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An Assessment of Waste Management at a Major European Based Air Cargo Terminal Operator: A Case Study of Frankfurt Cargo Services

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***Abstract*—*Air cargo terminal operators play a vital role in the global air cargo supply chain by acting as the key interface point between the air and surface transport modes. However, air cargo terminals produce both hazardous and non-hazardous wastes as a by-product from their operations. Using an in-depth qualitative longitudinal research design, this study has examined waste management at Frankfurt Cargo Services (FCS), one of the major European based air cargo terminal operators. The study period was from 2008 to 2019. The qualitative data was examined by document analysis. The case study found that Frankfurt Cargo Services (FCS) total annual non-hazardous wastes increased from 770 tonnes in 2009 to 1,525 tonnes in 2019. The company's hazardous wastes fluctuated over the study period from a low of 5 kilograms in 2009 to a high of 2.52 tonnes in 2010. The case study revealed that there were no reported hazardous wastes from 2014 to 2019. Frankfurt Cargo Services primary waste management method is the recovery of wastes. The annual recovered wastes increased from 770 tonnes in 2008 to 1,530 tonnes in 2019. The company's waste recovery rate increased from 95.3% in 2008 to 100% in 2019. Frankfurt Cargo Services (FCS) disposed wastes increased from 36.37 tonnes in 2008 to a high of 58 tonnes in 2017 and 58 tonnes again in 2018, respectively. There were no reported disposed wastes in 2019. During the study period, there were no reported wastes that were disposed to landfill.*

***Keywords*— Air cargo, cargo terminal operator, case study, Frankfurt Cargo Services, hazardous wastes, non-hazardous wastes.**

I. INTRODUCTION

The world air cargo industry has grown rapidly in recent decades and is now an integral part of the global economy, carrying goods valued at around $USD 6.8 trillion on an annual basis. This represents around 35 per cent of world export trade (by value) (International Air Transport Association, 2022). The air cargo supply chain is responsible for articulating the flows, both physical and documentary, of air cargo consignments from their origin to their destination (Larrodé et al., 2018). One of the very important actors in the air cargo supply chain is the air cargo terminal operator (Caves, 2015; Chen et al., 2008; Chen & Chou, 2006; Rong & Grunow, 2009). For the global movement of air cargo from an airport to an airport, the air cargo terminal is a key success factor for the terminal operator's client airlines, and hence, for the quality of air cargo transportation provided (Rodbundith et al., 2019). Air cargo terminals are facilities in which individual air cargo consignments are processed into cargo loads ready for loading onto an airline's aircraft and, following transport to their destination, are broken down again into individual shipments for delivery to the ultimate customer (Chinn & Vickers, 1998).

Waste management and the disposal of wastes are now regarded as being amongst the most important issues in the environmental management of the global airline industry

(Baxter, 2020; Li et al., 2003). Like passenger and air cargo carrying airlines, air cargo terminals also generate both hazardous and non-hazardous wastes. According to El-Din M. Saleh (2016, p. 4), "hazardous wastes are classified as hazardous if they exhibit one or more of ignitability, corrosivity, reactivity, or toxicity".

The aim of this study is to examine how a major European-based air cargo terminal operator manages its non-hazardous and hazardous wastes. A further aim of the study is to examine the annual volumes of hazardous and non-hazardous waste and the annual recovery rates of a major European-based air cargo terminal.

One such major air cargo terminal operator that has sustainably managed their air cargo handling operations is Frankfurt Cargo Services GmbH, Frankfurt Airport's largest neutral air cargo handling agent (Frankfurt Cargo Services, 2021). Since 1999, Fraport AG, a major shareholder in Frankfurt Air Cargo Services GmbH, has been regularly audited and validated by government accredited and inspected environmental auditors. Frankfurt Air Cargo Services GmbH has also been included in these environmental audits and accreditation. As such, Frankfurt Cargo Services GmbH was selected as case company for the study. A further factor in selecting Frankfurt Cargo Services GmbH as the case firm was the readily available case documentation which allowed for the in-depth analysis of the company's waste management. The study period is from 2008 to 2019.

The remainder of the paper is organized as follows: the literature review is presented in Section 2, and this sets the context for the in-depth case study. Section 3 describes the study's research methodology. Section 4 presents the case study based on Frankfurt Air Cargo Services GmbH waste management. Section 5 presents the study's conclusions.

II. BACKGROUND

2.1 The Role and Functions of an Air Cargo Terminal

Air cargo terminals serve as a temporary storage facility before the next operation can be performed, that is, loading the consignment onto its assigned flight (van Oudheusden & Boey, 1994). The cargo terminal operator (CTO) provides the handling facilities necessary to accept air cargo consignments from international air freight forwarders and shippers; check shipment weights; and prepare aircraft load plans. They also store consignments until they are cleared for export by the customs authority. The cargo terminal operator (CTO) then arranges for the air cargo consignment to be loaded onto the designated aircraft (Damsgaard, 1999). At the destination airport, an air cargo terminal operator accepts cargo from incoming flights and stores the cargo consignments until they have been cleared and released by the receiving country's customs authority. A freight forwarder then typically thereafter collects the consignment and arranges delivery to the end-customer (Martin Jones, 2013). Domestic cargo requires no customs clearance and proceeds directly from the check-in area to a pre-delivery holding area within the terminal, where it is stored pending arrangement of delivery to the final customer (Ashford et al., 2011).

