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Performance and Efficiency Evaluation of Air Cargo Carriers

Cargolux and Lufthansa Cargo Case Studies

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Dedicatory

To my mother and sister, for their encouragement, faith, patience, and affection, without which I could not have completed this course.

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Resumo

A indústria da carga aérea tem sofrido uma grande mudança, tornando-se hoje em dia uma indústria muito competitiva e dinâmica. As companhias aéreas tradicionais, que anteriormente se focavam apenas no transporte de passageiros já compreenderam a importância e a rentabilidade do segmento da carga aérea enquanto que as companhias aéreas que só transportam carga estão a crescer consideravelmente devido à elevada procura. A carga aérea é um dos maiores meios de transporte no mundo atualmente devido a diversos fatores, tais como, o crescimento do comércio mundial ou a elevada procura por entregas de bens a tempo.

De forma a compreender e melhorar o desempenho e a eficiência de companhias aéreas de carga num mercado complexo como o dos dias de hoje, foi criado um conjunto de áreas chave (KPAs) e indicadores chave (KPIs). Estes permitem estudar como as companhias aéreas de carga podem operar de uma forma mais eficiente para responder às necessidades do competitivo mercado da carga aérea e para ajudar os decisores a selecionar as melhores alternativas para garantir uma melhor avaliação em termos de desempenho e eficiência de diversas companhias aéreas.

Esta pesquisa avalia o desempenho e a eficiência da Cargolux e da Lufthansa Cargo, ao longo de dez anos (2006 – 2015). Para fazer tal avaliação, é usada uma ferramenta de análise multicritério de apoio à decisão (MCDA), mais especificamente, o MACBETH (*Measuring Attractiveness by a Categorical Based Evaluation Technique*), usando pesos de critérios e escalas de valor para cada KPA e cada KPI, derivados dos resultados de um inquérito aplicado a especialistas da indústria.

De acordo com os resultados dos inquéritos, este estudo conclui que a área chave mais relevante do caso de estudo do desempenho é a área operacional e para o caso de estudo da eficiência é a área da produtividade. Os resultados confirmam que a carga aérea é uma indústria complexa e volátil e que alguns eventos globais têm desafiado o crescimento desta indústria.

Palavras-chave

Carga aérea, Benchmarking, Desempenho, Eficiência, MCDA, MACBETH

Resumo Alargado

Introdução

Esta secção resume, em língua portuguesa, o trabalho de investigação desta dissertação. Primeiramente é apresentado o enquadramento da dissertação, de seguida são abordados os casos de estudo e são apresentadas as principais conclusões, terminando com as perspetivas de trabalhos futuros.

Enquadramento da Dissertação

A carga aérea era tradicionalmente considerada como um subproduto do transporte aéreo de passageiros; contudo, nos últimos anos, foi adotada uma nova estratégia de mercado pelas companhias de transporte de passageiros e mercadorias.

A indústria da carga aérea tem um grande impacto na economia global, isto porque é o principal meio de transporte de produtos perecíveis, de luxo e tecnológicos. As empresas de vendas *online* dependem de um serviço de entregas rápidas e eficientes dos produtos aos seus clientes. A rapidez, a segurança e a confiança são características do transporte aéreo e são fatores essenciais para o transporte de mercadorias na cadeia de abastecimento moderna. À medida que o serviço porta a porta se intensifica, os integradores de carga aérea desenvolveram-se e expandiram-se rapidamente ao longo dos últimos anos.

Com o transporte aéreo, os mais diversos países podem estar eficientemente ligados a mercados distantes e às cadeias globais de abastecimento, independentemente da sua localização. A carga aérea tem um importante papel na economia e é responsável pelo desenvolvimento económico e social de certas regiões. Este mercado está intimamente relacionado com o comércio internacional cuja expansão tem permitido a remoção de restrições e o aumento de oportunidades de negócio, através de melhores comunicações e contactos internacionais.

Apesar da limitada informação na literatura sobre a carga aérea e dos poucos dados revelados pela indústria, tem havido um aumento gradual do número de trabalhos científicos relativos a este tema. Devido ao aumento de produtos transportados por via aérea torna-se relevante estudar este assunto, abordando todas as áreas de atividade das companhias aéreas de carga. Com o aumento da concorrência e as constantes mudanças, no mercado do transporte aéreo, as companhias aéreas são desafiadas a gerir as suas operações mais eficientemente de forma a que possam adaptar-se e responder às necessidades do mercado cada vez mais competitivo. Assim, surge a necessidade de realizar uma avaliação do desempenho e eficiência das companhias de carga aérea, de forma a compreender como estas podem operar de uma forma mais eficiente.

Objetos e Objetivos

O objeto desta dissertação é contribuir para um maior desempenho e eficiência das companhias aéreas de carga; os objetivos são avaliar o desempenho e a eficiência, usando uma ferramenta de análise multicritério de apoio à decisão, e com duas finalidades: *self-benchmarking* e *peer-benchmarking*.

Além disso, este trabalho apresenta três objetivos secundários, mais específicos, tal como indicado em seguida.

O primeiro é identificar as áreas e os indicadores de desempenho e selecionar quais são as áreas chave e os indicadores chave para avaliar o desempenho e a eficiência de companhias aéreas de carga.

O seguinte objetivo é criar uma base de dados para todos os indicadores chave para um período de dez anos (2006 a 2015) para a Cargolux e a Lufthansa Cargo de forma a implementar esses dados na ferramenta multicritério de apoio à decisão.

Por fim, o último objetivo é analisar e comparar os resultados dos casos de estudo, sendo que o primeiro consiste na análise do desempenho da Cargolux e o segundo na da eficiência da Cargolux e da Lufthansa Cargo.

Principais Conclusões

A indústria do transporte aéreo é complexa, dinâmica, e, ao mesmo tempo, vulnerável, sujeita a mudanças sazonais, ciclos económicos e eventos externos. Recentemente, o mercado da carga aérea passou por diversos desafios, tais como, ataques terroristas ou crises financeiras, que criaram a necessidade de realizar uma avaliação global da evolução do desempenho e eficiência das companhias aéreas de carga.

Os resultados desta dissertação evidenciam a importância deste tipo de avaliação de forma a compreender como as companhias de carga aérea lidam com os assuntos relacionados com o desempenho e a eficiência e como é possível obter melhores resultados no que diz respeito a esses itens. Com o modelo MACBETH é possível avaliar qualquer companhia aérea de carga, tendo em conta a sua particularidade e complexidade, e desde que os dados dos indicadores chave sejam disponibilizados.

De acordo com a opinião dos especialistas, este estudo mostra que a área operacional é a mais relevante e que a área ambiental é a menos relevante, no que diz respeito ao desempenho. Por outro lado, no que diz respeito à eficiência, a produtividade é a área mais relevante e a sustentabilidade é a menos relevante. Além disso, analisando as pontuações globais de eficiência obtidas através dos dados recolhidos é possível concluir que a Cargolux e a Lufthansa

Cargo seguiram a mesma tendência ao longo do período estudado. Relativamente aos resultados da análise de sensibilidade, 2015 foi o melhor ano para todos os indicadores chave do desempenho da Cargolux.

As maiores dificuldades deste estudo, surgiram na obtenção de dados para todos os indicadores chave, para os dez anos estudados, e para as companhias aéreas selecionadas. Contudo, pode dizer-se que os principais objetivos propostos inicialmente foram atingidos.

Perspetivas de Trabalhos Futuros

A indústria da carga aérea enfrenta alguns desafios. Este estudo permitiu identificar várias linhas de investigação para futuros trabalhos de pesquisa, que se deverão focar nos seguintes tópicos:

1. Desenvolver e implementar um outro modelo de análise, mais robusto e flexível;
2. Ampliar o estudo a mais companhias aéreas de carga;
3. Ampliar o conjunto de áreas e indicadores chave de desempenho e eficiência, implementando novas áreas de atividade, tais como, qualidade do serviço, pontualidade e segurança;
4. Aplicar a avaliação de desempenho e eficiência a todas as entidades envolvidas em todas as fases do transporte de mercadorias;
5. Desenvolver modelos de previsão da evolução do mercado da carga aérea de forma a que se possam tomar medidas de prevenção que garantam melhores resultados de desempenho e eficiência.

Abstract

The air cargo industry has been in a constant change becoming nowadays a very competitive and dynamic industry. Traditional airlines, that once only focused on the passenger transportation, already noticed the importance and profitability of the air cargo segment while the all-cargo carriers are considerably growing due to the high demand. Air cargo is one of the major means of transport in the world today due to several factors, such as the growing global trade or the high demand for timely deliveries.

To understand and improve the overall performance and efficiency of air cargo carriers in the today's complex market it was created a set of the most relevant key performance areas (KPAs) and key performance indicators (KPIs). These allow studying how air cargo carriers can operate more efficiently to respond the needs of a globally competitive market, and to help decision makers to select the best alternatives to ensure the best assessment regarding performance and efficiency of several air cargo carriers.

This research evaluates the overall performance and efficiency of Cargolux and Lufthansa Cargo, over the course of ten years (2006 – 2015). Thus it was used a MCDA (Multi-Criteria Decision Analysis) tool, more specifically, MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique), using criteria weights and value scales for each KPI and KPA, derived from the results of a survey applied to industry experts.

Based on the survey results, this study finds that the most relevant key performance area for the performance case study is the operational KPA and for the efficiency case study is the productivity KPA. The results confirm that the air cargo is a complex and vulnerable industry and that some global events have challenged the evolution of this industry.

Keywords

Air cargo, Benchmarking, Performance, Efficiency, MCDA, MACBETH

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List of Acronyms

ACI-NA	Airports Council International – North America
ACMI	Aircraft, Crew, Maintenance, and Insurance
AFTK	Available Freight Tonne Kilometre
AHP	Analytic Hierarchy Process
ATK	Available Tonne Kilometre
DEA	Data Envelopment Analysis
FTK	Freight Tonne Kilometre
GDP	Gross Domestic Product
IATA	International Air Transport Association
MACBETH	Measuring Attractiveness by a Categorical Based Evaluation Technique
MCDA	Multi-Criteria Decision Analysis
KPA	Key Performance Area
KPI	Key Performance Indicator
RPK	Revenue Passenger Kilometre
RTK	Revenue Tonne Kilometre
SFA	Stochastic Frontier Analysis
TFP	Total Factor Productivity
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
USD	United States Dollar

Chapter 1 - Introduction

1.1. Motivation

Air cargo was traditionally considered as a by-product of passenger air transport, but in the last decade, a defined strategy for air cargo has gained an important position in the strategies of most combination airlines. Thus contributing to increasing the profit of these airlines [1] and allowing the development and growth of all-cargo carriers and integrators[1].

Worldwide, air cargo transport grew about 50% faster than passenger air transport from 1995 to 2004 [2] and continued to grow considerably in recent years. According to Figure 1-1, in 2015, the volume of air freight had an average of 17 billion freight tonne kilometres (FTKs) flown per month, showing a recovery from the global financial crisis that began in 2007.

