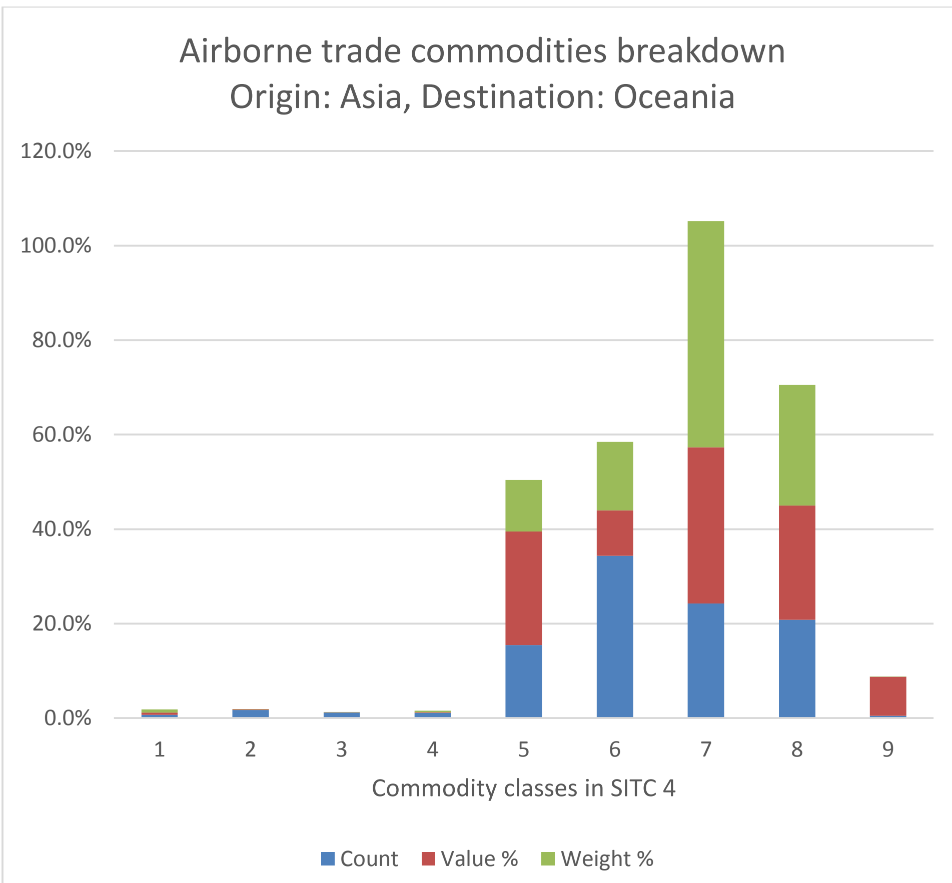



Air freight service choice split
11.8%
7.4%
56.6%
54.9%
33.4%
36.0%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

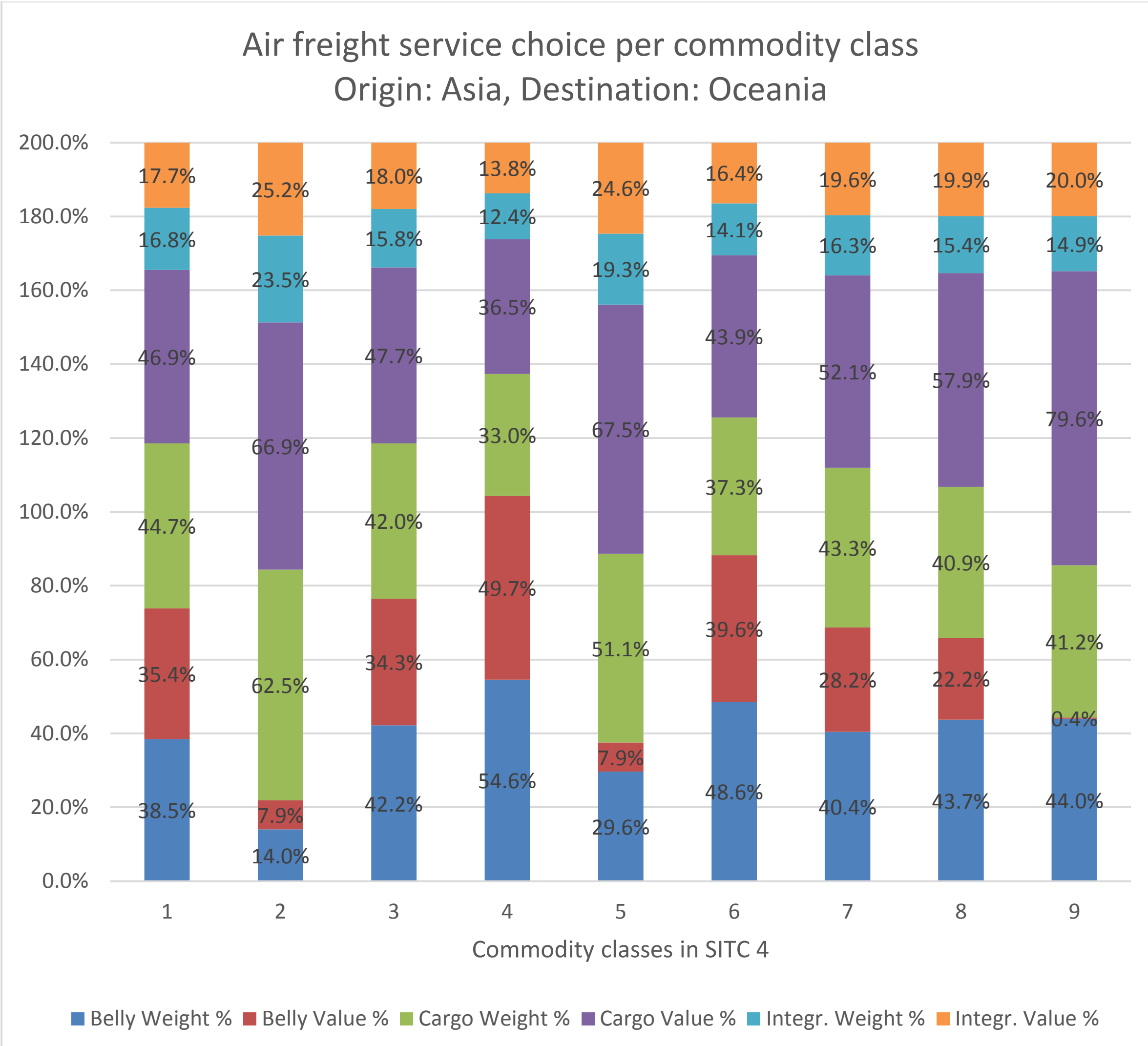
### *To Oceania*



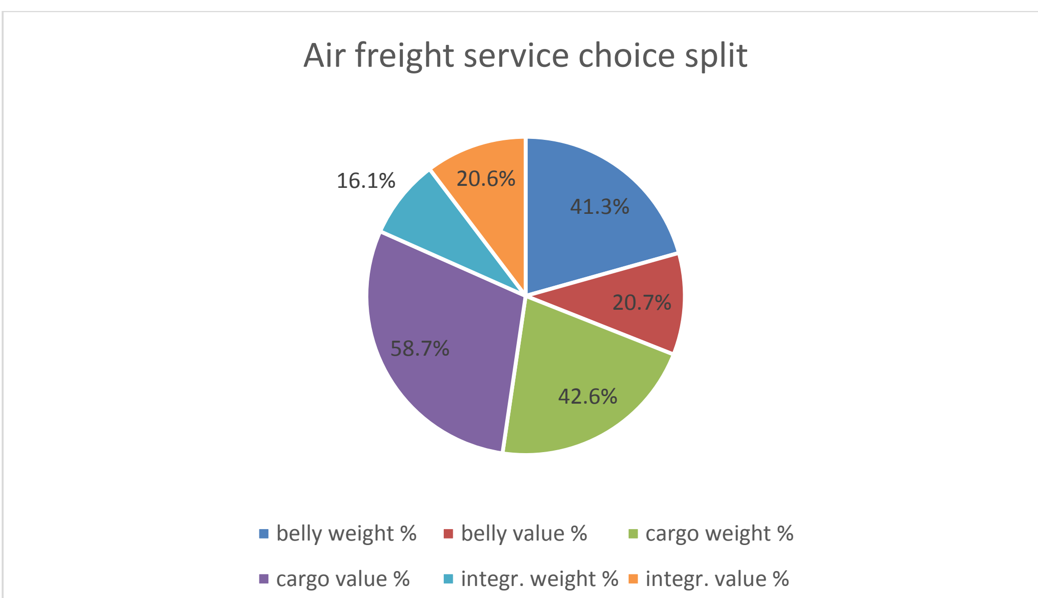
Mode split: Air
1.7%
24.8%
Air Value
Air Weight

Airborne trade commodities breakdown
Origin: Asia, Destination: Oceania
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %



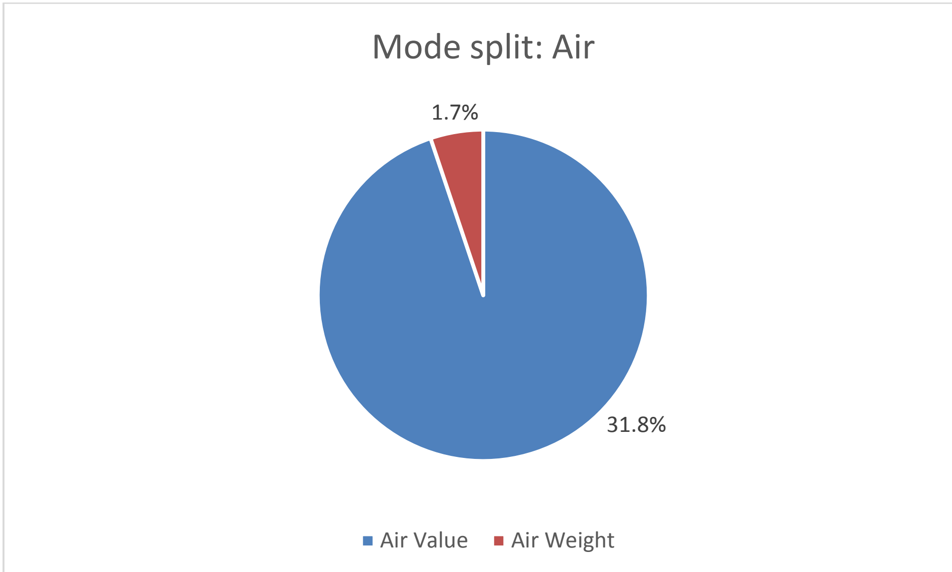
Air freight service choice per commodity class
Origin: Asia, Destination: Oceania
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
17.7%
16.8%
46.9%
44.7%
35.4%
38.5%
25.2%
23.5%
66.9%
62.5%
7.9%
14.0%
18.0%
15.8%
47.7%
42.0%
34.3%
42.2%
13.8%
12.4%
36.5%
33.0%
49.7%
54.6%
24.6%
19.3%
67.5%
51.1%
7.9%
29.6%
16.4%
14.1%
43.9%
37.3%
39.6%
48.6%
19.6%
16.3%
52.1%
43.3%
28.2%
40.4%
19.9%
15.4%
57.9%
40.9%
22.2%
43.7%
20.0%
14.9%
79.6%
41.2%
0.4%
44.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

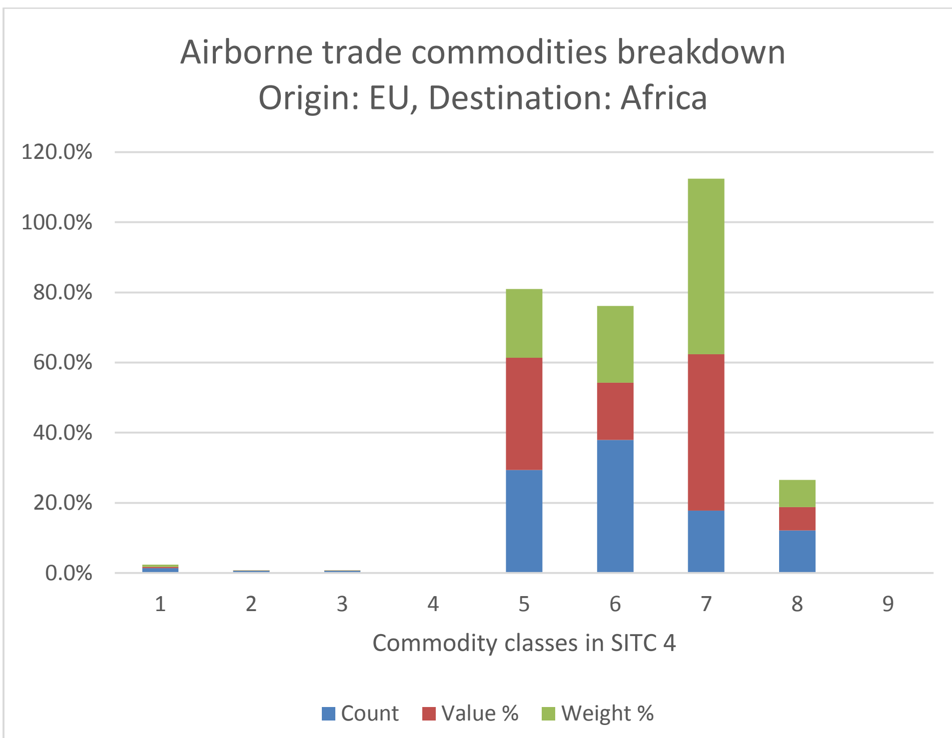



Air freight service choice split
16.1%
20.6%
41.3%
20.7%
42.6%
58.7%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

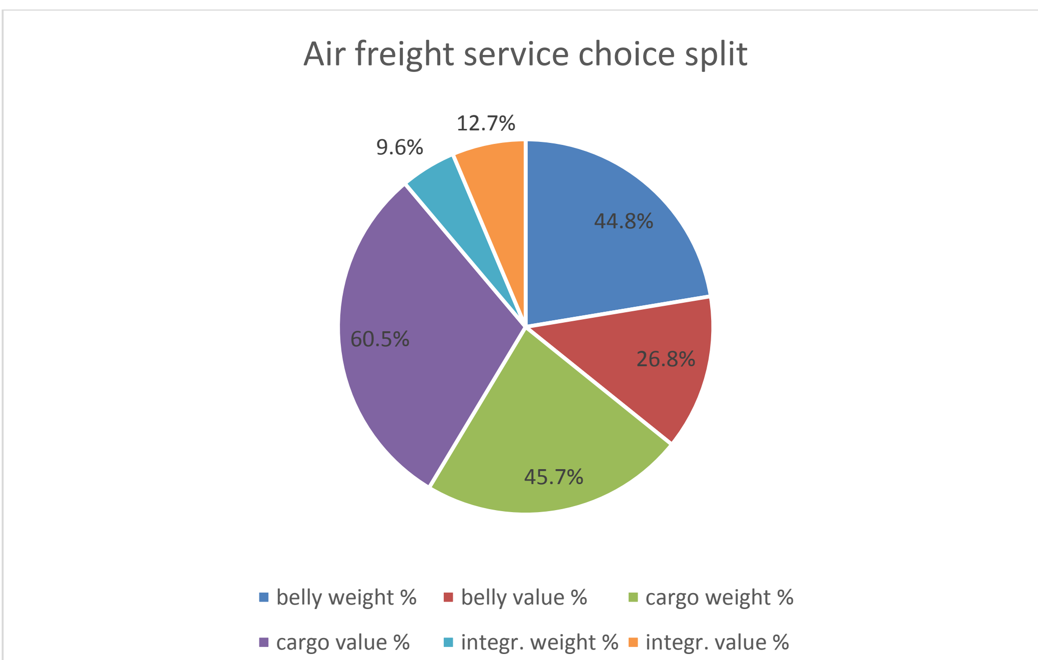
## Europe

### *To Africa*

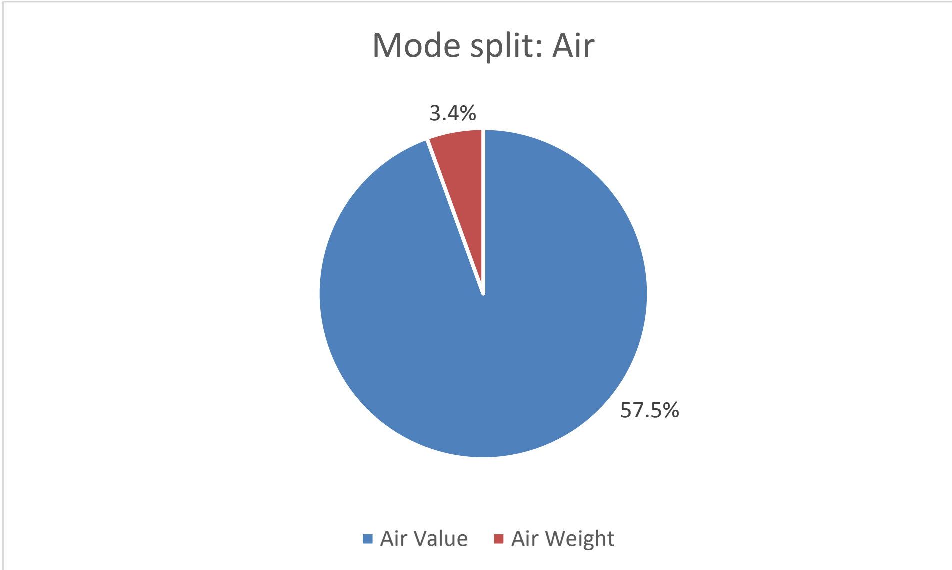


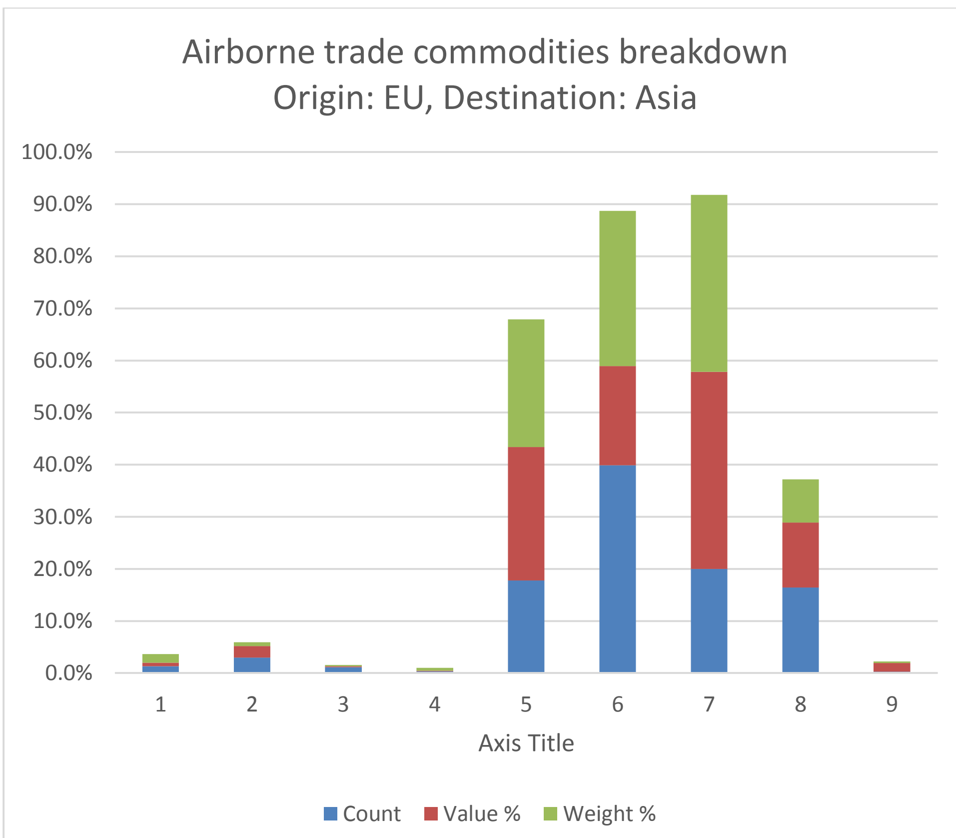

Air freight service choice per commodity class
Origin: EU, Destination: Africa
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
7.8%
6.5%
37.3%
31.0%
54.8%
62.5%
9.6%
7.6%
45.9%
36.1%
44.5%
56.4%
10.6%
8.2%
50.5%
39.3%
38.9%
52.5%
4.3%
4.1%
20.3%
19.5%
75.5%
76.4%
15.2%
12.5%
72.5%
59.7%
12.3%
27.7%
8.5%
7.0%
40.7%
33.4%
50.8%
59.6%
12.7%
9.9%
60.5%
47.1%
26.8%
43.1%
11.2%
7.7%
53.4%
36.7%
35.4%
55.7%
20.0%
20.0%
80.0%
80.0%
0.0%
1 2 3 4 5 6 7 8 9
Commodity classes in SITC 4
Belly Weight % Belly Value % Cargo Weight % Cargo Value % Integr. Weight % Integr. Value %


Air freight service choice split
12.7%
9.6%
44.8%
60.5%
26.8%
45.7%
belly weight % belly value % cargo weight %
cargo value % integr. weight % integr. value %

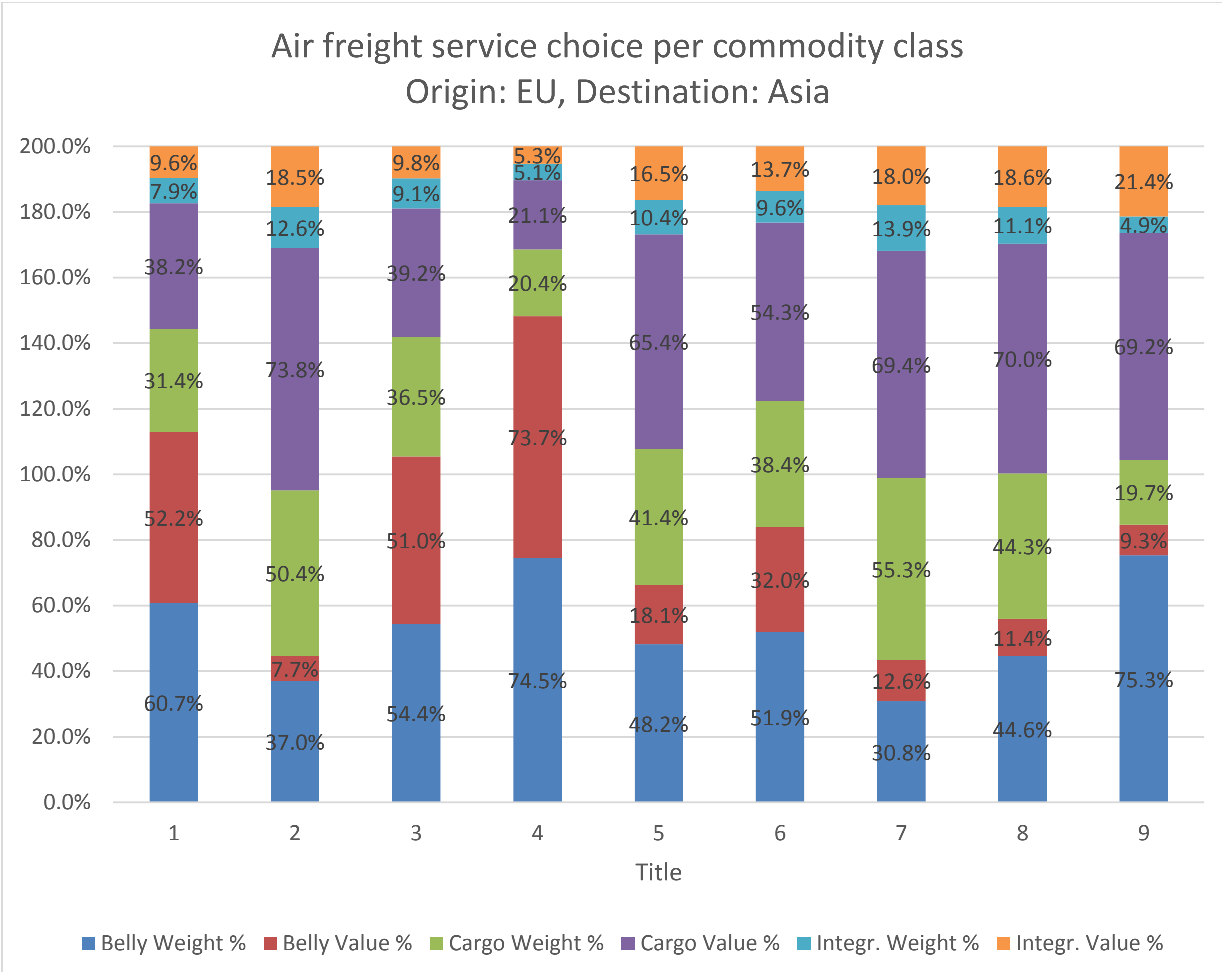
### *To Asia*



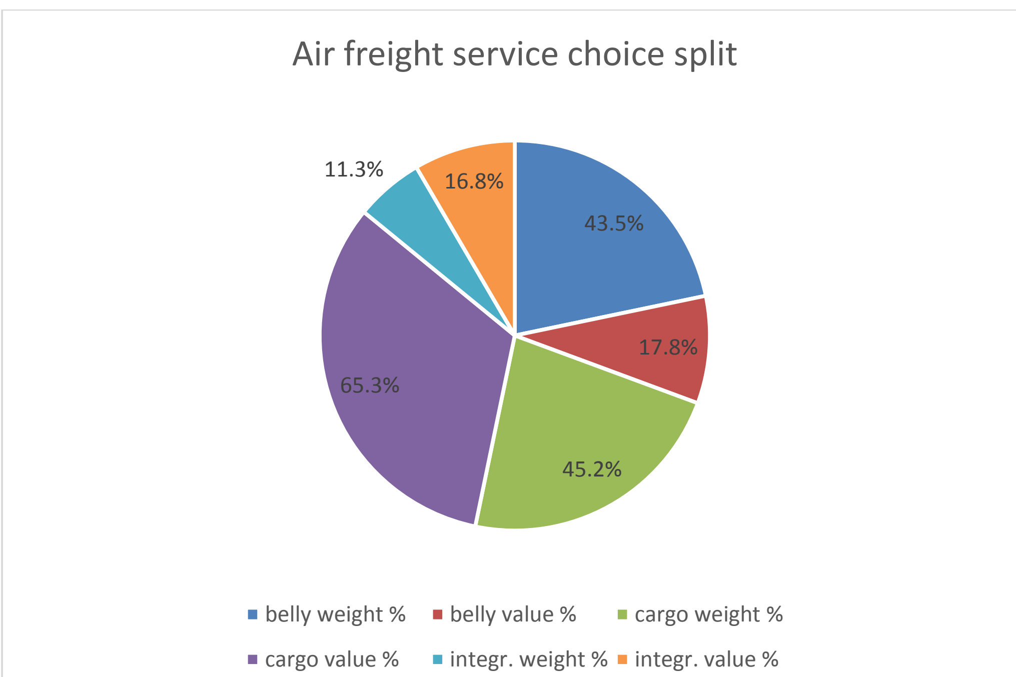
Mode split: Air
3.4%
57.5%
Air Value
Air Weight

Airborne trade commodities breakdown
Origin: EU, Destination: Asia
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1
2
3
4
5
6
7
8
9
Axis Title
Count
Value %
Weight %

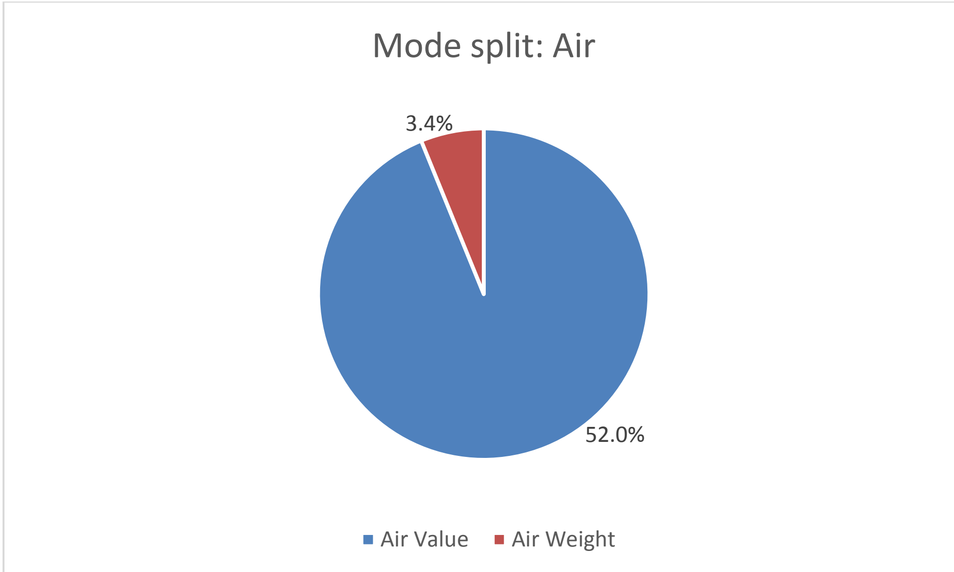


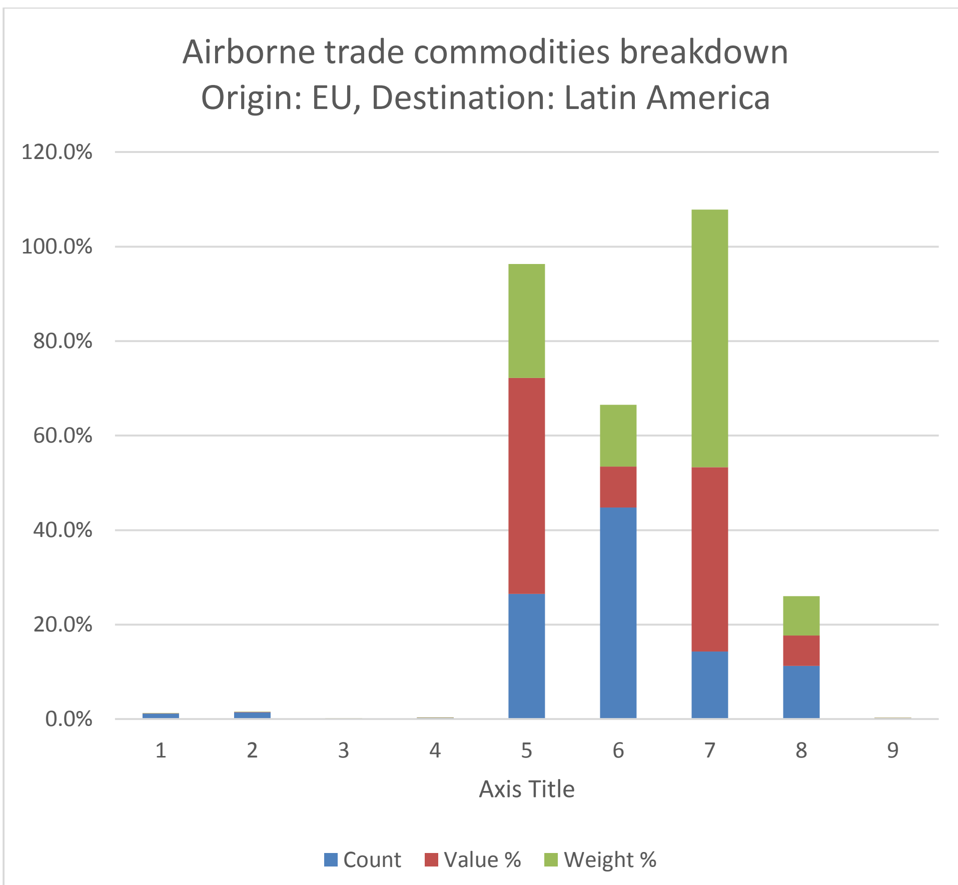
Air freight service choice per commodity class
Origin: EU, Destination: Asia
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Title
9.6%
7.9%
38.2%
31.4%
52.2%
60.7%
18.5%
12.6%
73.8%
50.4%
7.7%
37.0%
9.8%
9.1%
39.2%
36.5%
51.0%
54.4%
5.3%
5.1%
21.1%
20.4%
73.7%
74.5%
16.5%
10.4%
65.4%
41.4%
18.1%
48.2%
13.7%
9.6%
54.3%
38.4%
32.0%
51.9%
18.0%
13.9%
69.4%
55.3%
12.6%
30.8%
18.6%
11.1%
70.0%
44.3%
11.4%
44.6%
21.4%
4.9%
69.2%
19.7%
9.3%
75.3%
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

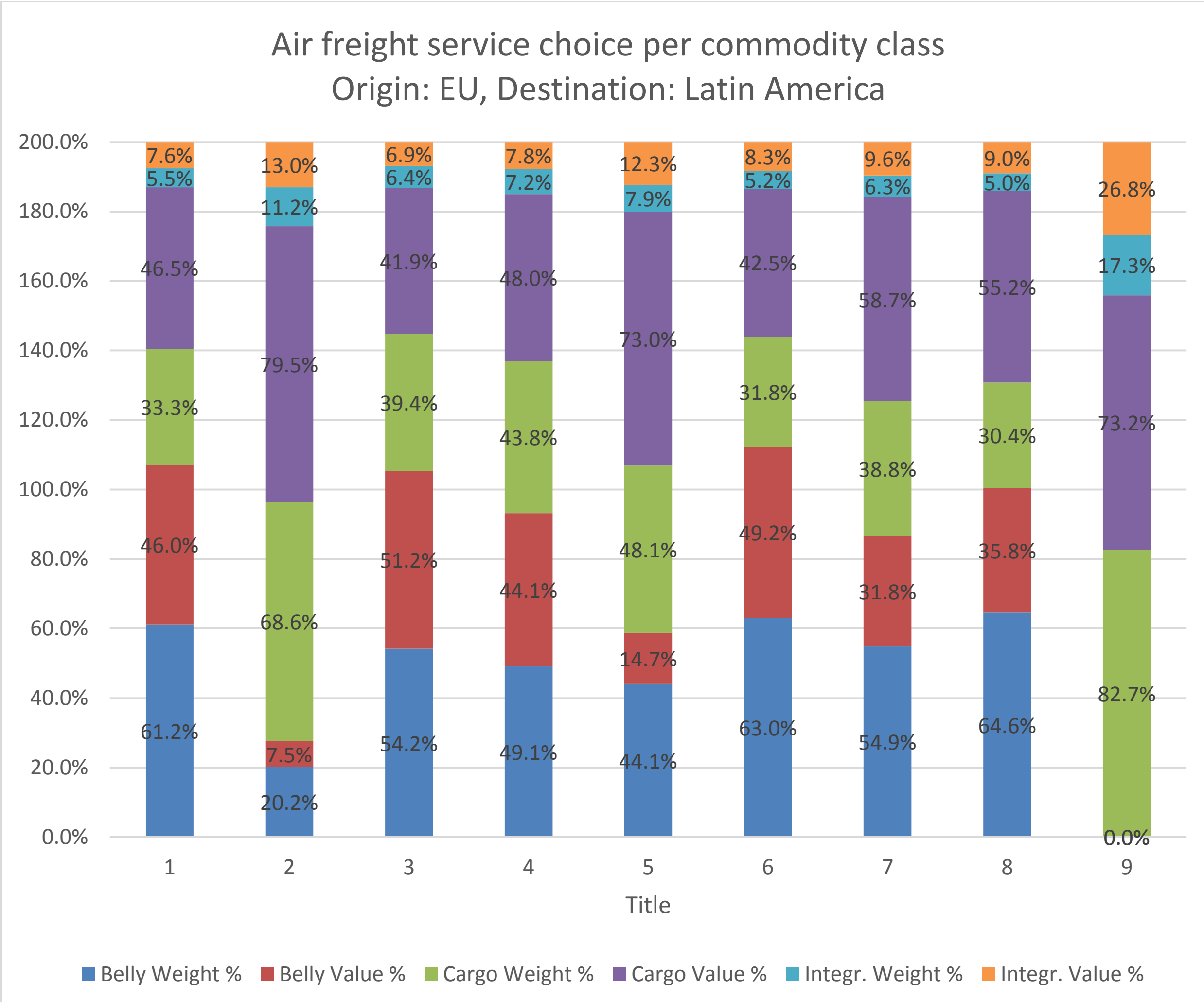



Air freight service choice split
43.5%
17.8%
45.2%
65.3%
11.3%
16.8%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

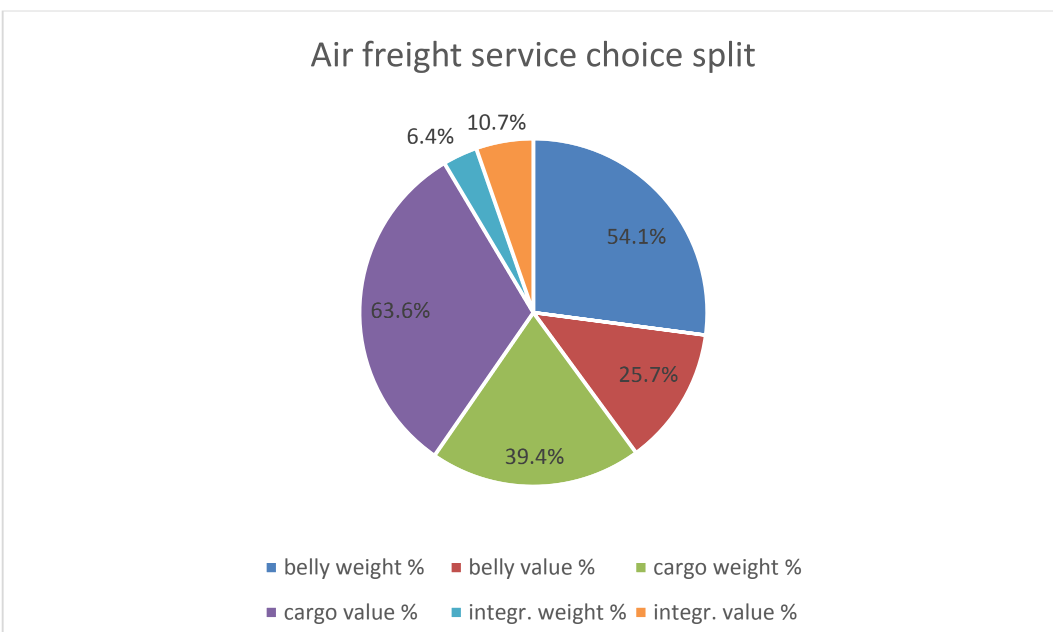
### *To Latin America*



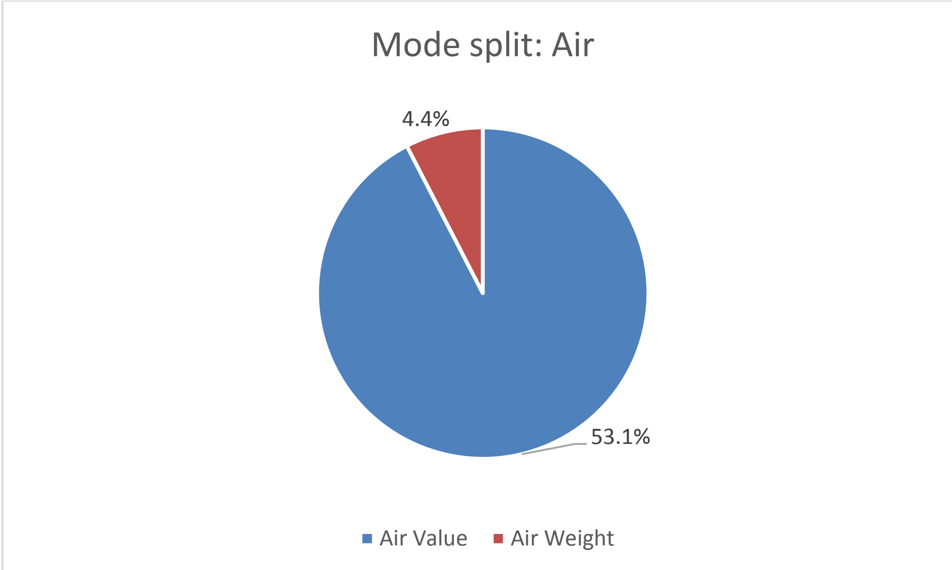


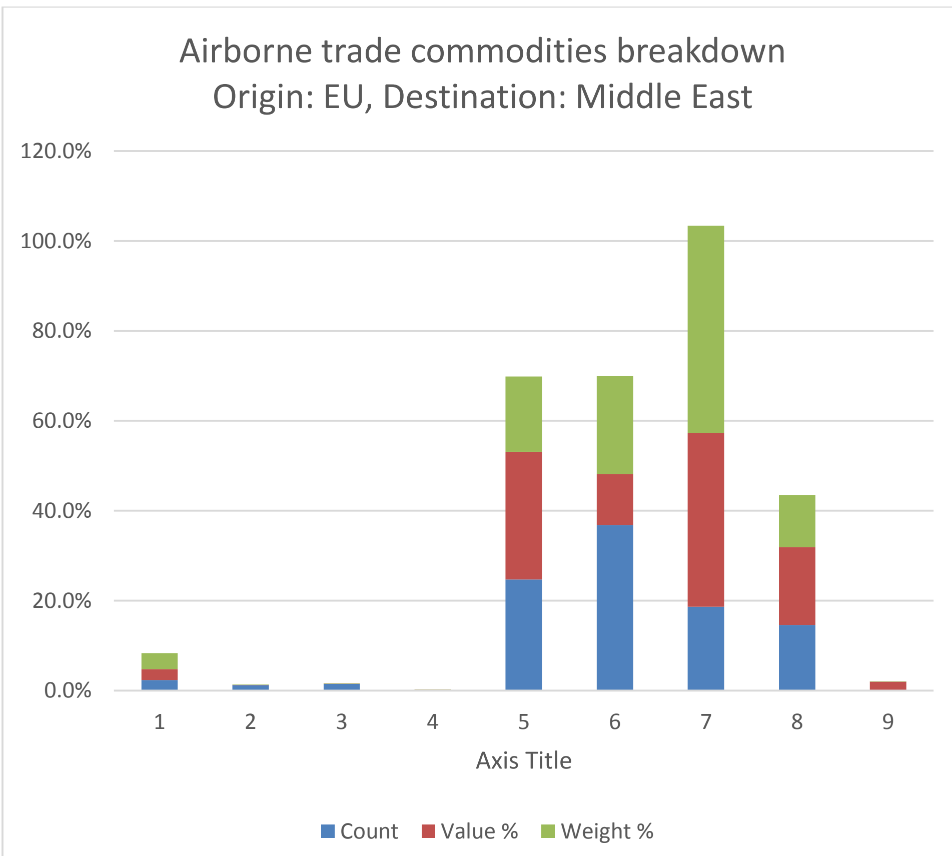
Air freight service choice per commodity class
Origin: EU, Destination: Latin America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1 2 3 4 5 6 7 8 9
Title
7.6% 5.5% 46.5% 33.3% 46.0% 61.2%
13.0% 11.2% 79.5% 68.6% 7.5% 20.2%
6.9% 6.4% 41.9% 39.4% 51.2% 54.2%
7.8% 7.2% 48.0% 43.8% 44.1% 49.1%
12.3% 7.9% 73.0% 48.1% 14.7% 44.1%
8.3% 5.2% 42.5% 31.8% 49.2% 63.0%
9.6% 6.3% 58.7% 38.8% 31.8% 54.9%
9.0% 5.0% 55.2% 30.4% 35.8% 64.6%
26.8% 17.3% 73.2% 82.7% 0.0%
Belly Weight % Belly Value % Cargo Weight % Cargo Value % Integr. Weight % Integr. Value %