The air cargo terminal provides for three principal cargo handling activities: (1) the import activities (for example, arrival of the cargo load from the aircraft, breakdown, storage of cargo pending delivery, cargo retrieval and cargo delivery), (2) the export activities (for example, unloading the cargo from customer's trucks, export cargo acceptance, export cargo handling, build-up of cargo, flight processing, retrieval of loaded aircraft unit load devices (ULDs) and cargo assembly), and (3) the transfer activity (arrival of cargo, transfer cargo handling, build-up of transfer cargo, retrieval of ULDs and cargo assembly (Ashford et al., 2011; Chen, 2004). Aircraft unit load devices, or ULDs, are pallets and containers which are used to carry air cargo, mail and passenger baggage on wide-body passenger and freighter aircraft (Baxter & Kourousis, 2015; Lu & Chen, 2011). Prior to air cargo being moved to the aircraft for departure, it is delivered to the airport to an air cargo terminal by trucks where it is then unloaded for inspection, information verification, sorting, and packing (Rodbundith & Sopadang, 2021). At the airport, the airline's cargo terminal provider (in-house or outsourced) receives the goods and documentation from the shipper, air freight forwarder, or logistics services provider. Following inspection, the freight and verifying that it is ready for air carriage, the handling company (air cargo terminal operator) loads the aircraft containers (ULDs) and builds pallets (that is, consolidates items onto aircraft pallets), and once these ULDs and pallets have been loaded they are delivered to the aircraft, where they are loaded onto the aircraft for uplift to their destination (Popescu et al., 2010).

Another major function of an air cargo terminal is information processing (Hu & Huang, 2011). Air Cargo terminal operator's computer systems are typically interface with the National Customs Administration (thus allowing the electronic clearance of air cargo consignments). Air freight forwarders and the client airlines systems are also often linked the cargo terminal operator's computer system. Prior to being exported, international air cargo consignments must be cleared for export by the relevant Customs Authority. On arrival at its destination, the air cargo consignment will undergo the relevant customs clearance formalities (Martin Jones, 2013).

An air cargo terminal can be divided into two main systems: the landside and the airside. Landside operations deal with the interchange of air cargo between air freight forwarders and logistics operators and the airport's ground handlers (GH), which receive cargo from the landside, sort the cargo and then deliver it to the corresponding aircraft (the airside) for uplift to its destination (Romero-Silva & Mota, 2018). Landside operations in air cargo terminals are comprised of many freight forwarders delivering and collecting cargo at the air cargo terminal's loading docks (Romero-Silva & Mota, 2022). Air cargo terminals handling international air cargo consignments are divided into an import area and an export area (Laniel et al., 2011: Senguttuvan. 2006). These air cargo terminals may also include an area dedicated for transfer or transshipment air cargoes (Han & Chang, 2015). An important source of air cargo for airlines is transshipment cargo, which is air cargo that is uplifted from its point of origin to its final destination via an intermediate hub airport (Merkert & Alexander, 2018).

2.2 Services Provided by Air Cargo Terminal Operators

Specialized air cargo handling firms offer a range of services from cargo warehousing through to trucking (Morrell & Klein, 2018).

The services offered by cargo handling firms include:

1. Warehousing

   Freight acceptance, build-up, and storage

   ULD build-up and breakdown

   Shipment inventory control

   Truck loading and unloading

   Express handling services

   Security services
2. Documentation
3. Handling of dangerous goods, live animals, perishables, and other special cargoes
4. Transport to and from the aircraft
5. Trucking (road feeder services) (Morrell & Klein, 2018, p. 168).

The International Air Transport Association (IATA) Standard Ground Handling Agreement (SGHA) defines the menu of services that will be offered to clients including general cargo and postal mail handling, document handling, customs control, and the handling of cargo irregularities and ramp services (Morrell & Klein, 2018, p. 168).

2.3 Types of Air Cargo Terminal Operators

An air cargo terminal operator (CTO) may be both a facility in which air cargo consignments are accepted, stored, and loaded or built up ready for air transportation, as well as the company that provides these air cargo handling services. In some instances, the air cargo handling services may be provided another firm operating within the cargo terminal. In such cases, they may be referred to as a Ground Service Provider (GSP). Air cargo terminal operators vary in size from the large multi-national firms, for example, Swissport and Worldwide Flight Services to a smaller operator that may only have operations at a single airport. The size and degree of sophistication may differ based on location as well as the annual air cargo tonnage (Donnison, 2018).

The providers of cargo handling services can be airlines (self-handling), one airline for another, airport authorities, or independent specialist ground handling firms that obtain a license to operate on the airport's facility. Airlines often service their own cargo (self-handling) and may also provide this service to other airlines (third party handling) (Morrell & Klein, 2018).

2.4 Waste Management Hierarchy

According to the Organisation for Economic Development (2003), "waste refers to materials that are not prime products (that is, products produced for the market) for which the generator has no further use in terms of his/her own purposes of production, transformation, or consumption, and of which he/she wants to dispose". The waste management hierarchy ranks the various types of wastes disposal methods from the most to the least desirable (Davies, 2016; Pitt & Smith, 2003). The waste management hierarchy is as follows: reduce, re-use, recycle, recovery, and disposal (Figure 1) (Davies, 2016; Okan et al., 2019). For firms using the hierarchy, reducing waste should be their primary concern (Baxter et al, 2018). In an ideal situation, waste should be avoided wherever possible. This means that in the waste management hierarchy, reducing or preventing waste should be the primary objective of the firm (Baxter & Srisaeng, 2021).