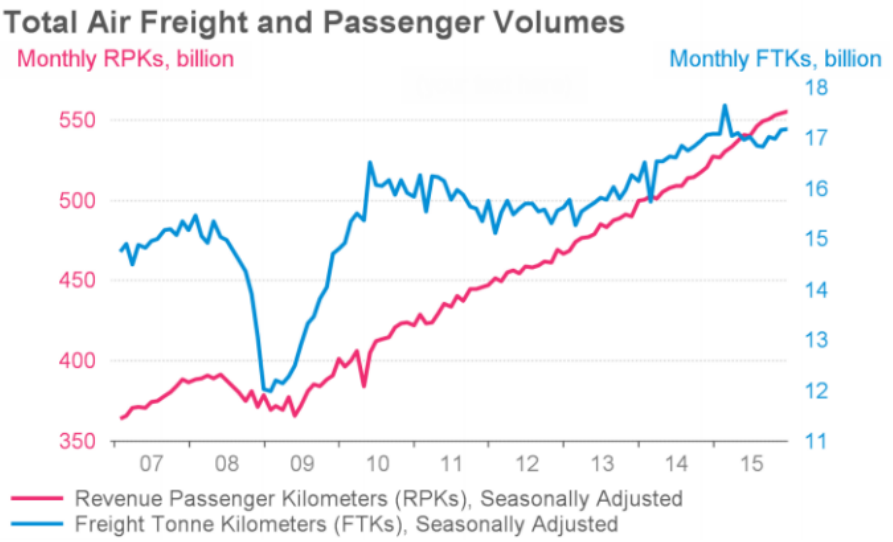


Figure 1-1: Total air freight and passenger volumes.

Source: [3].

The air freight industry has a great impact on the global economy probably because it is the main mode of transport of perishable products, luxury goods or high-value products [4]. The e-commerce websites like Amazon or eBay depend on the express delivery services to send the products to their customers. Another example of an industry that relies on air transport speed and efficiency is the pharmaceutical industry in transporting high-value, time, and temperature sensitive cargo. Air cargo also plays a key role in the carriage of live animals over long distances and in humanitarian aid [5].

[1] Integrators are air express carriers that provide a door-to-door service.

Although the air freight industry only covers a limited amount of world trade regarding tonnage, the share of air freight regarding value is substantial. In fact, according to [6], in 2014, airlines transported more than 35% of global trade by value but less than 1% of world trade by volume, which is equivalent to 6.8 trillion USD worth of goods transported annually.

Together, the speed and reliability necessary in the contemporary cargo supply chain made air cargo a dynamic industry. As the demand for door-to-door service rather than just airport to airport service increases, the integrators have developed and expanded quickly over the last years.

Despite the thinness of the air cargo literature and the limited data revealed by the industry, there has been a gradual shift of attention towards it in last years. The increase of goods transported by air makes relevant to study this subject addressing all the activity areas of air cargo carriers. With the constant changes and the increasing competition in the air transport market, the airlines are challenged to manage their operations efficiently to adapt and respond to the variations in the global competitive market creating the need to carry out a performance and efficiency evaluation to understand how air cargo carriers can operate more efficiently.

1.2. Object and Objectives

The object of this study is air cargo carriers performance and efficiency, and the objectives are to assess its performance and efficiency employing a Multi-Criteria Decision Analysis (MCDA) methodology to perform a self-benchmarking and a peer-benchmarking analysis.

Therefore, this work has three specific sub-objectives:

The first one is to identify the performance areas and the performance indicators and select which are the key performance areas and key performances indicators to evaluate the performance and efficiency of air cargo carriers.

The second one is to create a database for all the KPIs in a ten-year period (2006 to 2015) from Cargolux and Lufthansa Cargo which will be applied into the MCDA methodology.

The third one is to analyse the results from the performance case study of Cargolux and analyse and compare the results from the efficiency case study made to Cargolux and Lufthansa Cargo.

1.3. Methodology and Structure

This dissertation is structured into five chapters.

The first chapter presents the work introduction, the motivation, the object and the specific objectives, the methodology and the dissertation structure.

In chapter two is done a state of the art review concerning the airlines benchmarking and the air cargo industry in general, describing the evolution of air cargo, identifying the main players in the market and analysing the different business models adopted by the different type of carriers.

The third chapter consists of an analysis of the chosen MCDA tool, the MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) and its importance for this study, beginning with a state of the art review of the methodologies usually used by other authors to benchmark airline's, including MCDA. Besides, operational details, strengths and limitations of MACBETH are explained to support the utilisation of this tool in the airline's performance and efficiency evaluation. This chapter also includes the identification of the key performance areas and key performance indicators to study the performance and efficiency of air cargo carriers.

Chapter four describes the case studies where is conducted a performance analysis of Cargolux and afterwards, an efficiency analysis of Cargolux and Lufthansa Cargo, using MACBETH. Then, the obtained results of the two case studies are analysed and discussed.

The fifth chapter presents the work conclusions, the dissertation synthesis, a few concluding remarks, and some insights and challenges for future research.

In Figure 1-2 is presented the methodology and structure of this dissertation.

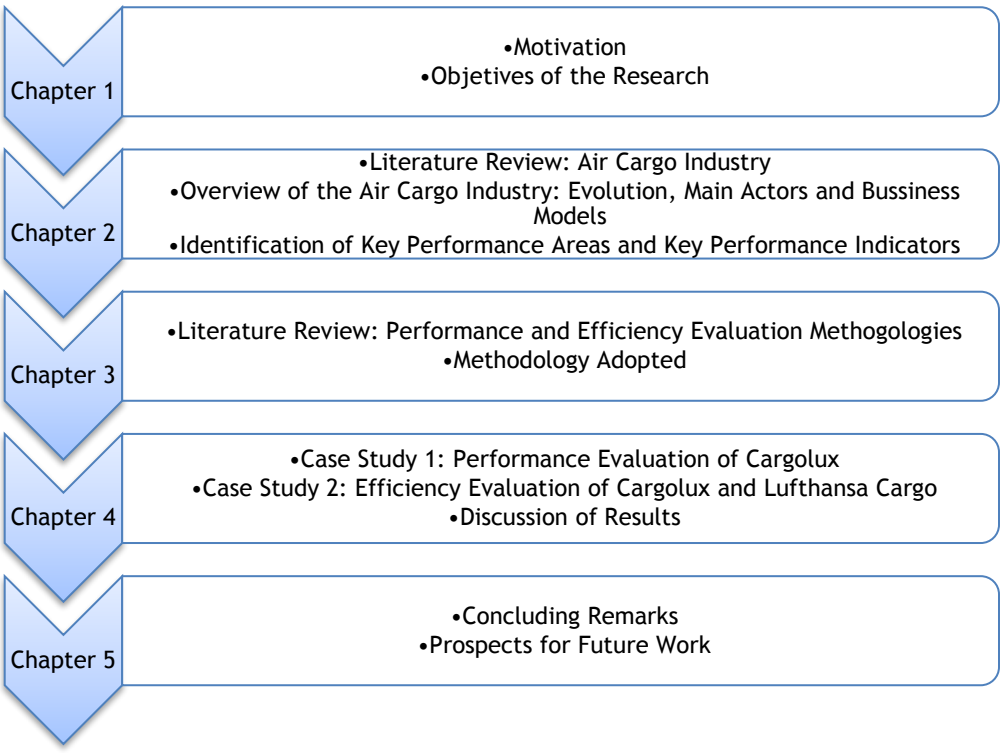


Figure 1-2: Dissertation structure and methodology.

Source: own composition.

Chapter 2 – The Air Cargo Industry

2.1. Introduction

This chapter describes the state of the art review concerning the characteristics of the air cargo industry, including the historical development of the air cargo services over the years and the expected evolution, the different business models and the main players existing in the market. Moreover, the term benchmarking is defined and are summarised a few studies about benchmarking applied to airlines.

2.2. Evolution of Air Cargo

Air cargo, which is defined in this study as anything other than people or personal baggage transported by air in freighter aircraft or under the main deck (belly) of passenger aircraft, is a major mode of transport in the world today not only for mail anymore, but also for perishable products, luxury goods and high-value products. Over the years, the importance of air cargo has been underestimated, however, in the globalised world that we live in, is essential to the development of many countries, allowing air transportation to become the preferred mode of transport for many commodities (Button & Stough, 2000)[2].

With air cargo, the most diverse countries, regardless of its location, can be efficiently connected to distant markets and to the global supply chains, having an advantage over those without such capability. Several authors concluded that freight transportation has a great impact on the economy and is responsible for the economic and social development of some areas [7]–[9]. Air cargo is closely linked to international trade whose expansion has been allowed by the removal of physical restrictions and growth of commercial opportunities through improved communications and international contacts [5].

The main traffic measure used by the aviation industry is the revenue (or freight) tonne kilometres (RTKs), which are preferred to transported tonnes because it aggregates both the weight and distance travelled. For instance, the capacity may be enough regarding weight but not regarding volume. These multiple dimensions are a key feature of freight, which renders both complexity and uncertainty to air cargo capacity management [10].

Figure 2-1 shows the evolution of the air freight transport from 1980 to 2012 worldwide. It is evident from this figure that there was an evident increase in air freight transportation – from about less than 50,000 million RTKs in 1980 to more than 200,000 million RTKs in 2012. According to [8], this growth is mainly due to the tonnes carried, which increase more than the

[2] Cited by [13].

kilometres flown. Thus resulting from significant developments in demand and supply side of the air cargo market liberalisation; such as a growing world trade, technological progress, increasing value/weight rate of goods, downward pressure on air freight yields, changing production processes and strategic importance of e-services.

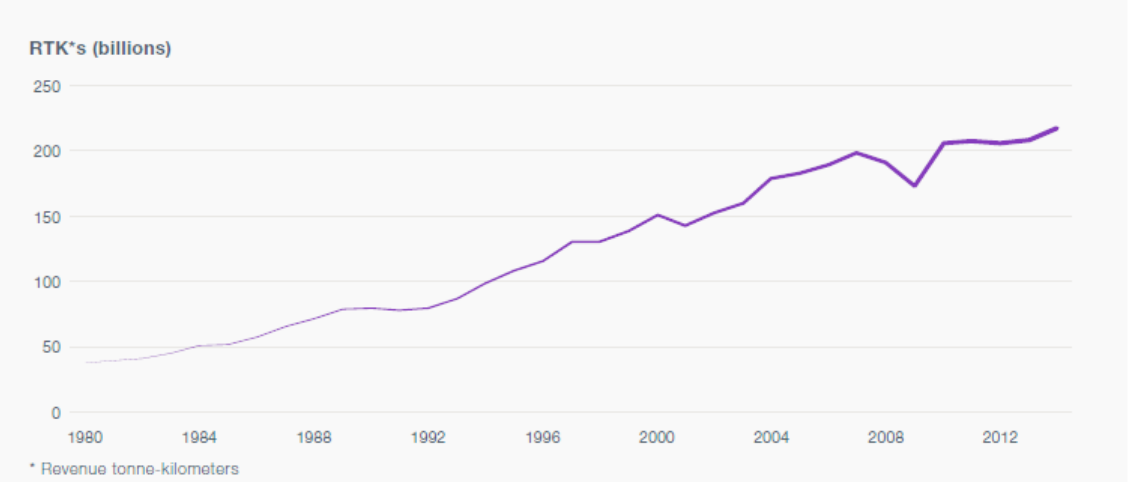


Figure 2-1: World air cargo traffic evolution in RTKs.

Source: [11].

Due to the vulnerability of the air transport industry, some global events in the past years, as the September 11th, 2001 terrorist attacks or the financial and economic crisis that started in 2007, led to a downturn in the aviation markets, with the number of freight and passengers carried decline. These events can be easily identified in Figure 2-1, with a considerable decrease in the RTKs transported, especially, the recession from 2008. As a result, the load-factor also suffered a decrease, as shown in Figure 2-2, since the load-factor represents the RTKs as a percentage of the available tonne kilometres (ATKs).