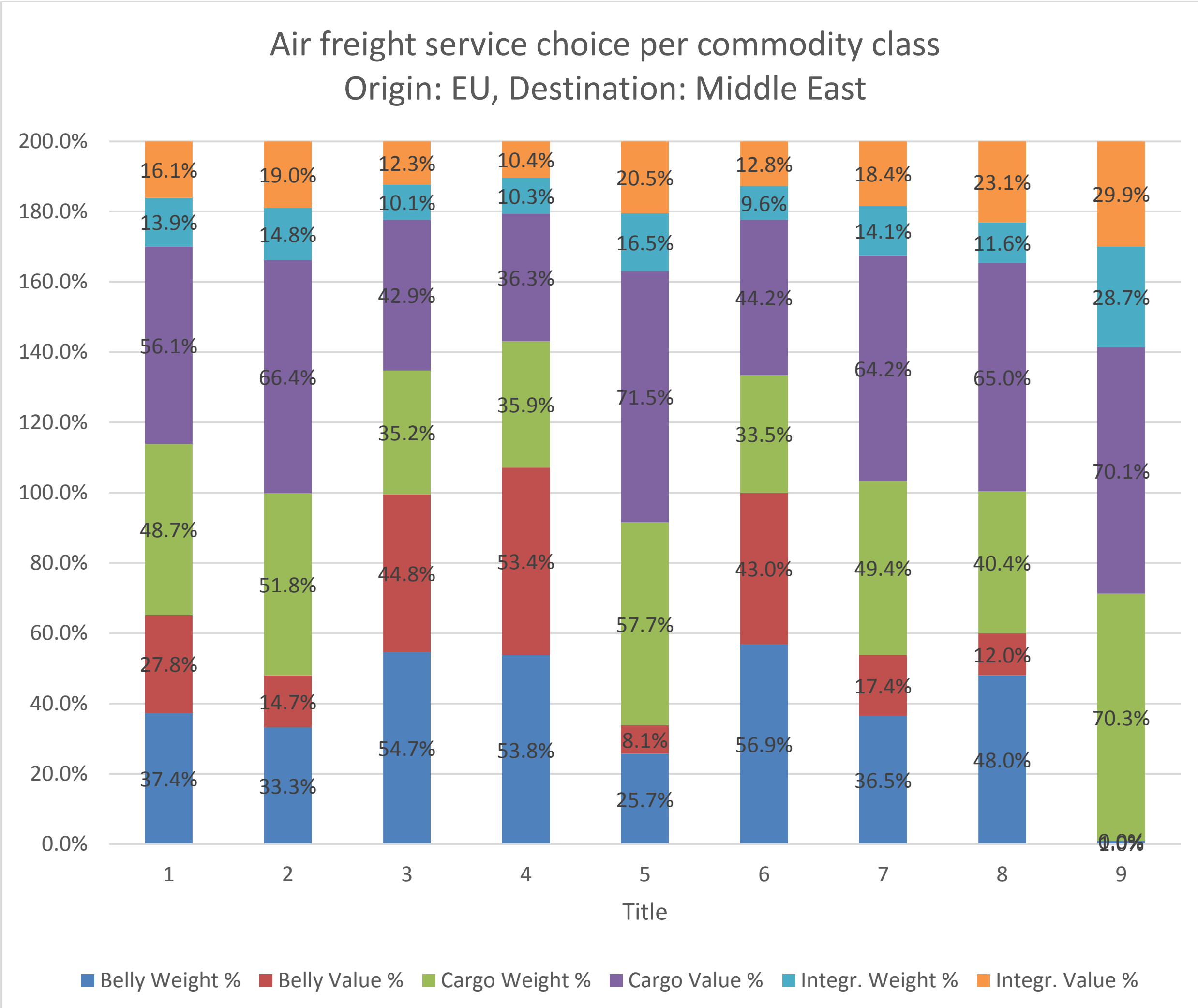



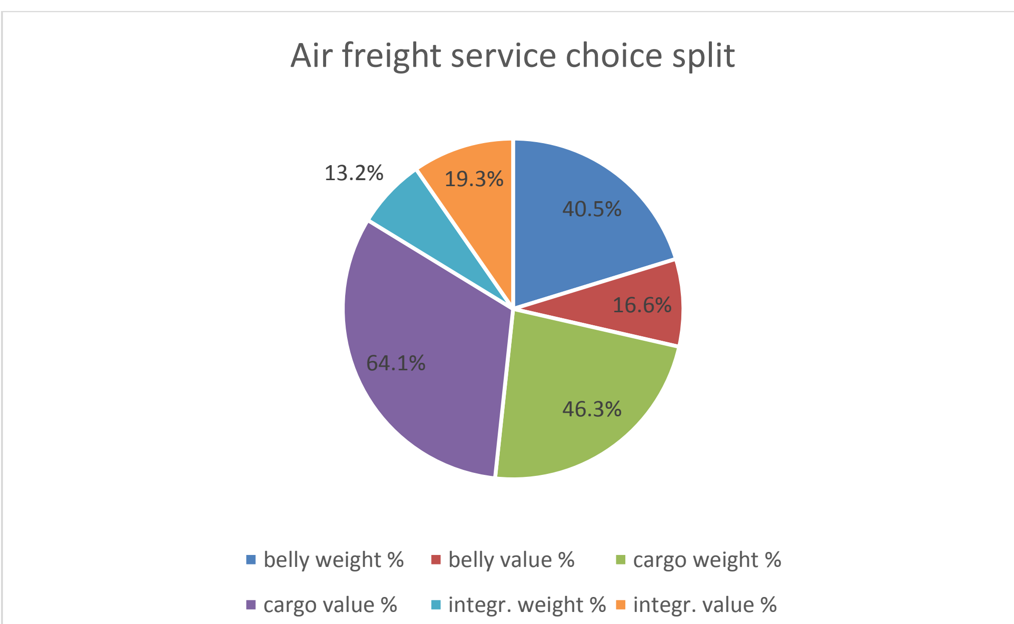
Air freight service choice split
54.1%
25.7%
39.4%
63.6%
6.4%
10.7%
belly weight % belly value % cargo weight %
cargo value % integr. weight % integr. value %

### *To Middle East*

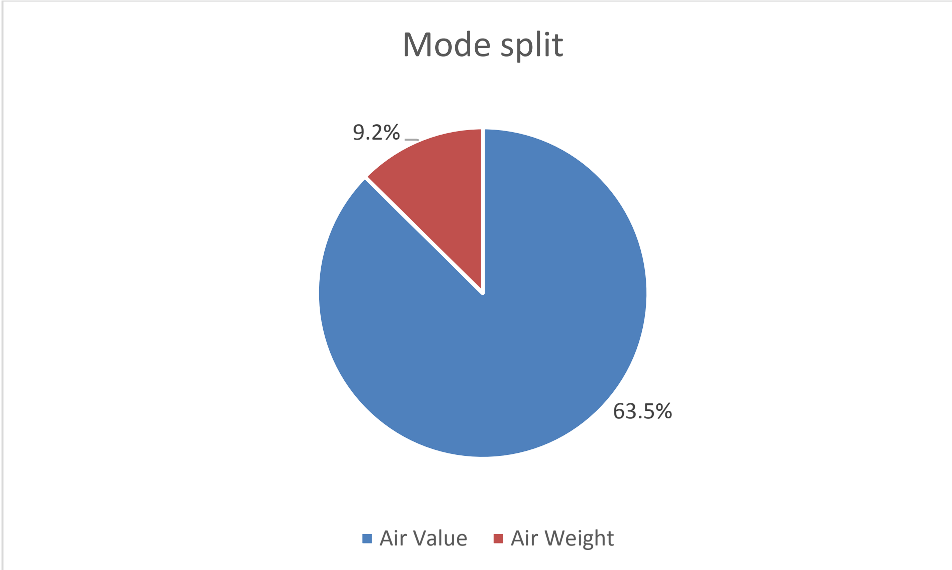


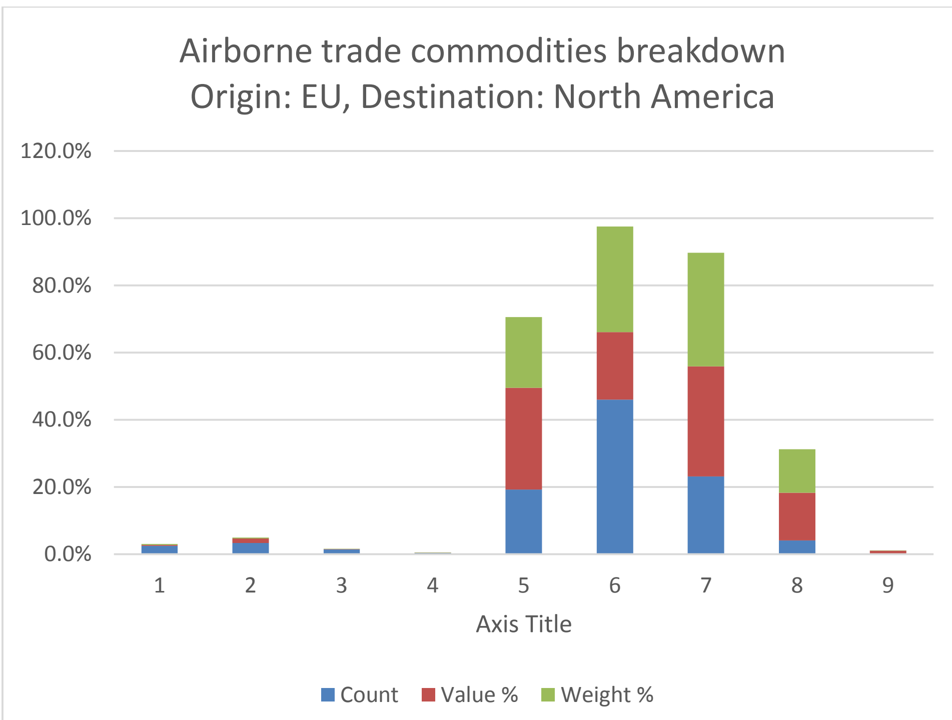



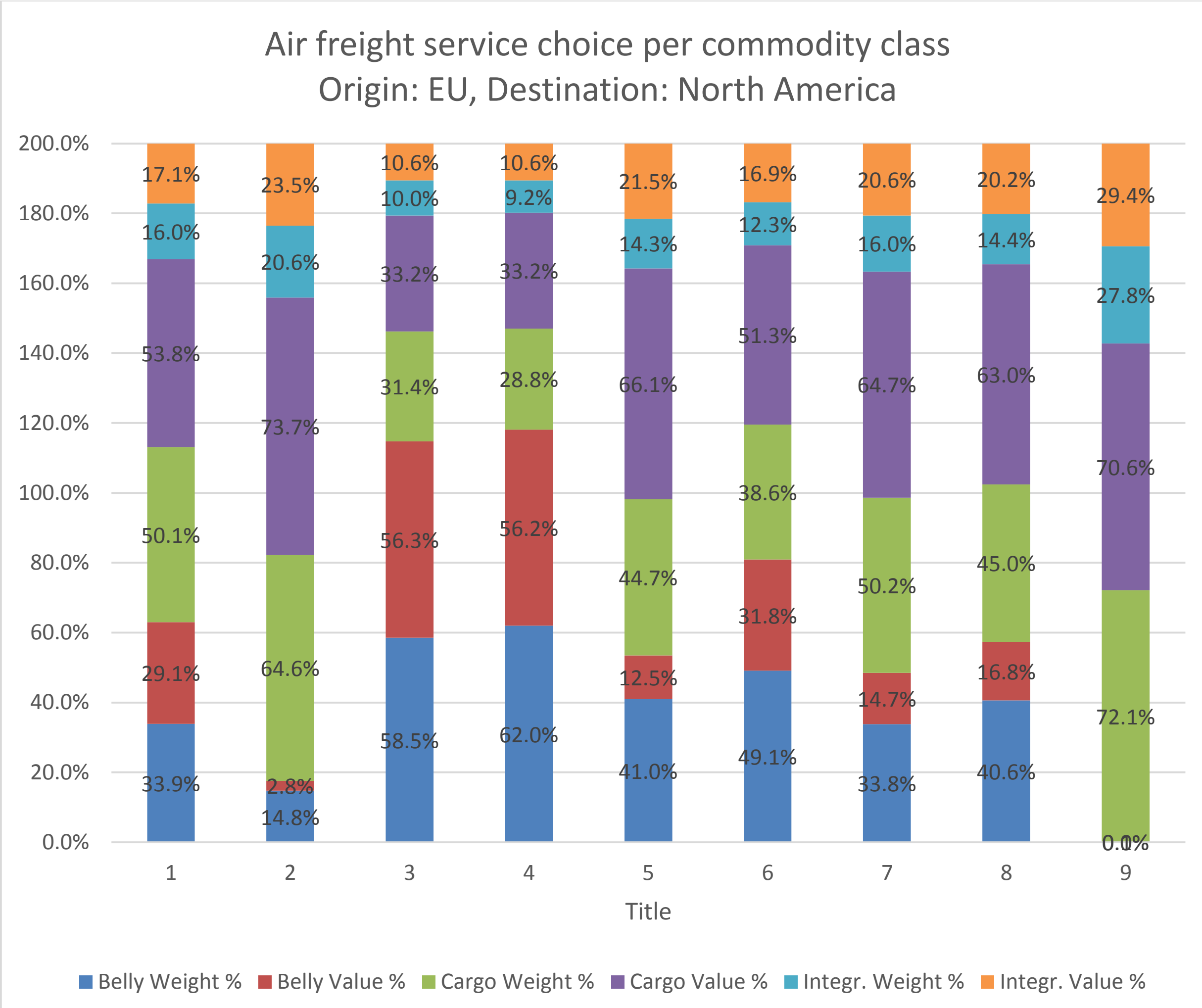

Air freight service choice per commodity class
Origin: EU, Destination: Middle East
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Title
16.1%
13.9%
56.1%
48.7%
27.8%
37.4%
19.0%
14.8%
66.4%
51.8%
14.7%
33.3%
12.3%
10.1%
42.9%
35.2%
44.8%
54.7%
10.4%
10.3%
36.3%
35.9%
53.4%
53.8%
20.5%
16.5%
71.5%
57.7%
8.1%
25.7%
12.8%
9.6%
44.2%
33.5%
43.0%
56.9%
18.4%
14.1%
64.2%
49.4%
17.4%
36.5%
23.1%
11.6%
65.0%
40.4%
12.0%
48.0%
29.9%
28.7%
70.1%
70.3%
0.0%
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %


Air freight service choice split
40.5%
16.6%
46.3%
64.1%
13.2%
19.3%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

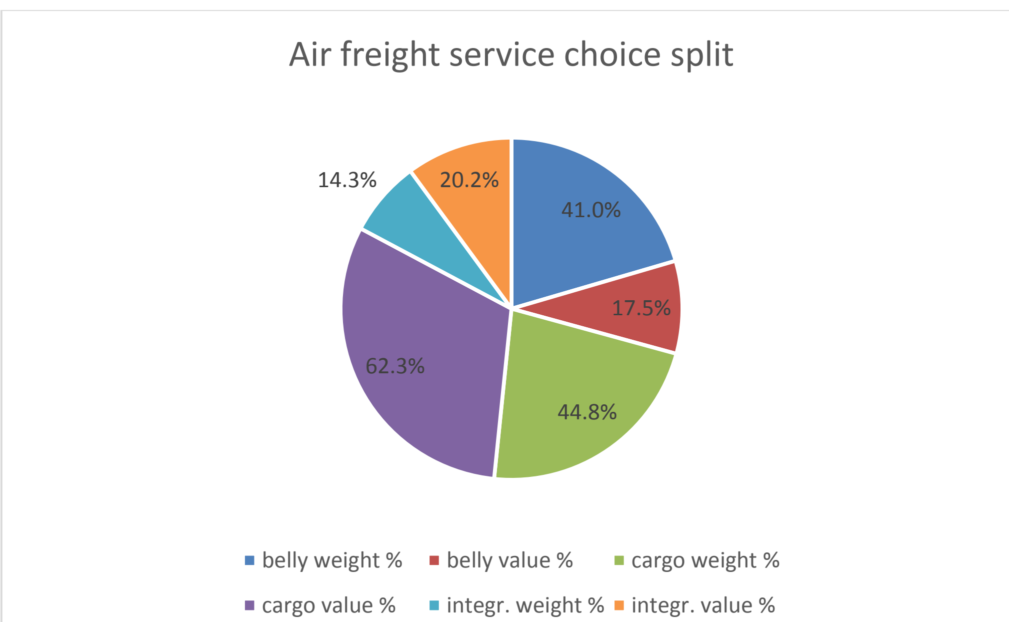
### *To North America*



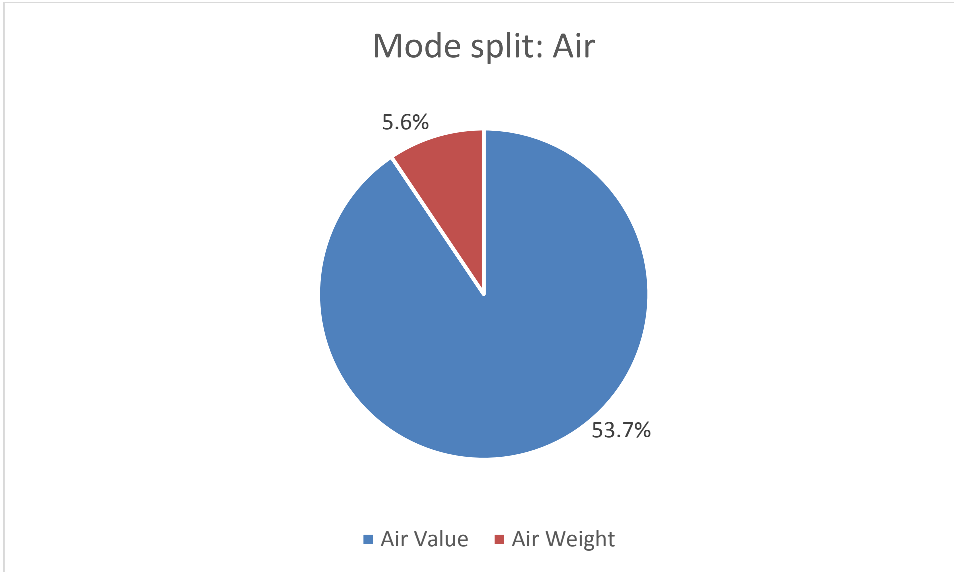


Air freight service choice per commodity class
Origin: EU, Destination: North America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Title
33.9% 29.1% 50.1% 53.8% 16.0% 17.1%
14.8% 2.8% 64.6% 73.7% 20.6% 23.5%
58.5% 56.3% 31.4% 33.2% 10.0% 10.6%
62.0% 56.2% 28.8% 33.2% 9.2% 10.6%
41.0% 12.5% 44.7% 66.1% 14.3% 21.5%
49.1% 31.8% 38.6% 51.3% 12.3% 16.9%
33.8% 14.7% 50.2% 64.7% 16.0% 20.6%
40.6% 16.8% 45.0% 63.0% 14.4% 20.2%
0.0% 0.0% 72.1% 70.6% 27.8% 29.4%
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

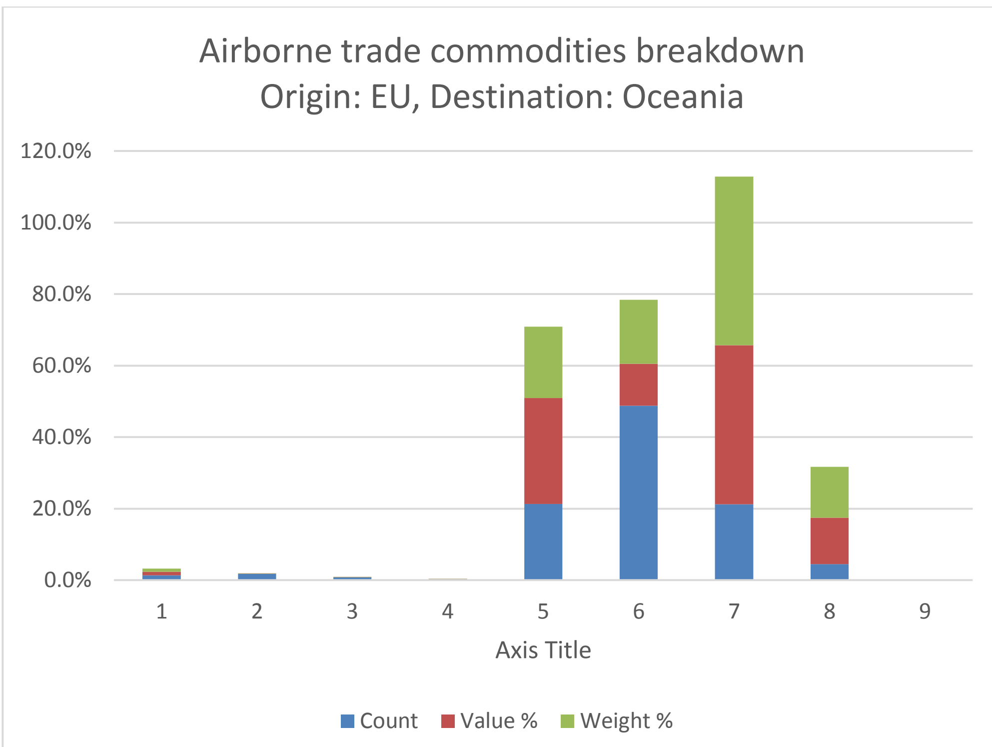



Air freight service choice split
41.0%
17.5%
44.8%
62.3%
14.3%
20.2%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

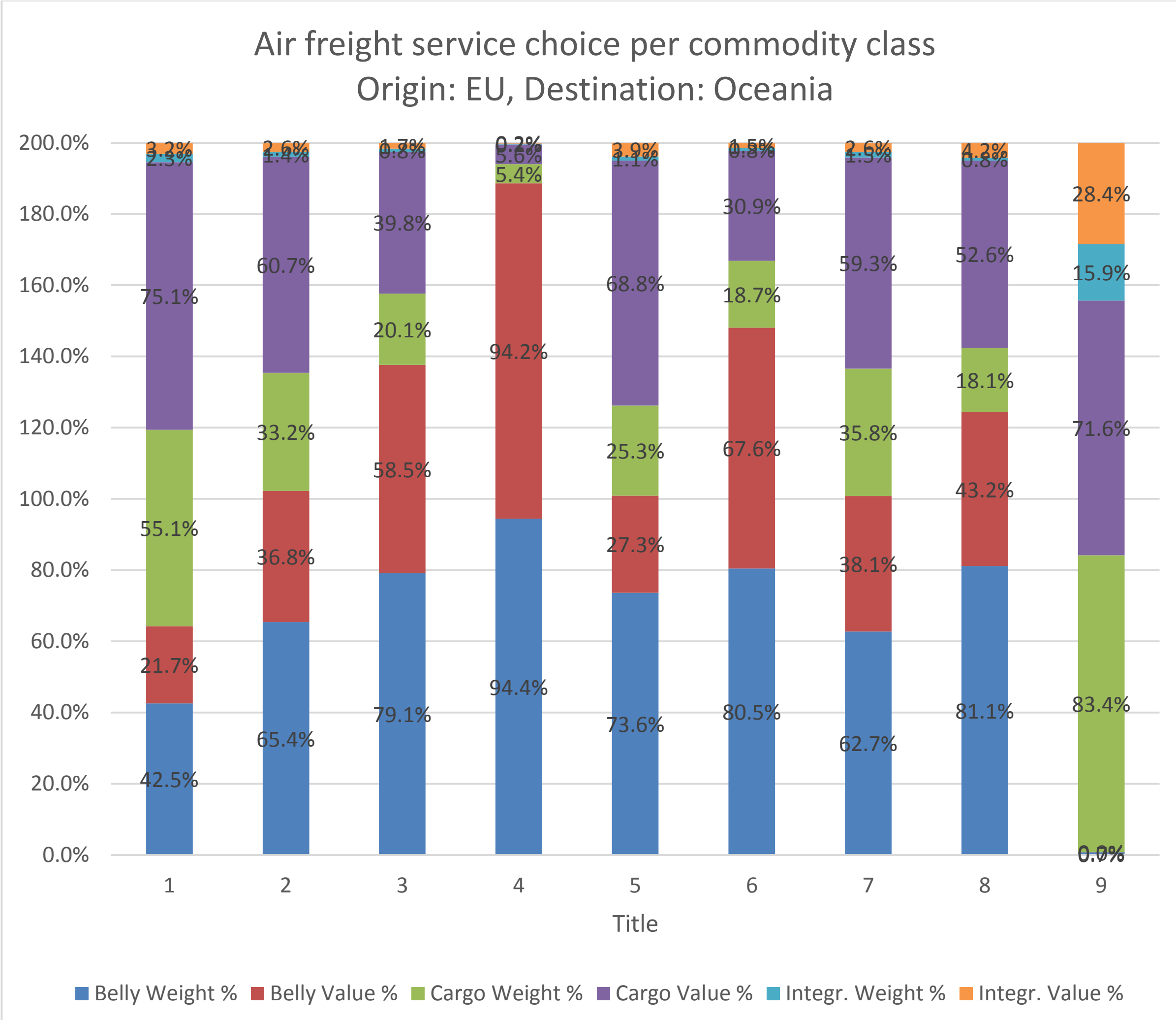
### *To Oceania*

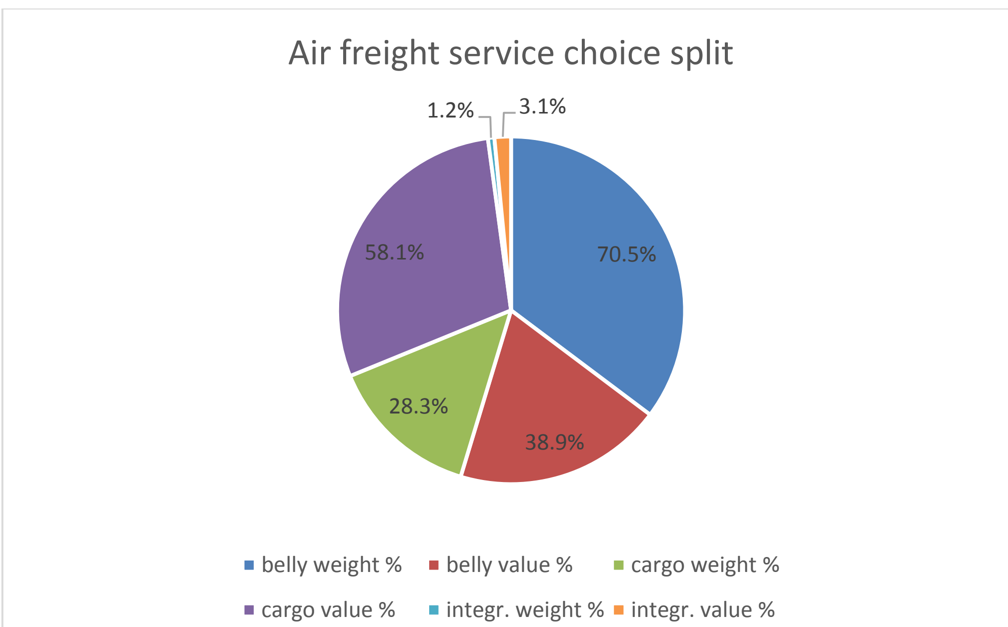


Mode split: Air
5.6%
53.7%
Air Value
Air Weight

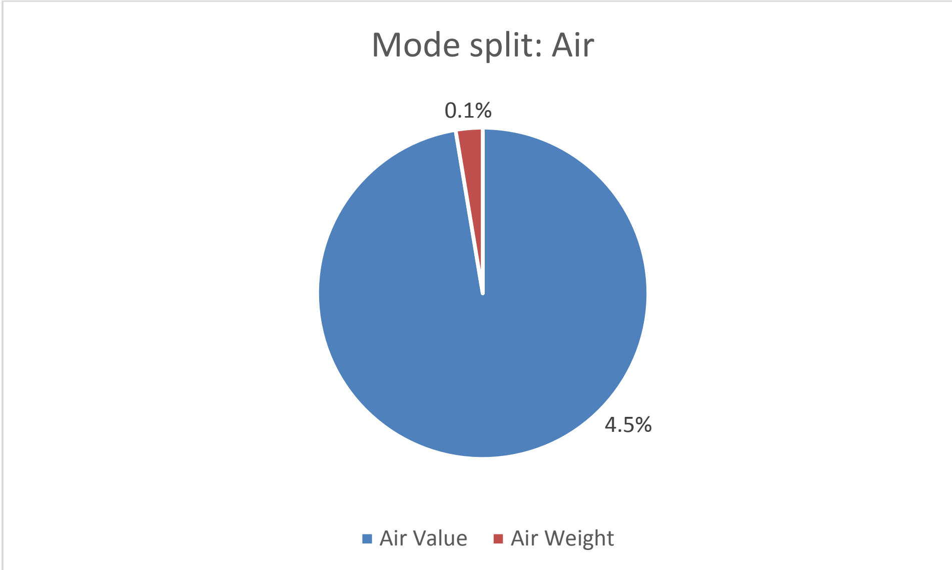
Airborne trade commodities breakdown
Origin: EU, Destination: Oceania
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Axis Title
Count
Value %
Weight %

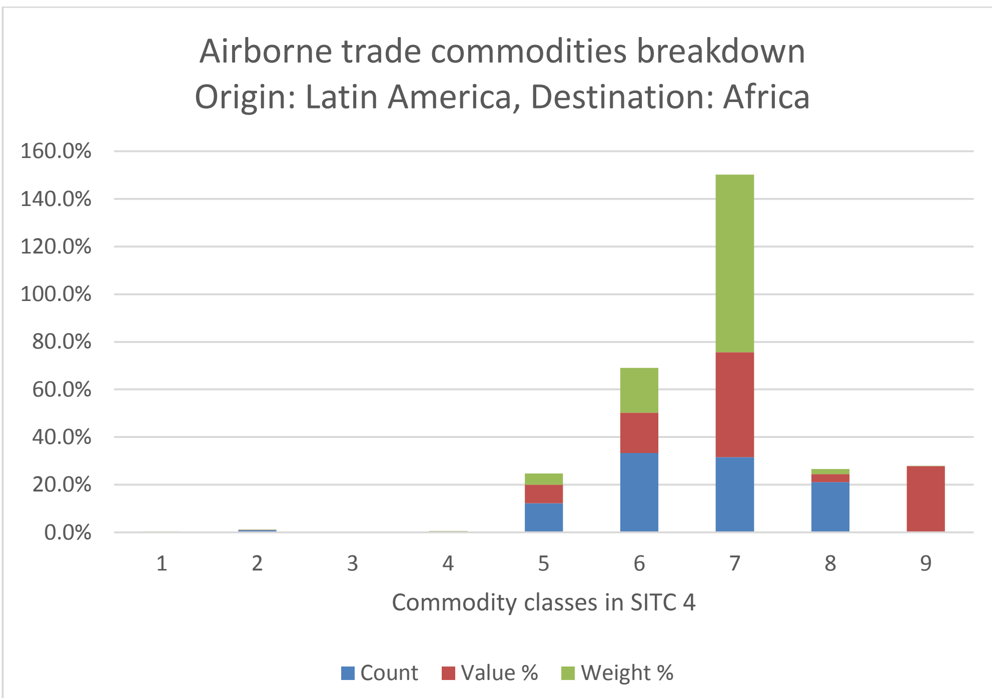

Air freight service choice per commodity class
Origin: EU, Destination: Oceania
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Title
42.5%
21.7%
55.1%
75.1%
2.3%
3.2%
65.4%
36.8%
33.2%
60.7%
1.4%
2.6%
79.1%
58.5%
20.1%
39.8%
0.8%
1.7%
94.4%
94.2%
5.4%
5.6%
0.2%
73.6%
27.3%
25.3%
68.8%
1.1%
2.9%
80.5%
67.6%
18.7%
30.9%
0.8%
1.5%
62.7%
38.1%
35.8%
59.3%
1.5%
2.6%
81.1%
43.2%
18.1%
52.6%
0.8%
4.2%
83.4%
71.6%
15.9%
28.4%
0.0%
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %


Air freight service choice split
1.2%
3.1%
70.5%
38.9%
28.3%
58.1%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

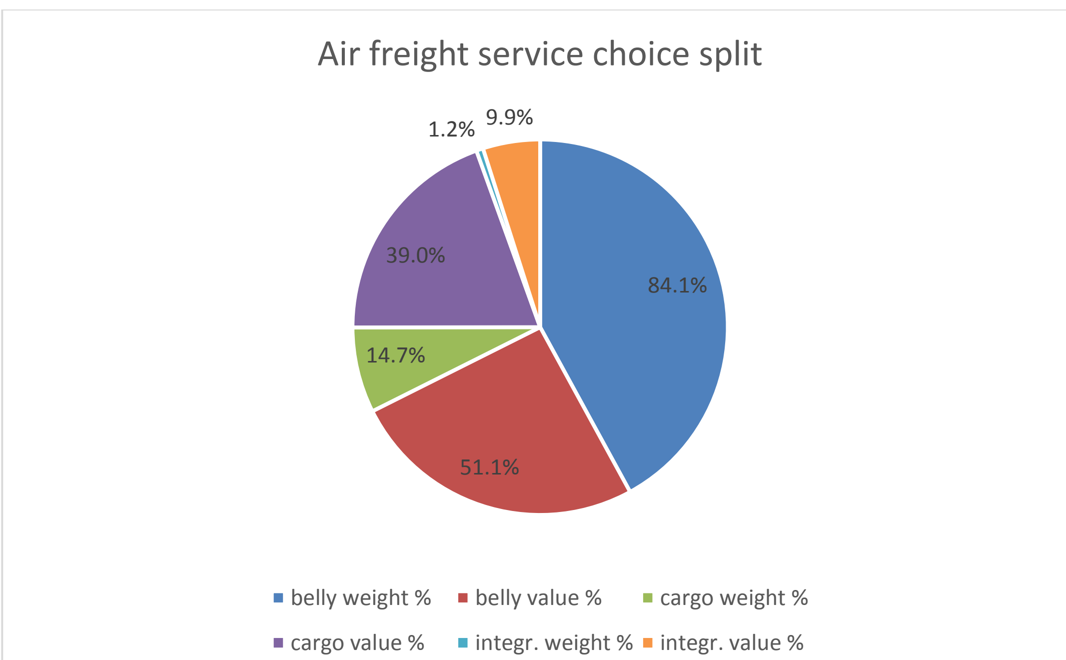
## Latin America

### *To Africa*

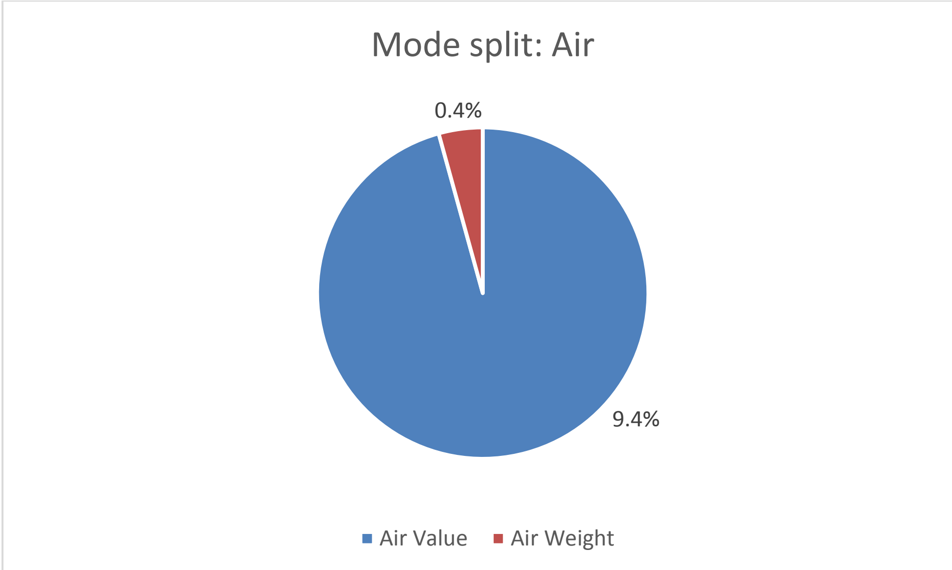


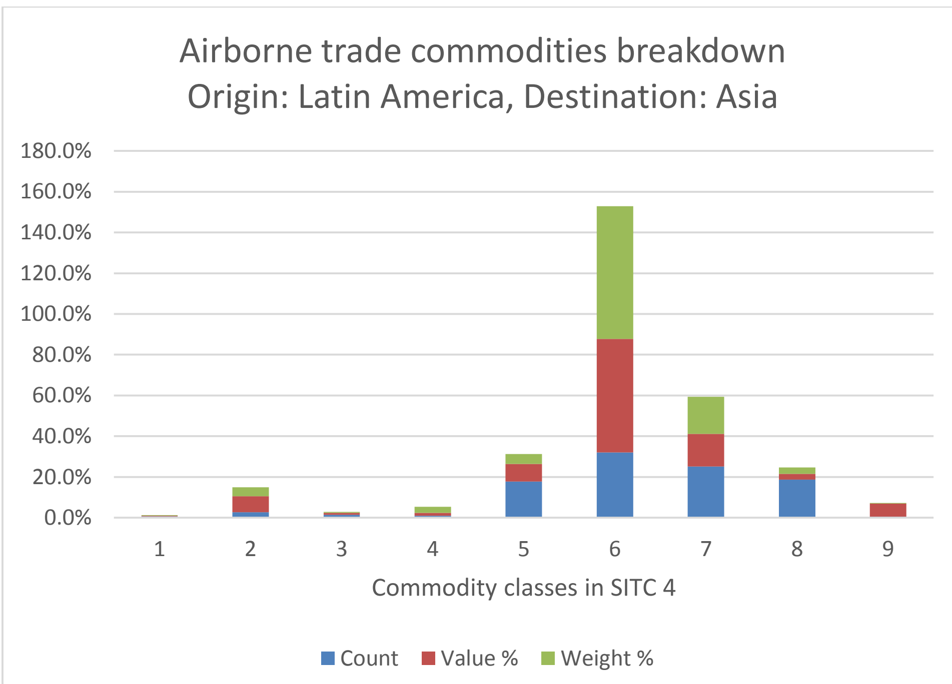



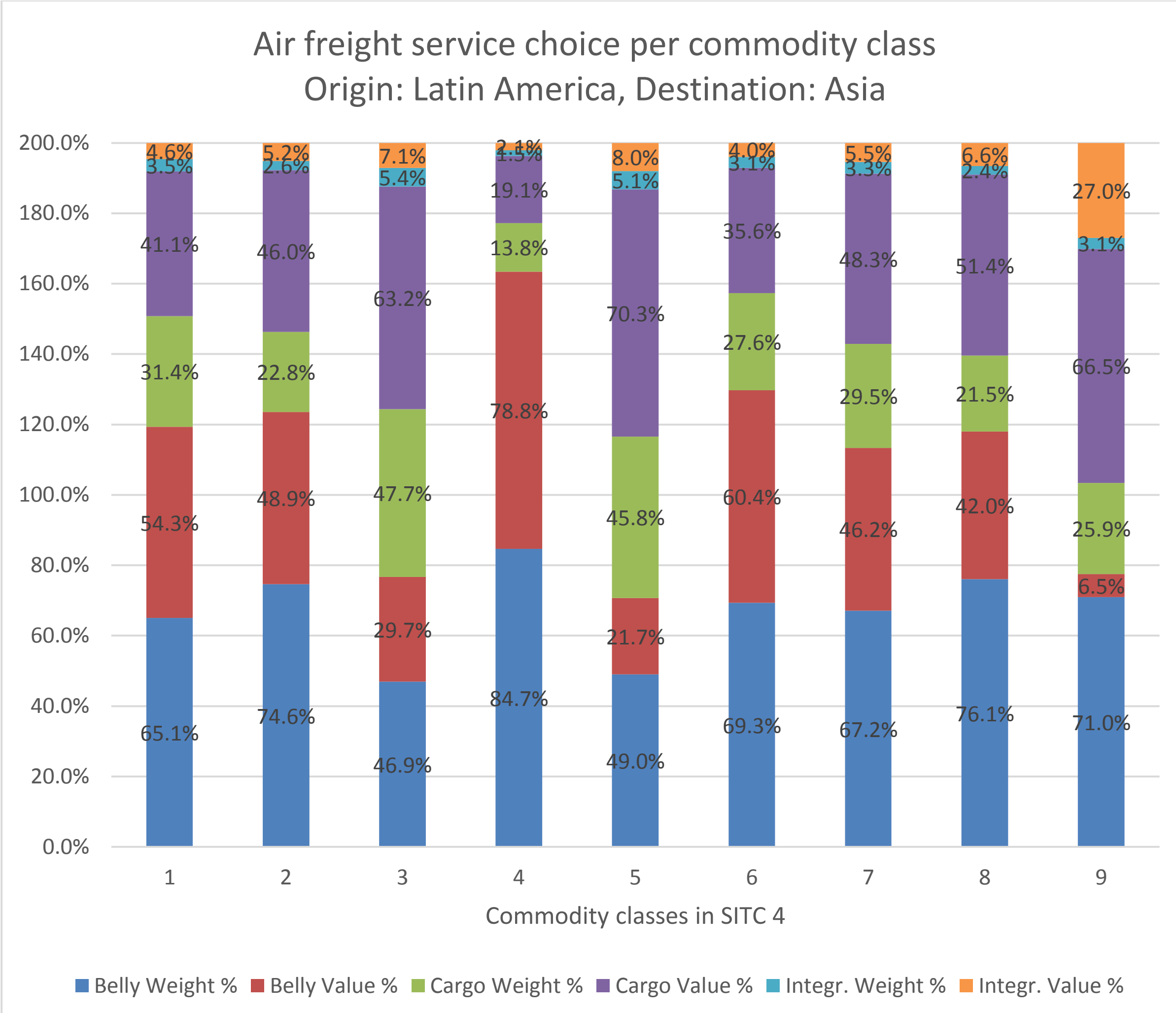

Air freight service choice per commodity class
Origin: Latin America, Destination: Africa
Commodity classes in SITC 4
Belly Weight % Belly Value % Cargo Weight % Cargo Value % Integr. Weight % Integr. Value %