The waste management hierarchy seeks to minimize the generation of wastes in the first instance. The aim of the hierarchy is for the firm to optimize the opportunities for reuse and recycling of materials, and to minimize the quantities of wastes that need to be disposed to landfill (Thomas & Hooper, 2013). According to the waste management hierarchy, re-use and recycling are the best methods of dealing with unavoidable waste (Pitt & Smith, 2003). Re-using waste, wherever possible, is regarded as more favorable than recycling because the waste items does not require further processing prior to being used again (Güren, 2015). Reuse of wastes occurs when something that has already achieved its original function is once again used for another purpose. The recycling of wastes involves the reprocessing of used materials that would otherwise be considered as waste (Zhu et al., 2008). Recycling of wastes involves the collection, sorting, processing, and their conversion into raw materials that can be used in the production of new products (Park & Allaby 2013). Recovery relates to the recovery of energy that can be recovered from waste (Zhu et al., 2008). Wastes that are regarded as unsuitable for reuse or recycling can be incinerated to generate heat or electricity (Makarichi et al., 2018; Waters 2020; Zhu et al., 2008). Finally, disposal in landfill sites is regarded as the least desirable option (Manahan, 2011; Okan et al., 2019; Williams, 2013). Waste that is disposed to landfill and open dumping, is environmentally unsafe due to the emission of greenhouse gases (GHGs) that are produced from the disposed wastes (Ahmed et al., 2020; Trabold & Nair, 2019).

Fig.1: The Waste Management Hierarchy

2.5 Production of Waste in Air Cargo Terminals

In providing air cargo handling services, cargo terminal operators generate various types of waste which includes tyres, fluids from equipment, universal wastes (light bulbs, electronics, and batteries), wood and wooden pallets as well as plastic packing material (Federal Aviation administration, 2013). Table 1 shows the distinct types of waste that are typically generated at an air cargo terminal.

Table 1 – Types of wastes generated in the air cargo industry

Stakeholder	Types of waste generated
Airlines	Paper Toner cartridges Light bulbs Batteries Plastic bottles and cans Food and general rubbish
Cargo Terminal Operator	Paper Toner cartridges Light bulbs Batteries Plastic bottles and cans Food and general rubbish Green waste from landscaping activities Plastic Tyres Wood/wooden pallets
Clients	Paper Toner cartridges Light bulbs Batteries Plastic bottles and cans Food and general rubbish
Government Agencies	Paper Toner cartridges Light bulbs Batteries Plastic bottles and cans Food and general rubbish

Source: adapted from Federal Aviation Administration (2013).

In addition to the general and food waste generated from offices, other significant sources of waste are plastic packing material and wood and wooden pallets (Federal Aviation Administration, 2013). To protect air cargo consignments from the elements, plastic is used to line the base of aircraft pallets and to cover the loaded cargo on the pallet. In addition, the base of structural air cargo unit load devices (ULDs) is also often lined with plastic to protect the contents of the container. Cargo terminal operators also often shrink wrap consignments on an industrial pallet to help prevent them from moving during the transportation process. At the destination, during the unloading and handling process, the cargo terminal operator (CTO) removes the plastic shrink wrapping so they can acquit the cargo consignments and make them ready for delivery to the consignee or their appointed freight forwarder or customs agency.

For aircraft safety purposes, it can be necessary for wood to be used to spread the weight of a heavy piece cargo on an aircraft pallet to ensure the assigned aircraft's maximum floor bearing weight is not exceeded (heavy cargo shoring). Also, in the air cargo industry, wooden pallets are placed on the base of aircraft pallets, when it is necessary to raise the height of cargo that exceeds the width of the base of the aircraft fuselage (over-hang) so that the consignment can fit within the curvature of the aircraft hold. When shipping goods by air, it is necessary for the consignment to be suitably packaged. The packaging needs to be able to withstand various storage, transit, and handling conditions throughout the transportation cycle, whilst also protecting the cargo. In addition, the packaging must comply with the shipping regulations of the countries of origin and destination. The packaging used also needs to satisfy airline packaging requirements. The use of wooden packaging is very common in the air cargo industry, especially for machinery. Once the customs clearance formalities are completed at the destination airport, the consignee (or their appointed freight forwarder or customs agency), may request the CTO to remove the outer wooden packaging so that they can take delivery of the machinery or the product being shipped – this, off course, generates wooden waste. Other types of wood waste come from the use of wooden pallets used by shippers or the origin CTO for loading air cargo consignments.

III. RESEARCH METHODOLOGY

3.1 Research Approach

The study's qualitative analysis was based on a longitudinal case study design (Derrington, 2019; Hassett & Paavilainen-Mäntymäki, 2013; Neale, 2019). The key advantage of a qualitative longitudinal research design is that it reveals change and growth in an outcome or phenomena over time (Kalaian & Kasim, 2008). A case study also allows for the exploration of complex phenomena (Remenyi et al., 2010; Yin, 2018). A case study also enables the researcher(s) to collect rich, explanatory information (Ang, 2014; Mentzer & Flint, 1997).

3.2 Data Collection

The qualitative data gathered for this study was obtained from Fraport AG's annual environmental and the annual abridged environmental statements. Hence, in this study, secondary data was used in the case study analysis. The study followed the recommendations of Yin (2018) in the data collection phase, that is, the study used multiple sources of case evidence, the data was stored and analyzed in a case study database, and there was a chain of case study evidence.

3.3 Data Analysis

The qualitative data collected was examined using document analysis. Document analysis is frequently used in case studies and focuses on the information and data from formal documents and company records (Grant, 2019; Oates, 2006; Ramon Gil-Garcia, 2012). In a case study existing documents are a critical source of qualitative data, and these documents may be publicly available or private in nature (Woods & Graber, 2017). The documents collected for the present study were examined according to four criteria: authenticity, credibility, representativeness, and meaning (Fitzgerald, 2012; Fulcher & Scott, 2011; Scott, 2014).