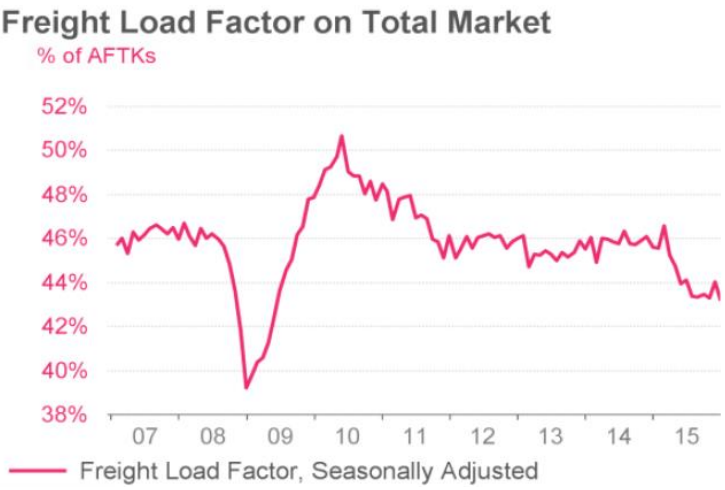


Figure 2-2: Freight load-factor worldwide.

Source: [12].

In fact, [13] verified that the freight market was impacted harder and quicker than the passenger market, while the first decreased 10% and the second only decreased 1% in 2009. Usually the cargo business is more vulnerable than the passenger business but, on the other hand, the cargo market recovers first.

Another factor that bounds the air transport development is that there are many direct and indirect costs involved as illustrated in Figure 2-3. These costs have a great impact on the economic structure of airlines. The direct costs are associated, for example, with the purchase/lease of aircraft, the maintenance of aircraft and own equipment, the staff or the fuel consumed. On the other hand, indirect costs are related, for example, to internal management and ground operations [14].

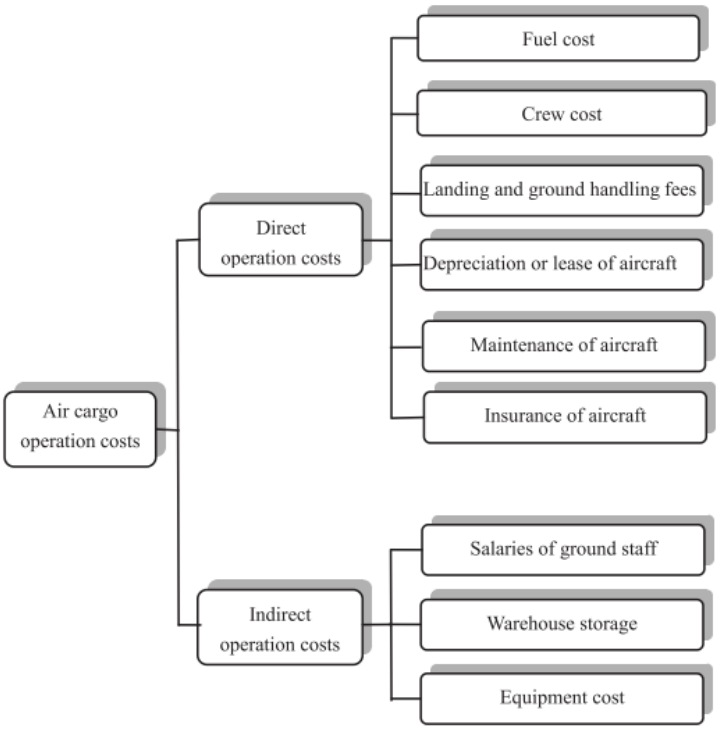


Figure 2-3: Air cargo operating costs.
Source: [14].

Labour cost is one example of the costs that contribute to the airlines' direct costs and represents those associated with the wages paid to workers and related taxes and benefits. Another example is the cost associated with the fuel used. Fuel price, and consequently, fuel cost have the highest impact on the airline's direct costs [15].

Jet fuel is a major variable cost component in the airlines' operations. Figure 2-4 shows that there were significant fluctuations in jet fuel prices, with a substantial increase between 2004 and 2008, followed by a fast decline to the 2004 price level again. Then the price rises again, until the end of 2014, when occurred a decrease in the price that remains until today. Thereat,

there have been continuous efforts of airlines and aircraft manufacturers to enhance operation and product efficiency to surpass the financial problems caused by the fluctuations in jet fuel prices (Air Transport Association, 2008)[3].

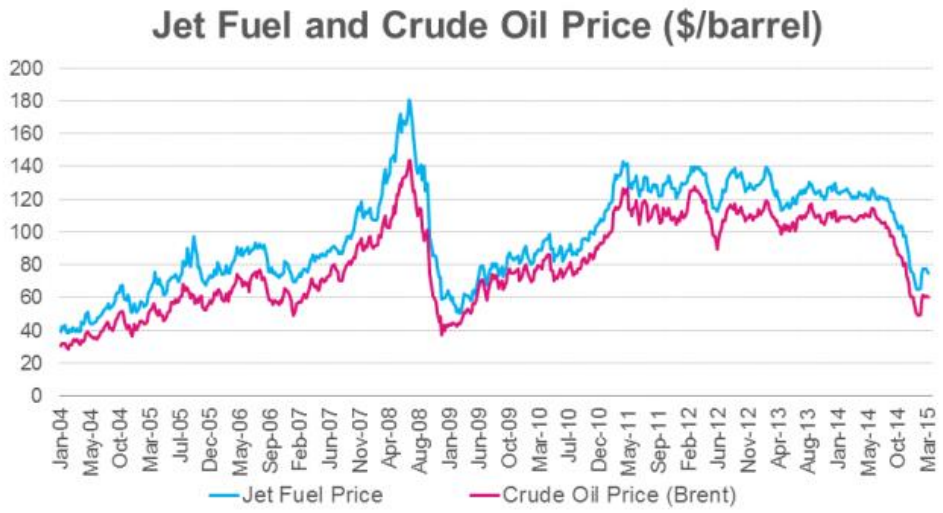


Figure 2-4: Evolution of jet fuel and oil price per barrel.
Source: [16].

Though, the industry seems now to have recovered from the global crisis started in 2007. Global forecasts indicate that with the global gross domestic product (GDP) and the world trade growth acceleration, air cargo traffic, measured in RTKs, will grow an average 4.7% per year over the next two decades [17].

2.3. Air Cargo Business Models

There are several business models in the air cargo market adopted by the three different types of air carriers [1], [18]: the all-cargo carriers, the combination carriers and the integrators. Each business model from each type of company will be described below.

2.3.1. All-Cargo Carriers

All-cargo carriers only operate dedicated freighters, which are passenger aircraft that have been altered for cargo operations. Freighters, for example, have no seats or windows and have larger doors than aircraft configured for passenger service and reinforced floors [18].

These carriers, instead of working directly with shippers, work with intermediaries called freight forwarders. All-cargo carriers often have long-term contracts with the forwarders, which provides some stability in demand for carriers. These long-term contracts provide

[3] Cited by [14].

economies of scale for the airlines enabling them to enter into long-term contracts to lower purchasing price and hedge against price uncertainty [19].

Approximately 10% to 15% of world air cargo traffic is moved by all-cargo carriers [18]. Cargolux, AirBridgeCargo or Kalitta Air are some examples of all-cargo carriers.

2.3.2. Combination Carriers

This type of carriers focus mainly on passengers but use the spare space in the belly of the aeroplanes to transport cargo. Although, sometimes these carriers also operate freighters to complement their cargo capacity. Cathay Pacific, Korean Air, Emirates, Lufthansa, Air France and KLM are some examples of combination carriers that incorporated air freight in their overall business model.

Today, more than 50% of international air cargo is moved in the bellies of passenger aircraft and that value will increase to more than 60% in the next 20 years, according to Figure 2-5. On the other hand, the freight moved by dedicated freighters will also increase, in a considerable way, from 93 billion to 160 billion FTK's, representing almost 40% of the transported cargo by 2035.

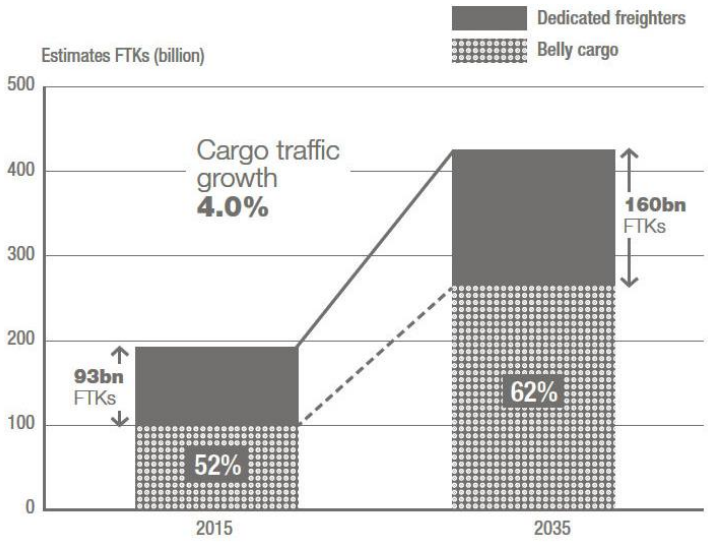


Figure 2-5: Worldwide share of belly and dedicated freighters.
Source: [21].

Despite the growth in the air cargo segment worldwide, combination airlines usually treat cargo business as a complementary service of overall group's revenue and the routes are based on the passenger business [20]. In fact, the revenue generated by cargo is much smaller than the revenue created by the transport of passengers, as seen in Figure 2-6. Note that for most of the airlines, the share of passenger and cargo revenues does not reach 100% because such airlines have other sources of revenue such as engineering, maintenance services or in-flight catering.

Figure 2-6: Passenger and cargo shares of revenues in 2013.
Source: [22].

Although, combination carriers are now starting to recognise the importance of the air cargo business. Such reason is taking these carriers to expand their fleet by the incorporation of newly dedicated freighters, to offer more reliability, more predictability and more control over timing and routing. As a result, the number of dedicated freighters is expected to grow by more than 50%, from 1.720 aeroplanes in 2014 to 2.930 by 2034 [11].

Like all-cargo carriers, combination carriers do not own the end-costumer relationship, so they have to source the cargo through the forwarders to provide the pickup and delivery services [1].

2.3.3. Integrators

Integrators (or integrated carriers) can be defined as "*vertically integrated express companies that provide time-definite, door-to-door services and, for that purpose, perform their own pick-up and delivery services, operate their own fleet of aircraft and trucks and tie all together with advanced information and communication technologies*" (Zondag, 2006)[4]. There are four major integrators in the world today: FedEx, UPS, TNT and DHL.

In contrast with non-integrated carriers, integrators work directly with shippers, offering an integrated transportation chain with a door-to-door service, acting simultaneously as forwarders and carriers. The cost for these services are higher than for other modes of transportation, however, as mentioned above, integrated carriers usually operate their freighters and delivery vehicles, providing all the handling services themselves until the cargo reaches its final destination [19].

[4] Cited by [13] (p. 81).

These companies have developed and expanded quickly over the last years, "*responding to the shippers' need for guaranteed service with late pickup and early delivery, and with seamless door-to-door service all over the world to support the concept of just-in-time manufacturing logistics and supply chain management*" [23] (p. 321).

Table 2-1 presents the biggest air carriers (all-cargo, combination and integrated carriers), regarding revenue tonne kilometres in 2015.

Table 2-1: Top 15 air cargo carriers in 2015.

Rank	***Airline***	***RTK (million)***
1	Federal Express	15,799
2	Emirates	12,157
3	United Parcel Service	10,807
4	Cathay Pacific Airways	9,935
5	Korean Air	7,761
6	Qatar Airways	7,660
7	Lufthansa	6,888
8	Cargolux	6,309
9	Singapore Airlines	6,083
10	Air China	5,718
11	China Southern Airlines	5,355
12	China Airlines	5,343
13	China Eastern Airlines	4,542
14	Etihad Airways	4,400
15	Polar Air Cargo	4,186
	Total	**112,943**

Source: [24].