Air freight service choice split
84.1%
51.1%
14.7%
39.0%
1.2%
9.9%
belly weight % belly value % cargo weight %
cargo value % integr. weight % integr. value %

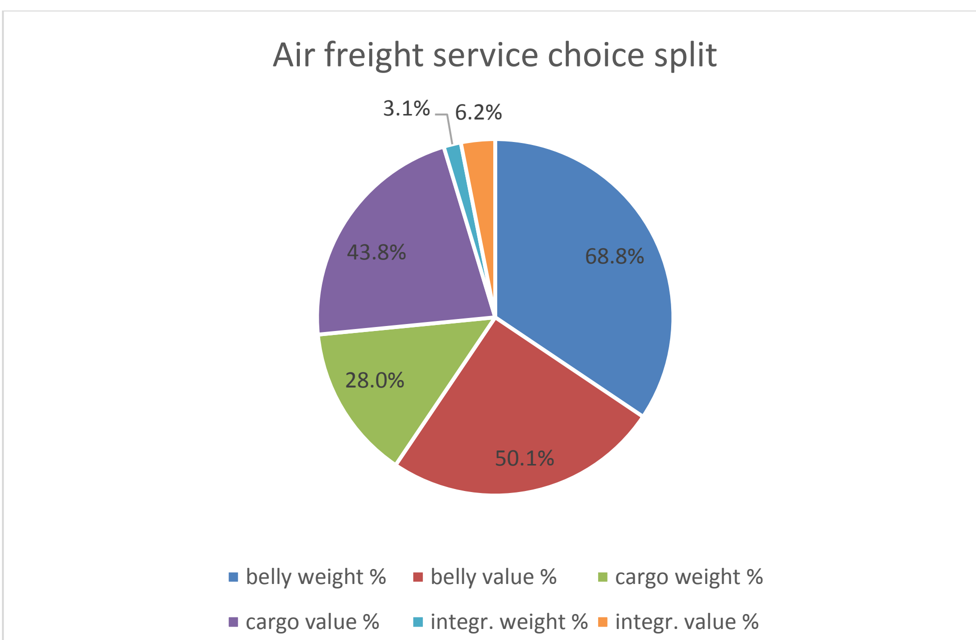
*To Asia*


Mode split: Air
0.4%
9.4%
Air Value
Air Weight


Airborne trade commodities breakdown
Origin: Latin America, Destination: Asia
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

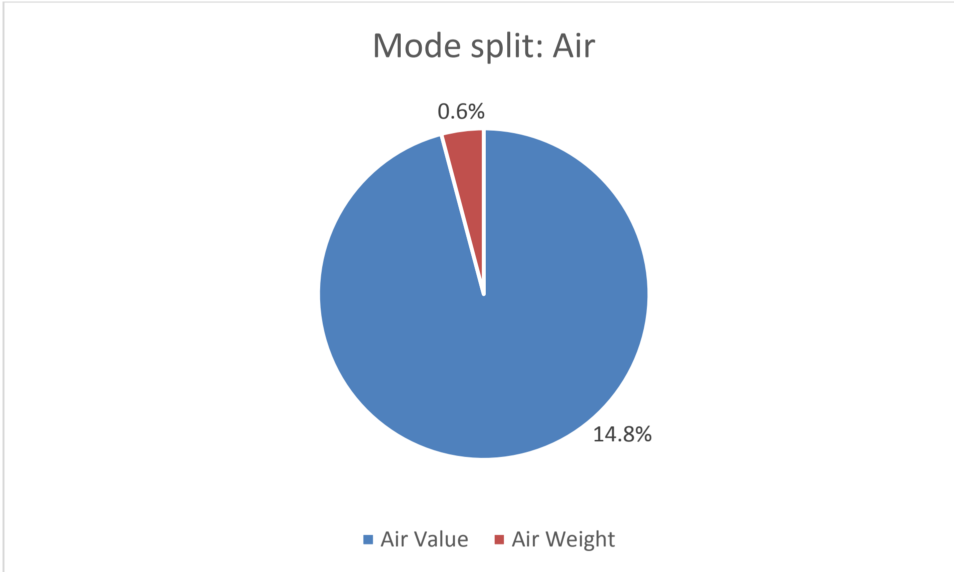


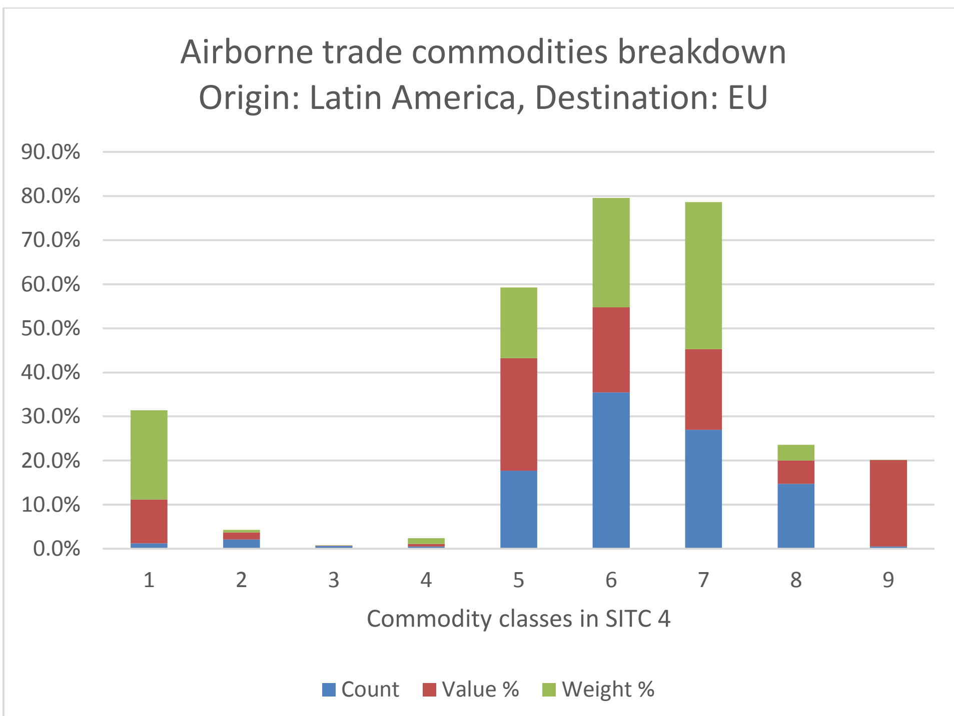
Air freight service choice per commodity class
Origin: Latin America, Destination: Asia
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
65.1%
54.3%
31.4%
41.1%
3.5%
4.6%
74.6%
48.9%
22.8%
46.0%
2.6%
5.2%
46.9%
29.7%
47.7%
63.2%
5.4%
7.1%
84.7%
78.8%
13.8%
19.1%
1.5%
2.1%
49.0%
21.7%
45.8%
70.3%
5.1%
8.0%
69.3%
60.4%
27.6%
35.6%
3.1%
4.0%
67.2%
46.2%
29.5%
48.3%
3.3%
5.5%
76.1%
42.0%
21.5%
51.4%
2.4%
6.6%
71.0%
6.5%
25.9%
66.5%
3.1%
27.0%
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

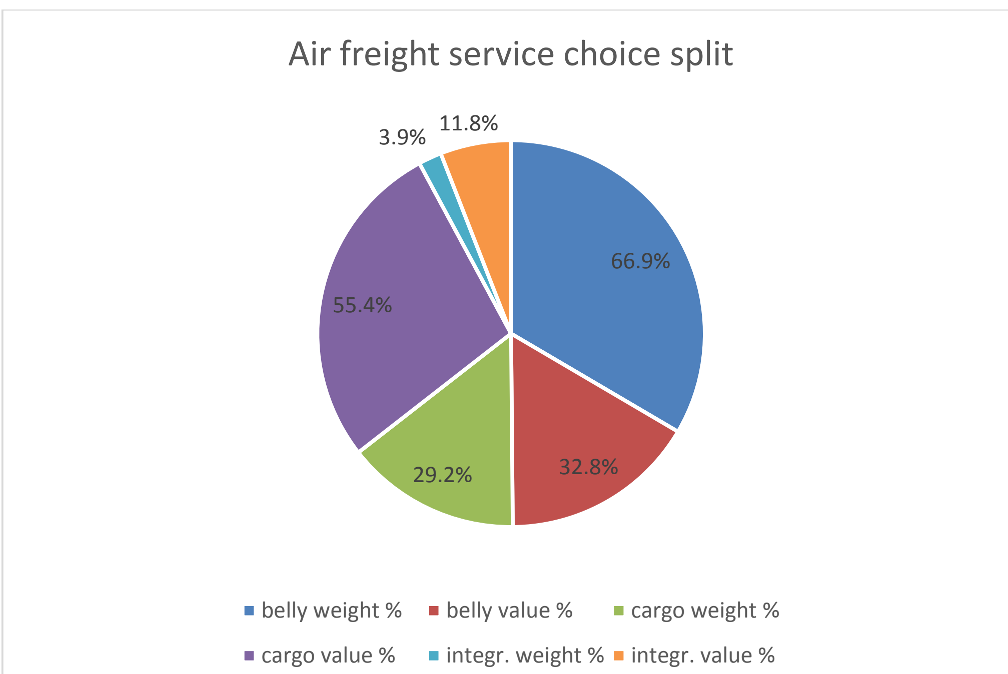
Air freight service choice split
68.8%
50.1%
28.0%
43.8%
3.1%
6.2%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To Europe*

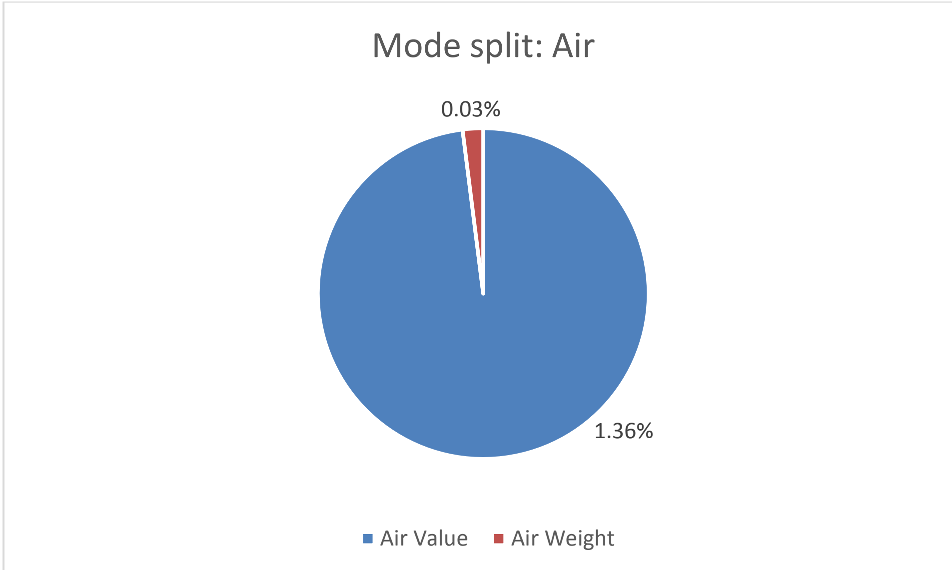

Mode split: Air
0.6%
14.8%
Air Value
Air Weight

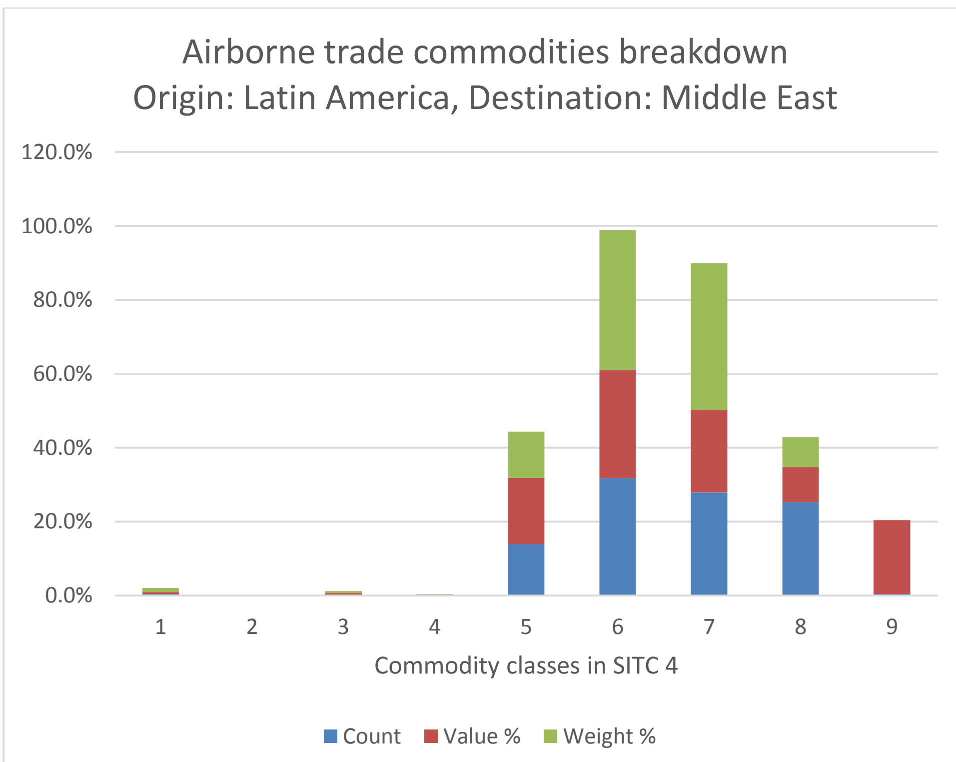

Airborne trade commodities breakdown
Origin: Latin America, Destination: EU
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

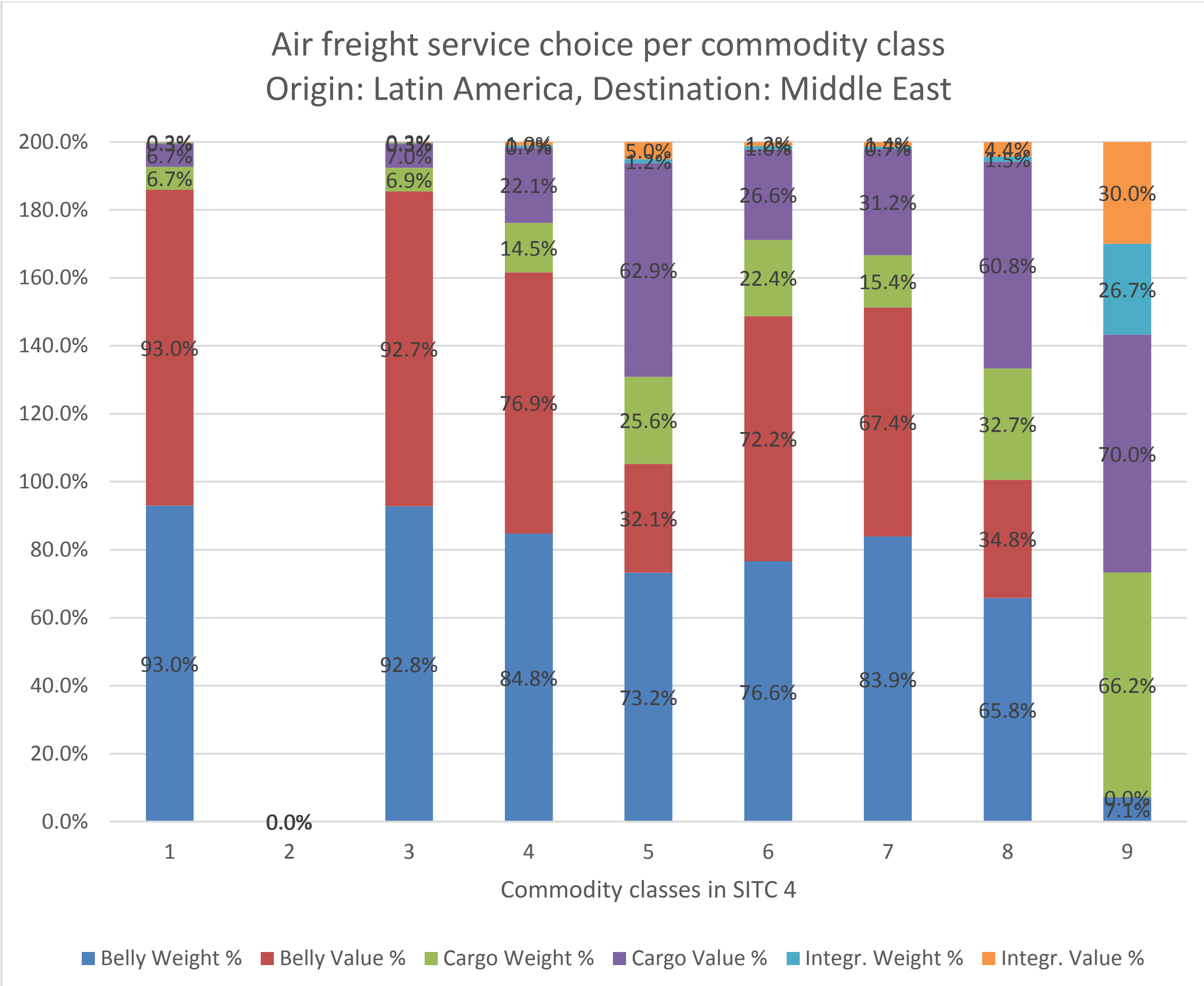

Air freight service choice per commodity class
Origin: Latin America, Destination: EU
Commodity classes in SITC 4
Belly Weight % Belly Value % Cargo Weight % Cargo Value % Integr. Weight % Integr. Value %

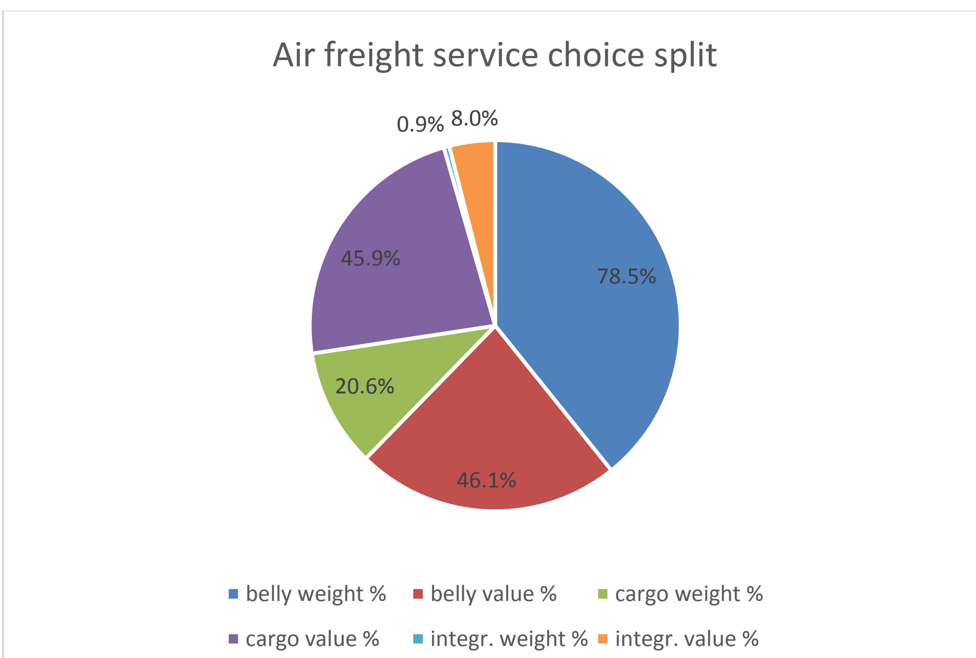

Air freight service choice split
66.9%
32.8%
29.2%
55.4%
3.9%
11.8%
belly weight % belly value % cargo weight %
cargo value % integr. weight % integr. value %

### *To Middle East*

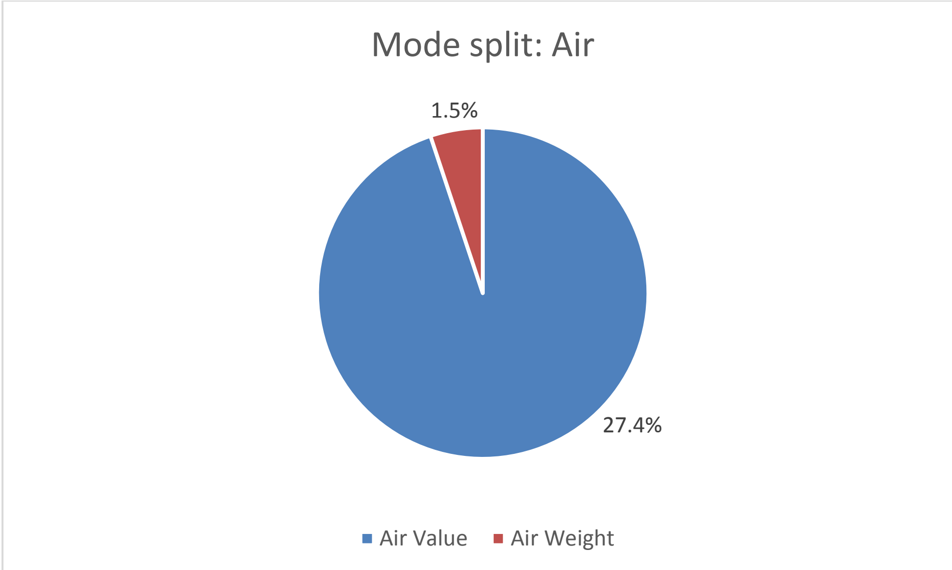


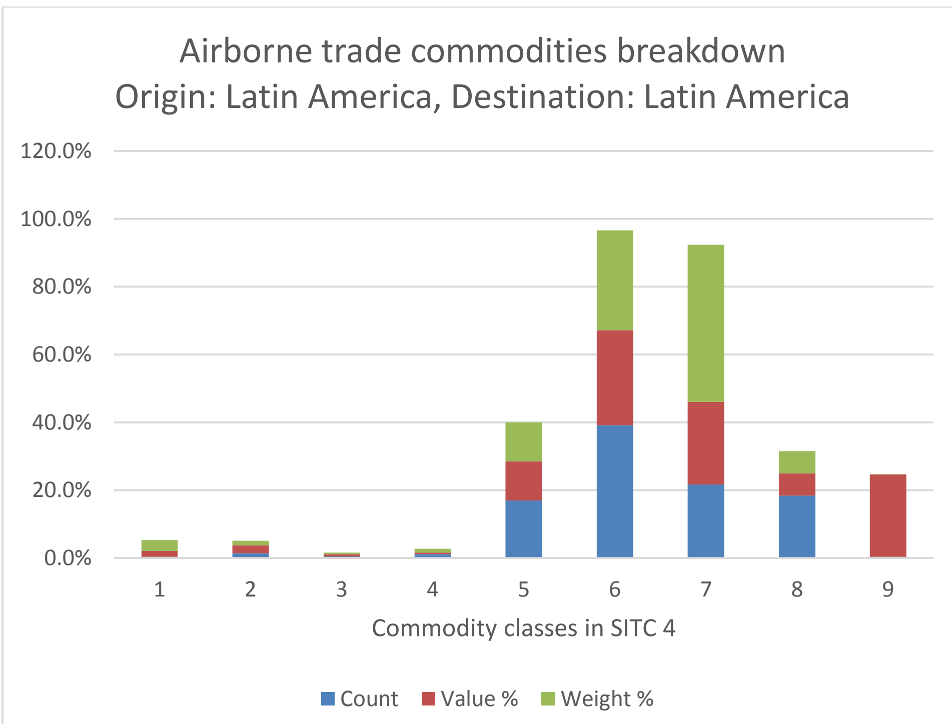



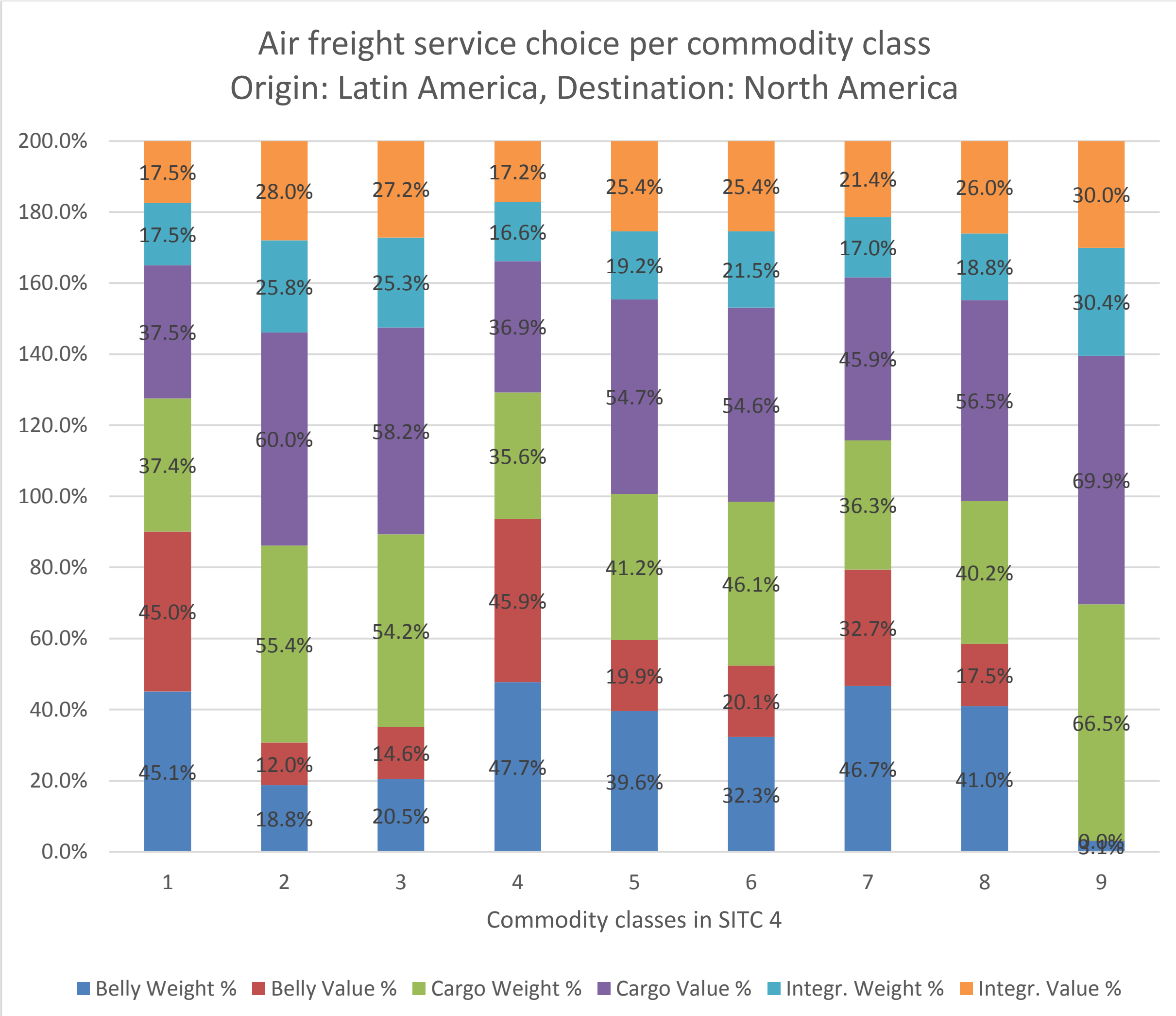

Air freight service choice per commodity class
Origin: Latin America, Destination: Middle East
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
93.0%
93.0%
6.7%
6.7%
0.3%
0.0%
92.8%
92.7%
6.9%
7.0%
0.3%
84.8%
76.9%
14.5%
22.1%
73.2%
32.1%
25.6%
62.9%
1.2%
5.0%
76.6%
72.2%
22.4%
26.6%
83.9%
67.4%
15.4%
31.2%
65.8%
34.8%
32.7%
60.8%
1.5%
4.4%
7.1%
0.0%
66.2%
70.0%
26.7%
30.0%
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

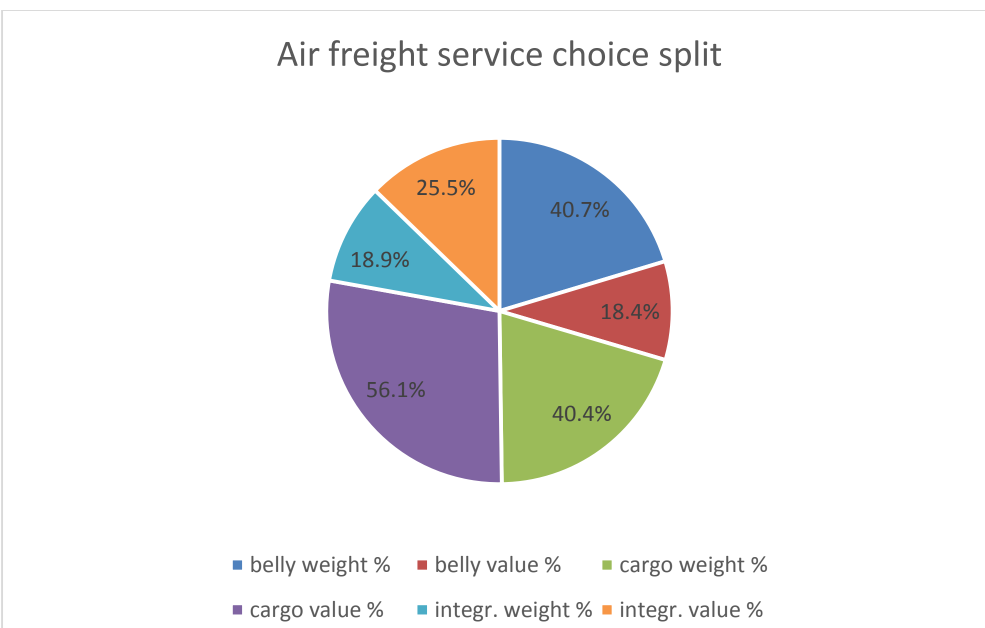

Air freight service choice split
0.9%
8.0%
78.5%
46.1%
20.6%
45.9%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To North America*

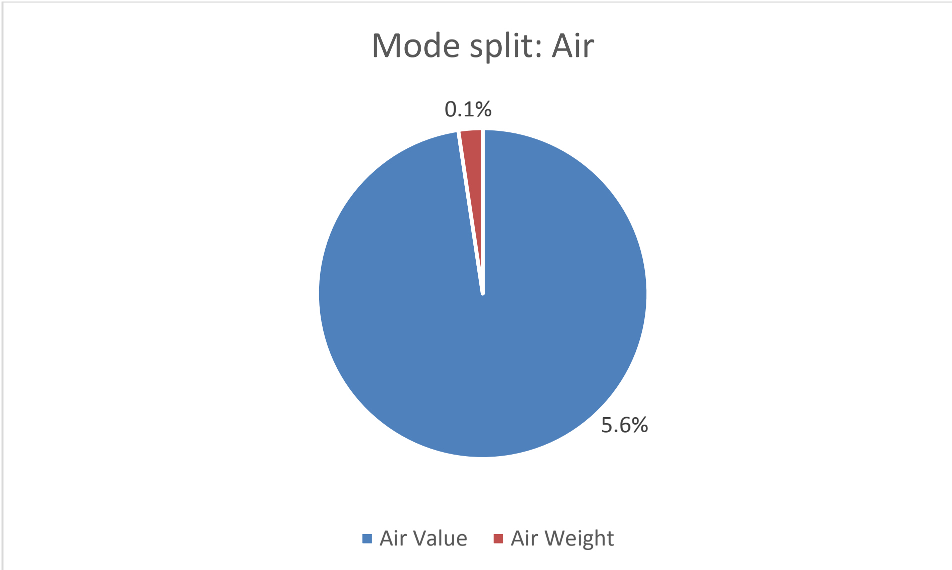


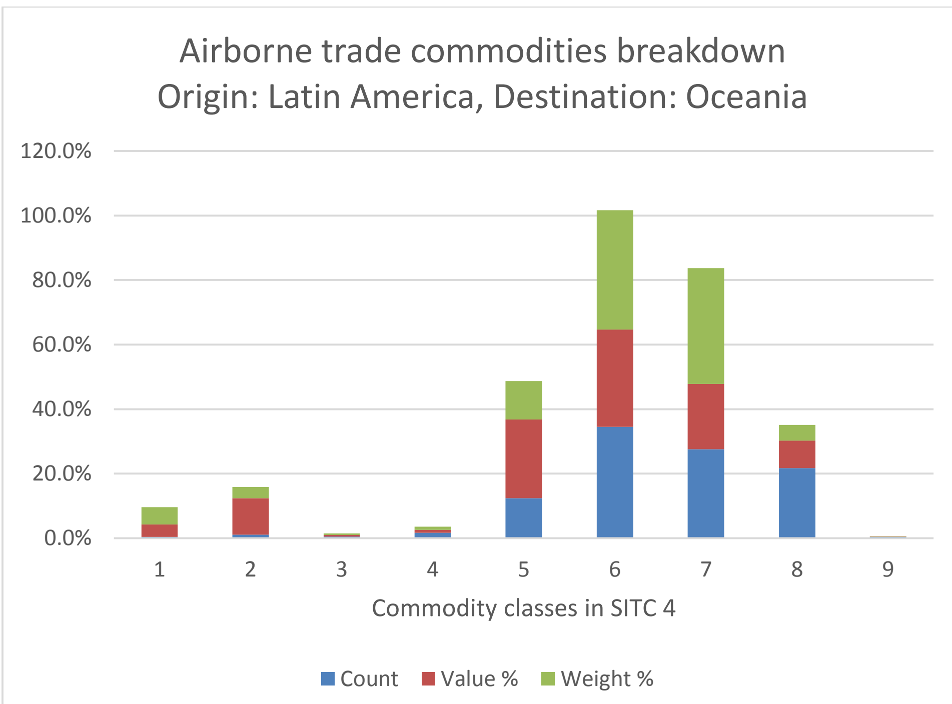



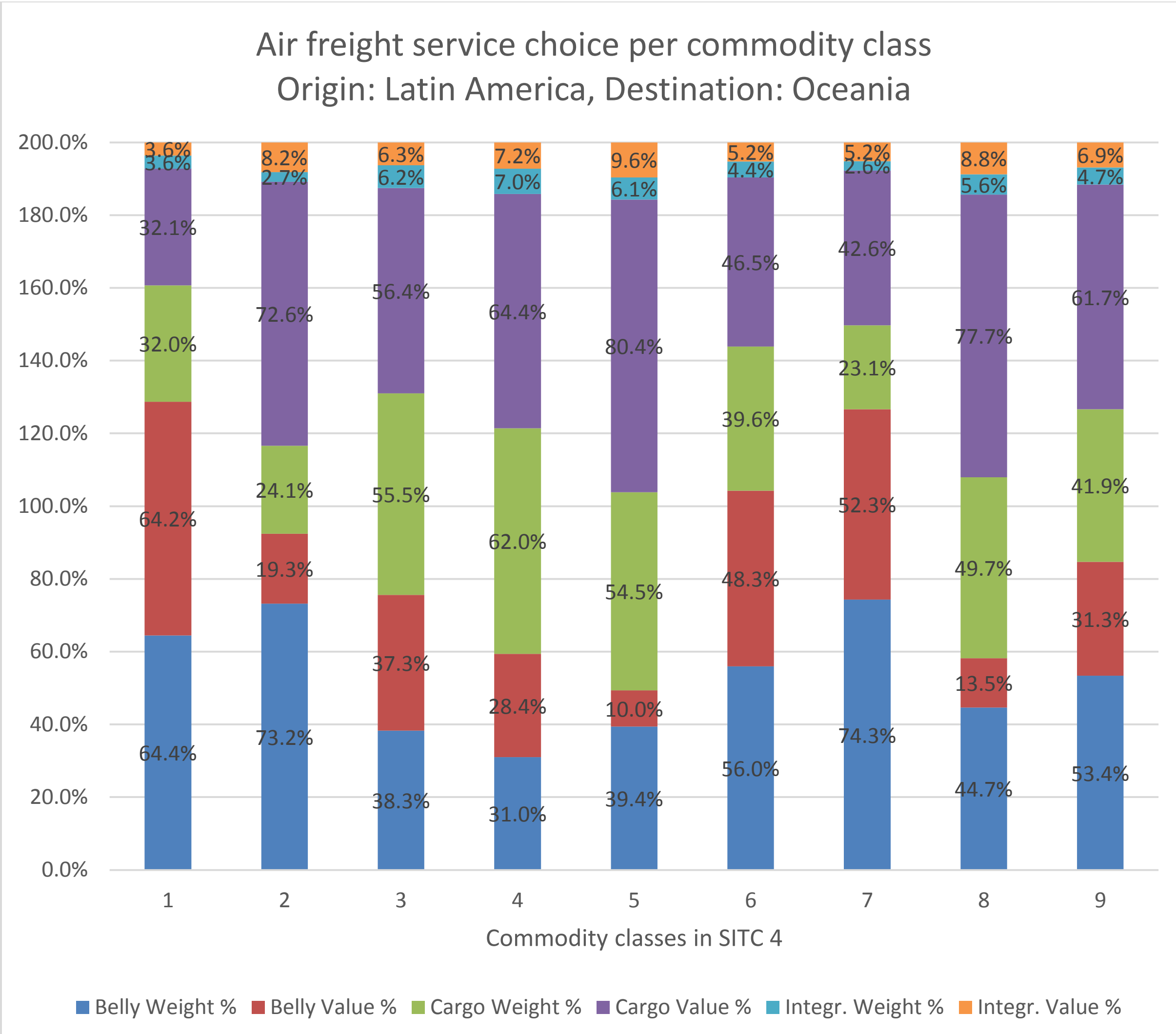

Air freight service choice per commodity class
Origin: Latin America, Destination: North America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %
17.5% 17.5% 37.5% 37.4% 45.0% 45.1%
28.0% 25.8% 60.0% 55.4% 12.0% 18.8%
27.2% 25.3% 58.2% 54.2% 14.6% 20.5%
17.2% 16.6% 36.9% 35.6% 45.9% 47.7%
25.4% 19.2% 54.7% 41.2% 19.9% 39.6%
25.4% 21.5% 54.6% 46.1% 20.1% 32.3%
21.4% 17.0% 45.9% 36.3% 32.7% 46.7%
26.0% 18.8% 56.5% 40.2% 17.5% 41.0%
30.0% 30.4% 69.9% 66.5% 0.0% 3.1%


Air freight service choice split
40.7%
18.4%
40.4%
56.1%
18.9%
25.5%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

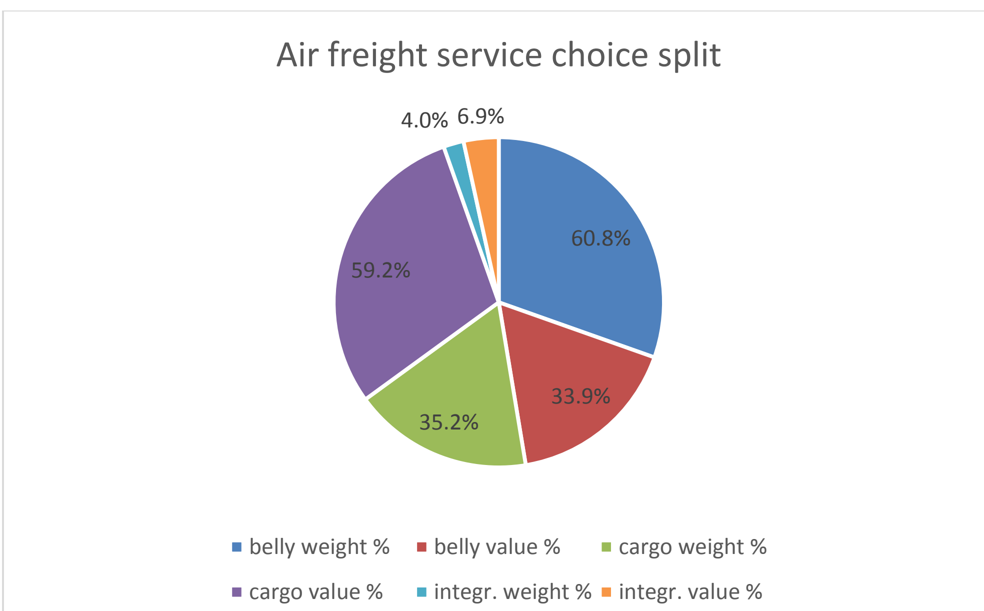
### *To Oceania*


Mode split: Air
0.1%
5.6%
Air Value
Air Weight


Airborne trade commodities breakdown
Origin: Latin America, Destination: Oceania
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %



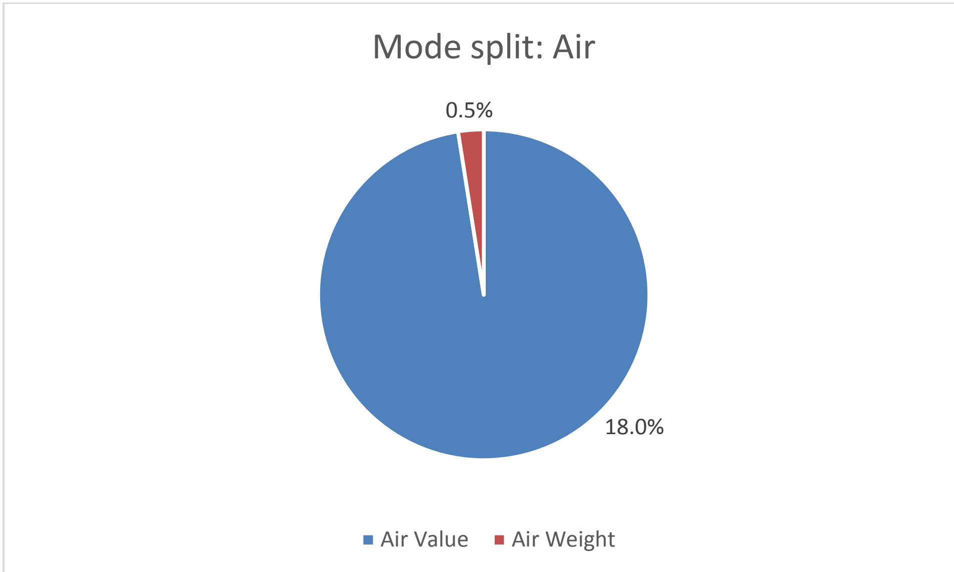
Air freight service choice per commodity class
Origin: Latin America, Destination: Oceania
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight % Belly Value % Cargo Weight % Cargo Value % Integr. Weight % Integr. Value %

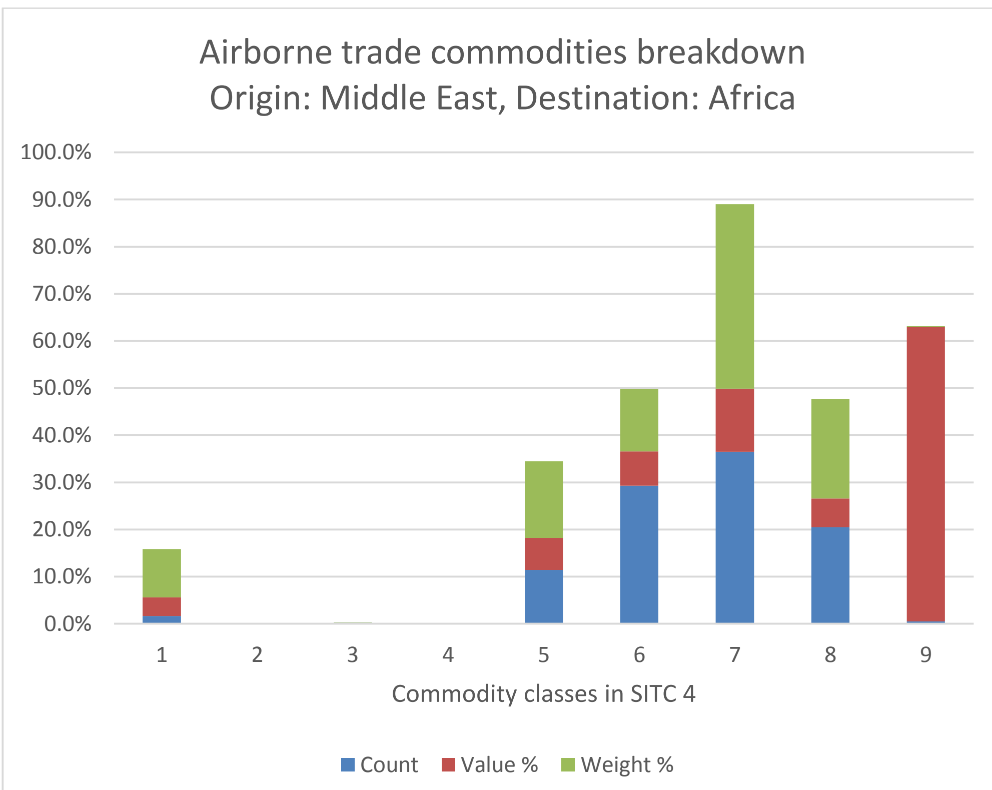



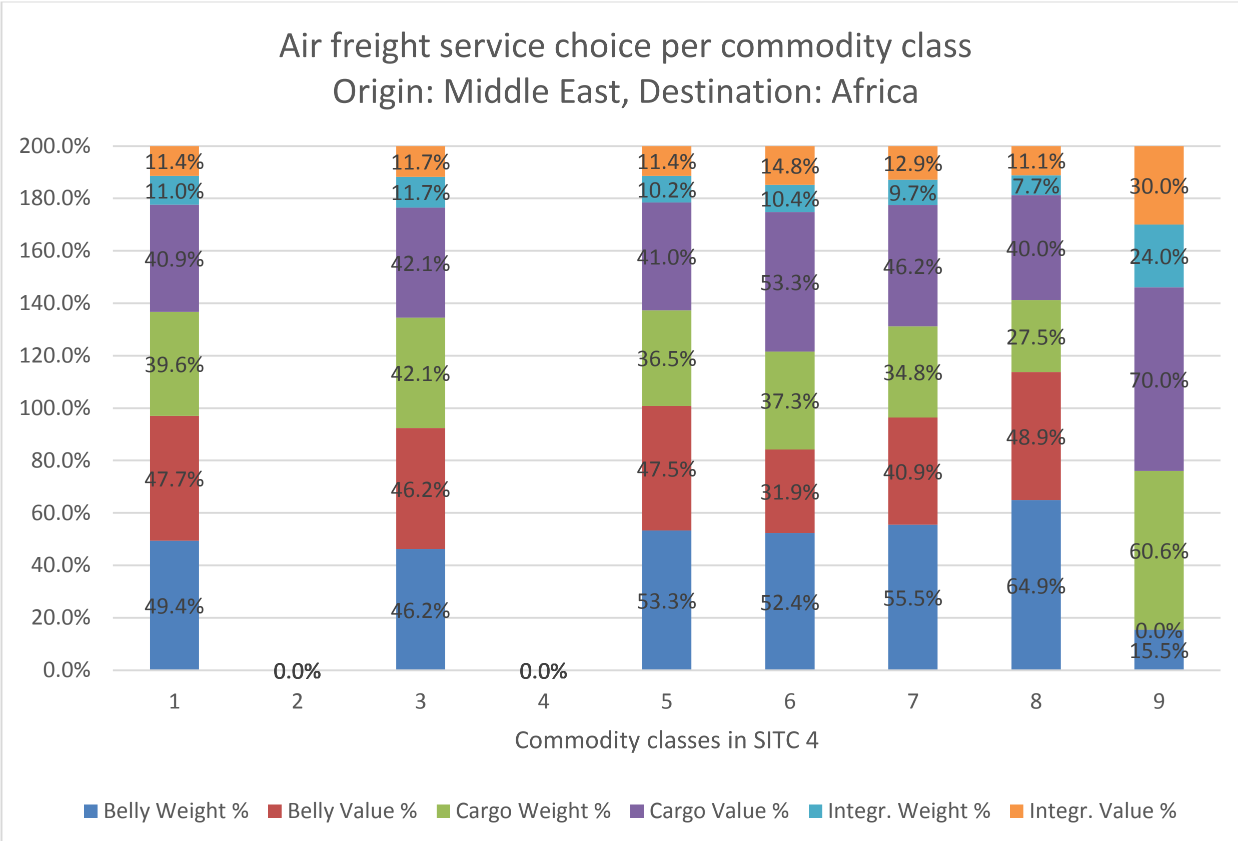
Air freight service choice split
60.8%
33.9%
35.2%
59.2%
4.0%
6.9%
belly weight % belly value % cargo weight %
cargo value % integr. weight % integr. value %

## Middle East

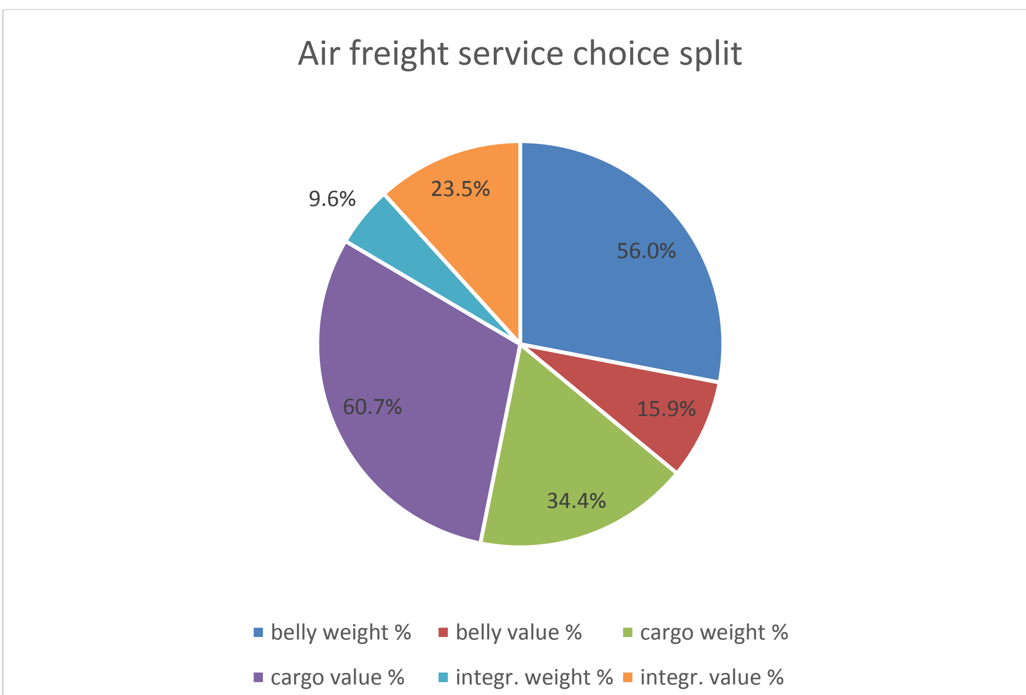
### *To Africa*



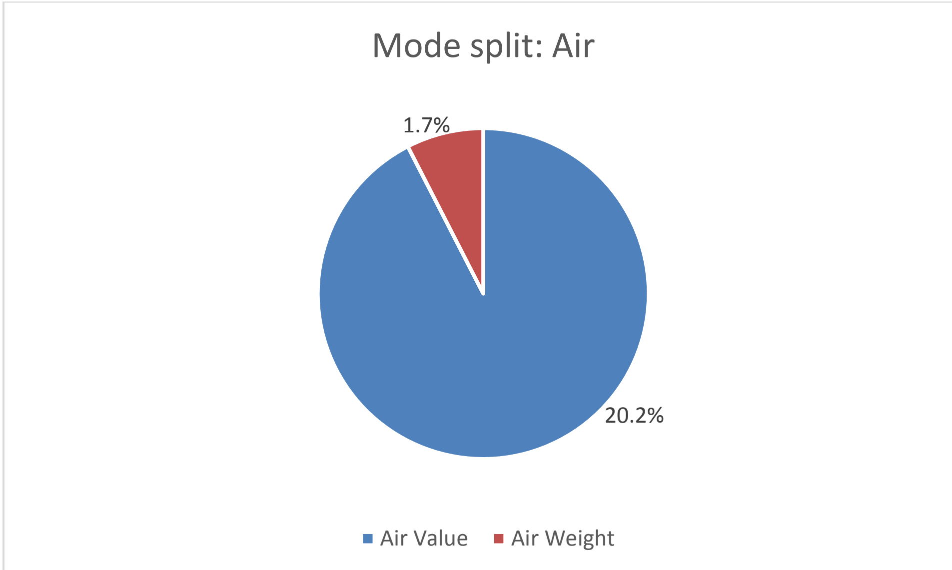


Air freight service choice per commodity class
Origin: Middle East, Destination: Africa
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
11.4%
11.0%
40.9%
39.6%
47.7%
49.4%
0.0%
11.7%
11.7%
42.1%
42.1%
46.2%
46.2%
0.0%
11.4%
10.2%
41.0%
36.5%
47.5%
53.3%
14.8%
10.4%
53.3%
37.3%
31.9%
52.4%
12.9%
9.7%
46.2%
34.8%
40.9%
55.5%
11.1%
7.7%
40.0%
27.5%
48.9%
64.9%
30.0%
24.0%
70.0%
60.6%
0.0%
15.5%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

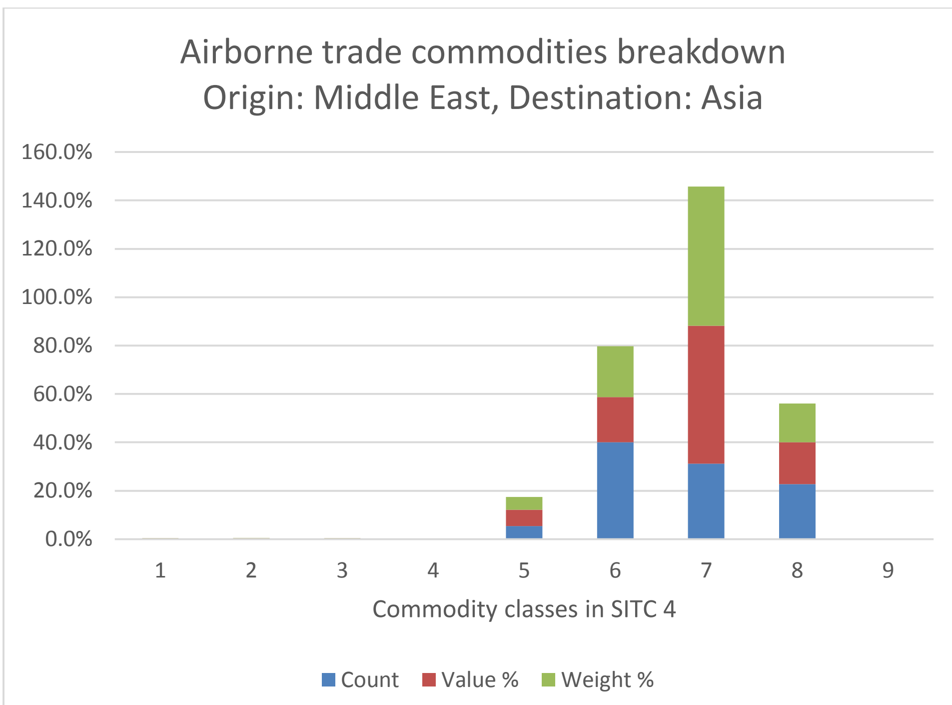



Air freight service choice split
9.6%
23.5%
56.0%
60.7%
15.9%
34.4%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

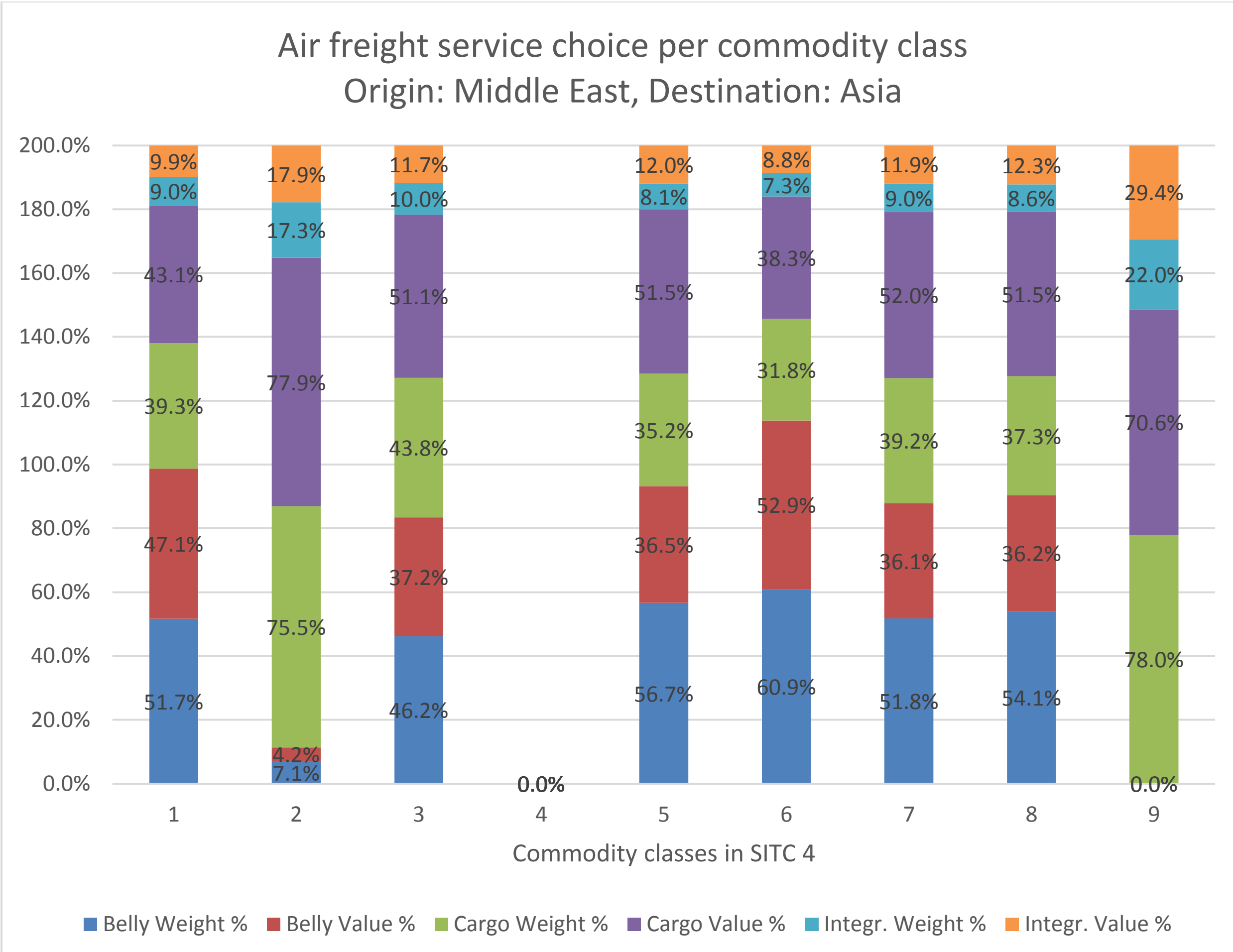
### *To Asia*



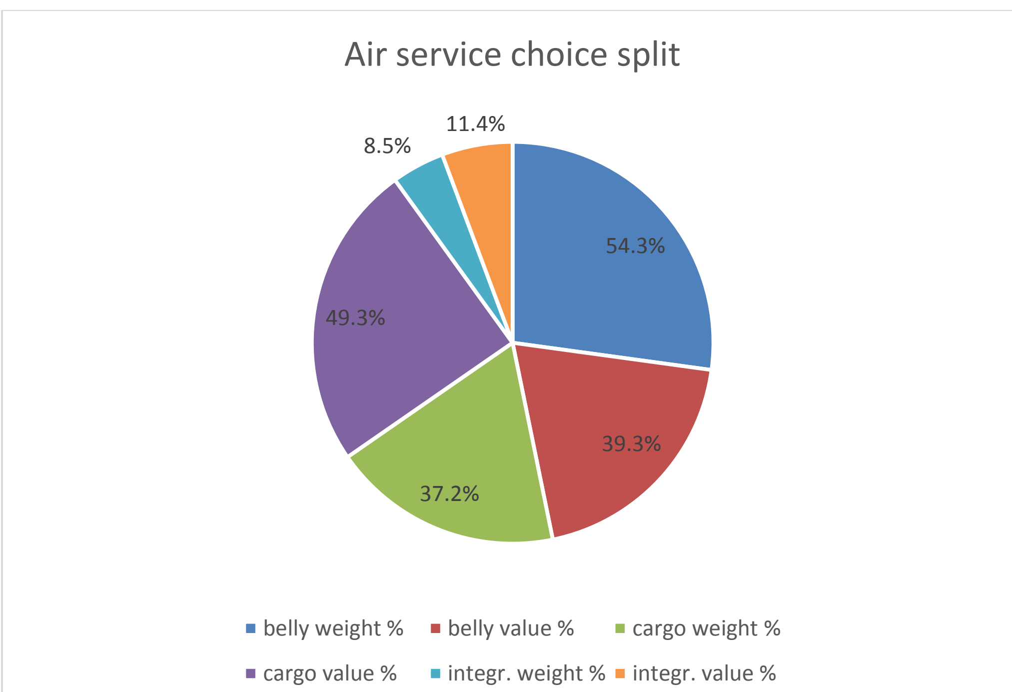
Mode split: Air
1.7%
20.2%
Air Value
Air Weight

Airborne trade commodities breakdown
Origin: Middle East, Destination: Asia
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

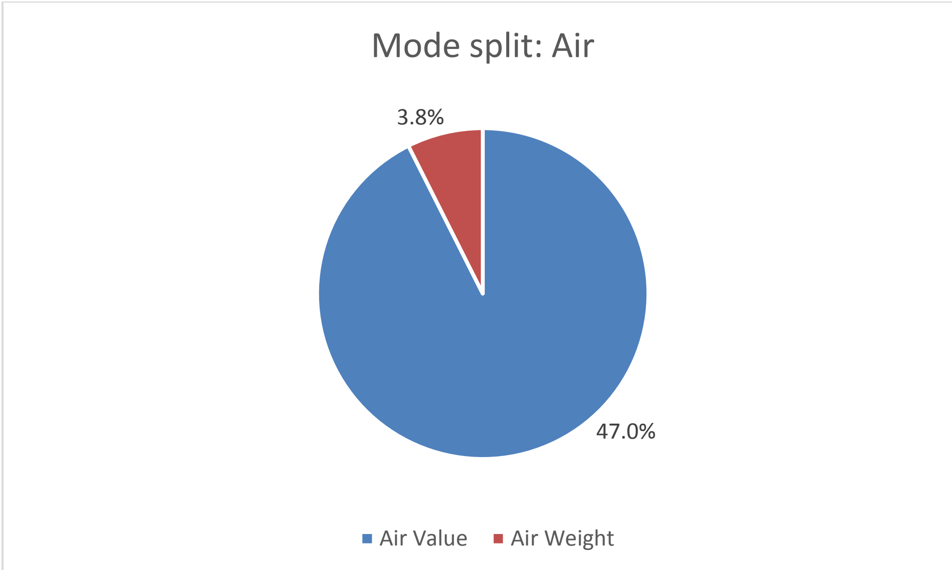


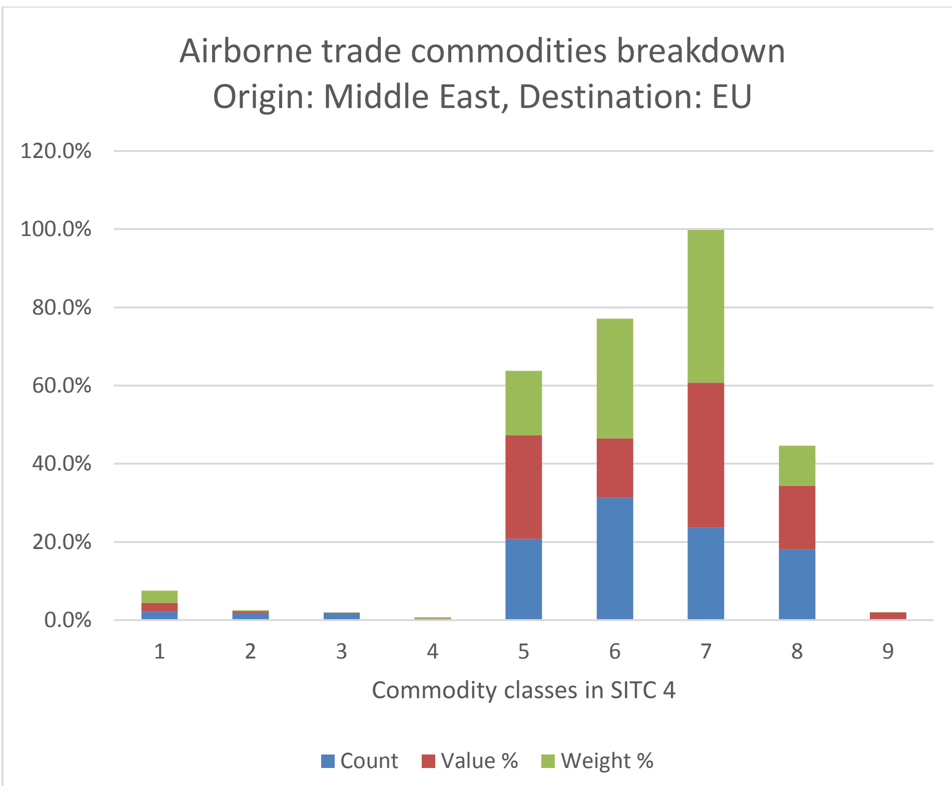
Air freight service choice per commodity class
Origin: Middle East, Destination: Asia
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
9.9%
9.0%
43.1%
39.3%
47.1%
51.7%
17.9%
17.3%
77.9%
75.5%
4.2%
7.1%
11.7%
10.0%
51.1%
43.8%
37.2%
46.2%
0.0%
12.0%
8.1%
51.5%
35.2%
36.5%
56.7%
8.8%
7.3%
38.3%
31.8%
52.9%
60.9%
11.9%
9.0%
52.0%
39.2%
36.1%
51.8%
12.3%
8.6%
51.5%
37.3%
36.2%
54.1%
29.4%
22.0%
70.6%
78.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

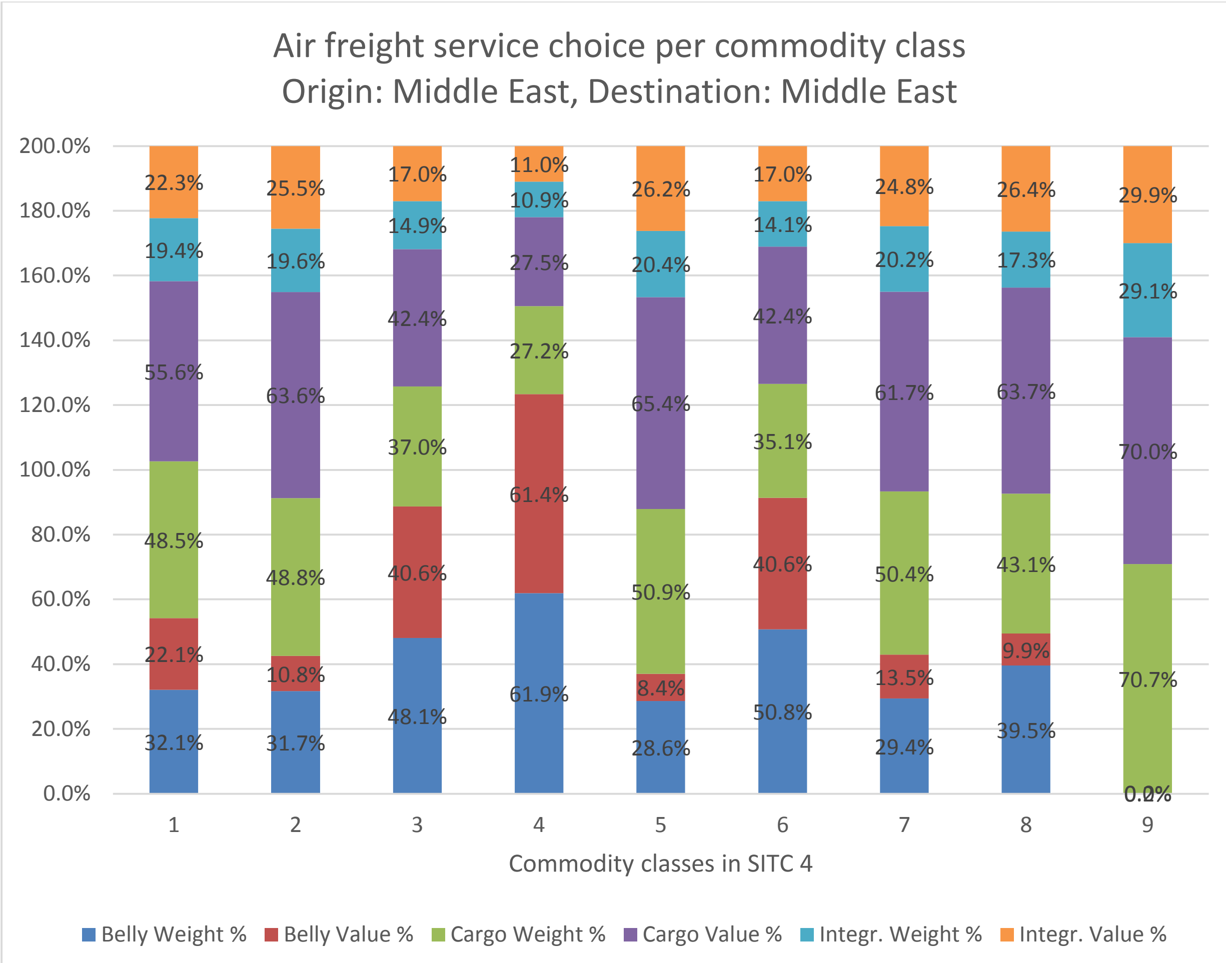



Air service choice split
11.4%
8.5%
54.3%
49.3%
39.3%
37.2%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

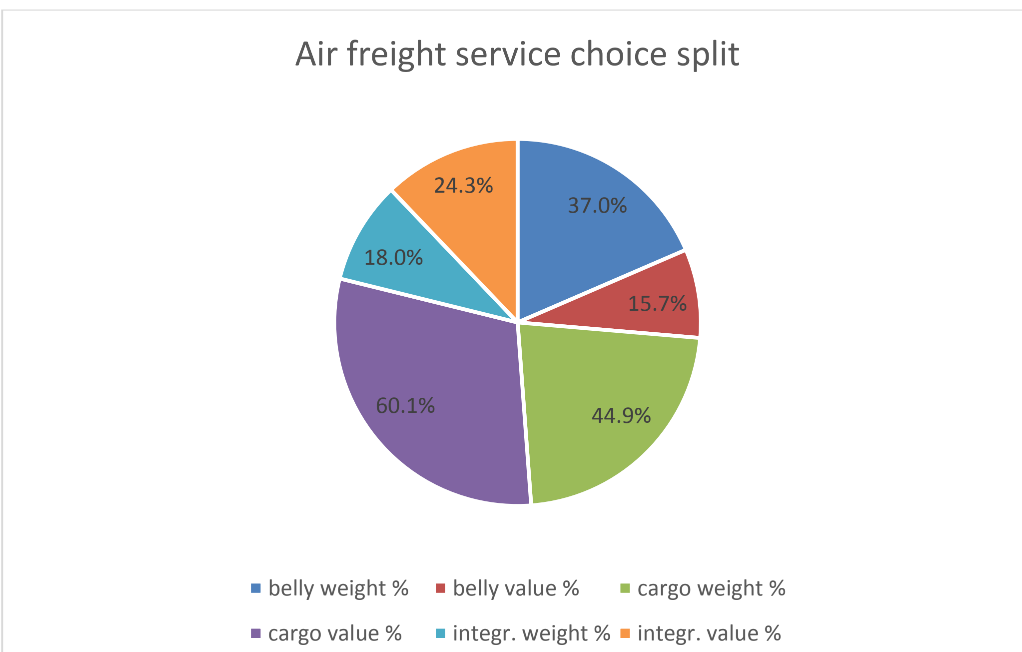
### *To Europe*


Mode split: Air
3.8%
47.0%
Air Value
Air Weight


Airborne trade commodities breakdown
Origin: Middle East, Destination: EU
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

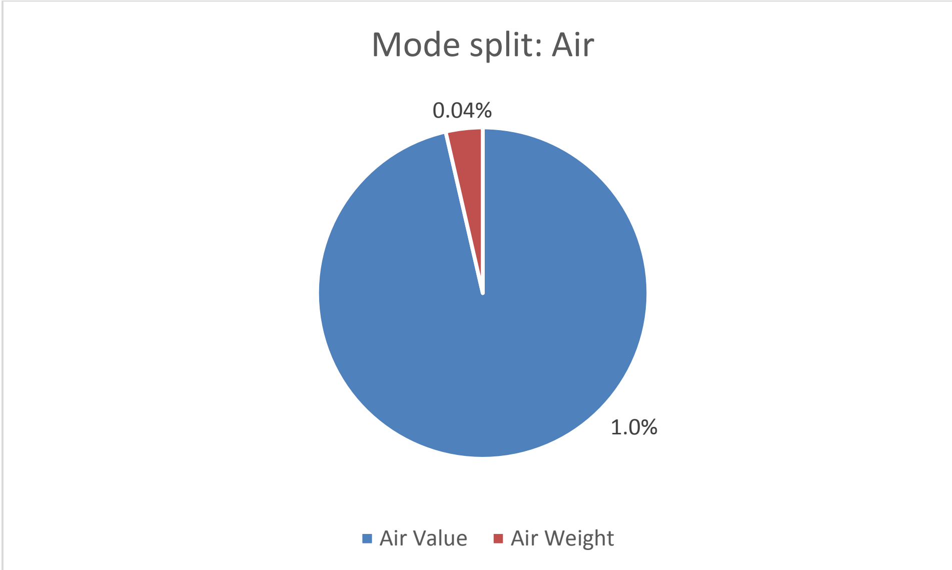


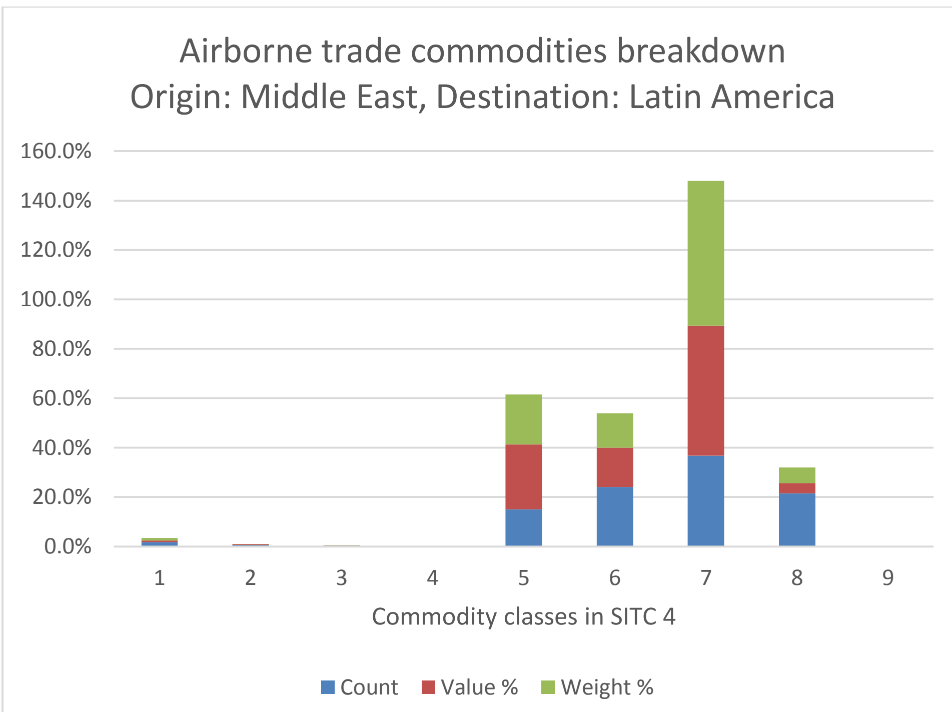
Air freight service choice per commodity class
Origin: Middle East, Destination: Middle East
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
22.3%
19.4%
55.6%
48.5%
22.1%
32.1%
25.5%
19.6%
63.6%
48.8%
10.8%
31.7%
17.0%
14.9%
42.4%
37.0%
40.6%
48.1%
11.0%
10.9%
27.5%
27.2%
61.4%
61.9%
26.2%
20.4%
65.4%
50.9%
8.4%
28.6%
17.0%
14.1%
42.4%
35.1%
40.6%
50.8%
24.8%
20.2%
61.7%
50.4%
13.5%
29.4%
26.4%
17.3%
63.7%
43.1%
9.9%
39.5%
29.9%
29.1%
70.0%
70.7%
0.0%
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

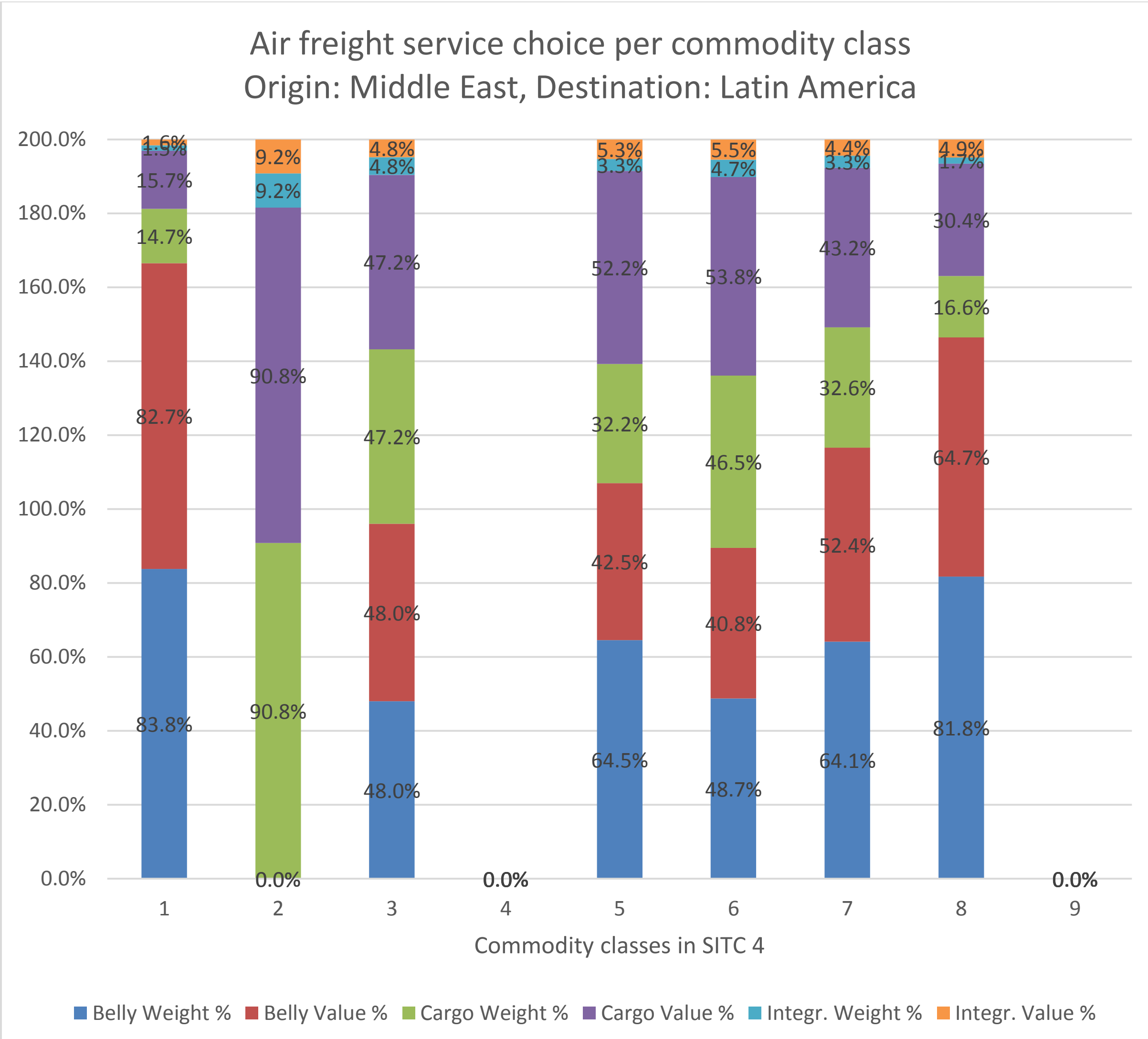



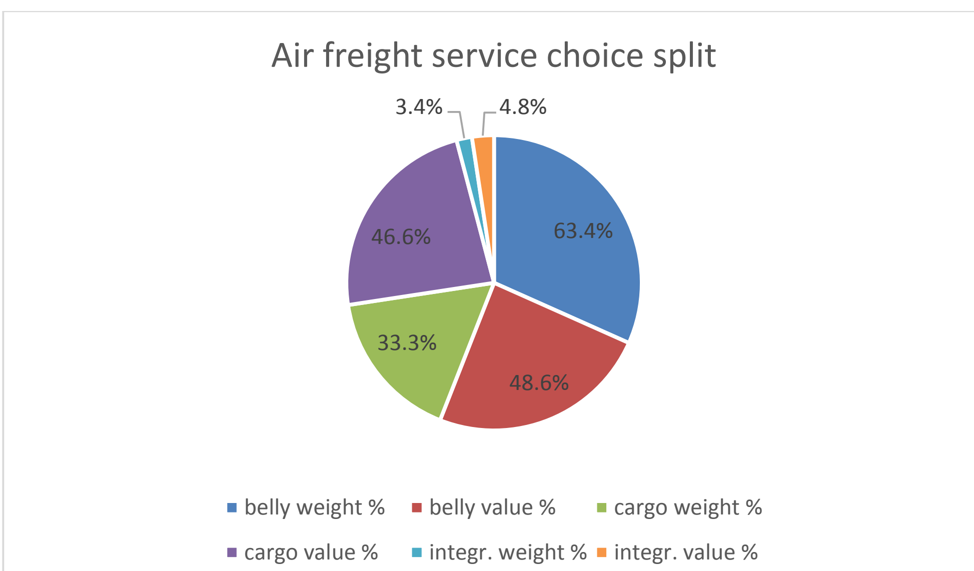
Air freight service choice split
37.0%
15.7%
44.9%
60.1%
18.0%
24.3%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To Latin America*