The key words used in the database searches included "Fraport AG environmental management framework", "Frankfurt Cargo Services wastes regulatory framework", "Frankfurt Cargo Services annual hazardous wastes", "Frankfurt Cargo Services annual non-hazardous wastes", "Frankfurt Cargo Services annual disposed wastes", "Frankfurt Cargo Services annual recovered wastes", "Frankfurt Cargo Services annual wastes recoverability ratio", and "Frankfurt Cargo Services wastes handling methods".

The study's document analysis was conducted in six distinct phases. The first phase involved planning the types and required documentation and ascertaining their availability for the study. In the second phase, the data collection involved sourcing the documents from Fraport AG and developing and implementing a scheme for managing the gathered documents. In the third phase, the documents were examined to assess their authenticity, credibility and to identify any potential bias in them. In the fourth phase, the content of the collected documents was carefully examined, and the key themes and issues were identified and recorded. The fifth phase involved the deliberation and refinement to identify any difficulties associated with the documents, reviewing sources, as well as exploring the documents content. In the sixth and final phase, the analysis of the data was completed (O'Leary, 2004). The documents were all in English. Each document was carefully read, and key themes were coded and recorded in the case study (Baxter, 2021; Baxter & Srisaeng, 2021).

IV. RESULTS

4.1 Frankfurt Cargo Services GmbH: A Brief Overview

Frankfurt Air Cargo Services have been providing air cargo handling services for more than 50 years. The company has a modern air cargo terminal at Frankfurt Airport. The company has two warehouses occupying an area of 52,000 m² (Fraport AG, 2022a). The cargo terminal is connected to the apron area and there is a 100-metre distance between the freighter aircraft parking positions and the air cargo terminal (Fraport AG, 2022b). An airport's apron area is the location where aircraft stands interface with airport terminal buildings, and they are the location where aircraft are handled whilst on the ground in between flights (Budd & Ison, 2017). The company handles around 40 airlines, which includes airlines operating dedicated freighter to Frankfurt Airport. In addition, Frankfurt Cargo Services (FCS) provides the air cargo handling services for man fifty international airlines (Frankfurt Cargo Services, 2022).

On November 2, 2015, Fraport AG and Worldwide Flight Services (WFS) formed a strategic air cargo handling partnership agreement at Frankfurt Airport. Under the terms of the agreement, which was signed in July 2015, Fraport AG sold a 51 percent share in Fraport Cargo Services GmbH (FCS) to WFS (Fraport AG, 2015; Worldwide Flight Services, 2015).

Figure 2 presents the total annual air cargo tonnages handled by Frankfurt Air Cargo Services (FCS) from 2008 to 2019 together with the year-on-year change (%). The air cargo industry is extremely cyclical in nature (Oedekoven, 2010; Reynolds-Feighan, 2017; Wittmer & Bieger, 2011). This cyclicality is demonstrated in the annual tonnages of air cargo handled by Frankfurt Cargo Services. As can be observed in Figure 2, there was a pronounced spike in handled air cargo tonnages in 2010 (+35.31%). World air cargo traffic grew in 2010 (Abeyratne, 2018). This growth reflected the recovery from the 2008 and 2009 global financial crisis, which resulted in a downturn in world air cargo demand. Figure 2 shows that the annual air cargo tonnages declined on a year-on-year basis in 2011, 2012, and 2013 before returning to positive growth from 2015 to 2017. The annual air cargo tonnages decreased on a year-on-year basis in 2018 (-7.80%) and 2019 (-6.56%), respectively (Figure 2). World air cargo traffic fell quite significantly in 2019. In 2019, the air cargo industry recorded its weakest air cargo traffic performance since the global financial crisis in 2009 (International Air Transport Association, 2020).

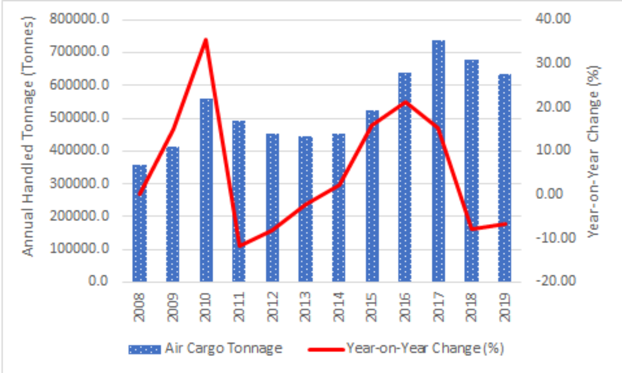

Fig.2: Frankfurt Cargo Services Annual Handled Air Cargo Tonnages and Year-on-Year Change (%): 2008-2019

Source: Data derived from Fraport AG (2012, 2014, 2018, 2019, 2020)

4.2 Fraport AG Environmental Management Framework

As previously noted, Fraport AG has held a shareholding in Frankfurt Cargo Services and, as such, Frankfurt Cargo Services has been included in Fraport AG's environmental management system (EMS).