2.4. The Main Players

The air cargo transport chain involves a series of players, such as shippers, forwarders, carriers and a consignee (Derigs et al., 2009)[5]. The shipper is the one that has a product shipped from one place to another. The forwarder arranges the door-to-door transport (air, road, sea, or rail) of the shipment and takes care of all the necessary documentation, acting as the intermediary between the shipper and the carriers. The carrier is responsible for the airport-to-airport transportation. For last, the consignee is the one that receives the product [4], [10].

However, if the integrators transport the good, all the phases of transportation are arranged by the integrated carrier, which provides a door-to-door service directly from the shipper to

[5] Cited by [10].

the consignee. Integrated carriers sell capacity directly to shippers. Thus, the decision problems for integrated carriers are mostly centralised, and no games on pricing and capacity allocation are played between airlines and forwarders. This way, integrators have relatively simpler problems in the transportation of goods than the non-integrated carriers [10]. Both scenarios of integrated and non-integrated services in the cargo supply chain are illustrated in Figure 2-7.

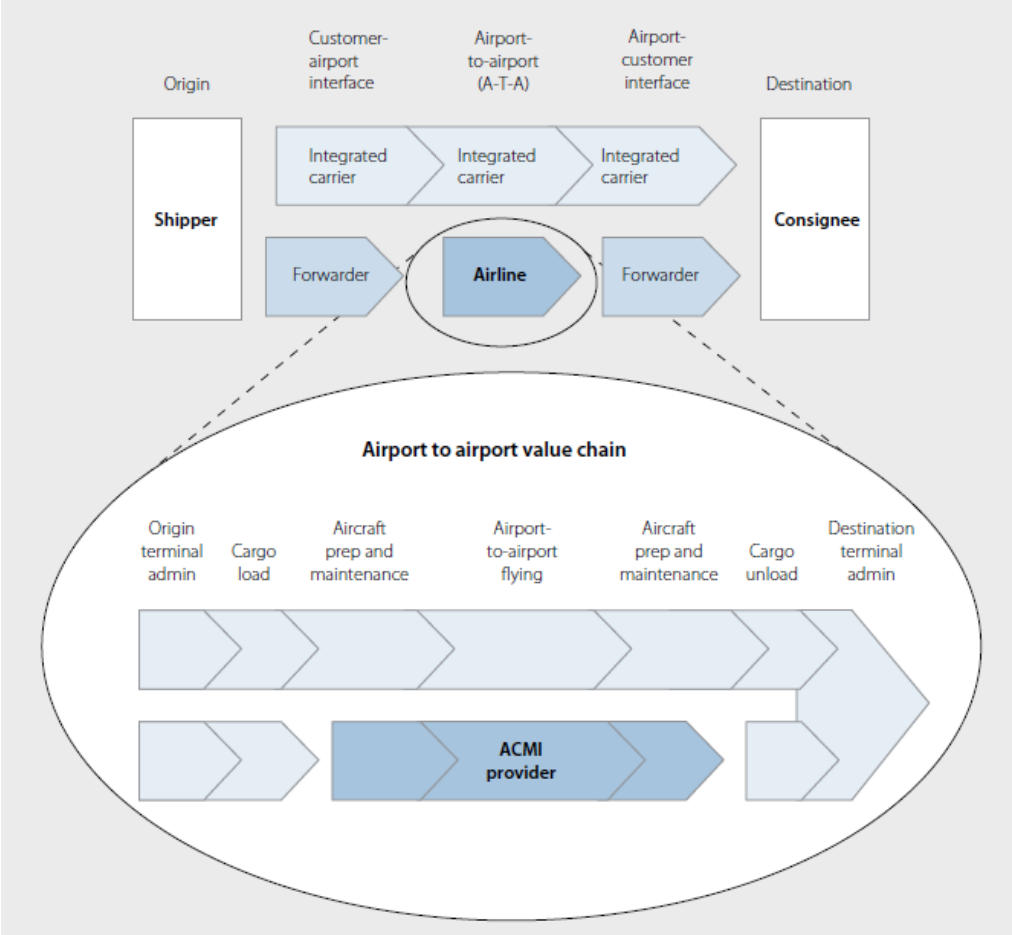


Figure 2-7: Air cargo supply chain.
Source: [18].

Air cargo carriers provide freight forwarders and shippers with services, such as, consultation, capacity booking, pickup, receiving, packaging, loading, transportation, dispatching, and cargo tracking. The cargo is classified into different levels according to the priority level required by the shipper and the type cargo, such as dangerous goods, live animals, perishable foods, and high-value items (Nobert & Roy, 1998)[6].

[6] Cited by [10].

At the airport, the air cargo carrier, responsible for the airport-to-airport transportation, receives the goods and the corresponding documentation. After, the cargo is inspected and loaded into the containers and pallets, which in turn are loaded into the aeroplane [18].

Finally, at the destination airport, the cargo is verified and moved to a warehouse, to deliver the cargo to the forwarder, which will deliver goods to the consignee, completing the supply chain process [10].

2.5. Air Cargo Carriers Benchmarking

Measuring airlines performance and efficiency is a key to success and efficient management of airlines. Benchmarking is the process of identifying best practices, understanding their meaning about business and adopting these practices to help airlines, and in this case, air cargo carriers, to improve their performance and efficiency. The comparison to a defined data set provides organisations with similar opportunities to establish performance goals with standards and measures that would be considered a performance benchmark. Over designated time frames, benchmarking can improve operating levels and lead to improved organisational efficiency and performance [19].

There are several related studies concerning the air transportation. Most of the studies focus on the passenger airlines, rather than the air cargo carriers. For example, [25] studied the efficiency and effectiveness of passenger airlines, using five key performance areas, namely, cost, productivity, service quality, price and management to help the airlines to identify its competitive advantages relative to another airline. Furthermore, [26] defined a set of key performance indicators, considering the financial ratios to have a more comprehensive study, and evaluated the performance of passenger airlines, dividing the total performance into three key performance areas: production, marketing and management. On the other hand, [27] defined a set of recommended key performance indicators to perform an operational and economic analysis of airlines.

Moreover, [28] analysed the impact of strategic management and fleet planning decisions on the efficiency of airlines focused on passengers, while [29] examined several passenger airlines in terms productivity, yield and cost competitiveness. Besides, [30] analysed the airlines regarding efficiency and instigated which factors account for differences in efficiency.

Although most of the studies focus on the passenger airlines and sometimes consider the cargo operations as a complementary service that enhances the group's overall performance [20], there are some studies related to air cargo market and, more specifically, to air cargo carriers. For example, [23] evaluated the competitiveness of integrators, studying several service factors: promptness, accuracy, safety, convenience, economic efficiency and dependability while [31] identified the competitive service factors of cargo carriers. Furthermore, [13]

analysed the evolution and the key characteristics of the air cargo industry in order to better understand the impact of the cost structure on the strategic behaviour of integrators; while [1] investigated the strategies of all-cargo and combination carriers and defined a set of key performance indicators grouped into the product, market and network strategies.

As mentioned above, the literature focusses more on the passengers' side than on the cargo market, and this research aims to fill this gap. Also, it will be investigated a larger range of key performance areas and key performance indicators which contribute to the overall performance and overall efficiency to create a competitive advantage for any air cargo carrier.

2.6. Conclusion

Air cargo transport is more complex than passenger one because it involves more players, more sophisticated processes, a wide combination of weight and volume, a complex integration and consolidation strategies and multiple itineraries of a network. Moreover, the air cargo has many players involved, and the role of intermediaries is crucial in the air cargo supply chain since each step in the process depends on the successful completion of the previous step.

The forecasts support a global economic growth which also leads to an improvement in air cargo. Nonetheless, there are concerning factors that could hinder the growth of the air cargo, like the rise of jet fuel prices, the turbulence in financial markets or the political uncertainty that could impair the overall development of the industry.

However, air cargo carriers can use benchmarking to measure their performance and efficiency to improve their operations and to reduce their vulnerability to the external factors mentioned above.

Chapter 3 – Performance and Efficiency Evaluation Methodologies

3.1. Introduction

This chapter consists of an analysis of the MCDA tool and its importance for this study. It begins with a state of the art review of the methodologies usually adopted by other authors to benchmark airlines. Besides, there are explained operational details, strengths and limitations of the different methodologies, especially, the Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH), to justify the use of this tool in the air cargo carriers' performance and efficiency evaluation. Also, are presented and defined the key performance areas and indicators and briefly explained the steps needed to assess air cargo carriers performance and efficiency with the MACBETH approach.

3.2. Methodologies

Researches on the measurement of airlines performance and efficiency have used several techniques such as Data Envelopment Analysis (DEA), Total Factor Productivity (TFP) method, Analytic Hierarchy Process (AHP) or Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The studies reviewed in Section 2.5 applied a single or combination of the methods mentioned above. For instance, while [28] used the DEA and [29] the TFP, [30] applied both DEA and TFP. On the other hand, [25] and [26] used TOPSIS. Regarding the AHP, both [23] and [31] applied this process.

Some studies to evaluate the different air transportation actors (e.g. airlines and airports) often adopted quantitative methods, relying on numerical and secondary data. They also formulated production functions using econometric techniques and advanced efficiency analysis tools [32]. In Table 3-1, is given a theoretical overview of the main approaches used.

Table 3-1: Methodologies to evaluate different air transportation actors.

Methodology	*Description*	*Weakness*
Partial Measure	This method uses partial ratio data to carry out performance comparison of the target sample in single dimension such as on financial and cost performance of an airline.	This method only focuses on certain fields of the performance. The evaluation result of this method would not be able to provide a more comprehensive evaluation of an airline's performance.

Methodology		*Description*	*Weakness*
Multi-Criteria Decision Analysis (MCDA)		One of the widely adopted methods. This method can be divided into two main steps: the first step is to acquire relative weights, and the second step is to rank the options. Firstly, it selects evaluation KPIs through expert survey or interview, and then chooses an optimal solution based on those selected KPIs. (e.g. AHP, TOPSIS and MACBETH)	Because the selection of indicators is based on expert's experience and their judgment, the results may be affected by subjective factors.
Frontier Analysis: Parametric approach	**Stochastic Frontier Analysis (SFA)**	Sometimes referred to as econometric frontier approach, is one of the main parametric approaches used by researchers to evaluate efficiency.	Although the parametric approaches take into account the effect error, which is not considered in non-parametric approach, the parametric methods still face challenges on separating random error from efficiency.
Frontier Analysis: Non-parametric approach	**Total Factor Productivity (TFP)**	In economies, TFP is a variable which accounts for effects in total output not caused by inputs. TFP allows for measuring cost efficiency and effectiveness and for distinguishing productivity differences in airline performance. This approach can also be used for investigating the impact of variations of input and output price on an airline's performance.	TFP requires an aggregation of all outputs into a weighted output index and all inputs into a weighted input index using pre-defined weights which can be biased from different viewpoints.
	Data Envelopment Analysis (DEA)	This is an approach that requires no assumptions about the functional form and calculates a maximal performance measure for each airline relative to all other airlines.	The key drawback of this technique is that it does not allow for random error in the data, assuming away measurement error and luck as factors affecting the outcome, which implies that the measured inefficiency is likely to be overstated.

Source: [32], [33].

After a thorough analysis of the different tools shown in Table 3-1, [34] concluded that Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) complied with the requirements needed to assess air cargo carriers performance and efficiency.

Furthermore, [35] studied the impact of the low-cost carriers in the airport's service quality and [36] studied the performance and efficiency of low-cost carriers and legacy carriers, both using the MACBETH approach. Also, [37] applied the Multi-Criteria Decision Analysis focusing on the airport benchmarking process and in the key performance area of safety. Thus, this dissertation will complement the research about the use of the MACBETH tool and apply this approach to the air cargo carriers benchmarking study.