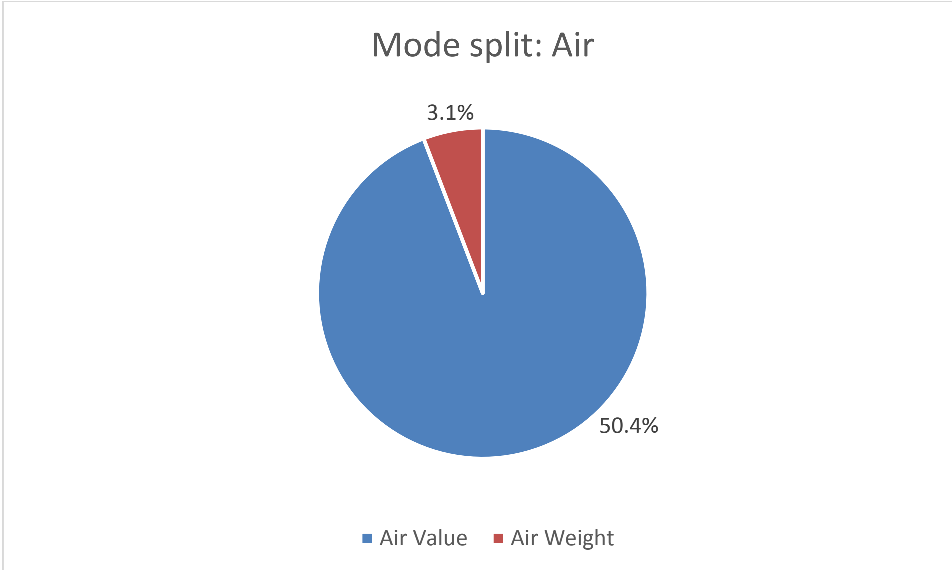


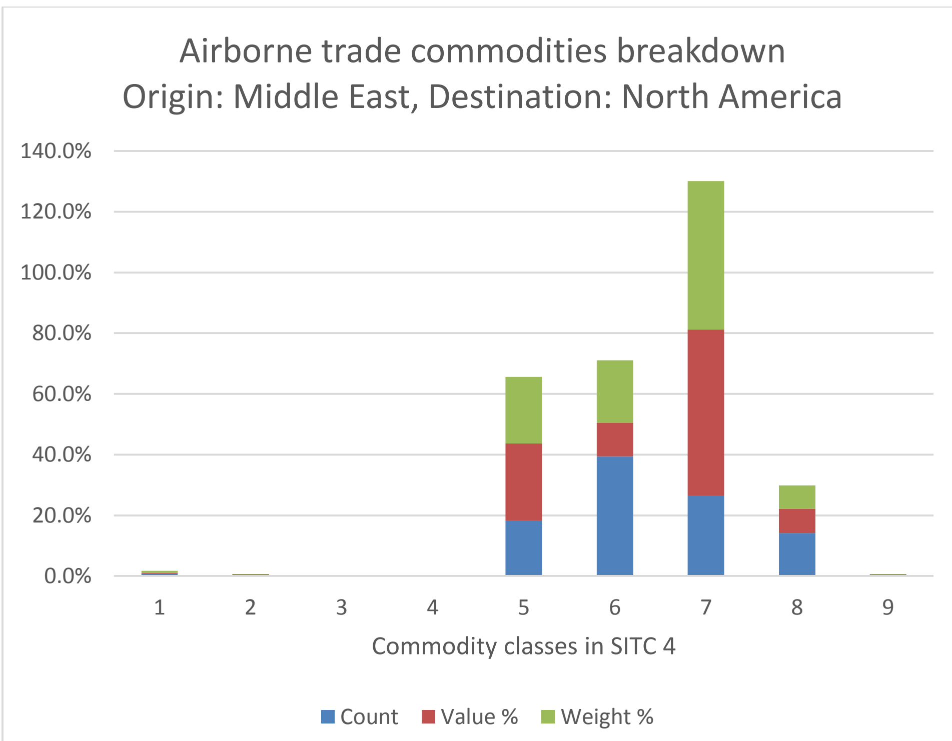



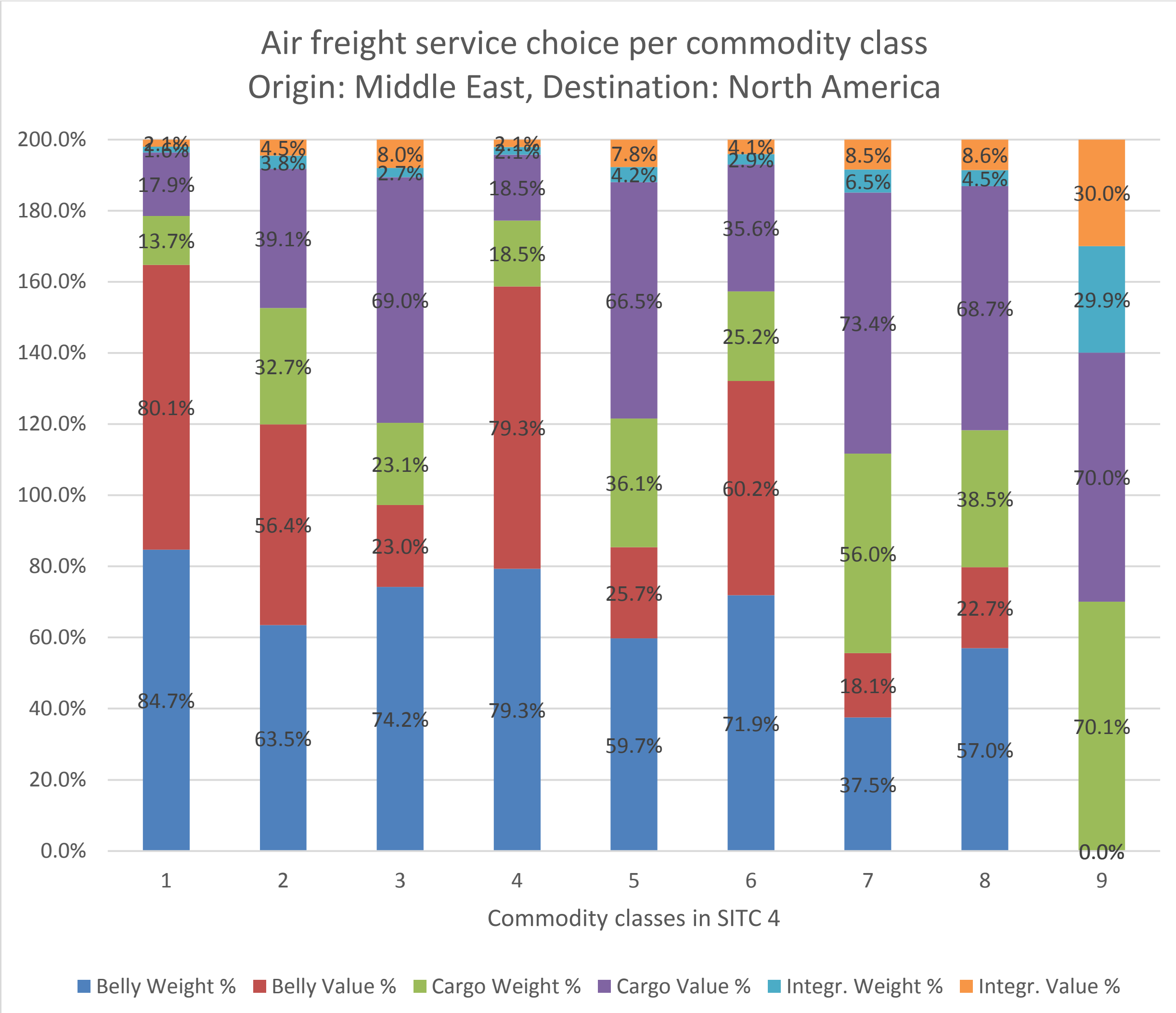

Air freight service choice per commodity class
Origin: Middle East, Destination: Latin America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1.6%
1.5%
15.7%
14.7%
82.7%
83.8%
9.2%
9.2%
90.8%
90.8%
0.0%
4.8%
4.8%
47.2%
47.2%
48.0%
48.0%
0.0%
5.3%
3.3%
52.2%
32.2%
42.5%
64.5%
5.5%
4.7%
53.8%
46.5%
40.8%
48.7%
4.4%
3.3%
43.2%
32.6%
52.4%
64.1%
4.9%
1.7%
30.4%
16.6%
64.7%
81.8%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

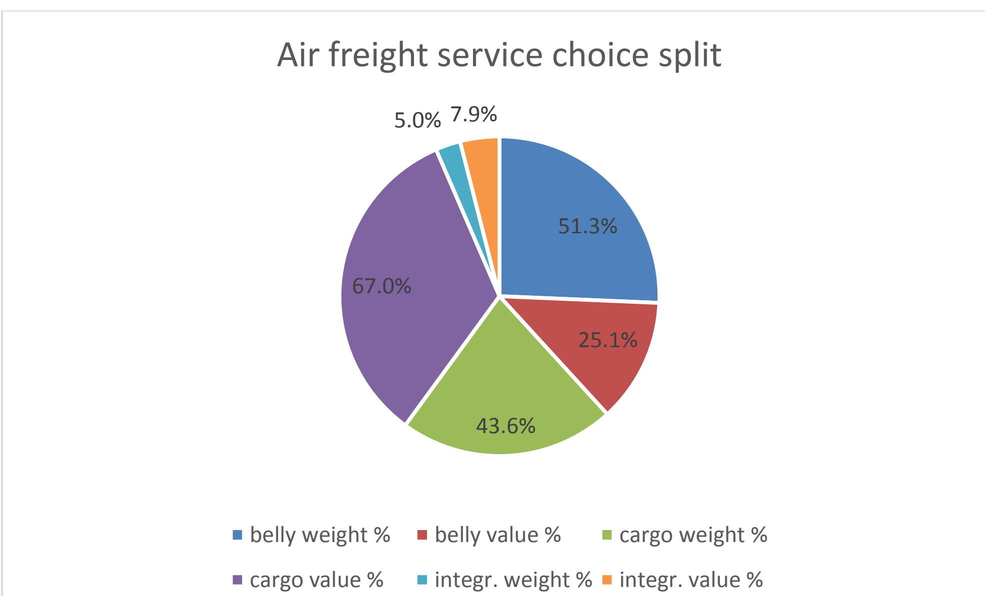

Air freight service choice split
3.4%
4.8%
63.4%
48.6%
33.3%
46.6%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To North America*

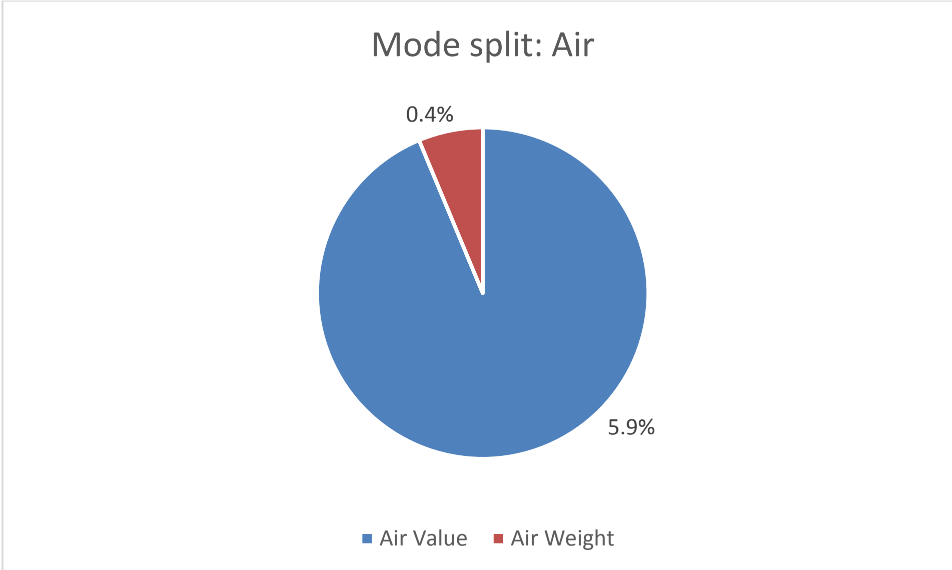


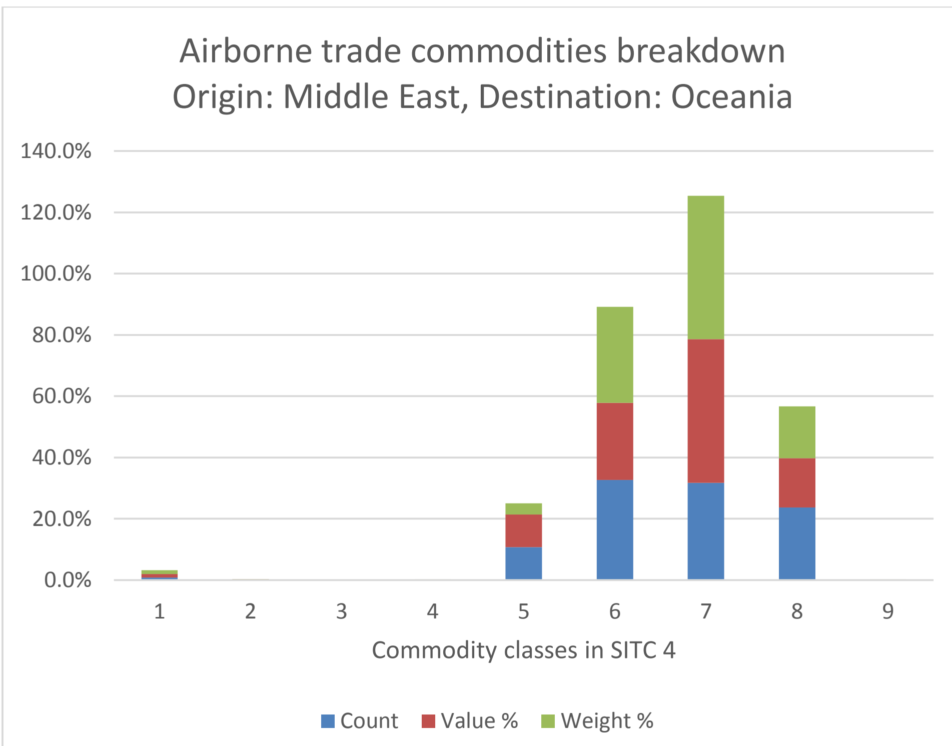

Air freight service choice per commodity class
Origin: Middle East, Destination: North America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %


Air freight service choice split
51.3%
25.1%
43.6%
67.0%
5.0%
7.9%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

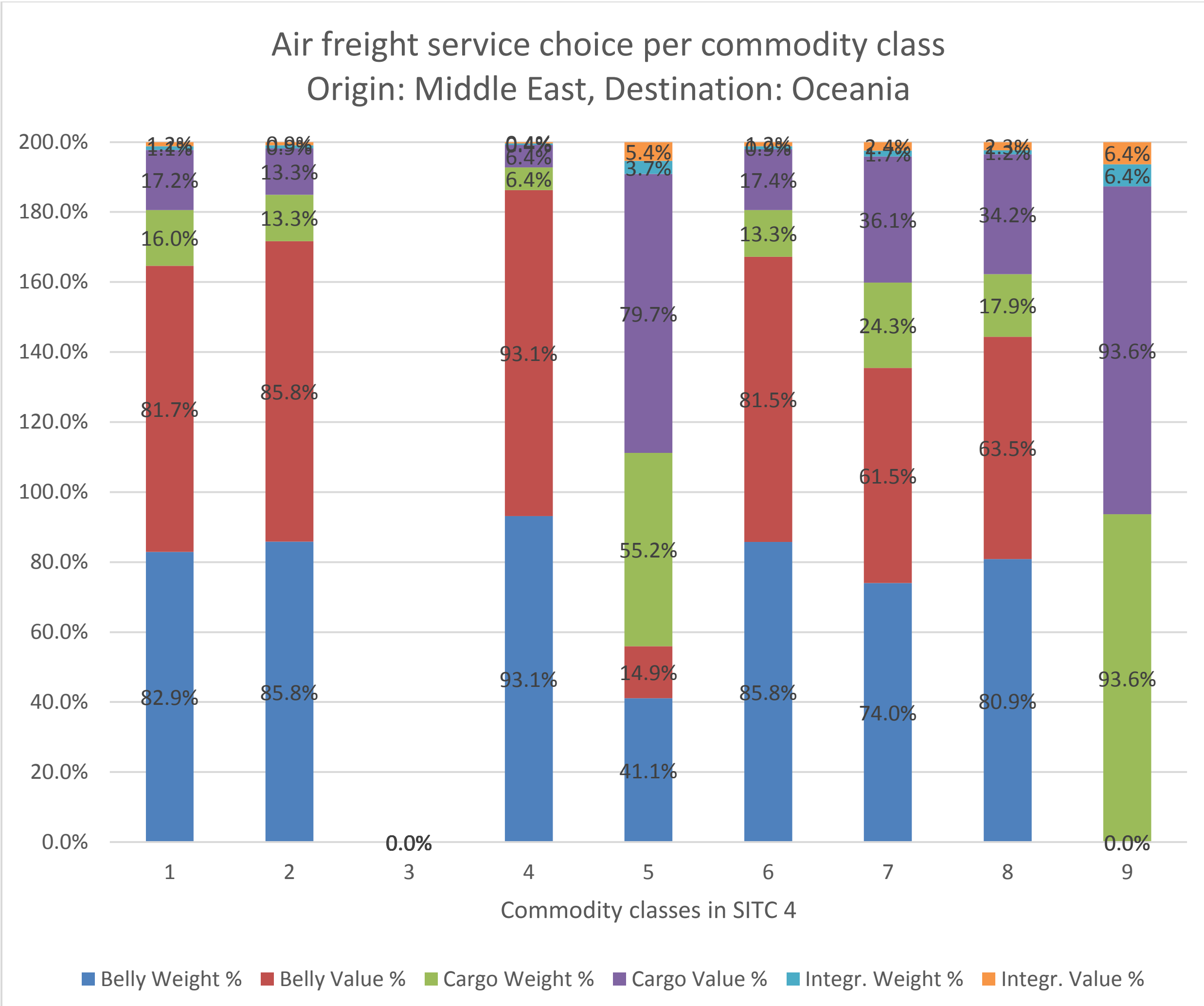
### *To Oceania*

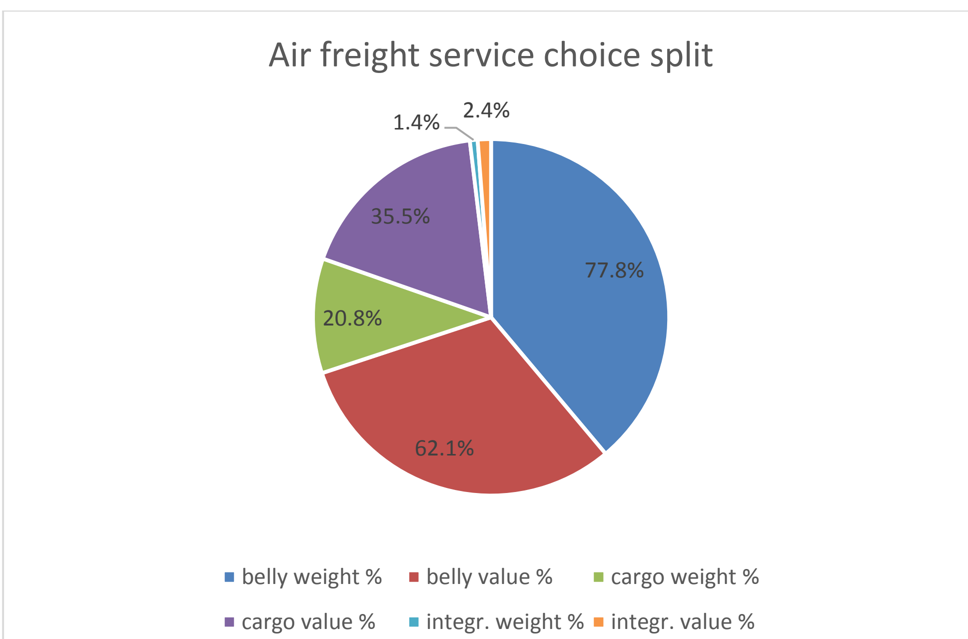


Mode split: Air
0.4%
5.9%
Air Value
Air Weight

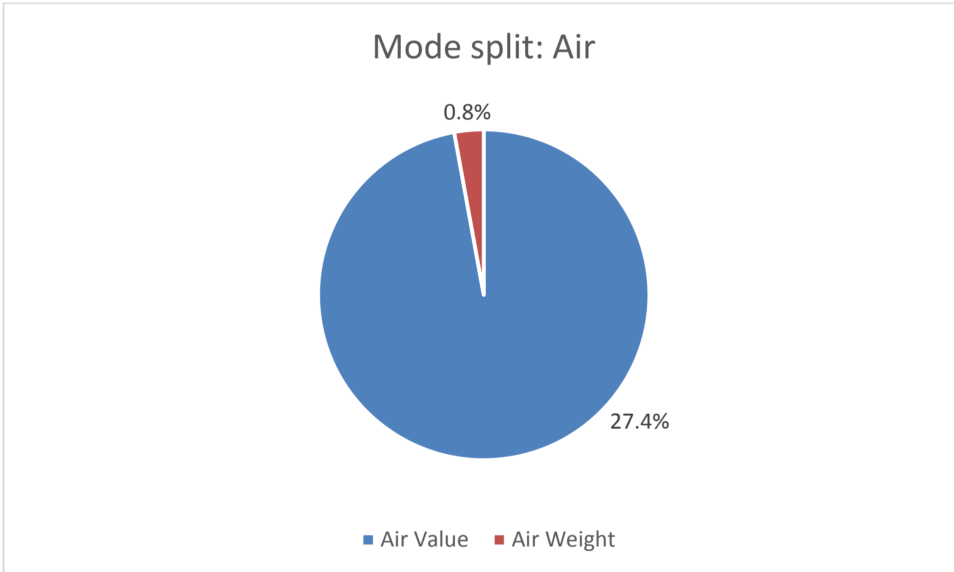
Airborne trade commodities breakdown
Origin: Middle East, Destination: Oceania
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

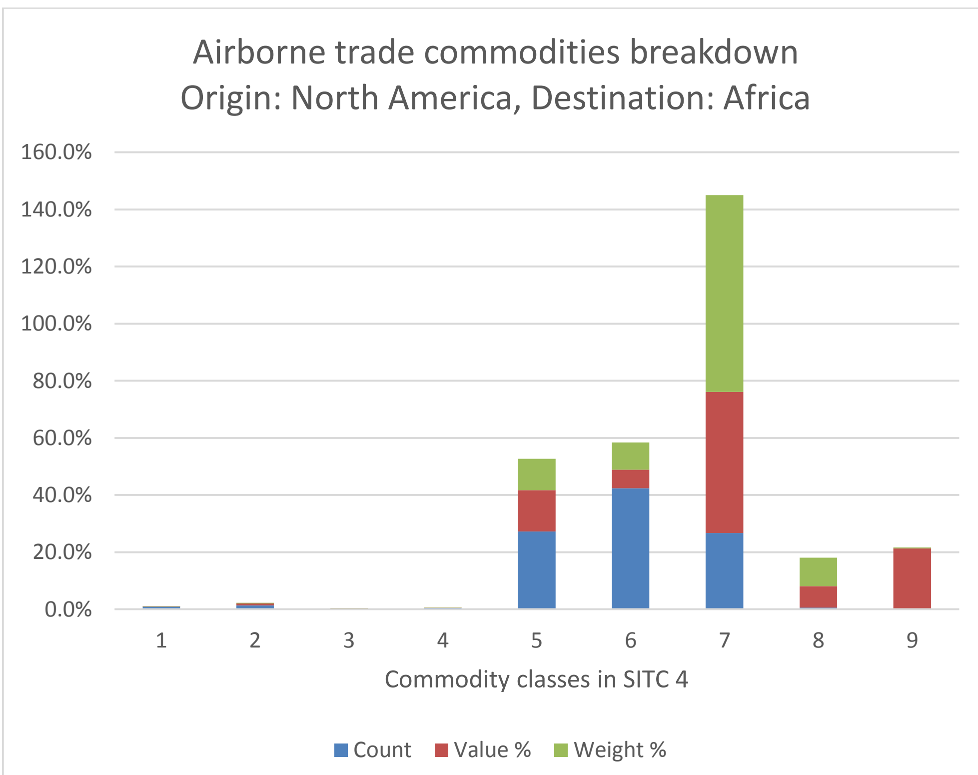

Air freight service choice per commodity class
Origin: Middle East, Destination: Oceania
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
82.9%
81.7%
16.0%
17.2%
85.8%
85.8%
13.3%
13.3%
0.0%
93.1%
93.1%
6.4%
6.4%
41.1%
14.9%
55.2%
79.7%
3.7%
5.4%
85.8%
81.5%
13.3%
17.4%
74.0%
61.5%
24.3%
36.1%
1.7%
2.4%
80.9%
63.5%
17.9%
34.2%
1.2%
2.3%
0.0%
93.6%
93.6%
6.4%
6.4%
1 2 3 4 5 6 7 8 9
Commodity classes in SITC 4
Belly Weight % Belly Value % Cargo Weight % Cargo Value % Integr. Weight % Integr. Value %

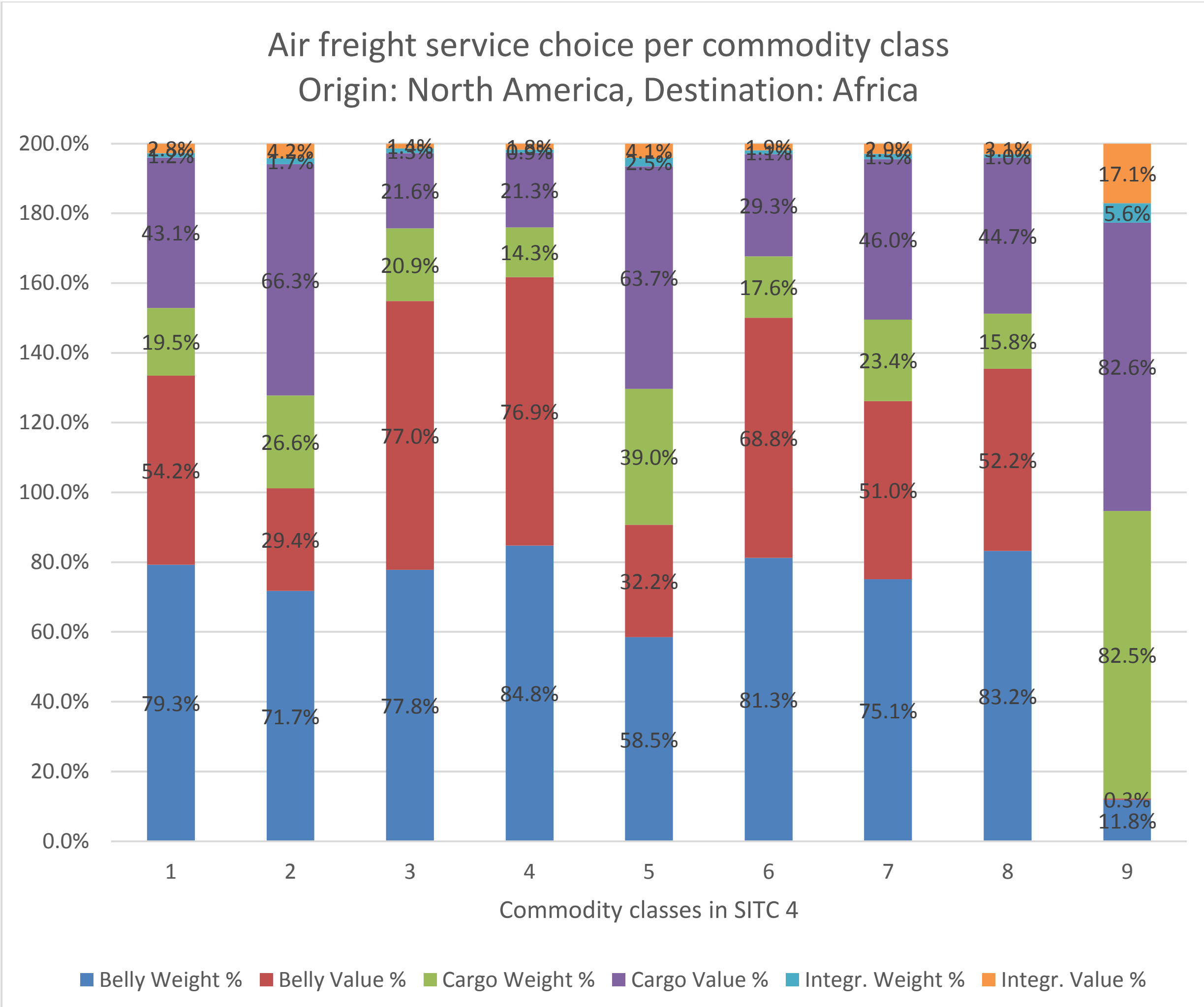

Air freight service choice split
77.8%
62.1%
20.8%
35.5%
1.4%
2.4%
belly weight % belly value % cargo weight %
cargo value % integr. weight % integr. value %

## North America

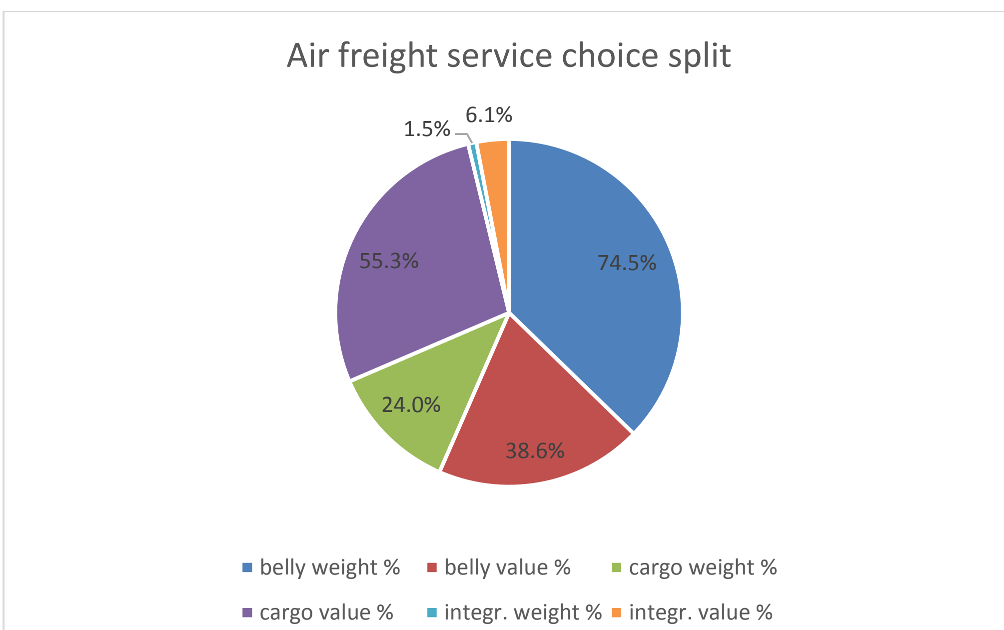
### *To Africa*



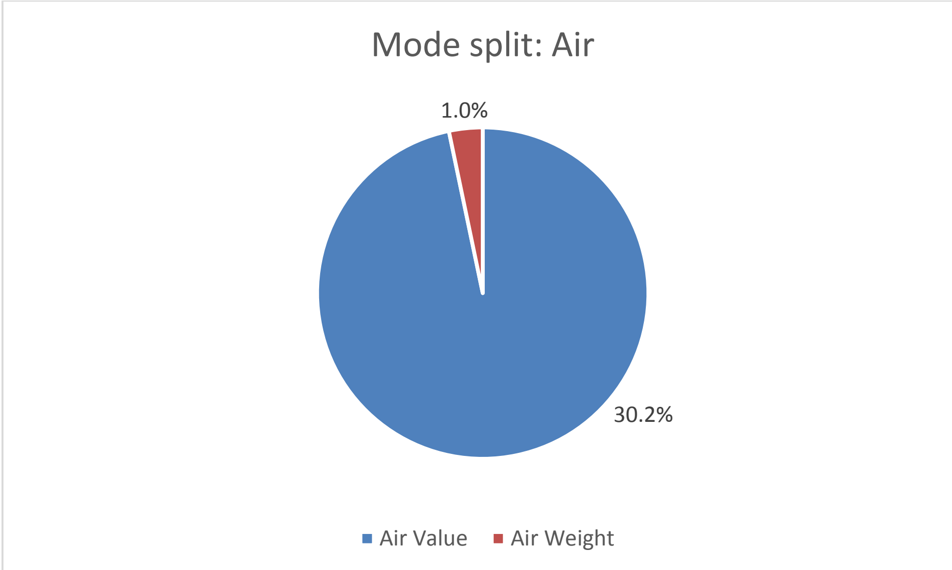


Air freight service choice per commodity class
Origin: North America, Destination: Africa
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1 2 3 4 5 6 7 8 9
Commodity classes in SITC 4
Belly Weight % Belly Value % Cargo Weight % Cargo Value % Integr. Weight % Integr. Value %
79.3% 54.2% 19.5% 43.1% 1.2% 2.8%
71.7% 29.4% 26.6% 66.3% 1.7% 4.2%
77.8% 77.0% 20.9% 21.6% 1.3% 1.4%
84.8% 76.9% 14.3% 21.3% 0.9% 1.8%
58.5% 32.2% 39.0% 63.7% 2.5% 4.1%
81.3% 68.8% 17.6% 29.3% 1.1% 1.9%
75.1% 51.0% 23.4% 46.0% 1.5% 2.9%
83.2% 52.2% 15.8% 44.7% 1.0% 3.1%
11.8% 0.3% 82.5% 82.6% 5.6% 17.1%

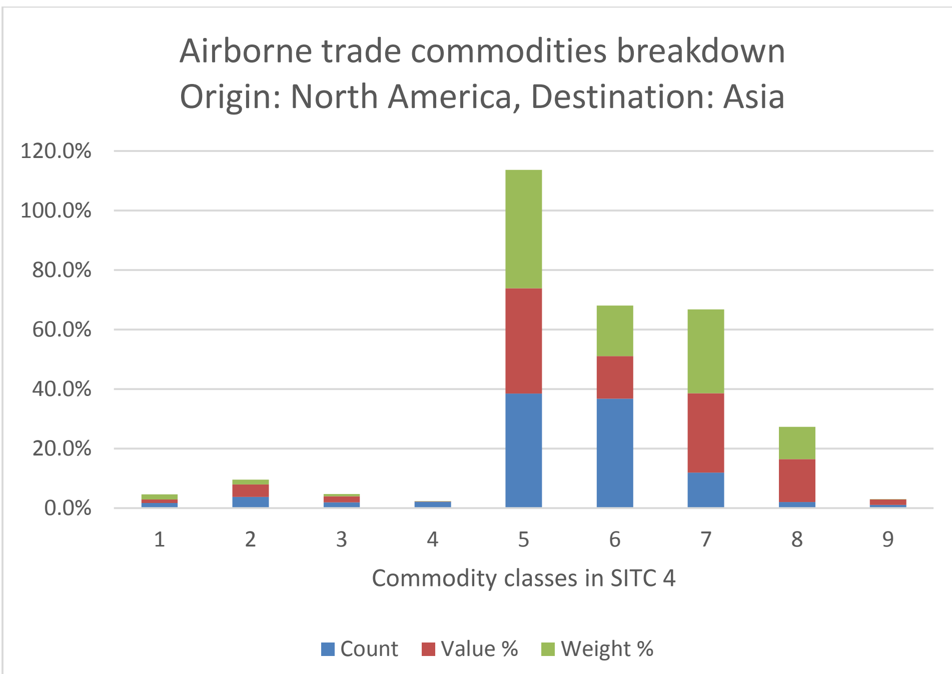



Air freight service choice split
74.5%
38.6%
24.0%
55.3%
1.5%
6.1%
belly weight % belly value % cargo weight %
cargo value % integr. weight % integr. value %

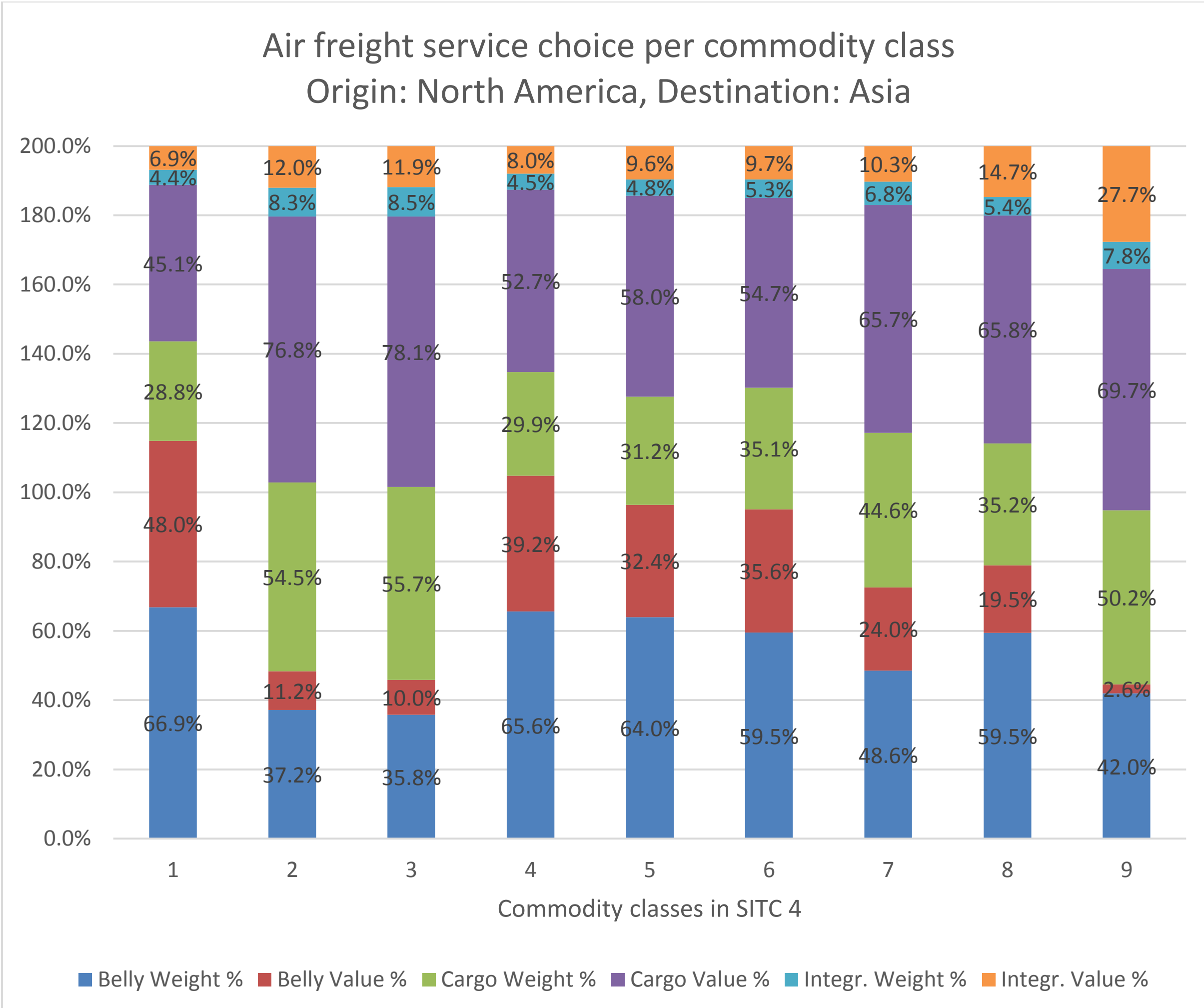
### *To Asia*

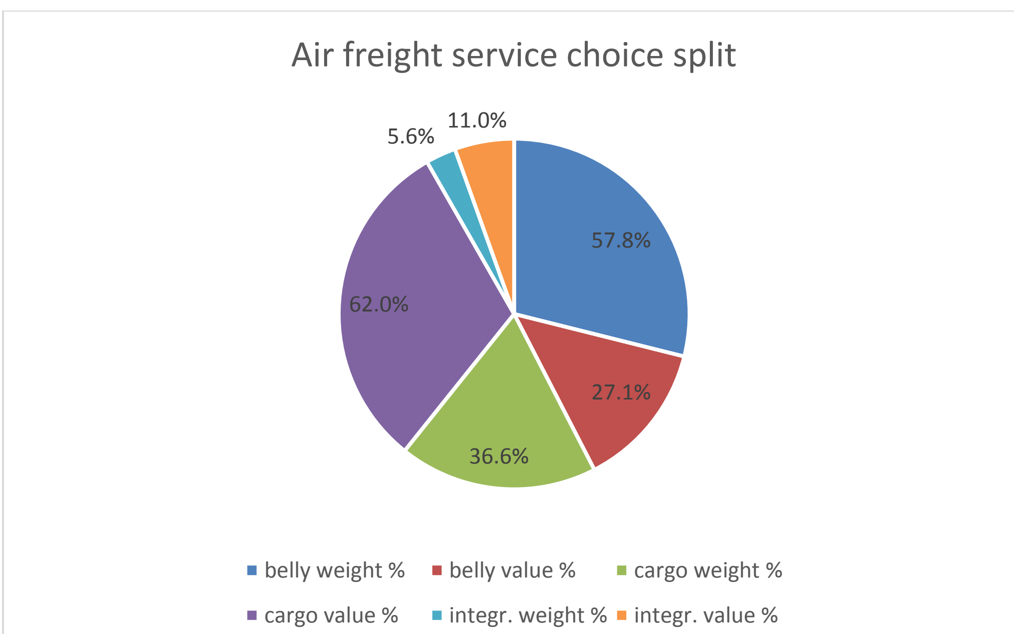


Mode split: Air
1.0%
30.2%
Air Value
Air Weight

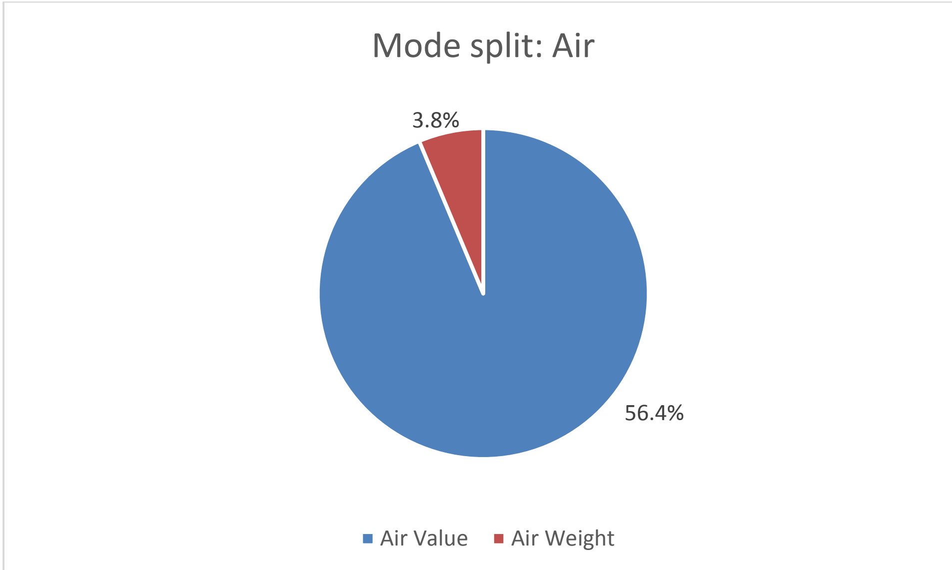



Airborne trade commodities breakdown
Origin: North America, Destination: Asia
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