From 1999 onwards, Fraport AG, as the manager and operator of Frankfurt Airport, has been regularly validated by government accredited and inspected environmental management auditors. The basis for such audits is the European regulation "Eco-Management and Audit Scheme" (EMAS) (Fraport AG, 2019). EMAS is a voluntary instrument of the European Union, which enables firms of any size and industry to examine and continuously enhance their environmental performance (International Airport Review, 2014). Since 2002, Frankfurt Airport's environmental audits have been carried out in compliance with the international standard ISO 14001 (Fraport AG, 2019). ISO 14001 is a global meta-standard for implementing Environmental Management Systems (EMS) (Heras-Saizarbitoria et al., 2011; Laskurain et al., 2017; Liu et al., 2020). The ISO 14001 Environmental Management System (EMS) has developed over time into one of the most widely used systems for managing corporate environmental aspects (Oliveira et al., 2011). Fraport AG's environmental audits, which comply with EMAS and ISO 14001 standards, also include the following Fraport AG subsidiaries: Fraport Cargo Services GmbH (FCS) since 2008, N*ICE Aircraft Services & Support GmbH (N*ICE) since 2009, and Energy Air GmbH since 2014 (Fraport AG, 2019).

4.2 Frankfurt Cargo Services GmbH Waste Related Regulatory Framework

Within Europe, the disposal of wastes is governed by various European regulations and directives. The European regulations automatically apply to each of the member states, whilst the directives must be separately transposed into national law by each member state. The basis of this legal framework is the Waste Framework Directive (2008/98/EC). This framework defines the key waste-related terms, lays down a five-step waste hierarchy, and contains key provisions for German waste disposal law (Umwelt Bundesamt, 2021).

Germany's first uniform national waste disposal act, the Abfallbeseitigungsgesetz (AbfG), was adopted in 1972. The Waste Management Act (KrWG), which is the current German main waste disposal statute (and the successor to the KrW-/AbfG act), incorporates the main structural elements of the Kreislaufwirtschafts- und Abfallgesetz (KrW-/AbfG). The disposal of specific types of product waste (respectively end-of-life vehicles, used batteries and end-of-life electronic and electrical devices) is governed by the ELV regulation (AltfahrzeugV), Batteriegesetz (BatterieG) and Elektro- und Elektronikgerätegesetz (ElektroG) (Umwelt Bundesamt, 2021).

Germany's Waste Management Act (KrWG) came into effect on 1 June 2012. The KrWG, which was enacted as Article 1 of the law titled "Gesetz zur Neuordnung des Kreislaufwirtschafts- und Abfallrechts", superseded the law titled Kreislaufwirtschafts- und Abfallgesetz (KrW-/AbfG) and transposes Directive 2008/98/EC into German law. The Waste Management Act (KrWG) is intended to tighten resource, climate, and environmental protection regulations (Umwelt Bundesamt, 2021).

One of the core provisions of Germany's Waste Management Act (KrWG) is the five-step (previously three step) hierarchy pursuant to Article 6, according to which the following ranking of waste management measures applies:

- Prevention
- Preparation for recycling
- Recycling
- Other types of recovery, particularly use for energy recovery
- Disposal (Umwelt Bundesamt, 2021)

4.4 Frankfurt Cargo Services GmbH Annual Wastes

Frankfurt Air Cargo Services (FCS) total annual wastes and the year-on-year change (%) from 2008 to 2019 are presented in Figure 3. As can be observed in Figure 3, the company's total annual wastes oscillated over the study period. There was a general upward trend from 2008 to 2010, when the annual wastes increased from 770 tonnes in 2008 to 1,120 tonnes in 2010. This was followed by a general downward trend from 2011 to 2013, with total wastes decreasing from 1,.080 tonnes in 2011 to 900 tonnes in 2013. From 2014 to 2017, there was again a general upward trend in the company's annual wastes. The highest amount of annual waste was recorded in 2017 (1,668 tonnes). Figure 5 shows that there were five years in the study period where the company's annual wastes increased on a year-on-year basis. These annual increases occurred in 2009 (+10.38%), 2010 (+31.76%), 2014 (+5%), 2015 (+0.1%), 2016 (+37.73%), 2017 (+28.01%), respectively (Figure 3). In each of these years, Frankfurt Cargo Services (FCS) handled increased volumes of air cargo, and this resulted in higher amounts of waste in these respective years. In 2009, the company was able to handle a 15.08% increase in its air cargo traffic, whilst at same time only experiencing an increase of 10.38% in its annual wastes. A similar situation occurred in 2010, when the company handled an increase of 35.31% in its air cargo traffic, yet annual wastes increased at a slightly lower annual rate of 31.76%. In 2014, the company increased its annual air cargo traffic by 2.16% but its wastes increased by 5%, which indicates that the annual waste volumes grew at a slightly higher rate than that of the air cargo traffic growth rate. In 2015, the company increased its annual air cargo traffic throughput by 15.97%, whilst at the same time its annual wastes increased by just 0.1%. This was a very favorable result and showed that the company was able to handle greater air cargo volumes whilst at the same time limiting its annual wastes. There was a slightly different situation in 2017 and 2018, when the annual wastes increased at a higher rate than the annual air cargo traffic growth rate, reflecting a different waste pattern in both 2017 and 2018. As can be observed in Figure 3, there were five years in the study period where Frankfurt Cargo Services (FCS) annual wastes decreased on a year-on-year basis. These annual decreases occurred in 2011 (-3.57%), 2012 (-9.35%), 2013 (-8.06%), 2018 (-0.05%), and 2019 (-8.51%), respectively (Figure 3). In each of these years, Frankfurt Cargo Services (FCS) handled less air cargo traffic, and, as a result, the lower levels of air cargo traffic handled resulted in smaller quantities of wastes generated. Its is important to note that solid wastes can be heterogenous in nature (Abdel-Shafy & Mansour, 2018; Norbu et al., 2005; Perazzini et al., 2016), and hence, wastes can fluctuate in line with a firm's activities and processes. Furthermore, air cargo is heterogenous in nature (Balliauw et al., 2016; Kupfer et al., 2011; Otto, 2017). In addition, cargo terminals experience variations in their air cargo flows and air cargo flows may vary by airline

(Ashford et al., 2013). Air cargo comes in all shapes, sizes, weights, and packaging and this heterogeneity can influence the amount of waste that is produced in handling air cargo traffic.