3.3. Measuring Attractiveness through a Category Based Evaluation Technique (MACBETH)

Measuring Attractiveness Through a Category-Based Evaluation Technique is a decision-aid approach to multi criteria value measurement with the goal of allowing measurement of the attractiveness or value options through non-numerical pairwise comparison questioning mode [38]. This methodology permits to evaluate options against multiple criteria. According to [38], MACBETH is a humanistic, interactive and constructive approach:

- Humanistic – it can help decision-makers ponder, communicate and discuss their value systems and preferences;
- Interactive – the reflection and learning process can best spread through socio-technical facilitation sustained by straightforward questioning-answering protocols;
- Constructive – it rests on the idea that full-bodied convictions about the kind of decisions to make that do not exist in the mind of the decision-maker, to help to form such convictions and to build robust preferences considering the different options to solve the problem.

The key factor that distinguishes MACBETH from other MCDA methods is that it needs only qualitative judgements about the difference of attractiveness between two elements at the time so that it can generate numerical scores for the options in each criterion and to weight the criteria [39]. The seven MACBETH semantic categories are described in Table 3-2.

Furthermore, [40] and [41] described the mathematical foundations of MACBETH. Consider X (with $\#X = n \geq 2$) be a finite set of elements (alternatives, choice options, courses of action) that an individual or a group, J, wants to compare in terms of their relative attractiveness (desirability, value).

Table 3-2: Significance of MACBETH semantic scales.

Semantic scale	*Equivalent numerical scale*	*Significance*
No	0	Indifference between alternatives.
Very Weak	1	An alternative is very weakly attractive over another.
Weak	2	An alternative is weakly attractive over another.
Moderate	3	An alternative is moderately attractive over another.
Strong	4	An alternative is strongly attractive over another.
Very Strong	5	An alternative is very strongly attractive over another.
Extreme	6	An alternative is extremely attractive over another.

Source: [42].

Ordinal value scales (defined on X) are quantitative representations of preferences that reflect, numerically, the order of attractiveness of the elements of X for J. The construction of an ordinal value scale is a straightforward process, provided that J is able to rank the elements of X by order of attractiveness – either directly or through pairwise comparisons of the elements to determine their relative attractiveness. Once the ranking is defined, one needs only to assign a real number $v(x)$ to each element x of X, in such a way that:

1. $v(x) = v(y)$ if and only if J judges the elements x and y to be equally attractive;
2. $v(x) > v(y)$ if and only if J judges x to be more attractive than y.

A value difference scale (defined on X) is a quantitative representation of preferences that is used to reflect, not only the order of attractiveness of the elements of X for J, but also the differences of their relative attractiveness, meaning, the strength of J's preferences for one element over another.

Using MACBETH, J is asked to provide preferential information about two elements of X at a time, firstly by giving a judgement as to their relative attractiveness (ordinal judgement) and secondly, if the two elements are not deemed to be equally attractive, by expressing a qualitative judgement about the difference of attractiveness between the most attractive of the two elements and the other. Moreover, to ease the judgemental process, six semantic categories shown above, are offered to J as possible answers.

By pairwise comparing the elements of X a matrix of qualitative judgements is filled in, with either only a few pairs of elements, or with all of them (in which case $n * (n-1)/2$ comparisons would be made by J).

It is necessary to obtain the maximum amount of data to develop a robust model. The next step is to create a value tree with nodes, or, in other words, a decision model. The nodes correspond to the key performance indicators that are going to be considered, and the decision makers define the attractiveness of each indicator. The next step is to fill the performance table of each indicator with the data collected [33].

The next step is where is defined the attractiveness of each indicator in the value tree. After considering the attractiveness of each node, the deciders must set the attractiveness difference between each pair of indicators in the model too. Subsequently to the introduction of these values for each node, it is possible to produce a robustness table still giving the opportunity to the decider to adjust the sensibility of the model [34].

Briefly, this study to assess air cargo carriers' performance and efficiency can be divided into six different steps (Figure 3-1): structuring (step 1); survey and meeting (step 2); evaluation (step 3); classification (step 4); and outputs (step 5). Although the sequence of the task is as shown, it is possible to redefine or adjust any task at any time.

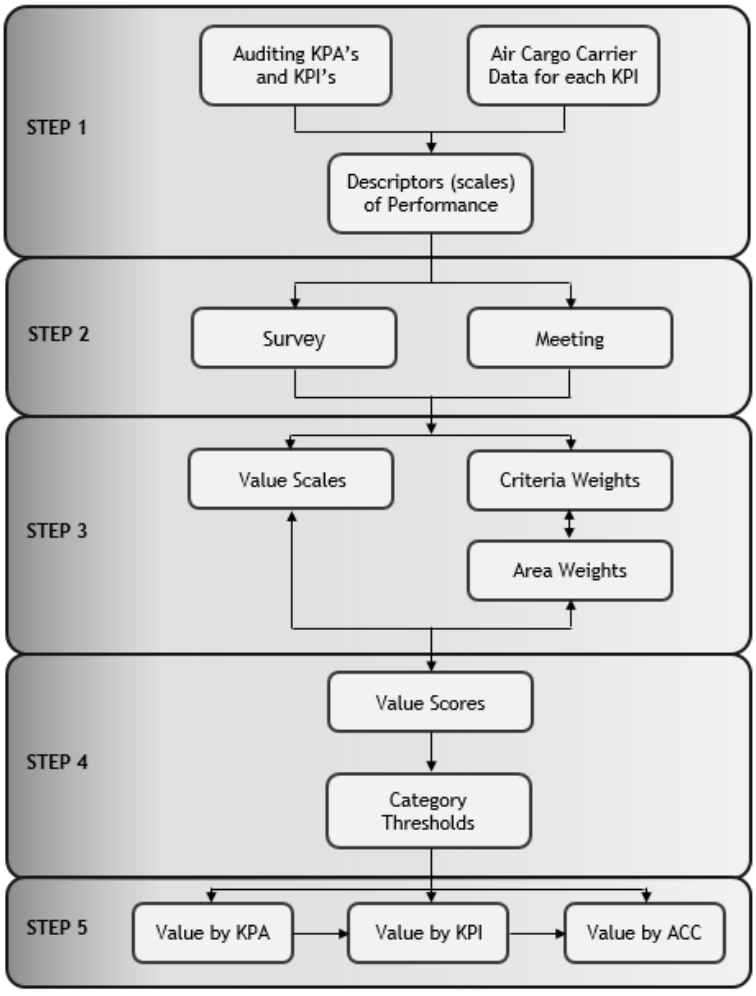


Figure 3-1: Activities needed to perform an air cargo carriers evaluation.

Source: [43]

3.3.1. Structuring

Structuring (step 1) consists of the definition of the value tree and in the data collection of Cargolux and Lufthansa Cargo to build the descriptors of performance consisting of a four-level scale for each key performance indicator.

In this step, it was necessary to define a set of KPA and KPI that could relate all the airline operations with the aim to evaluate all the different sectors of the company that influence the performance and efficiency. However, these set of KPA and KPI still was not defined by a recognized global organization. So to perform such evaluations, it was necessary to identify the most relevant indicators in the literature reviewed in Sections 2.4 and 3.2, in the annual reports of several air cargo carriers [44]–[62], from IATA [63] and in meetings and discussions with industry experts.

This study was divided into five KPAs for the performance case study and into two KPAs for the efficiency case study to obtain a more manageable set of KPIs. However, for each activity area were identified a significant number of performance indicators making the original set too large to be used, so it had to be narrowed down to reduce the number of performance indicators by understanding which are the ones more representative for each activity area. A meeting with several industry experts took place with the aim of obtaining a smaller set, which still represents each key performance area in a proper way. Though, due to some inconsistencies and lack of data in the air cargo industry, some airlines have been excluded from this evaluation.

Thus, it was created a set of five KPAs - fleet, financial, operational, personnel and environment, for the performance evaluation and a set of two KPAs - productivity and sustainability, for the efficiency evaluation. Each one of the KPA is composed with several KPI. The resulting sets of KPAs and KPIs are presented in Table 3-3 and Table 3-4, respectively.

After all the data collected, it was possible to fill the table of performance and to define the descriptors of performance of each key performance indicator. Only after the collection of all the data for all the years, it is possible to study the individual KPI. In Figure 3-2, it is possible to depict the data for all the KPIs of the operational KPA in the table of performance, from 2006 to 2015.

Table 3-3: Key performance areas and key performance indicators for air cargo carriers (performance).

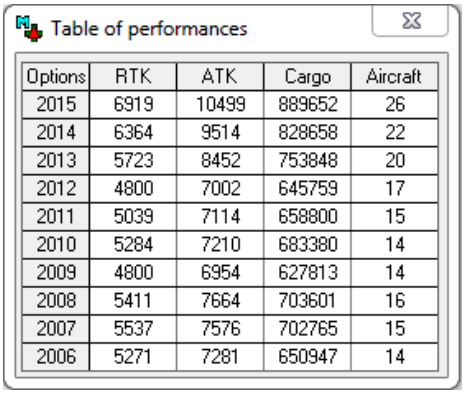
Key Performance Areas (KPAs)	*Key Performance Indicators (KPIs)*	*Units*	*Description*
***Fleet:** measures relating to airline's fleet and its utilisation.*	Number of Freighter Aircraft in Fleet	[number]	Number of freighter aircraft in the company's fleet.
	Average Fleet Age	[years]	Average age of the fleet.
	Average Aircraft Utilisation	[hours]	Average hours each aircraft is used in each day (block hours).
***Financial:** measures relating to company's costs, revenues, assets and liabilities.*	Operational Revenue	[USD '000]	Total operational revenue of the company.
	Operational Costs	[USD '000]	Total operational costs of the company.
	Operational Profit (Loss)	[USD '000]	Profit earned from core business operations, also known as EBIT.
	Equity Ratio	[%]	Ratio of shareholders' equity to total assets.
	Total Assets	[USD '000]	Total amount of assets of the company.
	Total Liabilities	[USD '000]	Total amount of financial obligations of the company.
***Operational:** measures relating to all the cargo and mail carried by airline and its capacity.*	Revenue Tonne Kilometres	[millions]	Traffic volume, measured in load tonnes from the carriage of cargo and mail multiplied by the kilometres flown.
	Available Tonne Kilometres	[millions]	Overall capacity, measured in tonnes available for the carriage of cargo/mail multiplied by the kilometres flown.
	Load-Factor	[%]	Revenue tonne kilometres expressed as a percentage of available tonne kilometres.
	Cargo and Mail Carried	[tonnes]	Total tonnes of cargo/mail carried by the company.
***Personnel:** measures relating to personnel productivity.*	Number of Employees	[number]	Total number of employees of the company.
	Injury Rate	[%]	Rate of injuries during working time.
	Revenue per Employee	[USD '000/ /employee]	Total operational revenue per total number of employees of the company.
	Labour Cost	[USD '000]	The cost of wages and benefits paid to workers, plus related taxes.
***Environmental:** measures relating to airline's performance, regarding CO_2 emissions and fuel used.*	CO_2 emissions	[tonnes]	Total tonnes of carbon dioxide emitted by all of the company's fleet.
	CO_2 emissions per Transported Tonne	[number]	Total tonnes of CO_2 emissions divided per total tonnes of cargo/mail transported.
	Fuel Used	[tonnes]	Total tonnes of jet fuel used.
	Fuel Cost	[USD '000]	Total costs related to the fuel used by all the aircraft.

Source: [64].