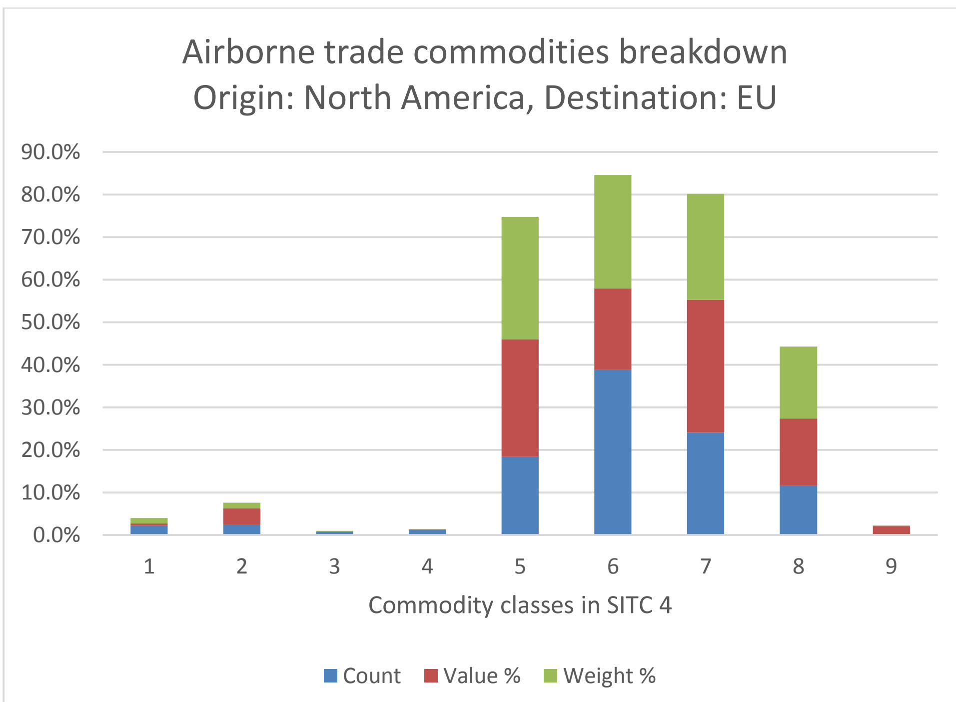

Air freight service choice per commodity class
Origin: North America, Destination: Asia
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
6.9%
4.4%
45.1%
28.8%
48.0%
66.9%
12.0%
8.3%
76.8%
54.5%
11.2%
37.2%
11.9%
8.5%
78.1%
55.7%
10.0%
35.8%
8.0%
4.5%
52.7%
29.9%
39.2%
65.6%
9.6%
4.8%
58.0%
31.2%
32.4%
64.0%
9.7%
5.3%
54.7%
35.1%
35.6%
59.5%
10.3%
6.8%
65.7%
44.6%
24.0%
48.6%
14.7%
5.4%
65.8%
35.2%
19.5%
59.5%
27.7%
7.8%
69.7%
50.2%
2.6%
42.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %


Air freight service choice split
57.8%
27.1%
36.6%
62.0%
5.6%
11.0%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

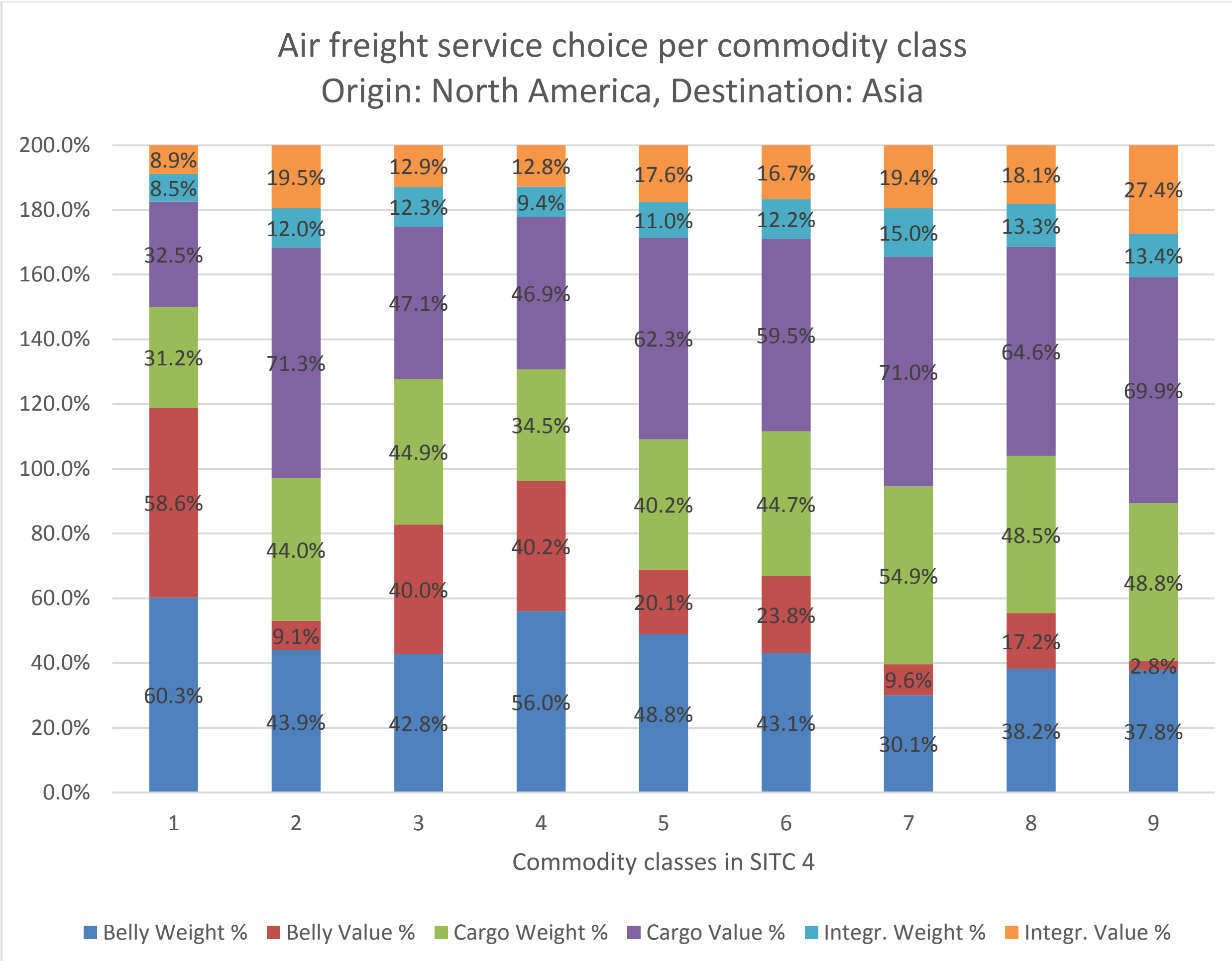
### *To Europe*

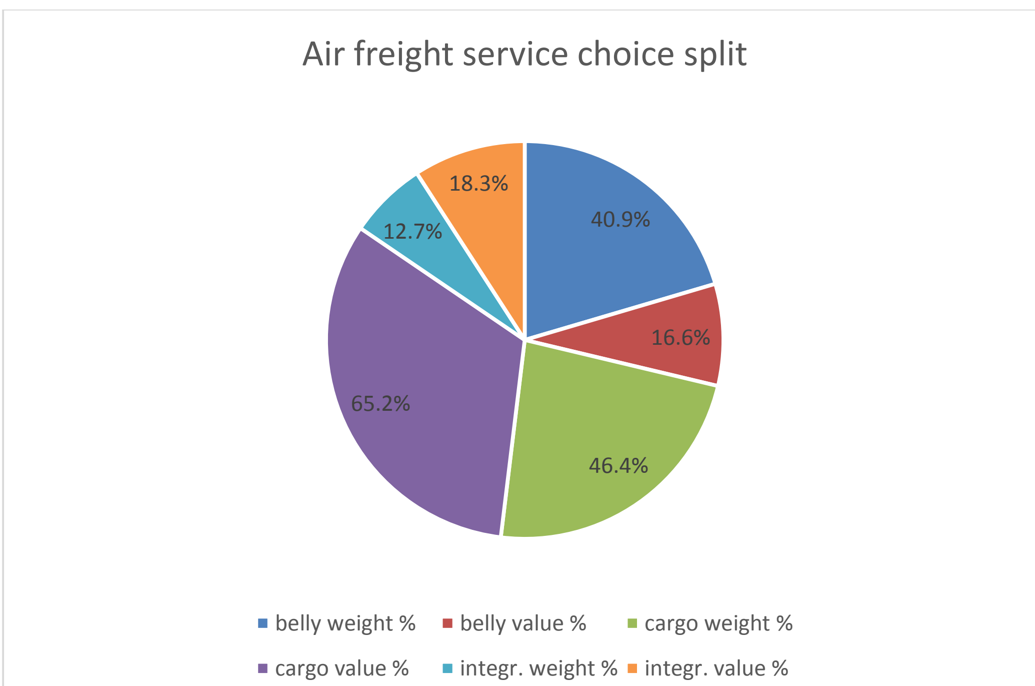


Mode split: Air
3.8%
56.4%
Air Value
Air Weight

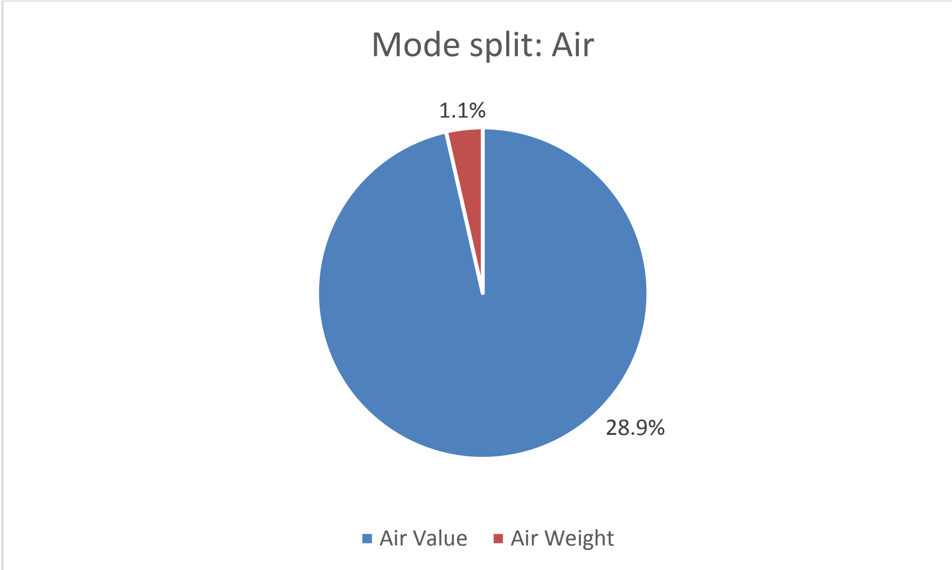



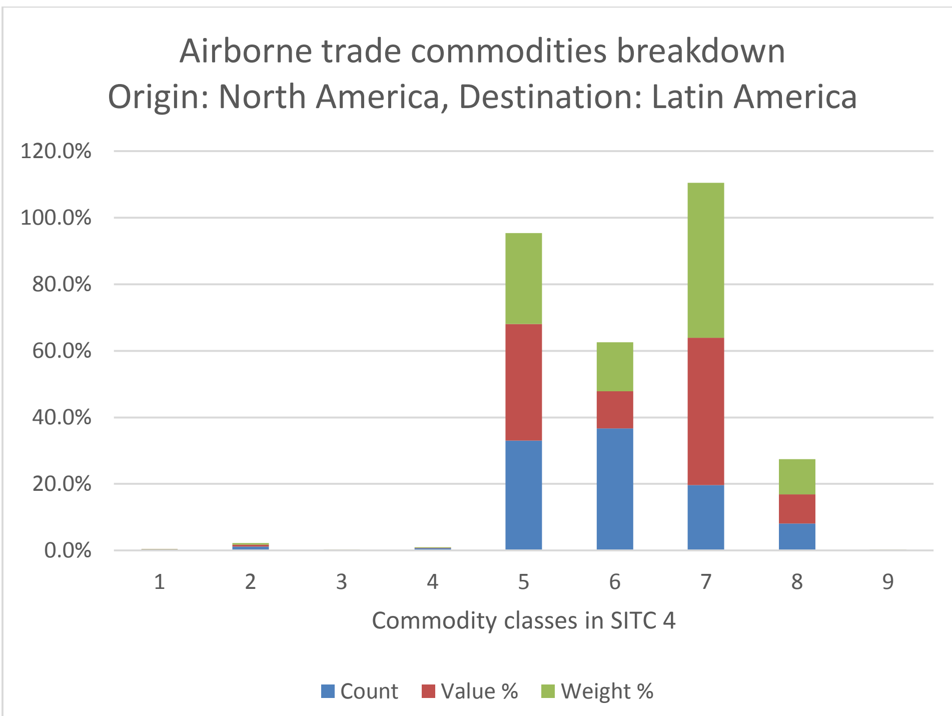
Airborne trade commodities breakdown
Origin: North America, Destination: EU
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %


Air freight service choice per commodity class
Origin: North America, Destination: Asia
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
8.9%
8.5%
32.5%
31.2%
58.6%
60.3%
19.5%
12.0%
71.3%
44.0%
9.1%
43.9%
12.9%
12.3%
47.1%
44.9%
40.0%
42.8%
12.8%
9.4%
46.9%
34.5%
40.2%
56.0%
17.6%
11.0%
62.3%
40.2%
20.1%
48.8%
16.7%
12.2%
59.5%
44.7%
23.8%
43.1%
19.4%
15.0%
71.0%
54.9%
9.6%
30.1%
18.1%
13.3%
64.6%
48.5%
17.2%
38.2%
27.4%
13.4%
69.9%
48.8%
2.8%
37.8%
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

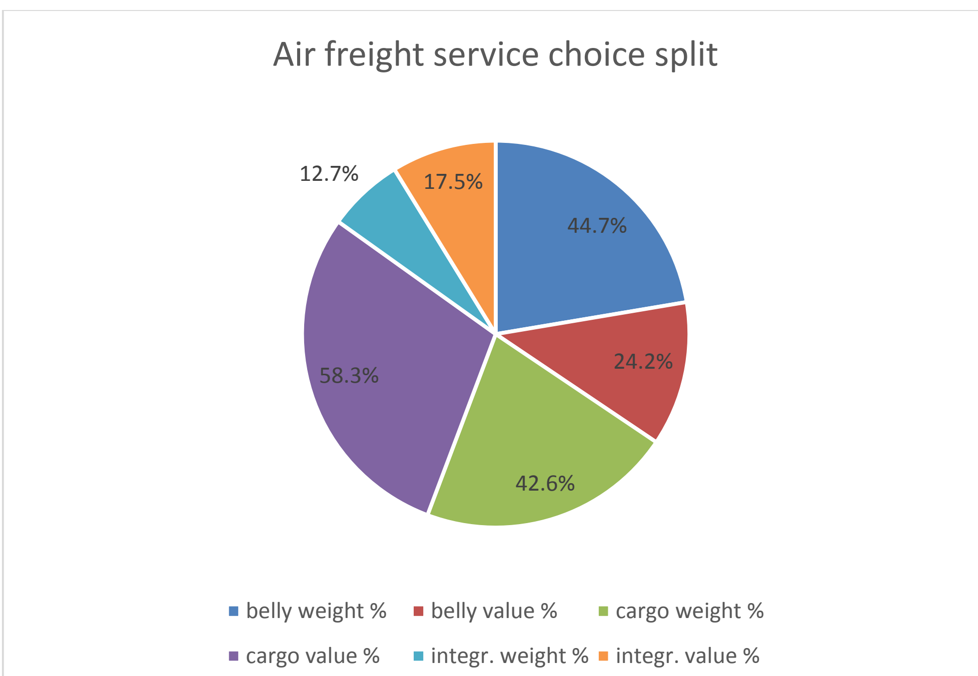

Air freight service choice split
40.9%
16.6%
46.4%
65.2%
12.7%
18.3%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To Latin America*

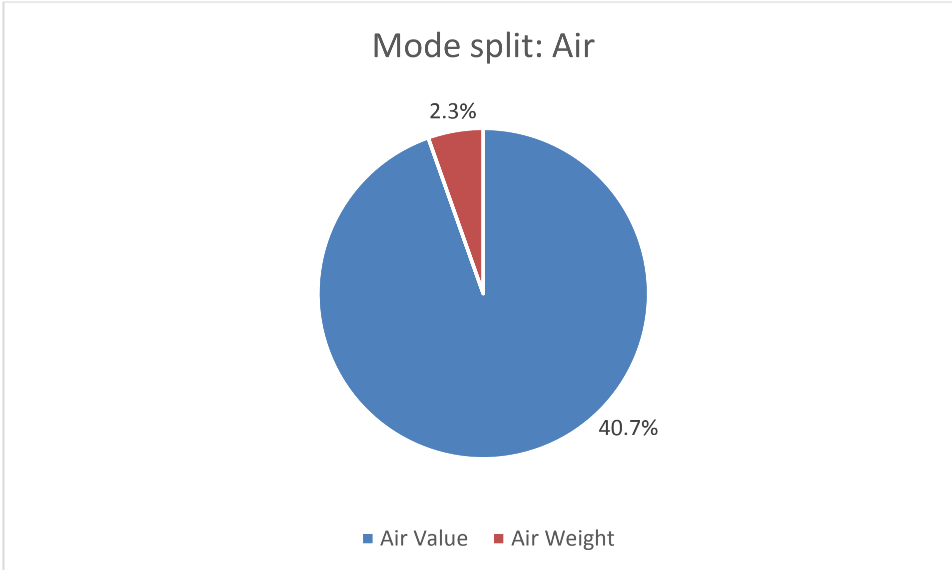


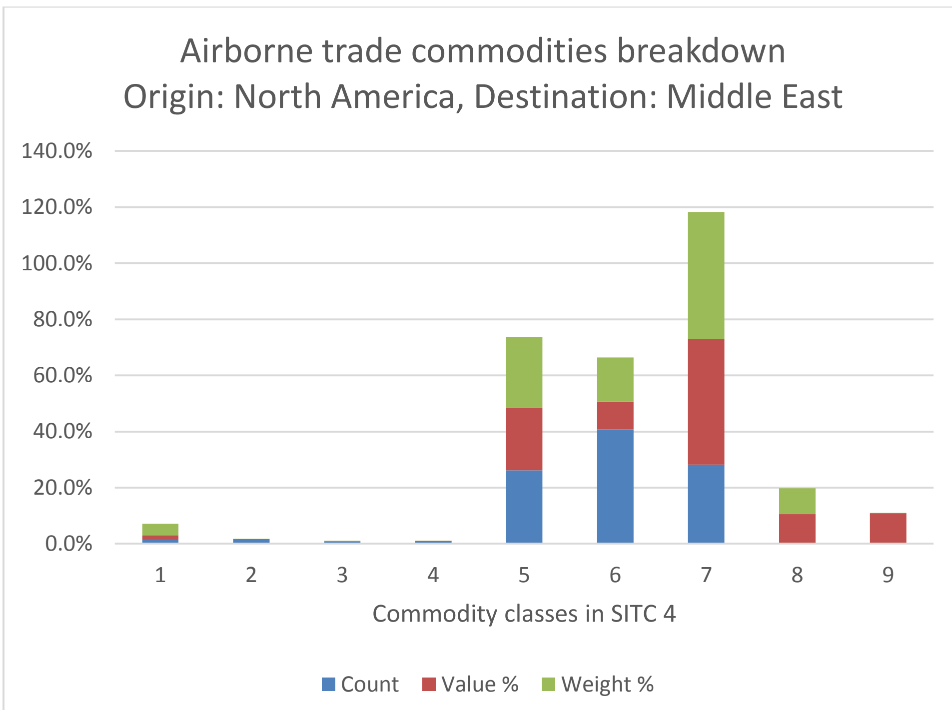



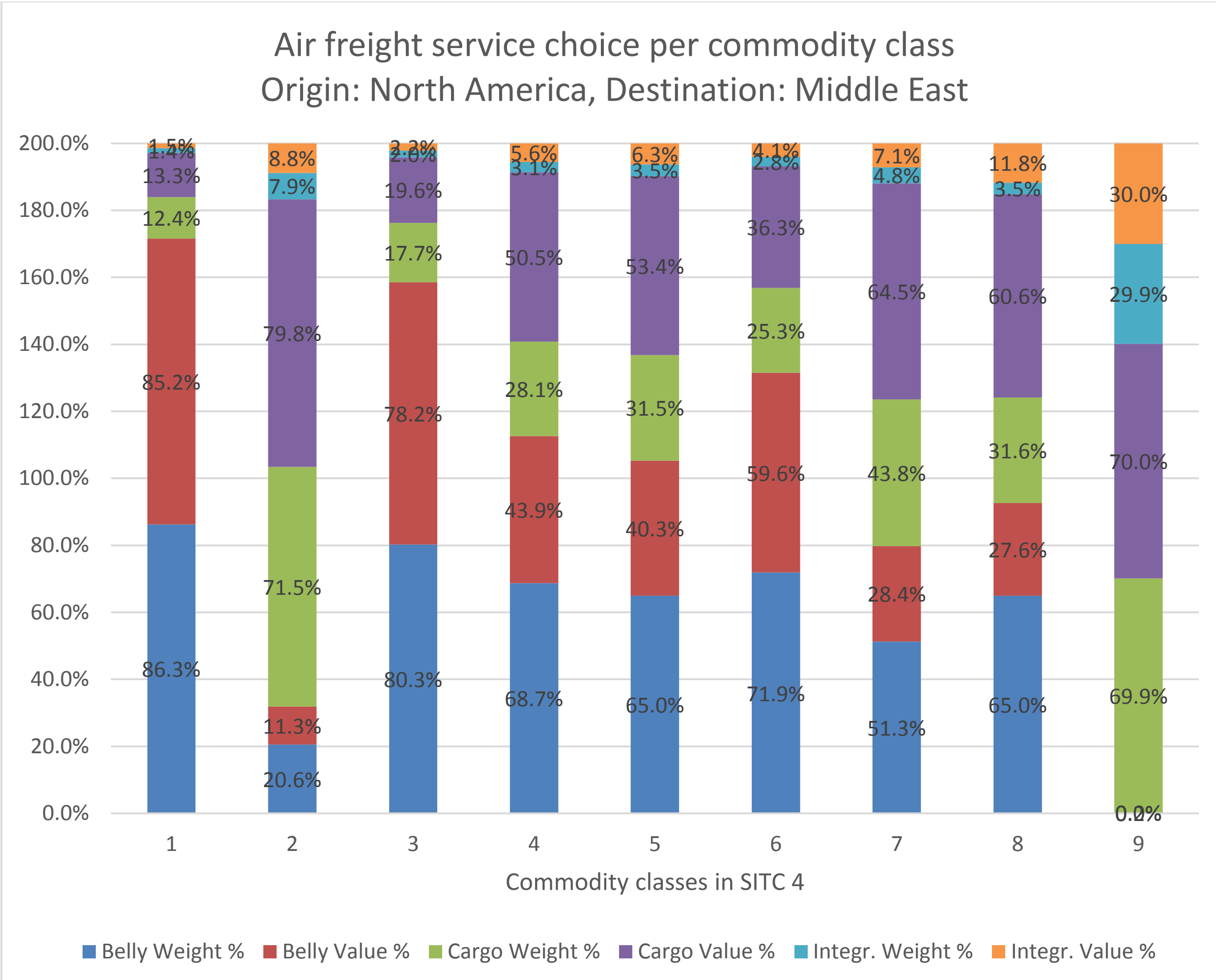

Air freight service choice per commodity class
Origin: North America, Destination: Latin America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
12.3%
10.0%
41.1%
33.4%
46.6%
56.6%
15.3%
13.0%
51.4%
43.6%
33.2%
43.4%
14.5%
13.6%
48.6%
45.5%
36.9%
40.9%
8.9%
8.2%
29.7%
27.3%
61.4%
64.5%
18.3%
13.1%
61.4%
43.9%
20.2%
43.0%
14.7%
9.9%
46.1%
33.3%
39.1%
56.7%
17.9%
13.8%
60.0%
46.3%
22.1%
39.8%
16.2%
10.7%
53.5%
35.9%
30.3%
53.4%
29.9%
23.3%
70.1%
68.9%
0.0%
7.8%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

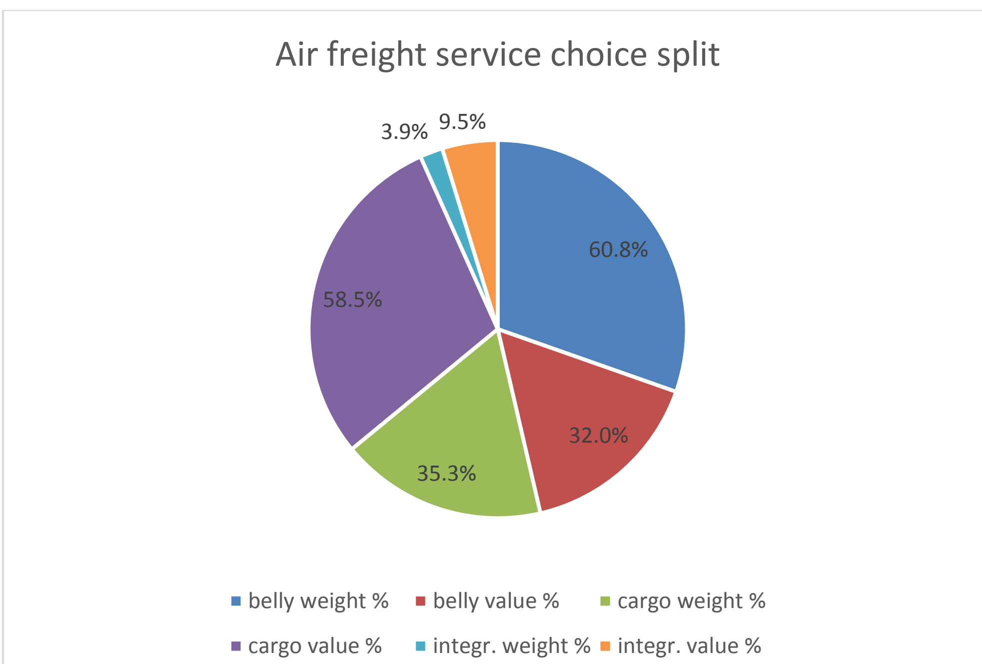

Air freight service choice split
12.7%
17.5%
44.7%
24.2%
42.6%
58.3%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To Middle East*

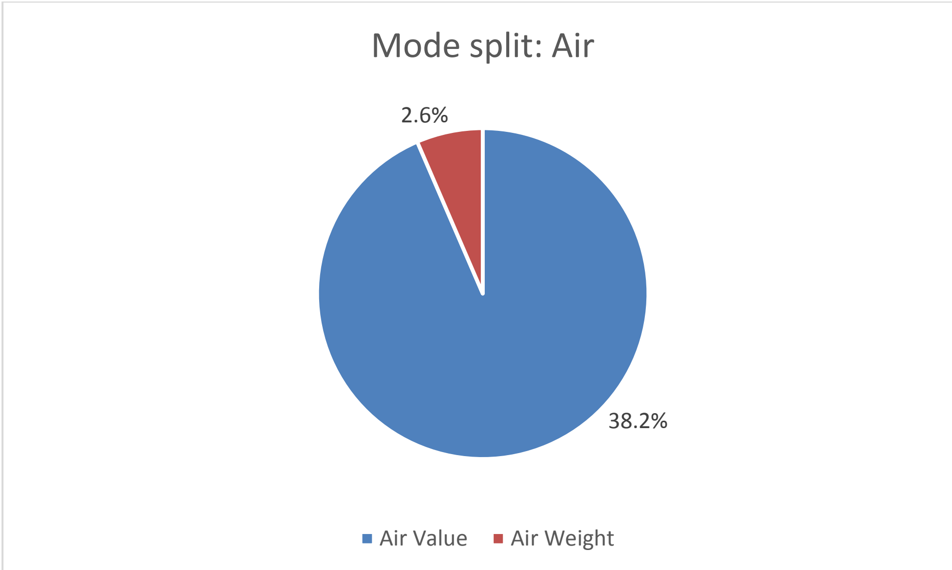


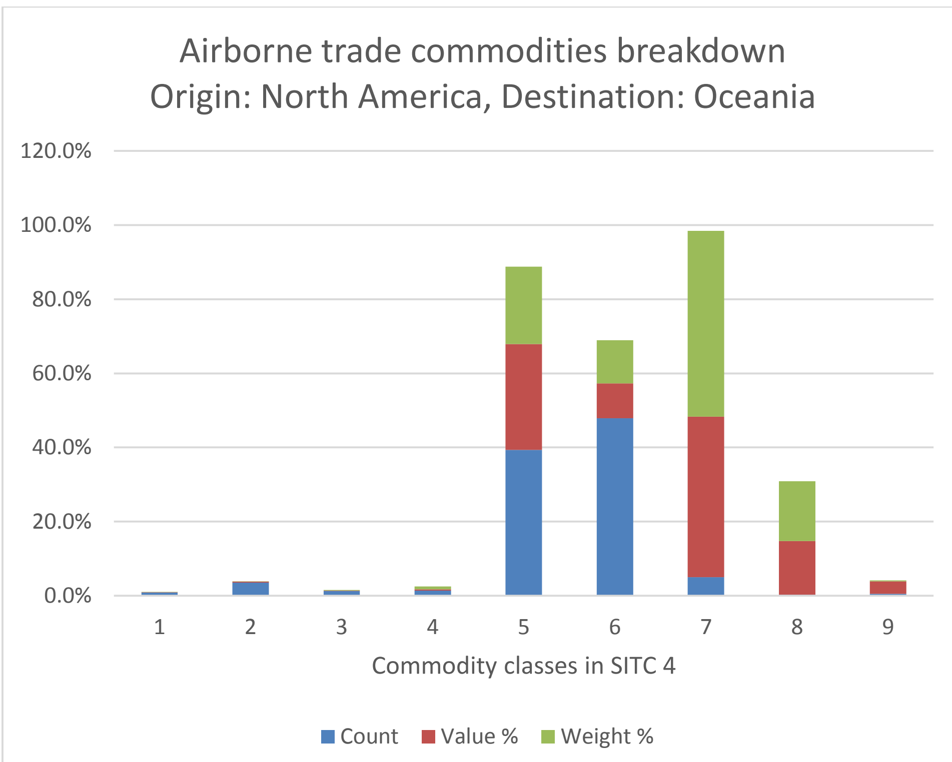

Air freight service choice per commodity class
Origin: North America, Destination: Middle East
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %
86.3%
85.2%
12.4%
13.3%
1.4%
1.5%
20.6%
11.3%
71.5%
79.8%
7.9%
8.8%
80.3%
78.2%
17.7%
19.6%
2.0%
2.2%
68.7%
43.9%
28.1%
50.5%
3.1%
5.6%
65.0%
40.3%
31.5%
53.4%
3.5%
6.3%
71.9%
59.6%
25.3%
36.3%
2.8%
4.1%
51.3%
28.4%
43.8%
64.5%
4.8%
7.1%
65.0%
27.6%
31.6%
60.6%
3.5%
11.8%
0.0%
69.9%
70.0%
29.9%
30.0%


Air freight service choice split
60.8%
32.0%
35.3%
58.5%
3.9%
9.5%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

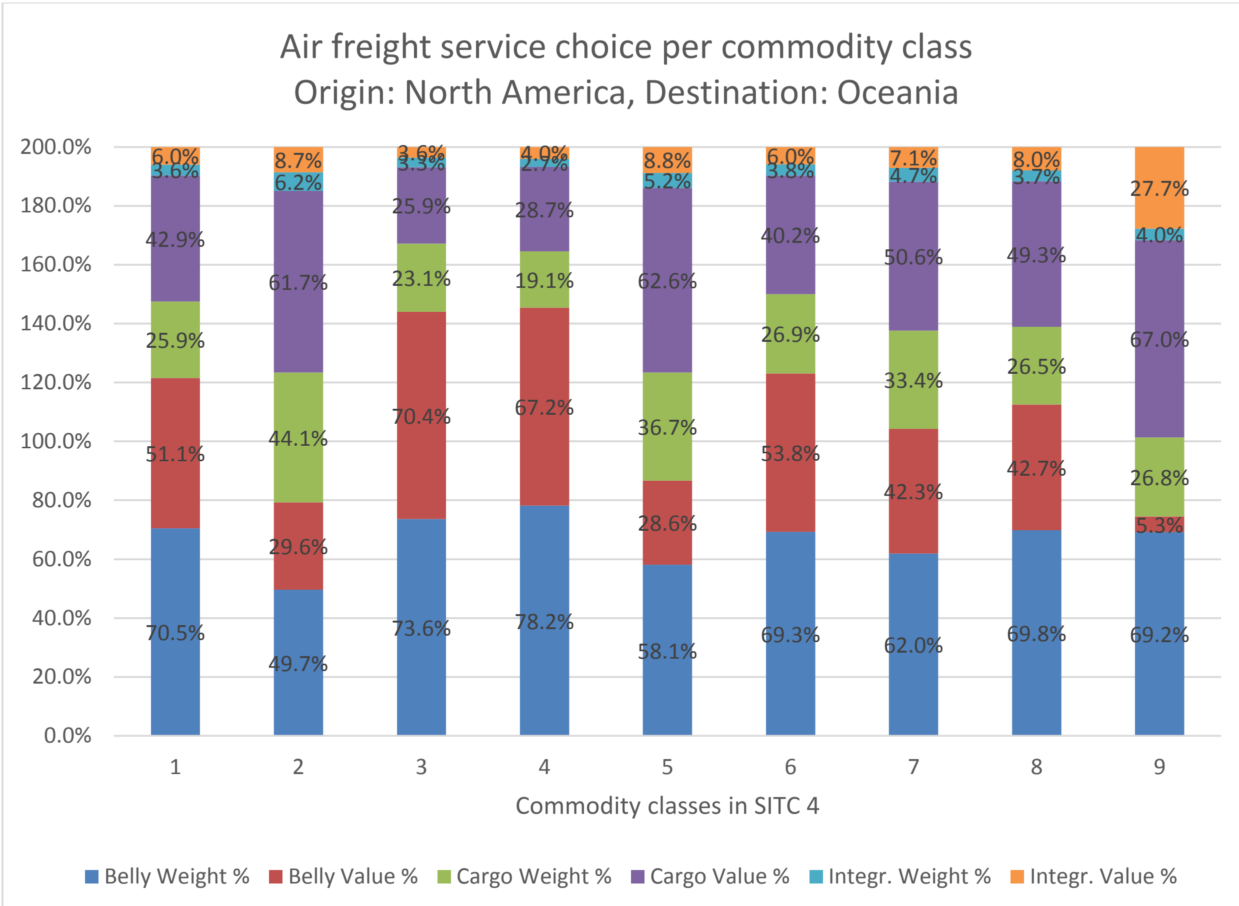
### *To Oceania*

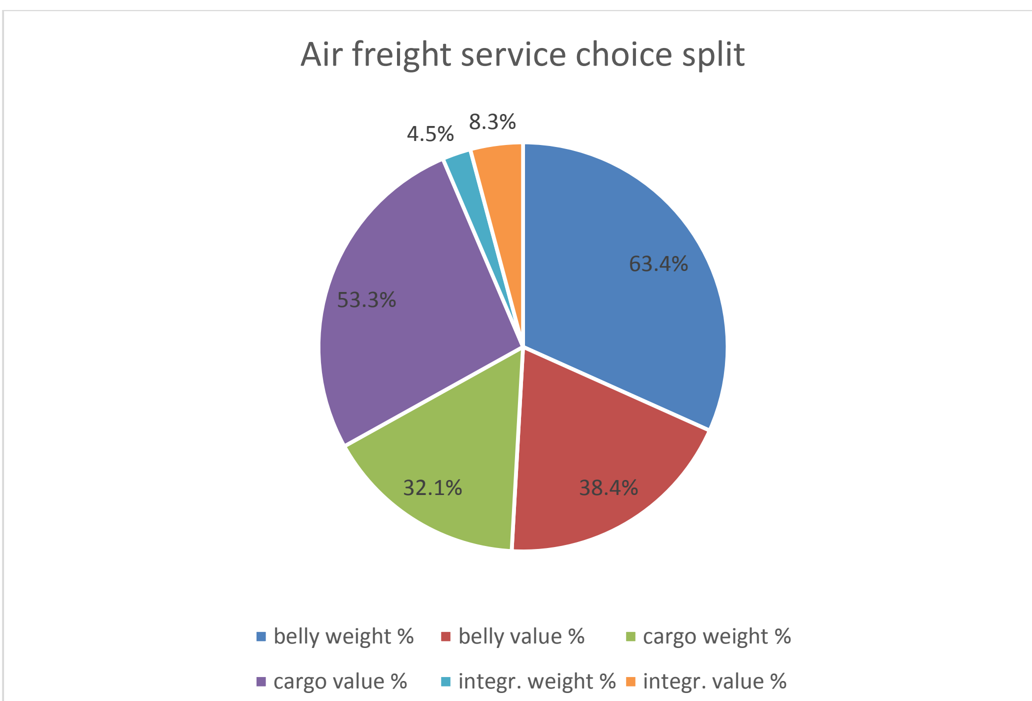


Mode split: Air
2.6%
38.2%
Air Value
Air Weight

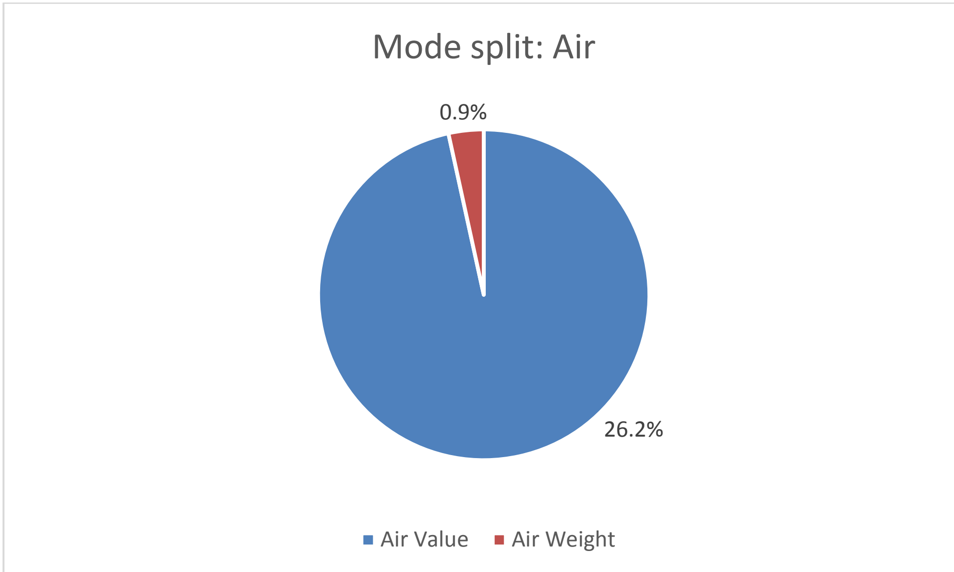
Airborne trade commodities breakdown
Origin: North America, Destination: Oceania
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

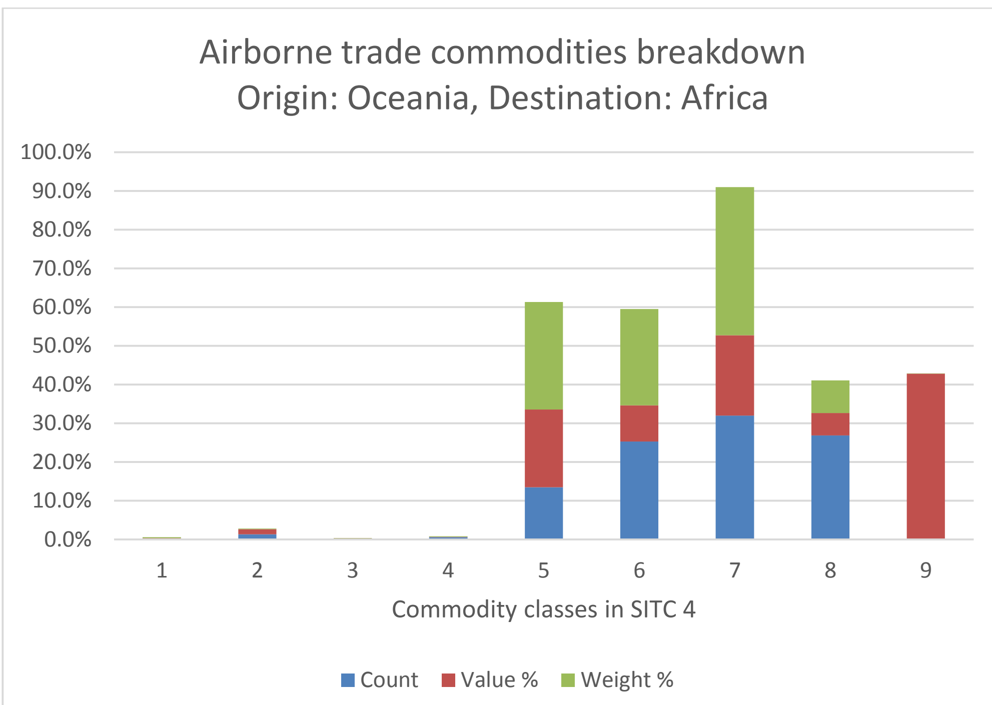

Air freight service choice per commodity class
Origin: North America, Destination: Oceania
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %
70.5%
51.1%
25.9%
42.9%
3.6%
6.0%
49.7%
29.6%
44.1%
61.7%
6.2%
8.7%
73.6%
70.4%
23.1%
25.9%
3.3%
3.6%
78.2%
67.2%
19.1%
28.7%
2.7%
4.0%
58.1%
28.6%
36.7%
62.6%
5.2%
8.8%
69.3%
53.8%
26.9%
40.2%
3.8%
6.0%
62.0%
42.3%
33.4%
50.6%
4.7%
7.1%
69.8%
42.7%
26.5%
49.3%
3.7%
8.0%
69.2%
5.3%
26.8%
67.0%
4.0%
27.7%