Fig.3: Frankfurt Cargo Services Total Annual Wastes and Year-on-Year Change (%): 2008-2019

Source: Data derived from Fraport AG (2012, 2014, 2018, 2019, 2020)

Figure 4 presents Frankfurt Cargo Services annual wastes per workload unit (WLU) and the year-on-year change (%) for the period 2008 to 2019. One workload (WLU) or traffic unit is equivalent to 100 kilograms of air cargo handled (Doganis, 2005; Graham, 2005; Teodorović & Janić, 2017). As can be observed in Figure 4, there are two discernible trends with this metric. From 2008 to 2015, there was a general downward trend in this metric, with the annual wastes per workload unit (WLU) decreasing from a high of 0.241 kilograms per workload unit (WLU) in 2008 to a low of 0.180 kilograms per workload unit (WLU) in 2015. From 2016 to 2019, there was an upward trend in the annual wastes per workload unit (WLU). The highest annual wastes per workload unit (WLU) was recorded in 2018 (0.246 kilograms per workload unit WLU). Figure 4 shows that the largest single annual decrease in this metric occurred in 2009, when the company's total annual wastes per workload unit (WLU) decreased by 14.52% on the 2008 levels. This may have been due to the very strong growth in handled tonnage in 2008, which was considerably higher than the annual growth in annual wastes in that year. That is, the company handled more air freight traffic, and thus, had a higher throughput to spread the generated wastes over. There was a further significant annual decrease in this metric in 2015, at which time it decreased by 13.87% on the 2014 levels (Figure 4). In 2015, Frankfurt Cargo Services (FCS) was able to handle higher volumes of air cargo, which grew at a higher rate than the associated wastes growth rate. Thus, the company was able to spread the total wastes over more workload units (WLU), thereby lowering the value per workload unit (WLU) in 2015. The significant decreases in this metric in 2009 and 2015 are a favorable result for the company as they were able to handle larger amounts of air cargo, which increased at a higher rate than the company's waste rate. Figure 4 shows that there was a pronounced spike in this metric in both 2016 (+13.33%), and 2017 (+11.27%), respectively. These two spikes in this metric could be attributed to the increase in the company's wastes being higher than the growth in its annual air cargo volumes handled. This trend led to a situation where there were fewer workload units (WLUs) to proportion the total wastes over in both 2016 and 2017, and thus, there was an increase in the annual wastes per workload (WLU) unit in both these years.

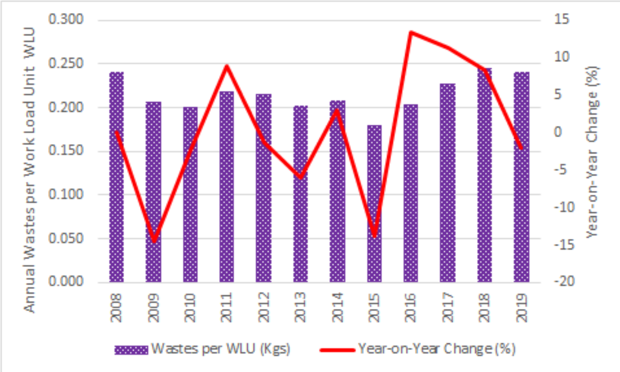

Fig.4: Frankfurt Cargo Services Total Annual Wastes Per Workload Unit (WLU) and Year-on-Year Change (%): 2008-2019

Source: Data derived from Fraport AG (2012, 2014, 2018, 2019, 2020)

Frankfurt Cargo Services (FCS) total annual hazardous wastes and the year-on-year change (%) for the period 2008-2019 are presented in Figure 5. As can be observed in Figure 5, once again there were two discernible trends with the annual amount of these wastes. Firstly, the company handled hazardous wastes in the period 2008 to 2013, whilst from 2014 to 2019 there were no reported hazardous wastes handled by the company. Figure 5 shows that there was a very significant spike in the amounts of hazardous wastes in 2010, when they increased from 5 kilograms in 2009 to 2,523 kilograms in 2010. Figure 5 also shows that there was another significant increase in these wastes in 2012, when they increased by 99.35% on the 2011 levels. There were two years in the study period where the company's hazardous wastes decreased on a year-on-year basis. These decreases were recorded in 2011 (-93.89%), and 2013 (-21.82%), respectively, and reflect the lower demand for the air transportation of hazardous cargoes in both 2011 and 2013. The air cargo sector is highly cyclical in nature (Manners-Bell, 2017), and the hazardous air cargoes handled by Frankfurt Cargo Services (FCS) have appeared to be cyclical in nature.