Table 3-4: Key performance areas and key performance indicators for air cargo carriers (efficiency).

Key Performance Areas (KPAs)	*Key Performance Indicators (KPIs)*	*Units*	*Description*
Productivity: *measures relating to company's efficiency taking into account the cargo transported or the fleet.*	Load-Factor	[%]	Revenue tonne kilometres expressed as a percentage of available tonne kilometres.
	Transported Tonnes per Number of Aircraft	[tonnes/aircraft]	Total transported tonnes per number of aircraft.
	Transported Tonnes per ATK	[tonnes]	Total transported tonnes per total ATKs.
	ATK per Labour Cost	[USD]	Available tonne kilometres per labour cost.
	RTK per Labour Cost	[USD]	Revenue tonne kilometres per labour cost.
Sustainability: *measures relating to airline's ability to support an activity over a long term.*	Operational Revenue per RTK	[USD]	Total operational revenue per total RTKs.
	Operational Revenue per ATK	[USD]	Total operational revenue per total ATKs.
	Operational Costs per ATK	[USD]	Total operational costs per total ATKs.
	Operational Revenue per Transported Tonnes	[USD/tonnes]	Total operational revenue per total transported tonnes.
	Operational Revenue per Number of Aircraft	[USD/aircraft]	Total operational revenue per number of aircraft.

Source: [64].



Options	RTK	ATK	Cargo	Aircraft
2015	6919	10499	889652	26
2014	6364	9514	828658	22
2013	5723	8452	753848	20
2012	4800	7002	645759	17
2011	5039	7114	658800	15
2010	5284	7210	683380	14
2009	4800	6954	627813	14
2008	5411	7664	703601	16
2007	5537	7576	702765	15
2006	5271	7281	650947	14

Figure 3-2: Example of a MACBETH performance table for operational KPA.

Source: own composition.

Descriptors of performance, presented in Table 3-5, are formed by four reference levels of accomplishment and allow the performance and efficiency assessment of each KPI by tracing the performance profile for each key performance area. For all the air cargo carriers descriptors were established two reference levels – the "good" and the "neutral" levels. These levels, which have a fundamental meaning for managers, were defined for each KPI. That is: the "good" level was established as the best level of performance in the ten year period of this study indicating that no improvement is required; the "neutral" level was established as the worst level of performance in the ten year period of this study stating that is neutral in terms

of need for improvement once that ensures regular working conditions, but below this level some action is required to improve the air cargo carrier performance or efficiency.

Table 3-5: Descriptors of performance structure.

Level	*Description*
L4 (Good)	The best value of air cargo carrier data collected, in the defined time span.
L3	The 1/3 of the difference between the best and the worst value of air cargo carrier data collected, in the defined time span.
L2	The 2/3 of the difference between the best and the worst value of air cargo carrier data collected, in the defined time span.
L1 (Neutral)	The worst value of air cargo carrier data collected, in the defined time span.

Source: [65].

3.3.2. Survey and Meetings

The second step (survey and meetings) represent the experts' judgments collected through survey and/or meetings, respectively. To obtain the judgment matrix for each KPA and KPI it was sent an online survey[7] [66] to several industry experts, 23 of whom responded. Then, after the statistical averaging, the results from the survey allowed to define a status quo scale of the KPAs and KPIs. Note that MACBETH model does not rely on the number of answers but the quality of the answers and its relevance to each case study.

The survey followed the next eight steps for all KPAs and associated KPIs:

1. Welcome message;
2. Personal information: name, email and professional expertise;
3. Which key performance area is more relevant?
4. Rank the KPA in order of relevance: It is possible to give the same rank to different areas, being 1 the least relevant and 6 the most relevant.
5. Choosing the area of expertise among the KPA.
6. In the KPA of expertise which KPI is more relevant?
7. Rank the KPI in order of relevance: It is possible to give the same rank to different areas, being 1 the least relevant and 6 the most relevant.
8. Fill the judgement matrix for all KPI answering to the 6 question so that A refers to the best option of the KPI over the course of 10 years; D refers to the worst option of the KPI over the course of 10 years; B and C are intermediate values equally distributed between A and D.

8.1. AD - A is more attractive than D. The difference is? (Question 1)

[7] The survey can be found online on https://goo.gl/forms/lB9aDoYpGySCkPS53.

8.2. AC - A is more attractive than C. The difference is? (Question 2)
8.3. BD - B is more attractive than D. The difference is? (Question 3)
8.4. AB - A is more attractive than B. The difference is? (Question 4)
8.5. BC - B is more attractive than C. The difference is? (Question 5)
8.6. CD - C is more attractive than D. The difference is? (Question 6)

The model aim is the descriptors or scales of performance. The descriptor of each KPI is defined, and the performance scale is converted to a value scale using qualitative judgments of differences in attractiveness between performance levels, two at a time. To ease the judgmental process the six semantic categories of the difference of attractiveness, shown in Section 3.3., are offered as possible answers. Figure 3-3 shows an example of the six questions of the online survey needed to fill the judgment matrix for the KPIs.

Revenue Tonne Kilometres variation *

Give us your individual judgement, remembering that the difference of attractiveness in AD is higher or equal to AC and BD, and that AC and BD is higher or equal to AB, BC and CD.

	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme
AD - Question 1	○	○	○	○	○	○	○
AC - Question 2	○	○	○	○	○	○	○
BD - Question 3	○	○	○	○	○	○	○
AB - Question 4	○	○	○	○	○	○	○
BC - Question 5	○	○	○	○	○	○	○
CD - Question 6	○	○	○	○	○	○	○

Figure 3-3: Example of a KPI judgment matrix question.
Source: own composition.

All the answers given by the experts and the survey results can be found in Annex I. With statistical averaging of the survey answers, it was possible to construct three outputs that reflect the expert's opinions for each KPA and associated KPI. The three outputs obtained were: KPAs status quo, KPIs status quo and the criteria judgment matrix. The results achieved will be shown in Section 4 where is given a more comprehensive interpretation of the results.

Figure 3-4 shows the judgment matrix of the revenue tonne kilometres KPI. It is also possible to see the difference of attractiveness and the descriptors of performance for this KPI. The MACBETH model produces this output for all the KPIs and KPAs.

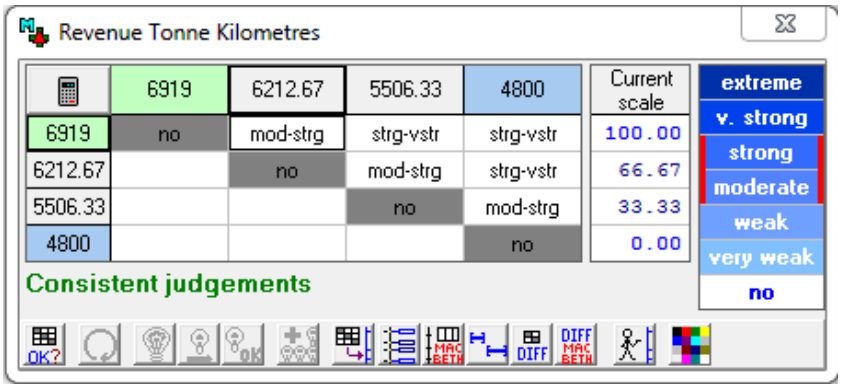


Figure 3-4: Example of a MACBETH judgements matrix.

Source: own composition.

Table 3-6 shows the relevance associated to all KPA retrieved by the expert's survey. For each ranking, it is possible to retrieve the status quo of the KPA, which remains unaltered in all the steps of the study so that it can be possible to obtain the KPA judgement matrix.

Table 3-6: Ranking of the airlines KPAs.

Key Performance Areas	*Ranking*	*Status Quo*
Operational	5,04	Very Strong
Financial	4,91	Strong-Very Strong
Fleet	4,83	Strong-Very Strong
Personnel	4,52	Strong-Very Strong
Environment	3,57	Moderate-Strong

Source: own composition.

Table 3-7 gives an example of the relevance associated to all KPIs in financial KPA retrieved by the expert's survey. For each ranking, it is possible to retrieve the status quo of the KPI, which also remains unaltered so that it can be possible to obtain the KPI judgement matrix.

Table 3-7: Ranking of all the KPIs in financial KPA.

Financial	*Ranking*	*Status Quo*
Operational Revenue	5,22	Very Strong
Operational Profit	5,22	Very Strong
Operational Costs	5,00	Very Strong
Equity Ratio	4,33	Strong
Total Assets	4,00	Strong
Total Liabilities	3,89	Moderate-Strong

Source: own composition.

The meeting (step 2), or decision conference, is a gathering of the key player who wishes to benchmark their air cargo carrier performance and efficiency. It is assisted by an impartial facilitator who is a specialist in decision analysis and works as a process consultant, using a model of relevant data and judgements created on the spot to assist the group of participants

with a balanced perspective on meeting's subject (experts, stakeholders, decision makers, etc.) in thinking more clearly about the issue. The process of a decision conference is illustrated in Figure 3-5.

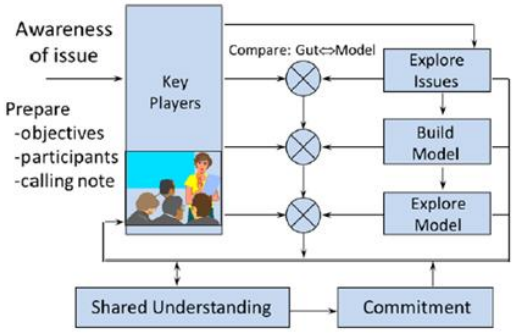


Figure 3-5: Building process of a decision conference.
Source: [67].

3.3.3. Evaluation

Evaluation (step 3) consists in the creation of the judgement matrices for all the KPA and all the associated KPI using the descriptors of performance and the ordinal value scales. With all the judgment matrices created with each KPA and KPI weight, ponderation can be obtained.

Value function consists of the criteria (option) values characterisation in a set of 3 linear equations. Value functions are built using the current scale achieved by the criteria judgment matrix. With these functions, MACBETH model can assign scores to each criteria value, according to the experts' judgments. Figure 3-6 depicts an example of a criteria value function obtained with the criteria judgment matrix of Figure 3-4.

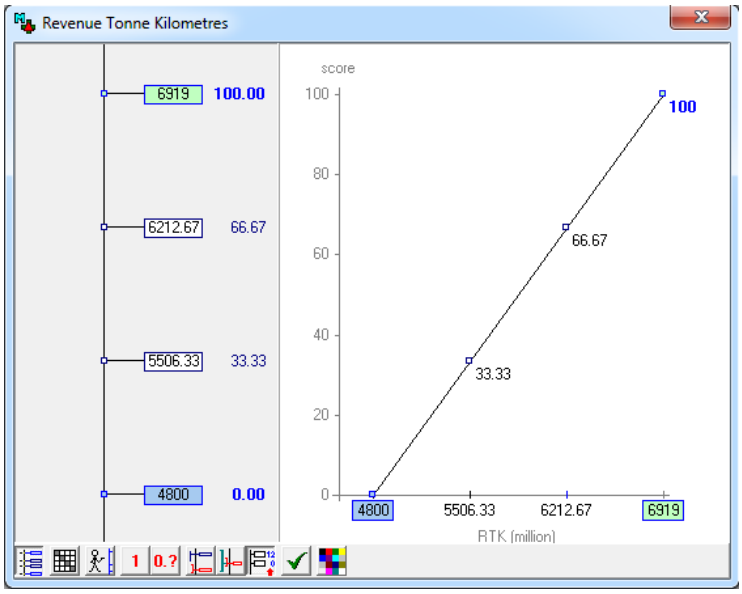


Figure 3-6: Example of a criteria value function from MACBETH.
Source: own composition.