Air freight service choice split
63.4%
38.4%
32.1%
53.3%
4.5%
8.3%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

## Oceania

### *To Africa*



Air freight service choice per commodity class
Origin: Oceania, Destination: Africa
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
6.3%
4.8%
32.1%
24.8%
61.6%
70.4%
16.2%
14.5%
82.9%
74.2%
0.9%
11.3%
10.8%
10.4%
55.2%
52.9%
34.0%
36.7%
6.8%
4.4%
34.8%
22.6%
58.5%
73.0%
12.6%
5.2%
64.3%
26.7%
23.1%
68.1%
7.8%
6.5%
39.8%
33.3%
52.5%
60.2%
12.2%
10.1%
62.5%
51.8%
25.2%
38.0%
14.5%
7.2%
65.5%
36.9%
20.1%
55.9%
30.0%
30.0%
70.0%
70.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

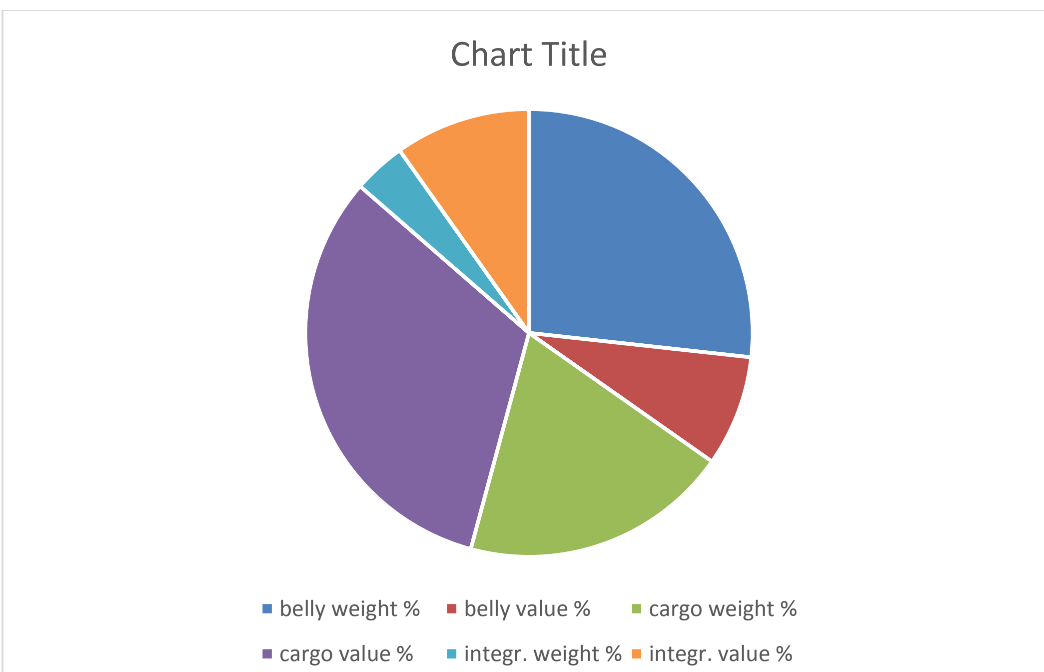
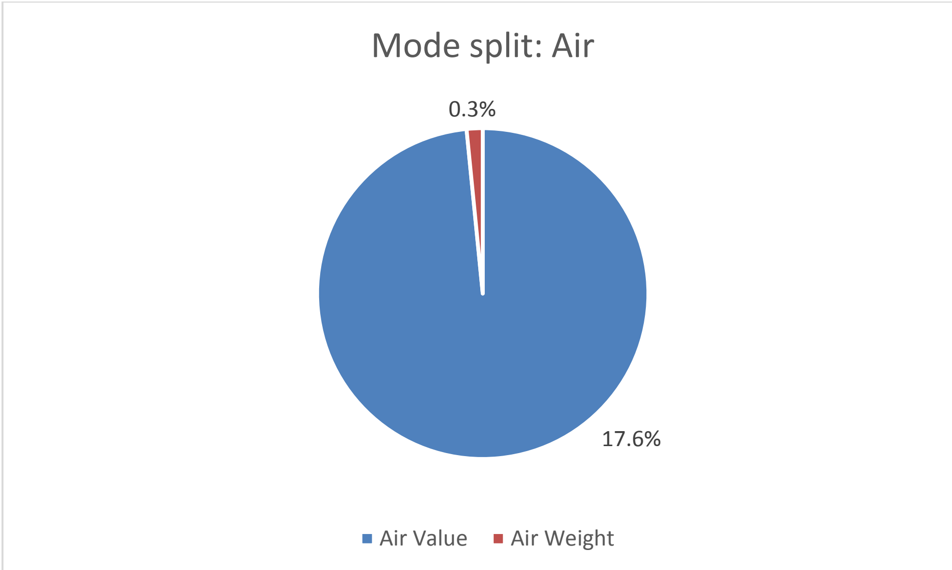
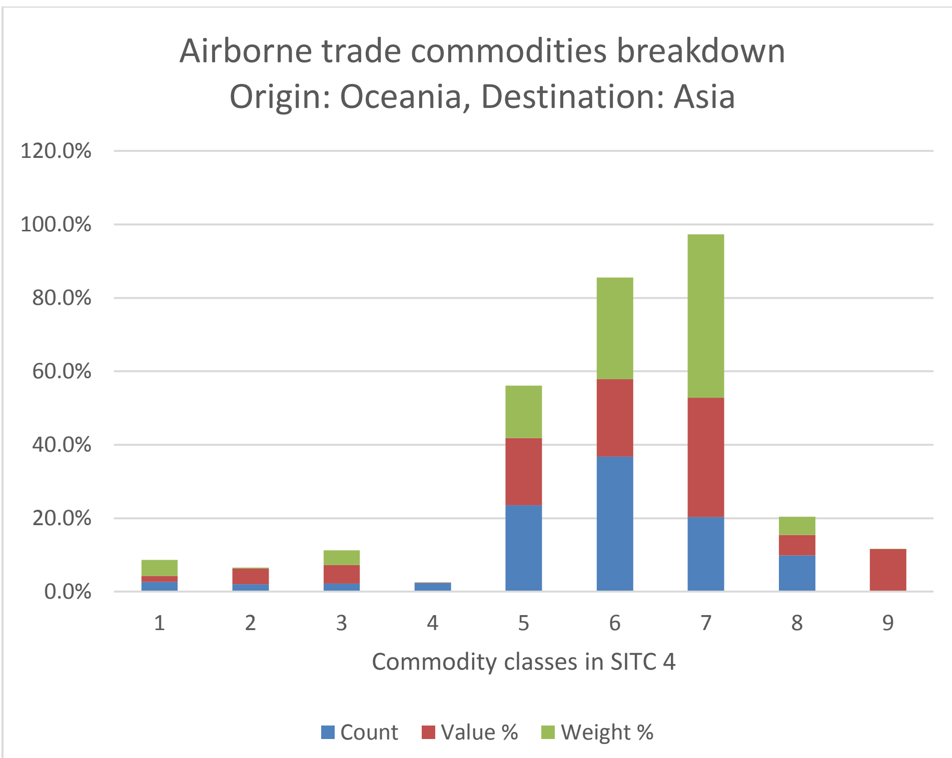



Chart Title
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To Asia*

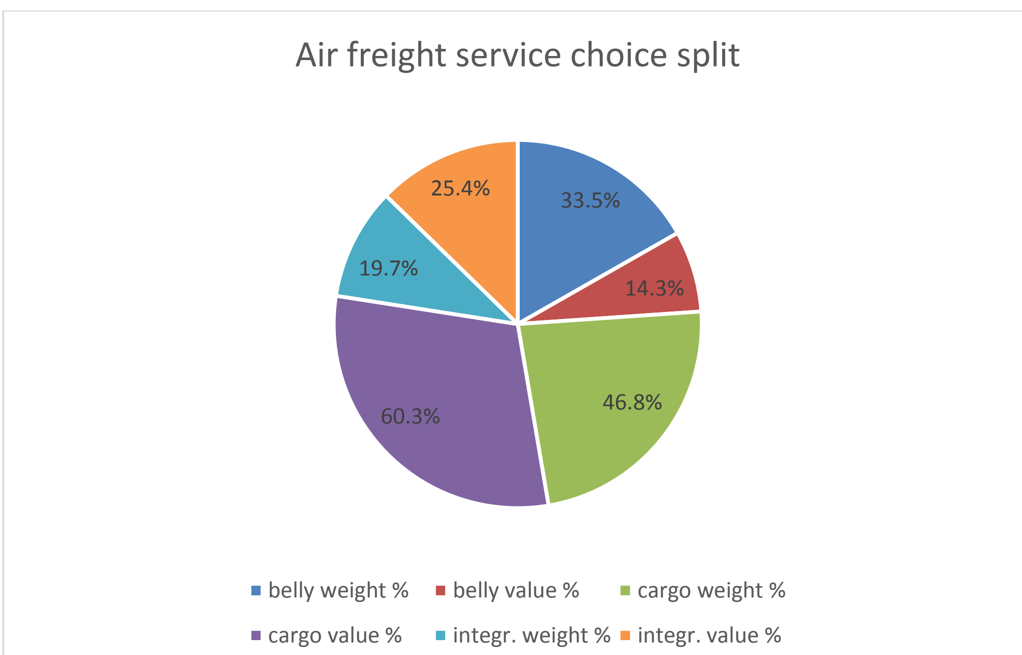


Mode split: Air
0.3%
17.6%
Air Value
Air Weight

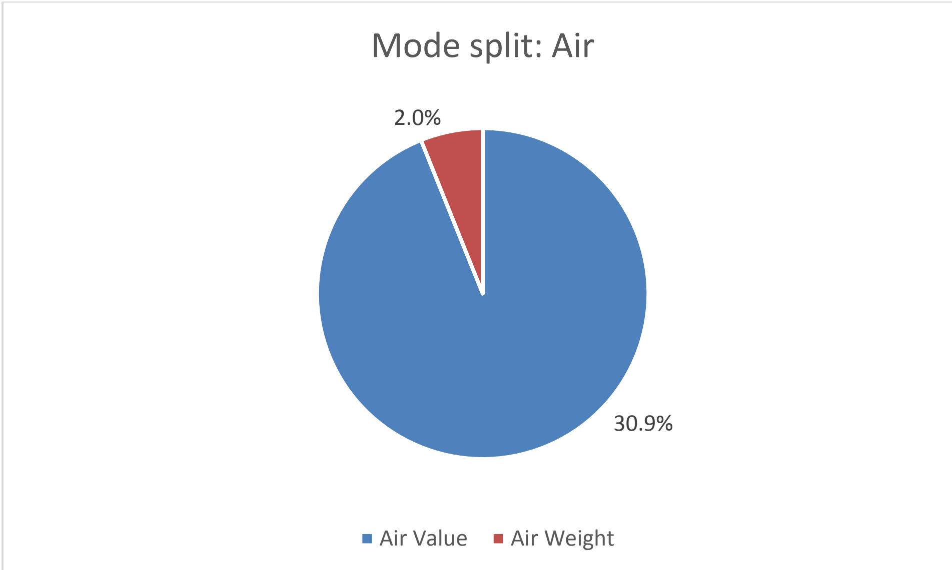



Airborne trade commodities breakdown
Origin: Oceania, Destination: Asia
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

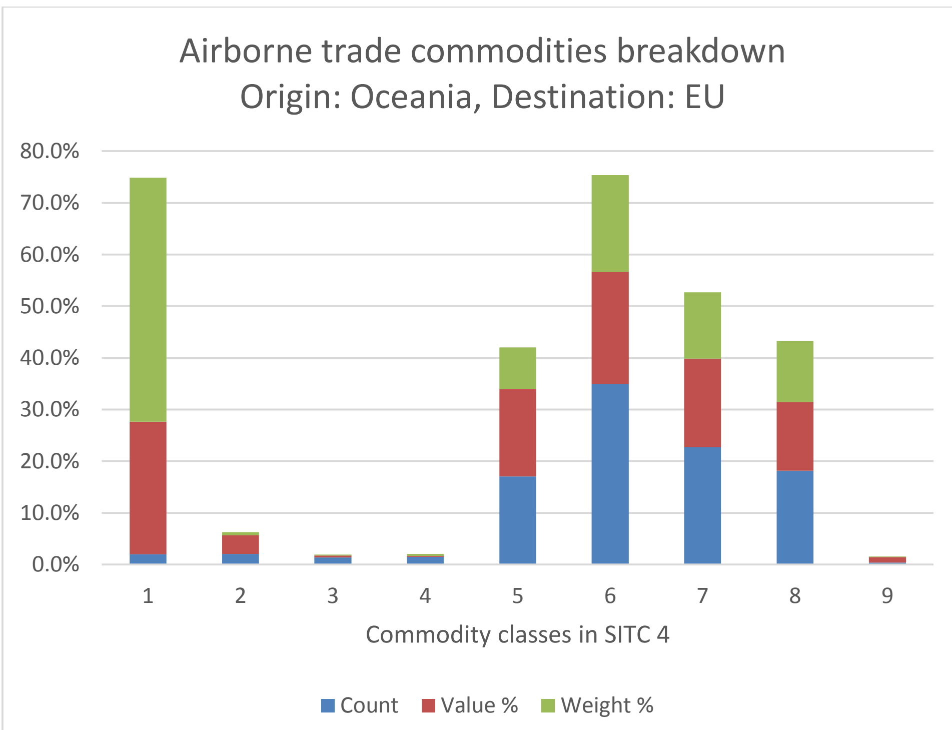

Air freight service choice per commodity class
Origin: Oceania, Destination: Asia
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %
14.8%
14.2%
35.1%
33.7%
50.1%
52.1%
29.6%
28.3%
70.2%
67.4%
0.2%
4.3%
25.7%
23.2%
61.1%
55.1%
13.2%
21.7%
19.9%
16.4%
47.5%
38.9%
32.6%
44.7%
25.9%
18.3%
61.6%
43.5%
12.5%
38.2%
23.4%
20.5%
55.8%
48.7%
20.8%
30.8%
24.7%
19.9%
58.7%
47.5%
16.7%
32.6%
26.1%
18.2%
62.1%
43.3%
11.8%
38.5%
30.0%
28.9%
70.0%
68.6%
0.0%
2.5%


Air freight service choice split
33.5%
14.3%
46.8%
60.3%
19.7%
25.4%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To Europe*

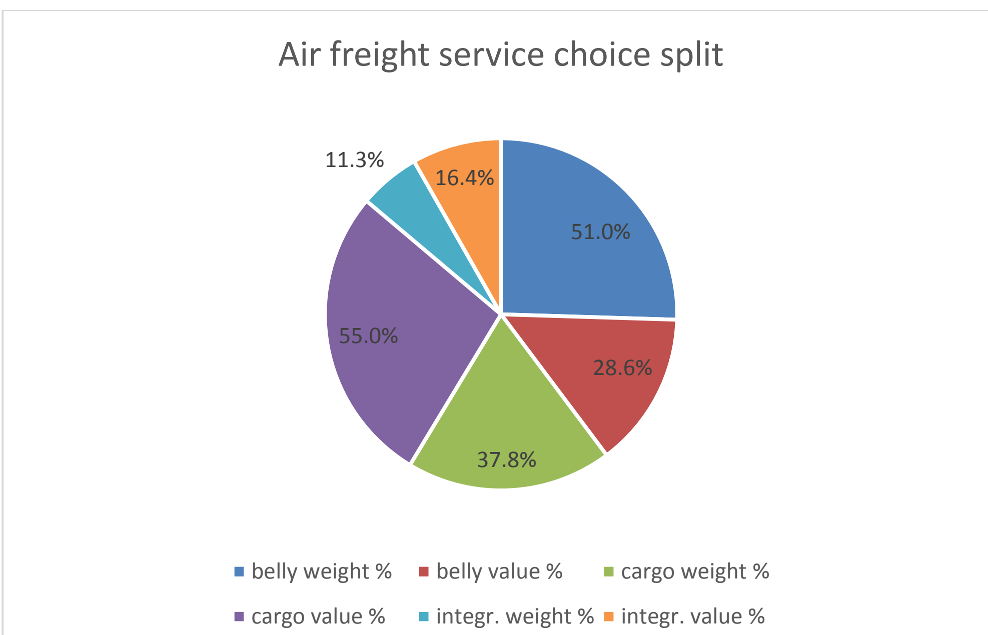


Mode split: Air
2.0%
30.9%
Air Value
Air Weight

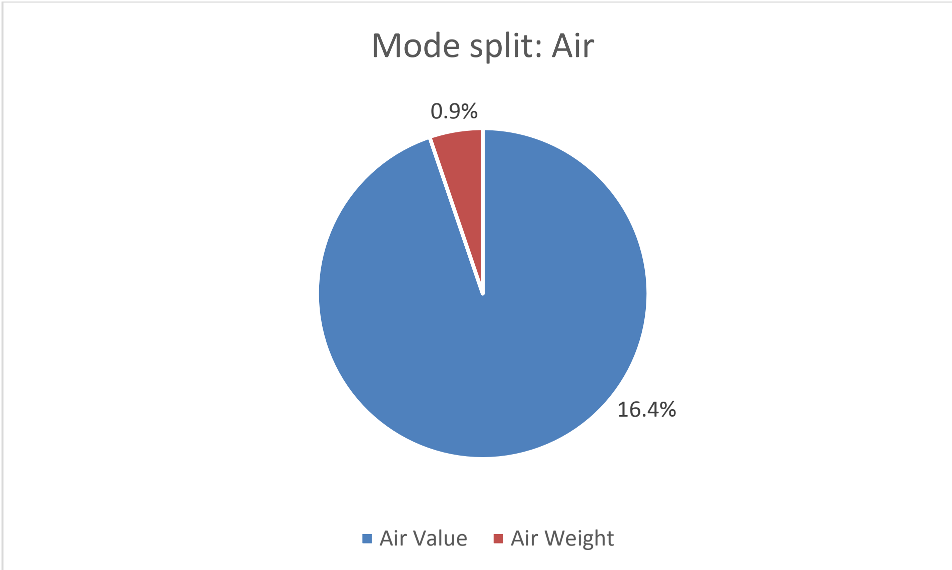



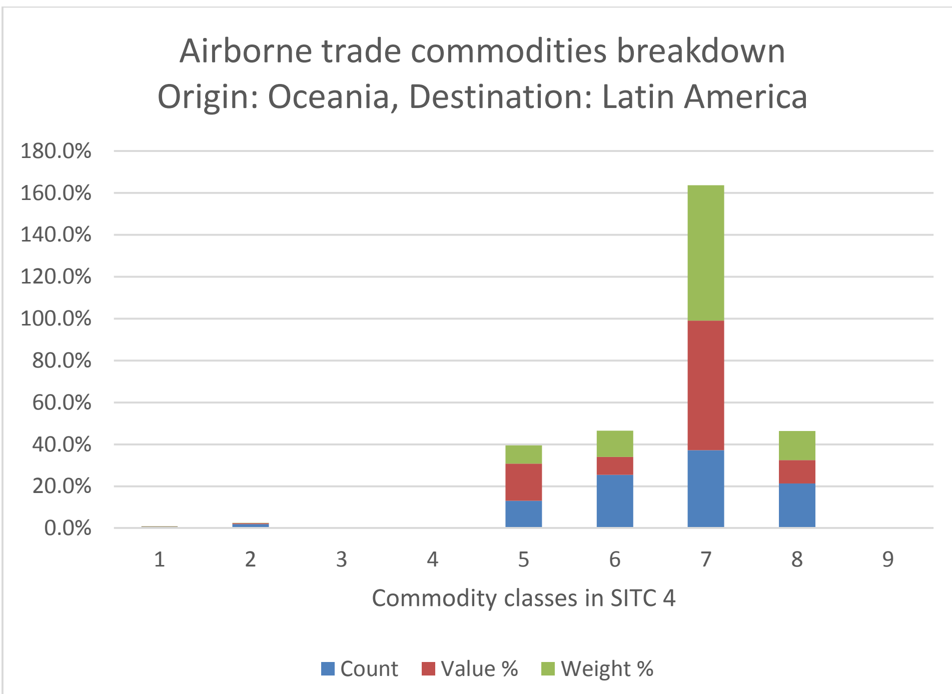
Airborne trade commodities breakdown
Origin: Oceania, Destination: EU
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %

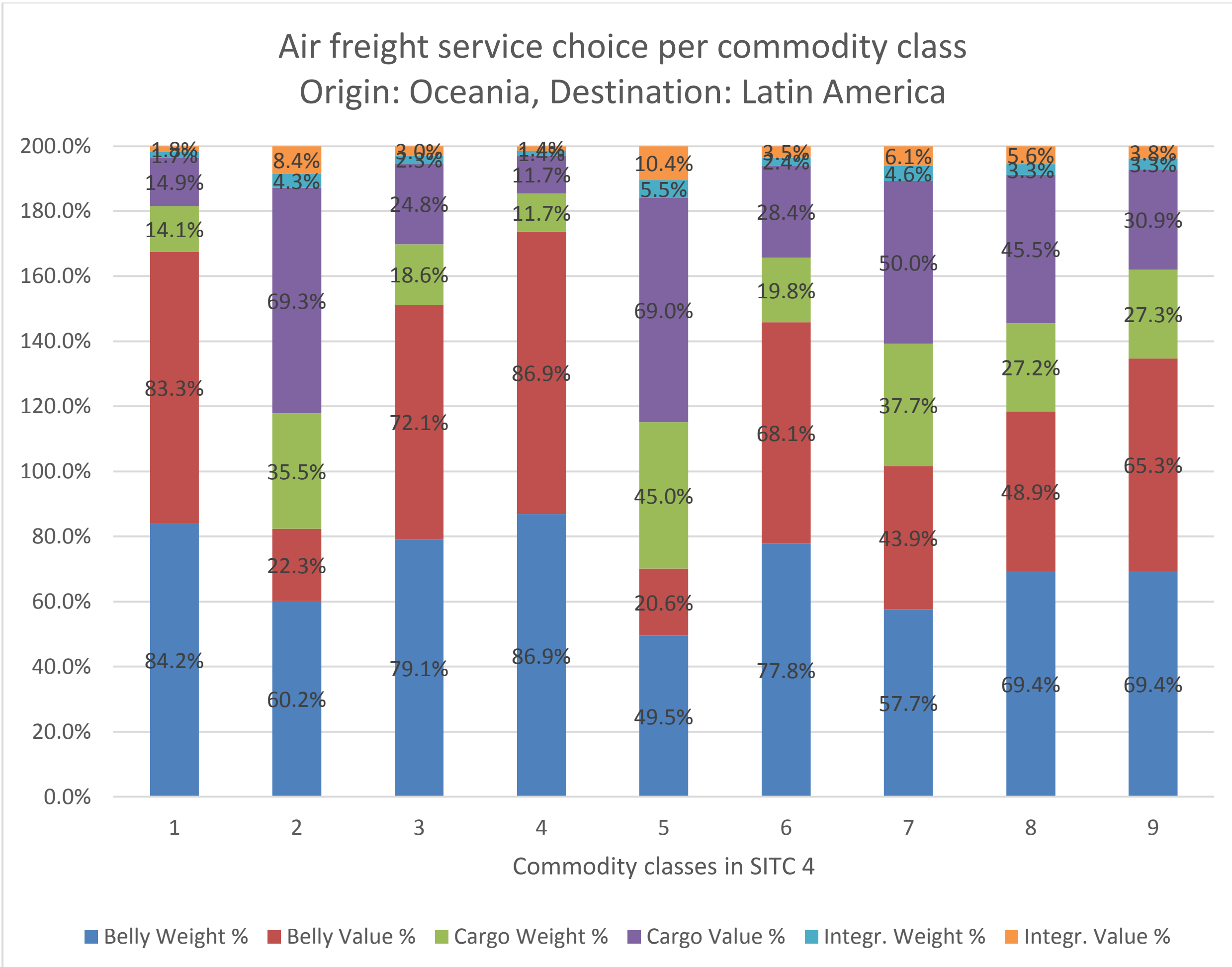

Air freight service choice per commodity class
Origin: Oceania, Destination: EU
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
9.2%
8.8%
30.8%
29.4%
60.1%
61.8%
21.8%
16.8%
73.4%
56.5%
4.8%
26.7%
17.1%
15.3%
57.3%
51.5%
25.6%
33.2%
9.8%
8.4%
32.9%
28.1%
57.3%
63.5%
20.2%
12.8%
67.8%
42.9%
11.9%
44.3%
17.7%
14.4%
59.2%
48.4%
23.1%
37.1%
19.3%
13.7%
64.8%
45.9%
15.9%
40.5%
18.0%
12.2%
60.3%
41.0%
21.8%
46.8%
23.7%
11.9%
67.7%
39.9%
8.6%
48.2%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %

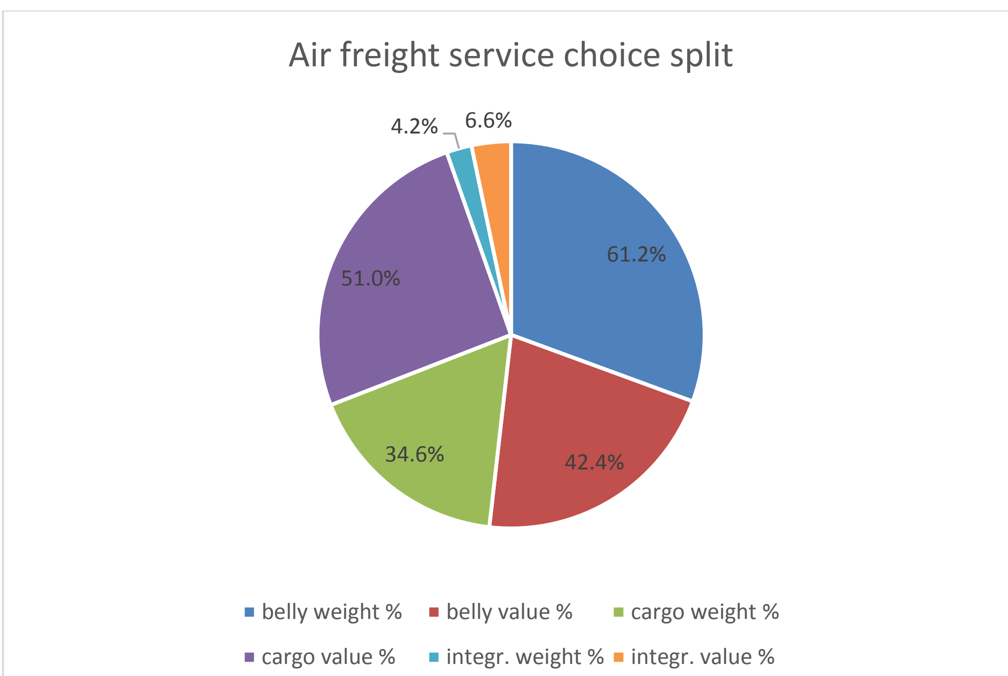

Air freight service choice split
11.3%
16.4%
51.0%
55.0%
28.6%
37.8%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

### *To Latin America*

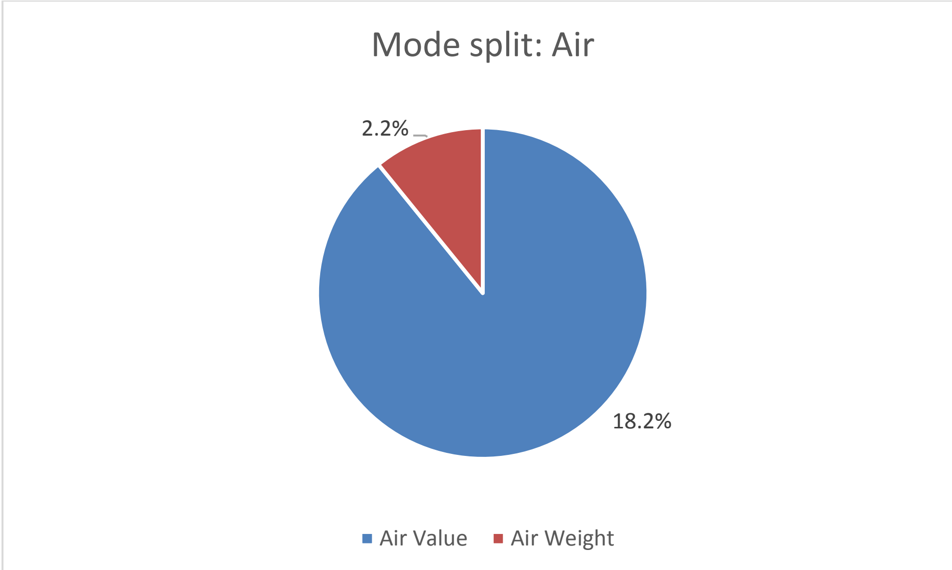


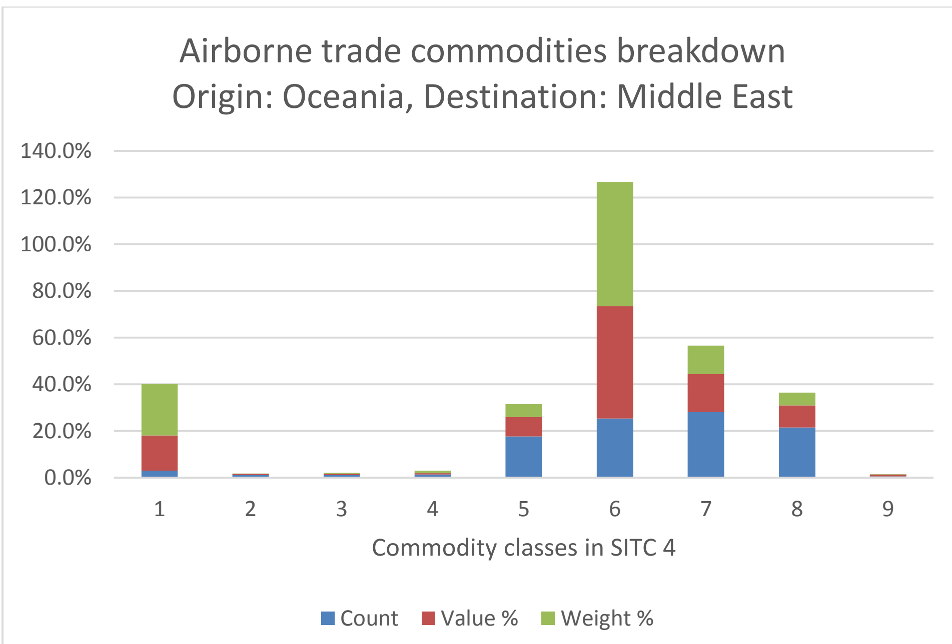



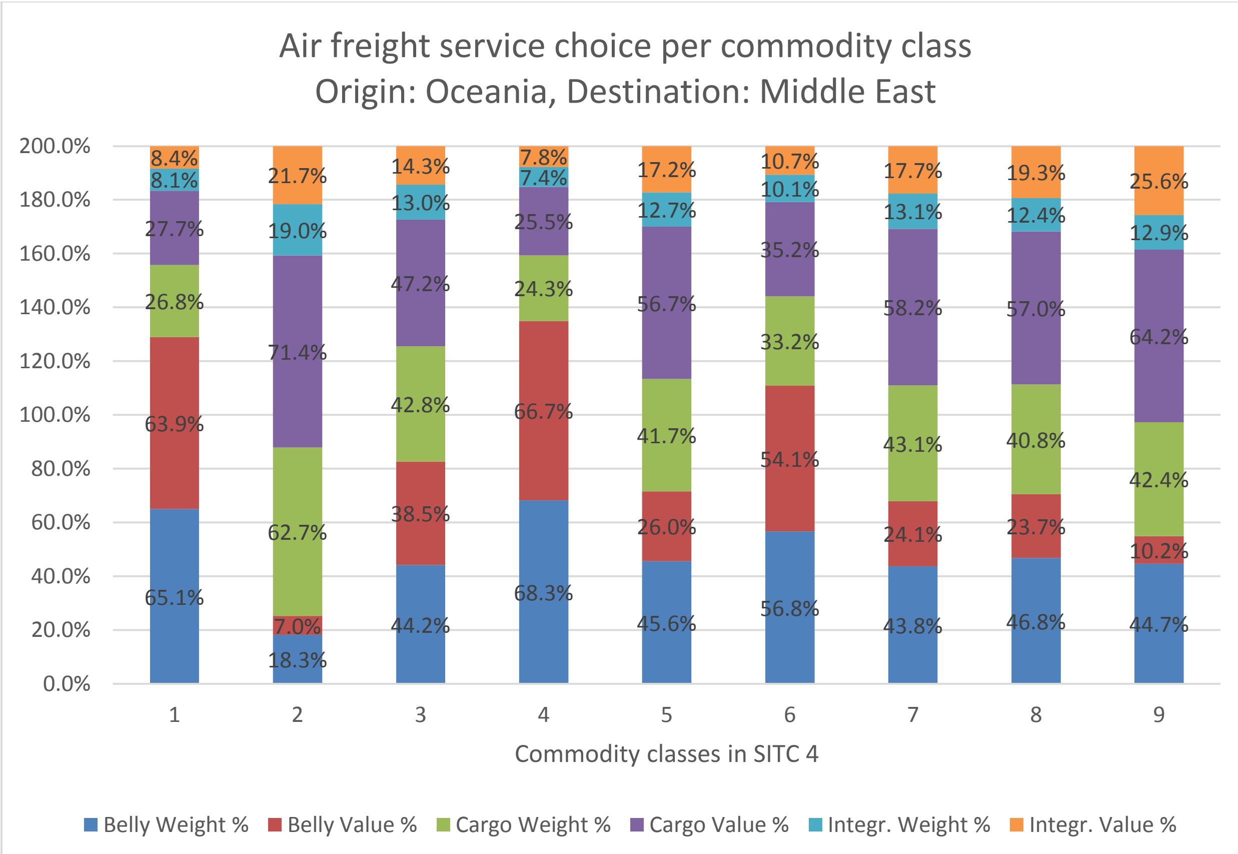

Air freight service choice per commodity class
Origin: Oceania, Destination: Latin America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
84.2% 83.3% 14.1% 14.9% 1.7% 1.8%
60.2% 22.3% 35.5% 69.3% 4.3% 8.4%
79.1% 72.1% 18.6% 24.8% 2.3% 3.0%
86.9% 86.9% 11.7% 11.7% 1.4% 1.4%
49.5% 20.6% 45.0% 69.0% 5.5% 10.4%
77.8% 68.1% 19.8% 28.4% 2.4% 3.5%
57.7% 43.9% 37.7% 50.0% 4.6% 6.1%
69.4% 48.9% 27.2% 45.5% 3.3% 5.6%
69.4% 65.3% 27.3% 30.9% 3.3% 3.8%
1 2 3 4 5 6 7 8 9
Commodity classes in SITC 4
Belly Weight % Belly Value % Cargo Weight % Cargo Value % Integr. Weight % Integr. Value %

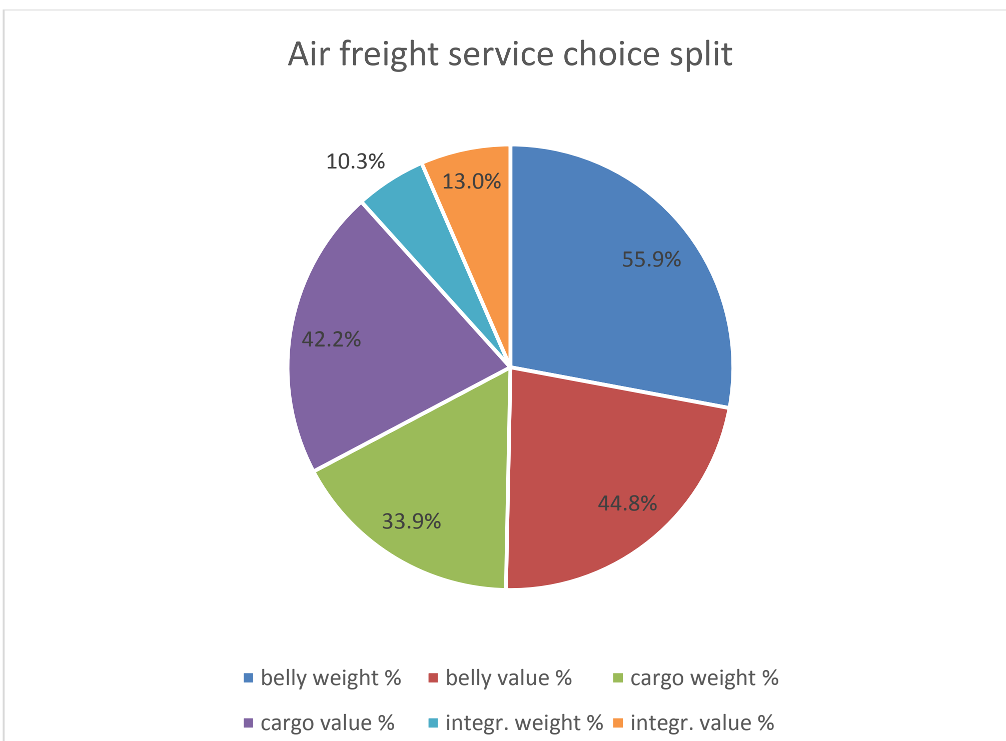

Air freight service choice split
4.2%
6.6%
61.2%
51.0%
34.6%
42.4%
belly weight % belly value % cargo weight %
cargo value % integr. weight % integr. value %

### *To Middle East*

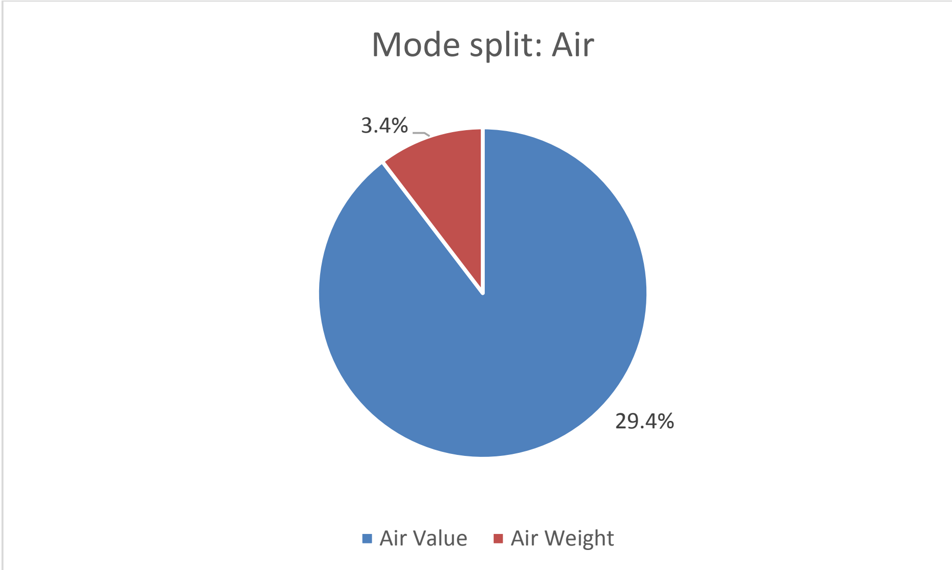


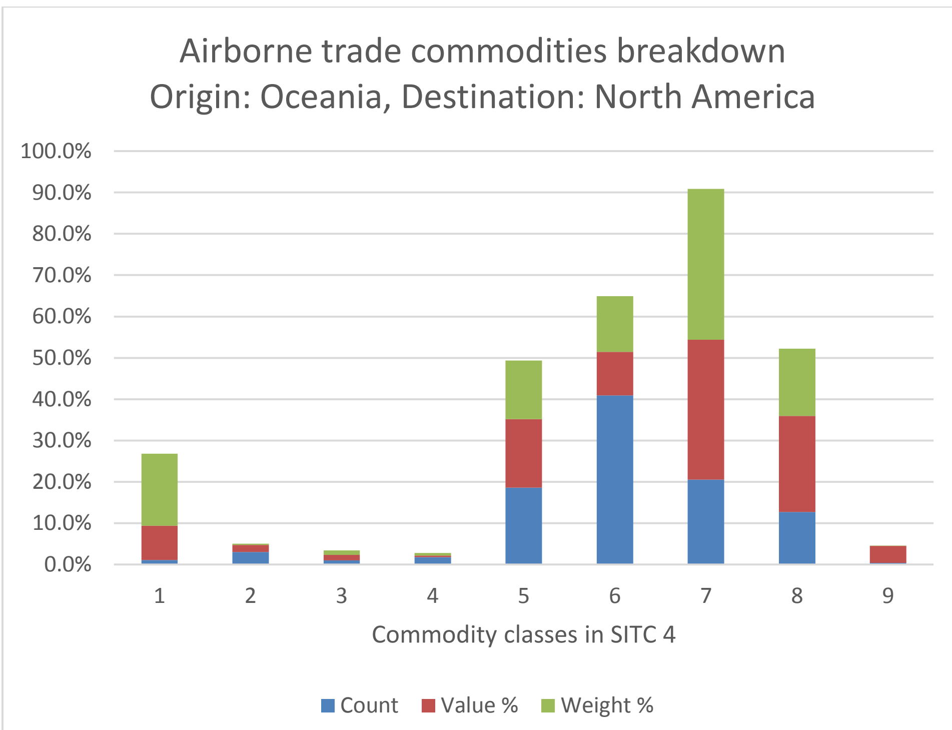

Air freight service choice per commodity class
Origin: Oceania, Destination: Middle East
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
65.1%
63.9%
26.8%
27.7%
8.1%
8.4%
18.3%
7.0%
62.7%
71.4%
19.0%
21.7%
44.2%
38.5%
42.8%
47.2%
13.0%
14.3%
68.3%
66.7%
24.3%
25.5%
7.4%
7.8%
45.6%
26.0%
41.7%
56.7%
12.7%
17.2%
56.8%
54.1%
33.2%
35.2%
10.1%
10.7%
43.8%
24.1%
43.1%
58.2%
13.1%
17.7%
46.8%
23.7%
40.8%
57.0%
12.4%
19.3%
44.7%
10.2%
42.4%
64.2%
12.9%
25.6%
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %


Air freight service choice split
55.9%
44.8%
33.9%
42.2%
10.3%
13.0%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

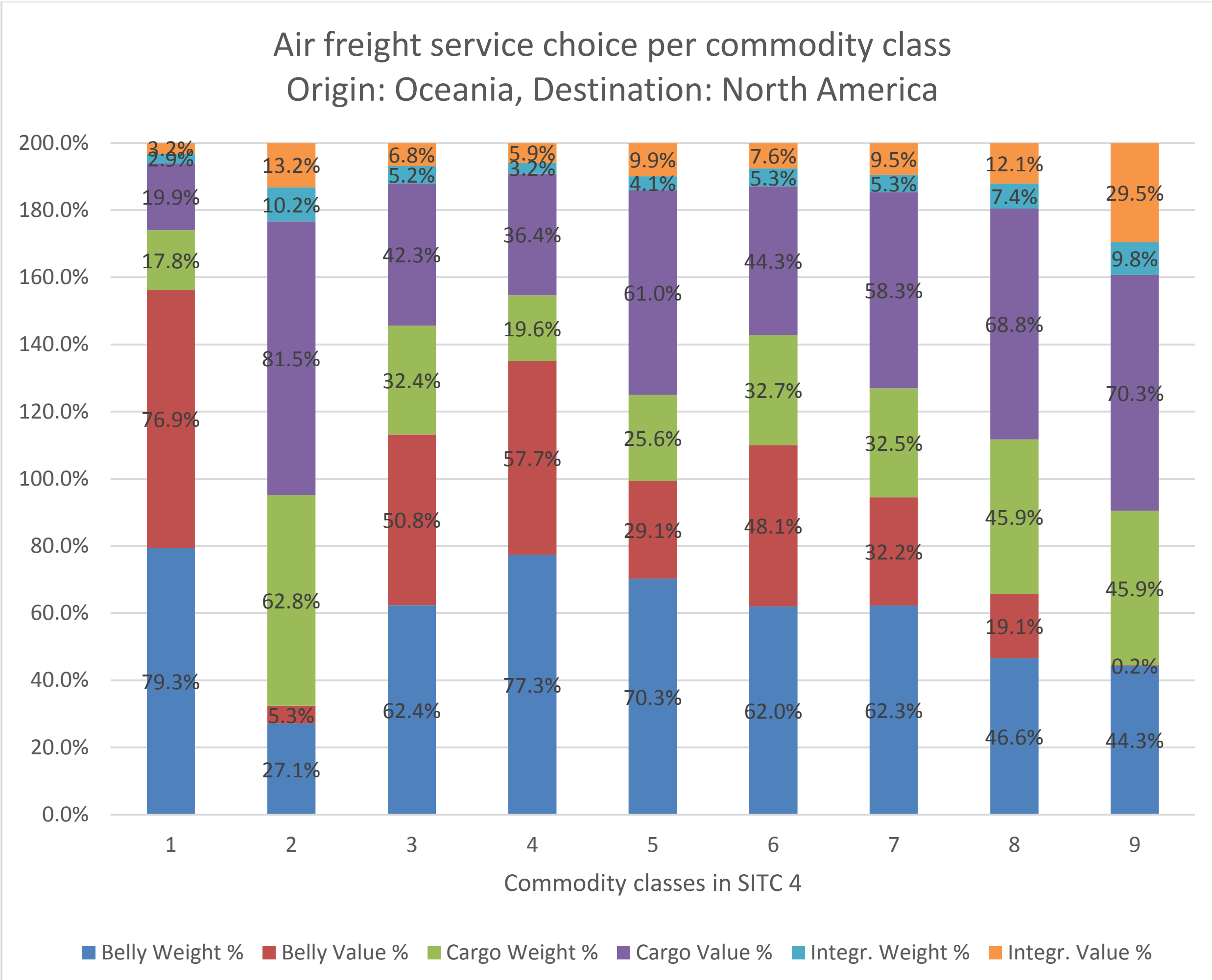
### *To Oceania*

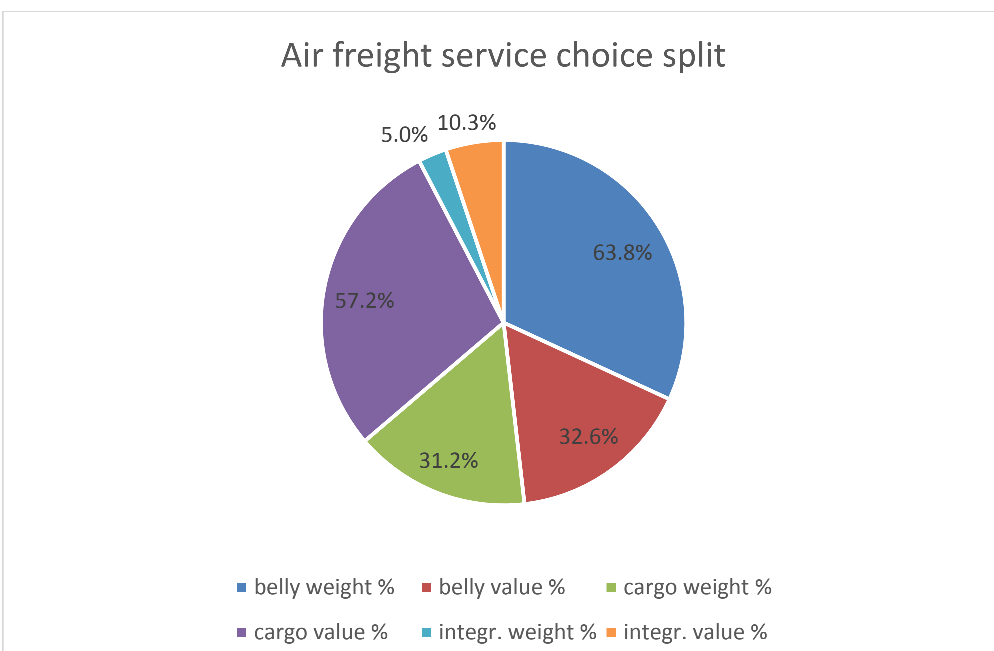


Mode split: Air
3.4%
29.4%
Air Value
Air Weight

Airborne trade commodities breakdown
Origin: Oceania, Destination: North America
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Count
Value %
Weight %


Air freight service choice per commodity class
Origin: Oceania, Destination: North America
200.0%
180.0%
160.0%
140.0%
120.0%
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
3.2%
2.9%
19.9%
17.8%
76.9%
79.3%
13.2%
10.2%
81.5%
62.8%
5.3%
27.1%
6.8%
5.2%
42.3%
32.4%
50.8%
62.4%
5.9%
3.2%
36.4%
19.6%
57.7%
77.3%
9.9%
4.1%
61.0%
25.6%
29.1%
70.3%
7.6%
5.3%
44.3%
32.7%
48.1%
62.0%
9.5%
5.3%
58.3%
32.5%
32.2%
62.3%
12.1%
7.4%
68.8%
45.9%
19.1%
46.6%
29.5%
9.8%
70.3%
45.9%
0.2%
44.3%
1
2
3
4
5
6
7
8
9
Commodity classes in SITC 4
Belly Weight %
Belly Value %
Cargo Weight %
Cargo Value %
Integr. Weight %
Integr. Value %


Air freight service choice split
5.0%
10.3%
63.8%
57.2%
32.6%
31.2%
belly weight %
belly value %
cargo weight %
cargo value %
integr. weight %
integr. value %

# Appendix B: Air freight rates regression analysis results

## Africa

### *To Asia*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.663802 |
| R Square | 0.440633 |
| Adjusted R Square | 0.432584 |
| Standard Error | 3.863263 |
| Observations | 142 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1634.191 | 817.0953 | 54.74749 | 2.92E-18 |
| Residual | 139 | 2074.547 | 14.9248 | | |
| Total | 141 | 3708.738 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | -5.9948 | 1.870468 | -3.20497 | 0.001676 | -9.69304 | -2.29655 | -9.69304 | -2.29655 |
| Kgs | -0.00959 | 0.001644 | -5.8308 | 3.69E-08 | -0.01284 | -0.00634 | -0.01284 | -0.00634 |
| Distance | 0.001547 | 0.000168 | 9.217899 | 4.33E-16 | 0.001215 | 0.001879 | 0.001215 | 0.001879 |

### *To Europe*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.834656 |
| R Square | 0.69665 |
| Adjusted R Square | 0.694499 |
| Standard Error | 1.114962 |
| Observations | 285 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 805.0823 | 402.5411 | 323.8098 | 9E-74 |
| Residual | 282 | 350.5657 | 1.243141 | | |
| Total | 284 | 1155.648 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.035903 | 0.182998 | 11.12526 | 4.45E-24 | 1.675687 | 2.396119 | 1.675687 | 2.396119 |
| Kgs | -0.00457 | 0.00033 | -13.8399 | 1.35E-33 | -0.00522 | -0.00392 | -0.00522 | -0.00392 |
| Distance | 0.000508 | 2.33E-05 | 21.7889 | 2.13E-62 | 0.000462 | 0.000554 | 0.000462 | 0.000554 |

## To Latin America

| Regression Statistics | |
|---|---|
| Multiple R | 0.625456 |
| R Square | 0.391195 |
| Adjusted R Square | 0.372463 |
| Standard Error | 4.023676 |
| Observations | 68 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 676.1991 | 338.0995 | 20.88327 | 9.9E-08 |
| Residual | 65 | 1052.348 | 16.18997 | | |
| Total | 67 | 1728.547 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 8.182604 | 2.712534 | 3.016591 | 0.003646 | 2.7653 | 13.59991 | 2.7653 | 13.59991 |
| Kgs | -0.01383 | 0.002354 | -5.87414 | 1.59E-07 | -0.01853 | -0.00913 | -0.01853 | -0.00913 |
| Distance | 0.000617 | 0.000229 | 2.694629 | 0.008959 | 0.00016 | 0.001075 | 0.00016 | 0.001075 |

## To Middle East

| Regression Statistics | |
|---|---|
| Multiple R | 0.766135 |
| R Square | 0.586963 |
| Adjusted R Square | 0.583291 |
| Standard Error | 2.020356 |
| Observations | 228 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 1305.147 | 652.5734 | 159.8725 | 6.29E-44 |
| Residual | 225 | 918.4133 | 4.081837 | | |
| Total | 227 | 2223.56 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.79049 | 0.501629 | 1.575846 | 0.116466 | -0.198 | 1.778981 | -0.198 | 1.778981 |
| Kgs | -0.00775 | 0.000715 | -10.8436 | 2.59E-22 | -0.00916 | -0.00634 | -0.00916 | -0.00634 |
| Distance | 0.001063 | 8.36E-05 | 12.70732 | 3.03E-28 | 0.000898 | 0.001228 | 0.000898 | 0.001228 |

## To North America

| Regression Statistics | |
|---|---|
| Multiple R | 0.660425 |
| R Square | 0.436162 |
| Adjusted R Square | 0.430965 |
| Standard Error | 2.610407 |
| Observations | 220 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 1143.85 | 571.925 | 83.93105 | 1E-27 |
| Residual | 217 | 1478.687 | 6.814224 | | |
| Total | 219 | 2622.537 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 4.216389 | 0.8057 | 5.233199 | 3.92E-07 | 2.62839 | 5.804389 | 2.62839 | 5.804389 |
| Kgs | -0.00806 | 0.000877 | -9.18266 | 3.44E-17 | -0.00978 | -0.00633 | -0.00978 | -0.00633 |
| Distance | 0.000457 | 5.51E-05 | 8.298411 | 1.12E-14 | 0.000349 | 0.000566 | 0.000349 | 0.000566 |

## To Oceania

| Regression Statistics | |
|---|---|
| Multiple R | 0.626892 |
| R Square | 0.392993 |
| Adjusted R Square | 0.378188 |
| Standard Error | 3.858597 |
| Observations | 85 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 790.4323 | 395.2162 | 26.54457 | 1.29E-09 |
| Residual | 82 | 1220.879 | 14.88877 | | |
| Total | 84 | 2011.312 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 4.410387 | 2.547939 | 1.730963 | 0.08722 | -0.65828 | 9.47905 | -0.65828 | 9.47905 |
| Kgs | -0.01189 | 0.002487 | -4.78243 | 7.53E-06 | -0.01684 | -0.00695 | -0.01684 | -0.00695 |
| Distance | 0.000552 | 0.000158 | 3.496314 | 0.000764 | 0.000238 | 0.000867 | 0.000238 | 0.000867 |

## Asia

### *To Africa*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.640858 |
| R Square | 0.410698 |
| Adjusted R Square | 0.401194 |
| Standard Error | 3.893308 |
| Observations | 127 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1309.92 | 654.9599 | 43.20929 | 5.77E-15 |
| Residual | 124 | 1879.573 | 15.15785 | | |
| Total | 126 | 3189.493 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 4.506963 | 1.960621 | 2.298743 | 0.023193 | 0.626346 | 8.387581 | 0.626346 | 8.387581 |
| Kgs | -0.01438 | 0.001933 | -7.43679 | 1.48E-11 | -0.0182 | -0.01055 | -0.0182 | -0.01055 |
| Distance | 0.000826 | 0.000174 | 4.747118 | 5.59E-06 | 0.000482 | 0.001171 | 0.000482 | 0.001171 |

### *To Europe*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.772111 |
| R Square | 0.596156 |
| Adjusted R Square | 0.59117 |
| Standard Error | 1.958951 |
| Observations | 165 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 917.7147 | 458.8574 | 119.5723 | 1.27E-32 |
| Residual | 162 | 621.6734 | 3.83749 | | |
| Total | 164 | 1539.388 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | -8.97558 | 2.552712 | -3.5161 | 0.000568 | -14.0165 | -3.9347 | -14.0165 | -3.9347 |
| Kgs | -0.01037 | 0.000745 | -13.9056 | 1.96E-29 | -0.01184 | -0.00889 | -0.01184 | -0.00889 |
| Distance | 0.001911 | 0.000253 | 7.555141 | 2.91E-12 | 0.001412 | 0.00241 | 0.001412 | 0.00241 |

## *To Latin America*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.449787 |
| R Square | 0.202308 |
| Adjusted R Square | 0.156726 |
| Standard Error | 6.481531 |
| Observations | 38 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 372.9073 | 186.4537 | 4.43829 | 0.019148 |
| Residual | 35 | 1470.359 | 42.01024 | | |
| Total | 37 | 1843.266 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 7.520412 | 18.12985 | 0.414808 | 0.680814 | -29.2851 | 44.32596 | -29.2851 | 44.32596 |
| Kgs | -0.01523 | 0.005215 | -2.92087 | 0.006073 | -0.02582 | -0.00465 | -0.02582 | -0.00465 |
| Distance | 0.000546 | 0.000959 | 0.56951 | 0.572647 | -0.0014 | 0.002494 | -0.0014 | 0.002494 |

## *To Middle East*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.719986 |
| R Square | 0.51838 |
| Adjusted R Square | 0.509293 |
| Standard Error | 2.010927 |
| Observations | 109 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 461.3631 | 230.6816 | 57.04536 | 1.53E-17 |
| Residual | 106 | 428.6457 | 4.043827 | | |
| Total | 108 | 890.0088 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.913192 | 1.605989 | 1.813955 | 0.072514 | -0.27084 | 6.097222 | -0.27084 | 6.097222 |
| Kgs | -0.00993 | 0.001247 | -7.96404 | 2E-12 | -0.0124 | -0.00746 | -0.0124 | -0.00746 |
| Distance | 0.000902 | 0.000218 | 4.145116 | 6.86E-05 | 0.000471 | 0.001334 | 0.000471 | 0.001334 |

## To North America

| Regression Statistics | |
|---|---|
| Multiple R | 0.603682 |
| R Square | 0.364432 |
| Adjusted R Square | 0.357635 |
| Standard Error | 2.767834 |
| Observations | 190 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 821.4417 | 410.7208 | 53.61257 | 3.94E-19 |
| Residual | 187 | 1432.589 | 7.660905 | | |
| Total | 189 | 2254.031 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 10.24821 | 1.318419 | 7.773103 | 4.96E-13 | 7.647323 | 12.8491 | 7.647323 | 12.8491 |
| Kgs | -0.01028 | 0.000996 | -10.3173 | 4.84E-20 | -0.01224 | -0.00831 | -0.01224 | -0.00831 |
| Distance | 0.000107 | 9.17E-05 | 1.164379 | 0.245754 | -7.4E-05 | 0.000288 | -7.4E-05 | 0.000288 |

## To Oceania

| Regression Statistics | |
|---|---|
| Multiple R | 0.685804 |
| R Square | 0.470327 |
| Adjusted R Square | 0.454974 |
| Standard Error | 1.467206 |
| Observations | 72 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 131.8933 | 65.94665 | 30.63447 | 3.01E-10 |
| Residual | 69 | 148.5359 | 2.152694 | | |
| Total | 71 | 280.4292 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 5.280012 | 1.411989 | 3.739415 | 0.000377 | 2.463171 | 8.096853 | 2.463171 | 8.096853 |
| Kgs | -0.00648 | 0.000855 | -7.58011 | 1.17E-10 | -0.00818 | -0.00477 | -0.00818 | -0.00477 |
| Distance | 0.00024 | 0.000167 | 1.438208 | 0.154896 | -9.3E-05 | 0.000572 | -9.3E-05 | 0.000572 |

## Europe

### *To Africa*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.73875 |
| R Square | 0.545752 |
| Adjusted R Square | 0.541934 |
| Standard Error | 3.371576 |
| Observations | 241 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 3250.456 | 1625.228 | 142.9712 | 1.65E-41 |
| Residual | 238 | 2705.47 | 11.36752 | | |
| Total | 240 | 5955.926 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 6.154121 | 0.694065 | 8.866777 | 1.82E-16 | 4.786825 | 7.521416 | 4.786825 | 7.521416 |
| Kgs | -0.0153 | 0.001123 | -13.6167 | 1.31E-31 | -0.01751 | -0.01308 | -0.01751 | -0.01308 |
| Distance | 0.000987 | 9.13E-05 | 10.81503 | 1.96E-22 | 0.000807 | 0.001167 | 0.000807 | 0.001167 |

### *To Asia*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.537704 |
| R Square | 0.289125 |
| Adjusted R Square | 0.280069 |
| Standard Error | 4.078194 |
| Observations | 160 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1062.009 | 531.0045 | 31.92732 | 2.32E-12 |
| Residual | 157 | 2611.172 | 16.63167 | | |
| Total | 159 | 3673.181 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 5.396995 | 5.518683 | 0.97795 | 0.329604 | -5.50345 | 16.29744 | -5.50345 | 16.29744 |
| Kgs | -0.01292 | 0.001624 | -7.95839 | 3.26E-13 | -0.01613 | -0.00971 | -0.01613 | -0.00971 |
| Distance | 0.000524 | 0.000546 | 0.960964 | 0.338048 | -0.00055 | 0.001602 | -0.00055 | 0.001602 |

## To Latin America

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.555061 |
| R Square | 0.308093 |
| Adjusted R Square | 0.286128 |
| Standard Error | 4.432471 |
| Observations | 66 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 551.1462 | 275.5731 | 14.02636 | 9.15E-06 |
| Residual | 63 | 1237.748 | 19.6468 | | |
| Total | 65 | 1788.895 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 13.21973 | 3.820898 | 3.45985 | 0.000975 | 5.584277 | 20.85519 | 5.584277 | 20.85519 |
| Kgs | -0.01424 | 0.002691 | -5.29214 | 1.63E-06 | -0.01962 | -0.00886 | -0.01962 | -0.00886 |
| Distance | 2.6E-05 | 0.000335 | 0.077424 | 0.938532 | -0.00064 | 0.000696 | -0.00064 | 0.000696 |

## To Middle East

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.625174 |
| R Square | 0.390843 |
| Adjusted R Square | 0.385176 |
| Standard Error | 2.767567 |
| Observations | 218 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1056.592 | 528.2958 | 68.97327 | 7.22E-24 |
| Residual | 215 | 1646.777 | 7.659429 | | |
| Total | 217 | 2703.369 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 3.48694 | 1.531915 | 2.276196 | 0.023819 | 0.467444 | 6.506435 | 0.467444 | 6.506435 |
| Kgs | -0.0104 | 0.000942 | -11.0423 | 9.53E-23 | -0.01226 | -0.00854 | -0.01226 | -0.00854 |
| Distance | 0.001182 | 0.000306 | 3.857814 | 0.000151 | 0.000578 | 0.001786 | 0.000578 | 0.001786 |

## To North America

| Regression Statistics | |
|---|---|
| Multiple R | 0.556562 |
| R Square | 0.309761 |
| Adjusted R Square | 0.305539 |
| Standard Error | 2.628561 |
| Observations | 330 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1013.937 | 506.9684 | 73.37445 | 4.75E-27 |
| Residual | 327 | 2259.351 | 6.909331 | | |
| Total | 329 | 3273.288 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 7.432629 | 1.370893 | 5.421744 | 1.15E-07 | 4.735747 | 10.12951 | 4.735747 | 10.12951 |
| Kgs | -0.00857 | 0.000709 | -12.0762 | 5.13E-28 | -0.00996 | -0.00717 | -0.00996 | -0.00717 |
| Distance | 0.000128 | 0.00016 | 0.801478 | 0.423437 | -0.00019 | 0.000443 | -0.00019 | 0.000443 |

## To Oceania

| Regression Statistics | |
|---|---|
| Multiple R | 0.685754 |
| R Square | 0.470259 |
| Adjusted R Square | 0.462109 |
| Standard Error | 7.155145 |
| Observations | 133 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 5908.174 | 2954.087 | 57.70141 | 1.16E-18 |
| Residual | 130 | 6655.493 | 51.1961 | | |
| Total | 132 | 12563.67 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | -8.09008 | 12.53896 | -0.6452 | 0.519938 | -32.8969 | 16.71675 | -32.8969 | 16.71675 |
| Kgs | -0.032 | 0.003045 | -10.5081 | 4.49E-19 | -0.03802 | -0.02597 | -0.03802 | -0.02597 |
| Distance | 0.001887 | 0.000683 | 2.762703 | 0.006564 | 0.000536 | 0.003238 | 0.000536 | 0.003238 |

## Latin America

### *To Africa*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.831589 |
| R Square | 0.691541 |
| Adjusted R Square | 0.681902 |
| Standard Error | 3.957745 |
| Observations | 67 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 2247.48 | 1123.74 | 71.74145 | 4.51E-17 |
| Residual | 64 | 1002.48 | 15.66374 | | |
| Total | 66 | 3249.959 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 4.810214 | 2.673894 | 1.798954 | 0.076741 | -0.5315 | 10.15193 | -0.5315 | 10.15193 |
| Kgs | -0.02296 | 0.002318 | -9.90149 | 1.56E-14 | -0.02759 | -0.01832 | -0.02759 | -0.01832 |
| Distance | 0.001529 | 0.000226 | 6.772453 | 4.66E-09 | 0.001078 | 0.00198 | 0.001078 | 0.00198 |

### *To Asia*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.546154 |
| R Square | 0.298285 |
| Adjusted R Square | 0.253013 |
| Standard Error | 4.068167 |
| Observations | 34 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 218.0866 | 109.0433 | 6.588726 | 0.004126 |
| Residual | 31 | 513.0494 | 16.54998 | | |
| Total | 33 | 731.136 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 30.1519 | 11.89094 | 2.535703 | 0.01648 | 5.900166 | 54.40364 | 5.900166 | 54.40364 |
| Kgs | -0.0132 | 0.00382 | -3.4548 | 0.001617 | -0.02099 | -0.00541 | -0.02099 | -0.00541 |
| Distance | -0.00076 | 0.000628 | -1.20928 | 0.235699 | -0.00204 | 0.000522 | -0.00204 | 0.000522 |

## To Europe

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.9214 |
| R Square | 0.848978 |
| Adjusted R Square | 0.844601 |
| Standard Error | 1.727748 |
| Observations | 72 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1157.891 | 578.9456 | 193.9442 | 4.75E-29 |
| Residual | 69 | 205.9729 | 2.985115 | | |
| Total | 71 | 1363.864 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 4.149642 | 1.421184 | 2.919848 | 0.004727 | 1.314457 | 6.984827 | 1.314457 | 6.984827 |
| Kgs | -0.01753 | 0.000982 | -17.8441 | 1.48E-27 | -0.01949 | -0.01557 | -0.01949 | -0.01557 |
| Distance | 0.001034 | 0.000124 | 8.335271 | 4.87E-12 | 0.000786 | 0.001281 | 0.000786 | 0.001281 |

## To Middle East

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.889182 |
| R Square | 0.790645 |
| Adjusted R Square | 0.784577 |
| Standard Error | 2.737873 |
| Observations | 72 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1953.325 | 976.6624 | 130.2921 | 3.72E-24 |
| Residual | 69 | 517.2203 | 7.495947 | | |
| Total | 71 | 2470.545 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 17.93432 | 5.067783 | 3.538888 | 0.000724 | 7.824366 | 28.04427 | 7.824366 | 28.04427 |
| Kgs | -0.02507 | 0.001557 | -16.1046 | 4.54E-25 | -0.02817 | -0.02196 | -0.02817 | -0.02196 |
| Distance | 0.000377 | 0.00034 | 1.107317 | 0.272002 | -0.0003 | 0.001055 | -0.0003 | 0.001055 |

## *To North America*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.860748 |
| R Square | 0.740888 |
| Adjusted R Square | 0.73369 |
| Standard Error | 0.682809 |
| Observations | 75 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 95.98323 | 47.99162 | 102.9358 | 7.68E-22 |
| Residual | 72 | 33.56846 | 0.466229 | | |
| Total | 74 | 129.5517 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 3.233109 | 0.262055 | 12.33751 | 1.96E-19 | 2.710712 | 3.755507 | 2.710712 | 3.755507 |
| Kgs | -0.00449 | 0.000378 | -11.8616 | 1.33E-18 | -0.00524 | -0.00373 | -0.00524 | -0.00373 |
| Distance | 0.000256 | 3.19E-05 | 8.021486 | 1.4E-11 | 0.000192 | 0.000319 | 0.000192 | 0.000319 |

## *To Oceania*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.766609 |
| R Square | 0.58769 |
| Adjusted R Square | 0.559254 |
| Standard Error | 1.491484 |
| Observations | 32 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 91.95145 | 45.97573 | 20.66768 | 2.63E-06 |
| Residual | 29 | 64.51117 | 2.224523 | | |
| Total | 31 | 156.4626 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 11.02468 | 1.995867 | 5.523753 | 5.92E-06 | 6.942671 | 15.10669 | 6.942671 | 15.10669 |
| Kgs | -0.00774 | 0.001272 | -6.08487 | 1.26E-06 | -0.01034 | -0.00514 | -0.01034 | -0.00514 |
| Distance | 0.000296 | 0.000143 | 2.07598 | 0.046867 | 4.39E-06 | 0.000588 | 4.39E-06 | 0.000588 |

## Middle East

### *To Africa*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.864706 |
| R Square | 0.747717 |
| Adjusted R Square | 0.744641 |
| Standard Error | 2.003711 |
| Observations | 167 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1951.479 | 975.7395 | 243.0321 | 9.01E-50 |
| Residual | 164 | 658.4368 | 4.014858 | | |
| Total | 166 | 2609.916 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1.334582 | 0.575994 | 2.317006 | 0.02174 | 0.197262 | 2.471903 | 0.197262 | 2.471903 |
| Kgs | -0.01365 | 0.001074 | -12.708 | 3.41E-26 | -0.01577 | -0.01153 | -0.01577 | -0.01153 |
| Distance | 0.001562 | 9.24E-05 | 16.90677 | 9.06E-38 | 0.00138 | 0.001745 | 0.00138 | 0.001745 |

### *To Asia*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.693542 |
| R Square | 0.481 |
| Adjusted R Square | 0.471115 |
| Standard Error | 3.33708 |
| Observations | 108 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1083.68 | 541.8402 | 48.65616 | 1.11E-15 |
| Residual | 105 | 1169.291 | 11.13611 | | |
| Total | 107 | 2252.971 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 21.43708 | 2.563145 | 8.363586 | 2.77E-13 | 16.35484 | 26.51932 | 16.35484 | 26.51932 |
| Kgs | -0.01567 | 0.002011 | -7.79443 | 4.92E-12 | -0.01966 | -0.01168 | -0.01966 | -0.01168 |
| Distance | -0.00132 | 0.000364 | -3.6354 | 0.000432 | -0.00205 | -0.0006 | -0.00205 | -0.0006 |

## To Europe

| Regression Statistics | |
|---|---|
| Multiple R | 0.927864 |
| R Square | 0.860932 |
| Adjusted R Square | 0.860057 |
| Standard Error | 0.788636 |
| Observations | 321 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 1224.395 | 612.1977 | 984.3261 | 5.9E-137 |
| Residual | 318 | 197.7788 | 0.621946 | | |
| Total | 320 | 1422.174 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | -0.84851 | 0.365198 | -2.32344 | 0.020786 | -1.56702 | -0.13001 | -1.56702 | -0.13001 |
| Kgs | -0.00831 | 0.000212 | -39.1758 | 9.9E-124 | -0.00873 | -0.00789 | -0.00873 | -0.00789 |
| Distance | 0.001557 | 7.29E-05 | 21.37299 | 1.86E-63 | 0.001414 | 0.0017 | 0.001414 | 0.0017 |

## To Latin America

| Regression Statistics | |
|---|---|
| Multiple R | 0.849769 |
| R Square | 0.722107 |
| Adjusted R Square | 0.713812 |
| Standard Error | 3.264377 |
| Observations | 70 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 1855.236 | 927.618 | 87.04996 | 2.34E-19 |
| Residual | 67 | 713.9625 | 10.65616 | | |
| Total | 69 | 2569.199 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | -27.7314 | 6.535956 | -4.2429 | 6.93E-05 | -40.7772 | -14.6856 | -40.7772 | -14.6856 |
| Kgs | -0.02131 | 0.001888 | -11.2858 | 3.81E-17 | -0.02508 | -0.01754 | -0.02508 | -0.01754 |
| Distance | 0.003319 | 0.00044 | 7.546653 | 1.58E-10 | 0.002441 | 0.004197 | 0.002441 | 0.004197 |

## To North America

| Regression Statistics | |
|---|---|
| Multiple R | 0.6222 |
| R Square | 0.387133 |
| Adjusted R Square | 0.382401 |
| Standard Error | 3.857099 |
| Observations | 262 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 2433.972 | 1216.986 | 81.802 | 2.91E-28 |
| Residual | 259 | 3853.199 | 14.87722 | | |
| Total | 261 | 6287.171 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 10.56124 | 2.605214 | 4.053888 | 6.67E-05 | 5.431147 | 15.69134 | 5.431147 | 15.69134 |
| Kgs | -0.0145 | 0.00115 | -12.6127 | 9.36E-29 | -0.01677 | -0.01224 | -0.01677 | -0.01224 |
| Distance | 0.000402 | 0.000191 | 2.109799 | 0.035835 | 2.68E-05 | 0.000778 | 2.68E-05 | 0.000778 |

## To Oceania

| Regression Statistics | |
|---|---|
| Multiple R | 0.801263 |
| R Square | 0.642023 |
| Adjusted R Square | 0.6336 |
| Standard Error | 3.261632 |
| Observations | 88 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 1621.752 | 810.8758 | 76.22271 | 1.09E-19 |
| Residual | 85 | 904.2507 | 10.63824 | | |
| Total | 87 | 2526.002 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 31.72157 | 3.893928 | 8.146418 | 2.87E-12 | 23.97939 | 39.46374 | 23.97939 | 39.46374 |
| Kgs | -0.02434 | 0.002115 | -11.5063 | 5.1E-19 | -0.02854 | -0.02013 | -0.02854 | -0.02013 |
| Distance | -0.00087 | 0.000272 | -3.21356 | 0.001853 | -0.00141 | -0.00033 | -0.00141 | -0.00033 |

## North America

### *To Africa*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.747691 |
| R Square | 0.559042 |
| Adjusted R Square | 0.554901 |
| Standard Error | 3.854708 |
| Observations | 216 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 4012.447 | 2006.223 | 135.0194 | 1.34E-38 |
| Residual | 213 | 3164.919 | 14.85878 | | |
| Total | 215 | 7177.366 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 10.72392 | 1.366376 | 7.848441 | 2.02E-13 | 8.03057 | 13.41727 | 8.03057 | 13.41727 |
| Kgs | -0.01717 | 0.00128 | -13.4157 | 3.77E-30 | -0.0197 | -0.01465 | -0.0197 | -0.01465 |
| Distance | 0.000755 | 9.42E-05 | 8.012457 | 7.3E-14 | 0.000569 | 0.00094 | 0.000569 | 0.00094 |

### *To Asia*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.854144 |
| R Square | 0.729561 |
| Adjusted R Square | 0.72598 |
| Standard Error | 1.907376 |
| Observations | 154 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1481.982 | 740.9909 | 203.6762 | 1.32E-43 |
| Residual | 151 | 549.3505 | 3.638083 | | |
| Total | 153 | 2031.332 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 10.74211 | 0.993274 | 10.81485 | 1.52E-20 | 8.779598 | 12.70462 | 8.779598 | 12.70462 |
| Kgs | -0.01878 | 0.000953 | -19.6991 | 1.43E-43 | -0.02066 | -0.0169 | -0.02066 | -0.0169 |
| Distance | 0.000294 | 6.88E-05 | 4.270031 | 3.44E-05 | 0.000158 | 0.00043 | 0.000158 | 0.00043 |

## To Europe

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.808059 |
| R Square | 0.65296 |
| Adjusted R Square | 0.650654 |
| Standard Error | 1.747752 |
| Observations | 304 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1729.946 | 864.9729 | 283.1672 | 6.72E-70 |
| Residual | 301 | 919.4457 | 3.054637 | | |
| Total | 303 | 2649.391 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 5.552313 | 0.933092 | 5.950444 | 7.42E-09 | 3.716103 | 7.388523 | 3.716103 | 7.388523 |
| Kgs | -0.01159 | 0.000496 | -23.3585 | 1.46E-69 | -0.01256 | -0.01061 | -0.01256 | -0.01061 |
| Distance | 0.000522 | 0.000109 | 4.801947 | 2.48E-06 | 0.000308 | 0.000735 | 0.000308 | 0.000735 |

## To Latin America

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.922429 |
| R Square | 0.850876 |
| Adjusted R Square | 0.846216 |
| Standard Error | 0.898715 |
| Observations | 67 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 294.9458 | 147.4729 | 182.5863 | 3.58E-27 |
| Residual | 64 | 51.69207 | 0.807689 | | |
| Total | 66 | 346.6378 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 4.8175 | 0.35172 | 13.69697 | 1.08E-20 | 4.114859 | 5.520142 | 4.114859 | 5.520142 |
| Kgs | -0.00813 | 0.000605 | -13.4541 | 2.54E-20 | -0.00934 | -0.00693 | -0.00934 | -0.00693 |
| Distance | 0.000452 | 3.89E-05 | 11.6226 | 2.03E-17 | 0.000374 | 0.000529 | 0.000374 | 0.000529 |

## To Middle East

| Regression Statistics | |
|---|---|
| Multiple R | 0.745854 |
| R Square | 0.556298 |
| Adjusted R Square | 0.552898 |
| Standard Error | 2.813494 |
| Observations | 264 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 2590.293 | 1295.147 | 163.6165 | 8.82E-47 |
| Residual | 261 | 2066.01 | 7.915746 | | |
| Total | 263 | 4656.303 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 7.933853 | 1.899923 | 4.175882 | 4.05E-05 | 4.192725 | 11.67498 | 4.192725 | 11.67498 |
| Kgs | -0.01464 | 0.000835 | -17.5199 | 5.75E-46 | -0.01628 | -0.01299 | -0.01628 | -0.01299 |
| Distance | 0.000627 | 0.000139 | 4.504094 | 1.01E-05 | 0.000353 | 0.000901 | 0.000353 | 0.000901 |

## To Oceania

| Regression Statistics | |
|---|---|
| Multiple R | 0.799363 |
| R Square | 0.638981 |
| Adjusted R Square | 0.634261 |
| Standard Error | 1.472069 |
| Observations | 156 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 586.8199 | 293.41 | 135.4 | 1.42E-34 |
| Residual | 153 | 331.549 | 2.166987 | | |
| Total | 155 | 918.369 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 5.971971 | 1.109954 | 5.380378 | 2.74E-07 | 3.779157 | 8.164785 | 3.779157 | 8.164785 |
| Kgs | -0.00847 | 0.000569 | -14.8982 | 1.38E-31 | -0.00959 | -0.00735 | -0.00959 | -0.00735 |
| Distance | 0.000526 | 7.53E-05 | 6.988773 | 8.02E-11 | 0.000377 | 0.000675 | 0.000377 | 0.000675 |

## Oceania

### *To Africa*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.884142 |
| R Square | 0.781707 |
| Adjusted R Square | 0.776856 |
| Standard Error | 1.529201 |
| Observations | 93 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 753.6606 | 376.8303 | 161.1449 | 1.81E-30 |
| Residual | 90 | 210.461 | 2.338456 | | |
| Total | 92 | 964.1216 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 4.009309 | 0.905482 | 4.427816 | 2.67E-05 | 2.21041 | 5.808208 | 2.21041 | 5.808208 |
| Kgs | -0.01197 | 0.000978 | -12.2397 | 7.41E-21 | -0.01392 | -0.01003 | -0.01392 | -0.01003 |
| Distance | 0.00053 | 5.49E-05 | 9.639885 | 1.6E-15 | 0.00042 | 0.000639 | 0.00042 | 0.000639 |

### *To Asia*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.87185 |
| R Square | 0.760122 |
| Adjusted R Square | 0.751238 |
| Standard Error | 1.917282 |
| Observations | 57 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 629.0112 | 314.5056 | 85.55721 | 1.82E-17 |
| Residual | 54 | 198.5023 | 3.675968 | | |
| Total | 56 | 827.5135 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | -13.0551 | 2.435839 | -5.35957 | 1.77E-06 | -17.9386 | -8.1715 | -17.9386 | -8.1715 |
| Kgs | -0.00842 | 0.001327 | -6.34698 | 4.71E-08 | -0.01108 | -0.00576 | -0.01108 | -0.00576 |
| Distance | 0.002516 | 0.000282 | 8.926981 | 3.24E-12 | 0.001951 | 0.003081 | 0.001951 | 0.003081 |

## *To Europe*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.926266 |
| R Square | 0.857969 |
| Adjusted R Square | 0.855834 |
| Standard Error | 1.504418 |
| Observations | 136 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 1818.354 | 909.1772 | 401.7087 | 4.3E-57 |
| Residual | 133 | 301.0156 | 2.263275 | | |
| Total | 135 | 2119.37 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | -34.271 | 2.777171 | -12.3402 | 8.57E-24 | -39.7641 | -28.7778 | -39.7641 | -28.7778 |
| Kgs | -0.01342 | 0.000609 | -22.0479 | 2.98E-46 | -0.01462 | -0.01221 | -0.01462 | -0.01221 |
| Distance | 0.002544 | 0.000151 | 16.79841 | 1.11E-34 | 0.002244 | 0.002843 | 0.002244 | 0.002843 |

## *To Latin America*

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.787935 |
| R Square | 0.620842 |
| Adjusted R Square | 0.594693 |
| Standard Error | 3.104333 |
| Observations | 32 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 2 | 457.6098 | 228.8049 | 23.74262 | 7.81E-07 |
| Residual | 29 | 279.4697 | 9.636886 | | |
| Total | 31 | 737.0795 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 19.20573 | 4.154144 | 4.623271 | 7.22E-05 | 10.70955 | 27.70191 | 10.70955 | 27.70191 |
| Kgs | -0.01813 | 0.002647 | -6.84715 | 1.61E-07 | -0.02354 | -0.01271 | -0.02354 | -0.01271 |
| Distance | -0.00023 | 0.000297 | -0.77573 | 0.44419 | -0.00084 | 0.000377 | -0.00084 | 0.000377 |

## To Middle East

| Regression Statistics | |
|---|---|
| Multiple R | 0.884105 |
| R Square | 0.781641 |
| Adjusted R Square | 0.778333 |
| Standard Error | 1.477914 |
| Observations | 135 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 1032.069 | 516.0344 | 236.2547 | 2.43E-44 |
| Residual | 132 | 288.3183 | 2.184229 | | |
| Total | 134 | 1320.387 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | -5.45849 | 1.480604 | -3.68666 | 0.000331 | -8.38727 | -2.52971 | -8.38727 | -2.52971 |
| Kgs | -0.01097 | 0.000598 | -18.3317 | 4.27E-38 | -0.01215 | -0.00978 | -0.01215 | -0.00978 |
| Distance | 0.001116 | 0.000103 | 10.85267 | 5.24E-20 | 0.000913 | 0.00132 | 0.000913 | 0.00132 |

## To North America

| Regression Statistics | |
|---|---|
| Multiple R | 0.780517 |
| R Square | 0.609206 |
| Adjusted R Square | 0.604228 |
| Standard Error | 3.008806 |
| Observations | 160 |

ANOVA

| | df | SS | MS | F | Significance F |
|---|---|---|---|---|---|
| Regression | 2 | 2215.668 | 1107.834 | 122.3732 | 9.29E-33 |
| Residual | 157 | 1421.308 | 9.052914 | | |
| Total | 159 | 3636.976 | | | |

| | Coefficients | Standard Error | t Stat | P-value | Lower 95% | Upper 95% | Lower 95.0% | Upper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 12.57522 | 2.190838 | 5.739914 | 4.75E-08 | 8.247901 | 16.90254 | 8.247901 | 16.90254 |
| Kgs | -0.01794 | 0.001148 | -15.6328 | 8.09E-34 | -0.02021 | -0.01567 | -0.02021 | -0.01567 |
| Distance | 8.98E-05 | 0.000149 | 0.602155 | 0.54794 | -0.0002 | 0.000384 | -0.0002 | 0.000384 |