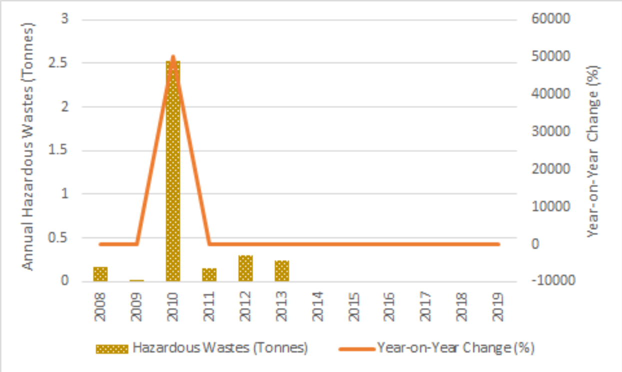

Fig.5: Frankfurt Cargo Services Annual Hazardous Wastes and Year-on-Year Change (%): 2008-2019

Source: Data derived from Fraport AG (2012, 2014, 2018, 2019, 2020)

Frankfurt Cargo Services (FCS) total annual nonhazardous wastes and the year-on-year change (%) for the period 2008-2019 are presented in Figure 6. As can be observed in Figure 6, Frankfurt Cargo Services (FCS) total annual non-hazardous wastes have largely exhibited a general upward trend throughout the study period, increasing from 770 tonnes in 2008 to 1,525 tonnes in 2019. This general upward trend is demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, more values are above the line than below. The largest single annual increase in the company's non-hazardous wastes was recorded in 2016, when these wastes increased by 36.84% on the previous year's levels. As previously noted, Frankfurt Cargo Services (FCS) recorded an increase in its annual wastes in 2016, which were associated with higher levels of air cargo handled by the company in 2016. Figure 6 also shows that there were four years throughout the study period when the total amounts of these non-hazardous wastes decreased on a year-on-year basis. These annual decreases were recorded in 2011 (-3.57%), 2012 (-9.9%), 2013 (-7.5%), and 2019 (-8.38%), respectively. Both Frankfurt Cargo Services (FCS) annual wastes and air cargo traffic decreased on a year-on-year basis in 2011, 2012, 2013, and 2019, and this translated into the annual decreases in non-hazardous wastes in these respective years. During the study period, non-hazardous wastes accounted for the largest share of the wastes produced by Frankfurt Cargo Services.

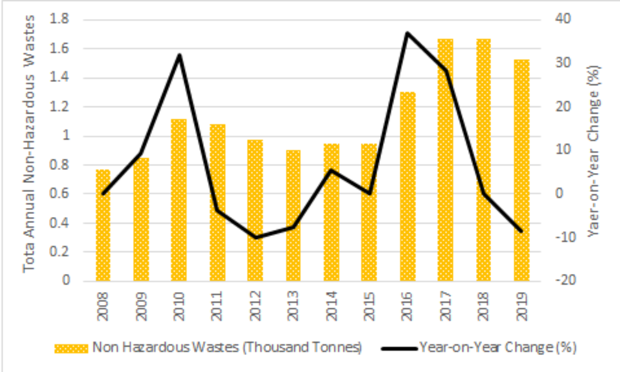

Fig.6: Frankfurt Cargo Services Annual Non-Hazardous Wastes and Year-on-Year Change (%): 2008-2019

Source: Data derived from Fraport AG (2012, 2014, 2018, 2019, 2020)

Figure 7 presents Frankfurt Cargo Services total annual disposed wastes and the year-on-year change (%) for the period 2008-2019. As can be observed in Figure 7, the company's annual disposed wastes oscillated throughout the study period. The largest single annual increase in disposed wastes was recorded in 2010, when they increased by 53.95% on the 2009 levels. In 2010, Frankfurt Cargo Services (FCS) total annual wastes and air cargo traffic both recorded strong growth on the 2009 levels, and thus, there were more wastes to be disposed of in 2010. Figure 7 shows that there were two further annual spikes in this metric during the study period. These occurred in 2016 (+19.29%) and 2017 (+21.84%), and these increases reflected the growth in the volume of air cargo handled and the associated wastes that are produced from these services. There were four years in the study when the company's disposed wastes declined on a year-on-year basis. These annual decreases occurred in 2009 (-3.68%), 2011 (-17.67%), 2012 (-16.66%), and 2014 (-1.81%), respectively. In 2009, the company produced more waste, but the types of waste that required disposal declined on a year-on-year basis, which was a favorable outcome. In 2012 and 2014, the quantity of wastes generated and the types of waste requiring disposal as the waste handling method decreased on a year-on-year basis, and once again, this was a favorable outcome for the company. In 2014, the company generated more waste, but the types of waste that required disposal decreased on a year-on-year basis Figure 7 shows that the annual disposed wastes remained constant in 2017 and 2018 at 58 tonnes. There were no disposed wastes recorded in 2019.

Since 2005, Germany has established very high criteria for the operation of landfill sites. Consequently, from 2005 onwards, Frankfurt has ceased to use landfill sites for the disposal of wastes (Frankfurt Green City, 2011). During the study period, there were no reported wastes that were disposed to landfill.

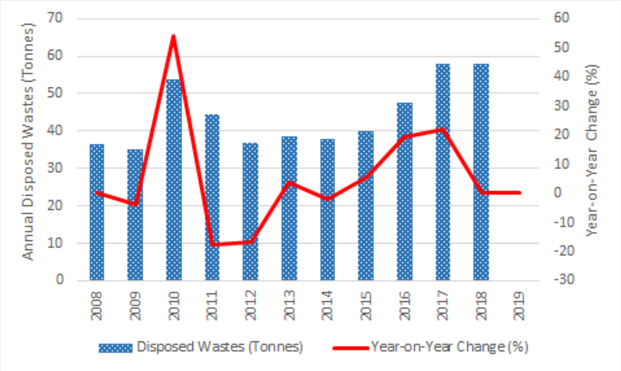

Fig.7: Frankfurt Cargo Services Annual Disposed Wastes and Year-on-Year Change (%): 2008-2019

Source: Data derived from Fraport AG (2012, 2014, 2018, 2019, 2020)