Judgement matrices and respective weight ponderations are obtained using the ordinal value scales (or status quo scales) obtained from experts' judgements. Firstly, status quo scale is used to reorganised, in a matrix form, the key performance indicators and the key performance areas from the most relevant to the least relevant ones. Then, the judgment matrix is filled in a pair-wise comparison using the difference between the ordinal values given by the experts.

3.3.4. Classification and Outputs

Step 4 (classification) utilizes the value functions and weight ponderation from step 3 to obtain the KPA and KPI score for each option (year).

Step 5 (outputs) produces a significant outputs diversity which allows monitoring performance and efficiency over time. These outputs consist of performance profiles, sensitivity analysis, options and difference profiles, and value by KPI, KPA and air cargo carriers.

Profiles of (quantitative or/and qualitative) performance can be traced both within and across areas. These allow understanding which year (option) presented the best and the worst profile, as well if the profile exceeded good or neutral values in any criteria or area.

Sensitivity analysis of the KPI weights in the KPA scores or the airport score allows the decision maker to observe the cost of increasing or decreasing these weights. This analysis is made in a pairwise form between years (options).

Using the options profile and corresponding difference profile it is possible to assess the pairwise profile of the options allowing to compare each KPI, KPA or the entire air cargo carrier between two years.

3.4. Conclusion

In this chapter were identified the advantages and disadvantages of the utilisation of several methodologies, concluding that the MCDA fits best the evaluation of performance and efficiency of air cargo carriers. Firstly, is done a state of the art review of which methodologies are adopted to study airlines, and it was explained and justified the use of MACBETH. Also, the mathematical foundations of MACBETH tool are referred.

There are also presented the lists of the selected KPAs and KPIs to analyse air cargo carriers' performance and efficiency, based on the literature review. Lastly, all the steps needed to assess air cargo carriers performance and efficiency using the MACBETH approach are briefly explained, including the explanation how the survey, to obtain the experts' judgments, was implemented.

Chapter 4 – Case Studies

4.1. Introduction

In this chapter are presented the two case studies of this research. The first case study consists in a self-benchmarking and the second in a peer-benchmarking analysis. Each case study will be first presented and defined and after that will be shown and commented the obtained results with the MACBETH approach. At the end of this chapter are given the main conclusions obtained from the analysis of the results.

4.2. Case Study 1 – Cargolux Performance

The first case study consists in a self-benchmarking analysis to evaluate Cargolux regarding performance over a period of ten years, from 2006 until 2015. Cargolux is a European air cargo carrier based at the Luxembourg Findel Airport established in 1970 and represents almost 5.7% of the air cargo market, regarding RTK, being the 8th biggest air cargo carrier in the world in 2015, according to Table 2-1.

As explained in Sections 3.3, 3.4 and 3.5, it was created a set of key performance areas and key performance indicators to assess air cargo carriers' performance across the years. After creating this set of KPAs and KPIs, presented in Table 3-3, the next step was to create a value tree in MACBETH, illustrated in Figure 4-1.

Later, it was implemented all the data collected for all the KPIs from 2006 to 2015 and the data corresponding to the key performance areas and key performance indicators status quo, according to the expert's judgments.

Lastly, with all that information it was possible to obtain the MACBETH outputs which allow the decision makers to understand Cargolux performance better and to analyse which are the best alternatives they should take to ensure the best assessment over time. Therefore, there are presented the key performance areas and key performance weights, the sensitivity analysis for the most sensitive KPIs and performance value profile outputs for the Cargolux performance case study.

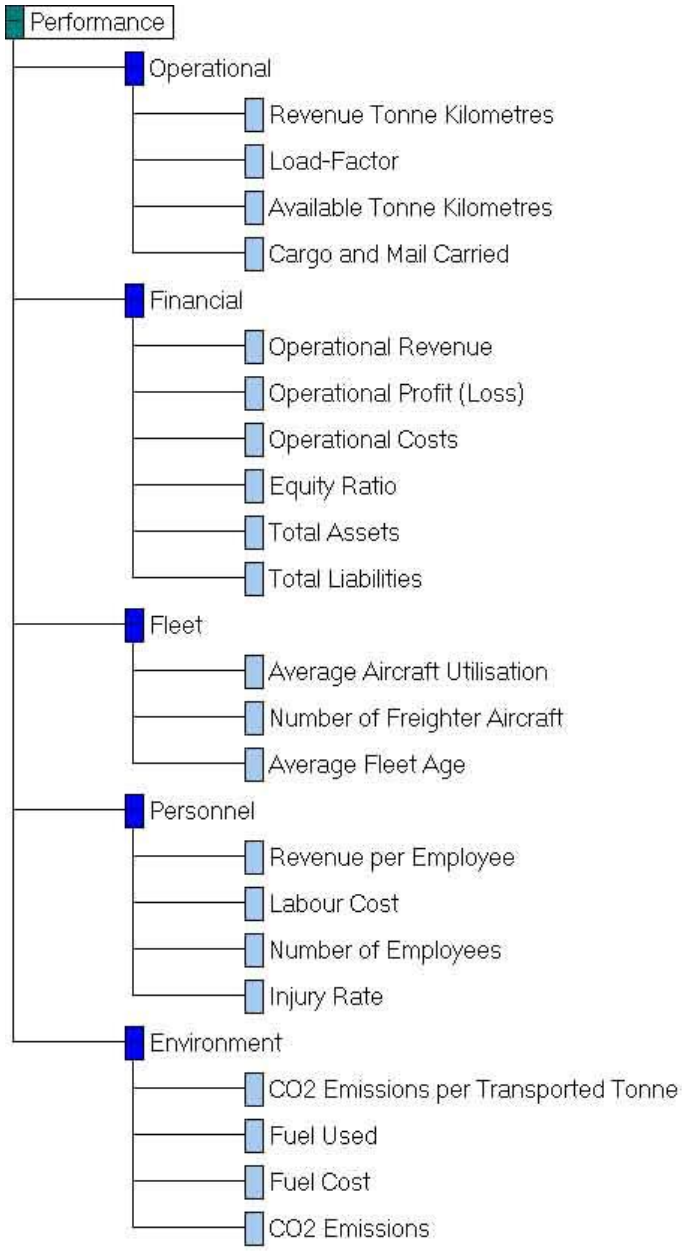


Figure 4-1: MACBETH value tree for the performance assessment.

Source: own composition.

4.2.1. Key Performance Areas and Key Performance Indicators Weights

Along with the survey results is possible to obtain the expert's judgments concerning the weight of each area of activity and the respective KPIs in the performance assessment. In Figure 4-2, it is possible to see the weight given to each key performance area. As observed the operational KPA is the most relevant regarding performance, weighing 25.71%. Following, the financial KPA is the second most relevant in the performance evaluation (22.86%), followed by the fleet (20.00%) and personnel (17.14%) KPAs. Finally, the KPA related to the environment weighs only 14.29% in the performance assessment.

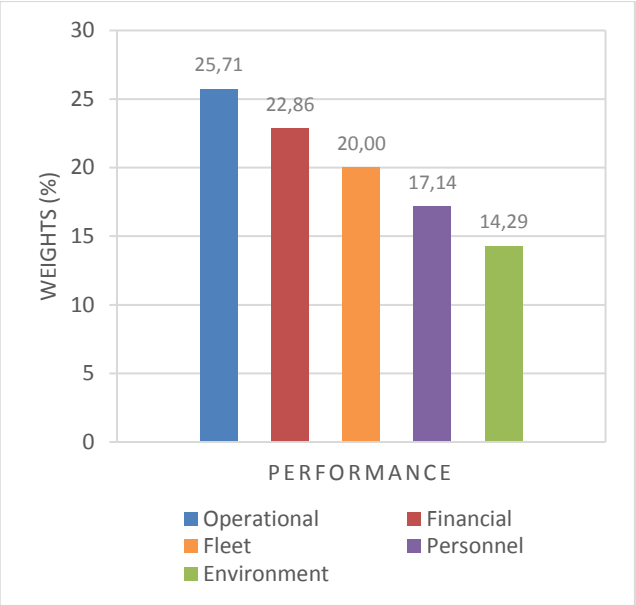


Figure 4-2: Performance KPAs weights.

Source: own elaboration.

Figure 4-3, Figure 4-4, Figure 4-5, Figure 4-6 and Figure 4-7 show the different weights given to each key performance indicator for the five key performance areas of the performance assessment. The Figures corresponding to the different areas are placed by order of relevance consistent with the results shown in Figure 4-2. According to Figure 4-3, the most relevant key performance indicator of the operational KPA is the revenue tonne kilometres, weighing 30.77%. Then, the load-factor and the available tonne kilometres reached a weight of 26.92% and 23.08%, respectively. Finally, the KPI related to the cargo carried weighs only 19.23% in the operational KPA.

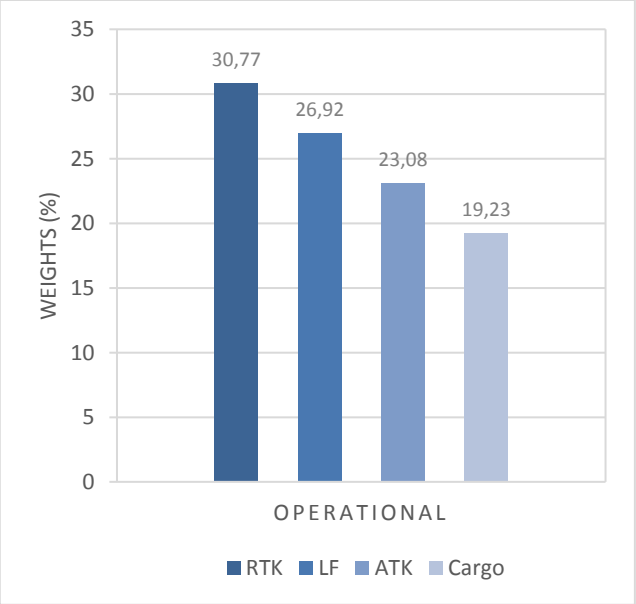


Figure 4-3: Operational KPIs weights.

Source: own elaboration.

Regarding the financial key performance area, Figure 4-4 presents the weights for each KPI. The most relevant key performance indicators are the operational revenue and operational profit, having both a weight of 20.45%. Then, the operational costs, the equity ratio and the total assets reached a weight of 18.19%, 15.91% and 13.64%, respectively. Finally, the KPI related to the total liabilities weighs only 11.36% in the financial KPA.

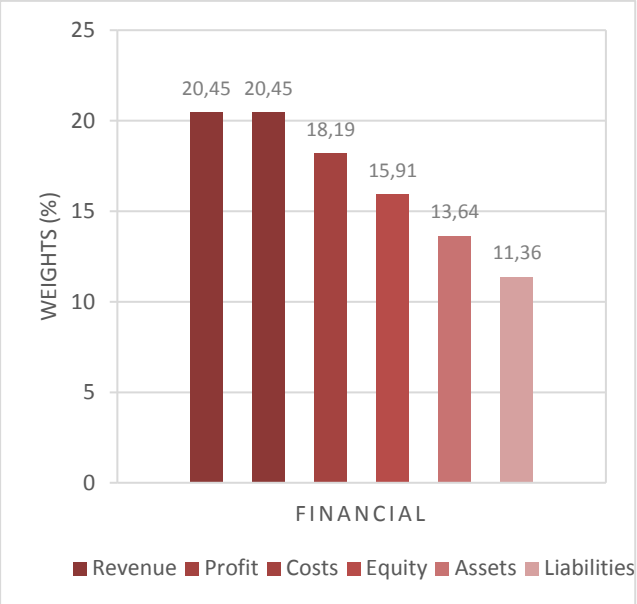


Figure 4-4: Financial KPIs weights.