Frankfurt Cargo Services (FCS) primary environmentally sustainable waste handling method is the recovery of wastes. Frankfurt Cargo Services total annual recovery wastes and the year-on-year change (%) from 2008-2019 are presented in Figure 8. As can be observed in Figure 8, Frankfurt Cargo Services annual recovered wastes has principally displayed an upward trend, increasing from 770 tonnes in 2008 to 1,530 tonnes in 2019. This general upward trend is demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, more values are above the line than below. Figure 8 shows that there was a quite pronounced increase in the annual amounts of recovered wastes in 2010 (+31.76%), 2016 (+38.46%), and 2017 (+27.77%), respectively. Figure 8 also shows that there were three years during the study period, when the annual recovered wastes decreased on a year-on-year basis. These decreases occurred in 2011 (-8.03%), 2012 (-9.02), and in 2019 (-4.96), respectively. These annual decreases reflected the lower volumes of waste produced by the company in these respective years. Figure 8 also shows that the annual recovered wastes remained constant in 2017 and 2018 at 1,610 tonnes. Overall, the amount of recovered wastes accounts for the largest share of disposed wastes by the company, and the recovery of wastes provides significant environmental benefits. The recycling or reusing wastes results in a reduction in the quantity of wastes sent for incineration, the conservation of natural resources, energy savings, and a reduction in pollution by reducing the requirement to collect new raw materials (United States Environmental Protection Agency 2020).

Fig.8: Frankfurt Cargo Services Annual Recovered Wastes and Year-on-Year Change (%): 2008-2019

Source: Data derived from Fraport AG (2012, 2014, 2018, 2019, 2020)

Figure 9 presents Frankfurt Cargo Services annual wastes recovery rate and the year-on-year change (%) for the period 2008 to 2019. As can be observed in Figure 9, the company's annual waste recovery rate has displayed an upward trajectory, increasing from 95.3% in 2008 to 100% in 2019. This overall increase is once again demonstrated by the year-on-year percentage change line graph, which is more positive than negative, that is, more values are above the line than below. Figure 9 shows that the highest single annual increase in this metric was recorded in 2019, when the company's waste recovery ratio increased by 3.52% on the 2018 ratio. There were two years in the study period where this annual ratio declined on a year-on-year basis. These declines were recorded in 2010 (-0.41%) and 2015 (-0.2%), respectively. In both 2010 and 2015, Frankfurt Cargo Services (FCS) recorded increases in the wastes that required disposal and, as such, these wastes may not have been suitable for re-use. In 2017 and 2018, the ratio remained the same, that is, 96.5% (Figure 9). The very high recovery of wastes by Frankfurt Cargo Services (FCS) is very favorable, and this helps to mitigate its impact on the environment. Material and resource recovery from waste has significant environmental benefits. Resource recovery in the form of material, energy, or fuel from waste, not only contributes directly to fulfilling and offsetting the resource demand of society, but it also saves energy, water, and avoids harmful greenhouse gas (GHG) emissions. In addition, these resources may have economic benefits (Uz Zaman, 2016).

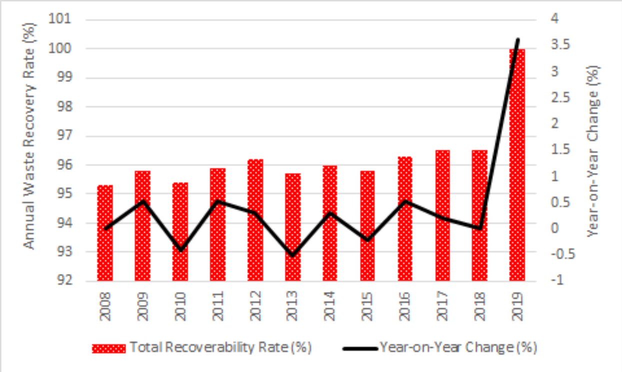

Fig.9: Frankfurt Cargo Services Annual Waste Recoverability Rate (%) and Year-on-Year Change (%): 2008-2019

Source: Data derived from Fraport AG (2012, 2014, 2018, 2019, 2020b)

V. CONCLUSION

In conclusion, this study has examined the waste management at Frankfurt Cargo Services (FCS), a major European-based air cargo terminal operator. To achieve the study's research objectives, Frankfurt Cargo Services (FCS) was selected as the case firm. The study's research was based on an in depth qualitative longitudinal research approach. The data collected for the study was analyzed by document analysis. The period of the study was from 2008 to 2019.

The case study found that Frankfurt Cargo Services (FCS) total annual non-hazardous wastes increased from 770 tonnes in 2009 to 1,525 tonnes in 2019. The company's hazardous wastes fluctuated over the study period from a low of 5 kilograms in 2009 to a high of 2.52 tonnes in 2010. The case study revealed that there were no reported hazardous wastes from 2014 to 2019.

Frankfurt Cargo Services primary waste management method is based on the recovery of wastes. The annual recovered wastes increased from 770 tonnes in 2008 to 1,530 tonnes in 2019. The company's waste recovery rate increased from 95.3% in 2008 to 100% in 2019. The recycling or reusing wastes results in a reduction in the amount of wastes that need to be disposed. Recovering wastes enable a firm to conserve natural resources, achieve energy savings, and a reduce pollution by reducing the requirement to collect new raw materials.

Frankfurt Cargo Services disposed wastes increased from 36.37 tonnes in 2008 to a high of 58 tonnes in 2017 and 58 tonnes in 2018, respectively. There were no reported disposed wastes in 2019, and, importantly, there were no reported wastes that were disposed to landfill during the study period.

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