Source: own elaboration.

Figure 4-5 presents the weights for each KPI of the fleet key performance area. The most relevant key performance indicator is the average aircraft utilisation, weighing 40.00%. Then, the number of aircraft reached a weight of 33.33%. Finally, the KPI related to the average fleet age weighs only 26.67% in the fleet KPA.

According to Figure 4-6, the most relevant key performance indicator of the personnel KPA is the revenue per employee, weighing 30.43%. Then, the labour cost KPI reached a weight of 26.09% and 21.74%, respectively. Finally, the KPIs related to the number of employees and the injury rate weighs both only 21.74% in the personnel KPA.

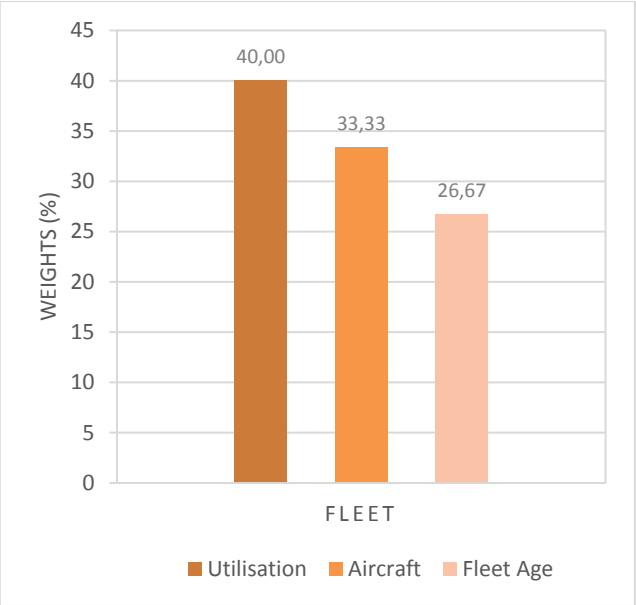


Figure 4-5: Fleet KPIs weights.

Source: own elaboration.

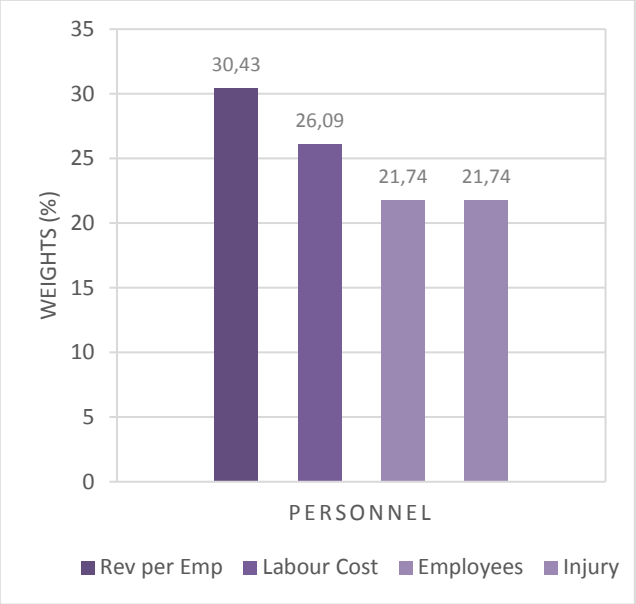


Figure 4-6: Personnel KPIs weights.

Source: own elaboration.

Finally, regarding the environment key performance area, Figure 4-7 presents the weights for each KPI. The most relevant key performance indicator is the CO_2 emissions per transported tonne, weighing 30.00%. Then, the fuel used and the fuel cost reached a weight of 26.67% and 23.33%, respectively. Finally, the KPI related to the CO_2 emissions weighs only 20.00% in the environment KPA.

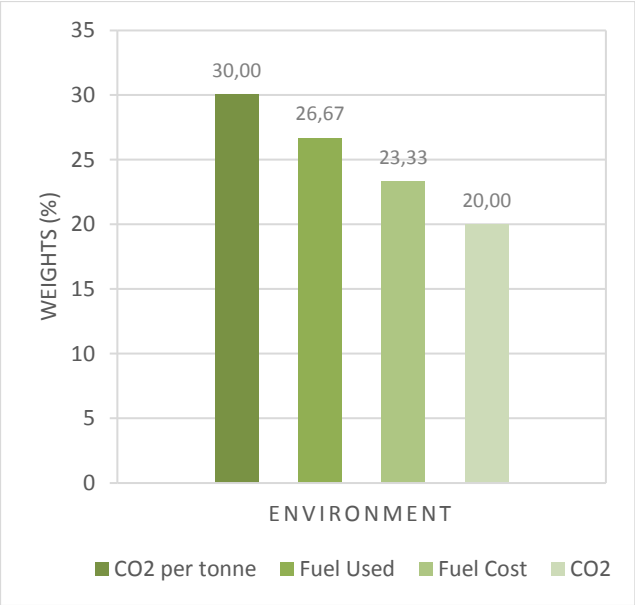


Figure 4-7: Environment KPIs weights.

Source: own elaboration.

4.2.2. Air Cargo Carriers Performance Evaluation

With the data collect implemented in the MACBETH approach, it is also possible to obtain the scores for each KPI and the overall scores of Cargolux performance for each year of the study. Table 4-1 presents the value scores for all the key performance indicators and the overall scores from 2006 to 2015 for the Cargolux performance case study.

Table 4-1: Cargolux performance table of scores.

		2006	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*All Upper*	*All Lower*	*Weights*
Operational	RTK	22.23	34.78	28.83	0.00	22.84	11.28	0.00	43.56	73.81	100.00	100.00	0.00	**0.0791**
	LF	86.75	97.06	60.24	36.58	100.00	63.20	30.67	19.87	11.04	0.00	100.00	0.00	**0.0692**
	ATK	9.22	17.54	20.03	0.00	7.22	4.51	1.35	42.26	72.22	100.00	100.00	0.00	**0.0593**
	Cargo	8.83	28.62	28.94	0.00	21.22	11.83	6.85	48.13	76.71	100.00	100.00	0.00	**0.0494**
Financial	Revenue	20.47	36.21	77.56	0.00	45.19	65.77	43.88	78.08	100.00	59.97	100.00	0.00	**0.0468**
	Profit	34.84	52.37	45.50	0.00	46.09	66.56	58.28	79.37	77.01	100.00	100.00	0.00	**0.0467**
	Costs	95.68	57.27	21.51	100.00	68.37	33.82	55.18	27.38	0.00	49.90	100.00	0.00	**0.0416**
	Equity	100.00	70.82	14.28	27.77	45.61	14.79	3.87	0.00	10.98	20.02	100.00	0.00	**0.0364**
	Assets	0.00	7.72	25.41	11.05	4.88	24.80	43.17	64.22	85.27	100.00	100.00	0.00	**0.0312**
	Liabilities	100.00	85.94	52.63	70.30	81.16	53.29	33.69	19.57	5.44	0.00	100.00	0.00	**0.0260**
Fleet	Utilisation	94.19	82.58	90.32	32.38	100.00	80.65	65.16	50.48	41.90	0.00	100.00	0.00	**0.0800**
	Aircraft	0.00	7.14	14.29	0.00	0.00	7.14	21.43	42.86	57.14	100.00	100.00	0.00	**0.0666**
	Fleet Age	0.00	12.75	23.68	30.96	45.47	50.91	65.40	100.00	61.78	54.53	100.00	0.00	**0.0533**

Personnel	Rev per Emp	34.44	50.74	100.00	0.00	66.84	75.67	46.84	82.75	88.09	25.81	100.00	0.00	**0.0522**
	Labour Cost	100.00	73.64	48.81	55.29	41.26	14.86	23.97	15.85	0.00	19.24	100.00	0.00	**0.0447**
	Employees	0.00	11.58	21.62	9.27	7.98	30.37	29.08	41.18	73.36	100.00	100.00	0.00	**0.0373**
	Injury	0.00	33.63	40.96	49.56	38.43	49.05	92.03	70.42	54.86	100.00	100.00	0.00	**0.0373**
Environment	CO2 per tonne	0.00	33.33	39.21	64.71	79.63	37.25	87.04	100.00	92.59	77.78	100.00	0.00	**0.0429**
	Fuel Used	60.69	73.79	86.90	100.00	99.91	99.82	99.73	56.11	27.32	0.00	100.00	0.00	**0.0381**
	Fuel Cost	84.28	72.07	7.77	100.00	62.92	20.64	28.71	10.76	0.00	68.89	100.00	0.00	**0.0333**
	CO2	63.92	52.65	54.47	99.32	79.97	74.62	100.00	57.79	22.82	0.00	100.00	0.00	**0.0286**
	Overall	**42.30**	**47.03**	**44.38**	**31.54**	**50.33**	**41.85**	**41.49**	**50.57**	**51.65**	**57.05**	**100.00**	**0.00**	

Source: own elaboration.

In Table 4-1 it is possible to observe that 2009 was the year with the lowest overall score (31.54) probably because it was the year in which the world financial crisis had a greater impact. Thus this happened because in 2009 some KPIs, such as revenue tonne kilometres, available tonne kilometres, cargo and mail carried, operational revenue, operational profit, number of aircraft and revenue per employee also had poor scores. However, in the last three years studied (2013, 2014 and 2015), Cargolux had a better score than the years before, achieving a maximum performance overall score of 57.05 in 2015. With the overall scores obtained in Table 4-1 is now possible to construct Figure 4-8 where it can be observed and is possible to better understand the evolution of the Cargolux performance from 2006 to 2015.

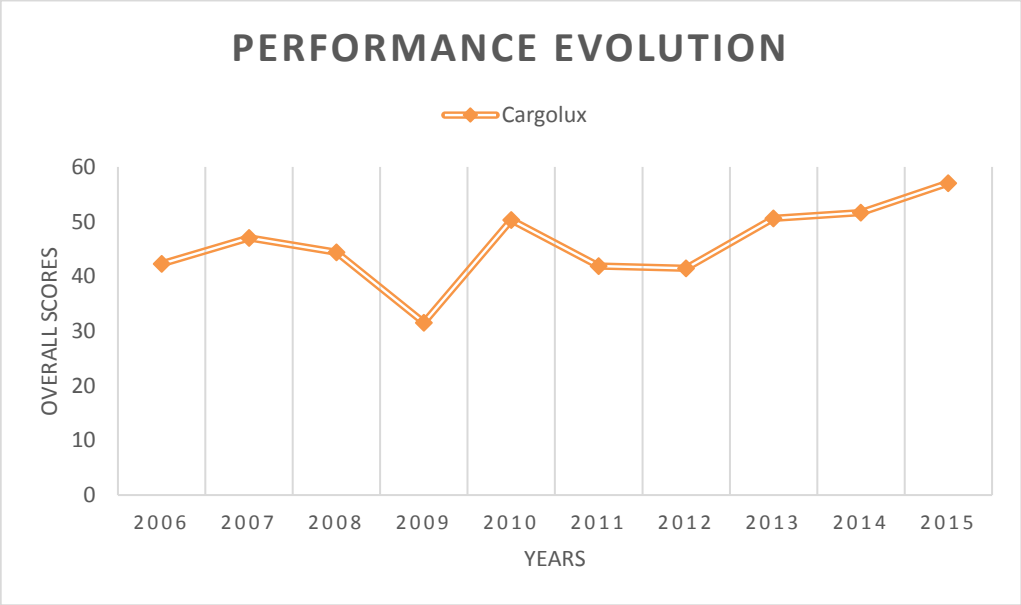


Figure 4-8: Cargolux performance evolution.

Source: own composition.

4.2.3. MACBETH Outputs

4.2.3.1. Sensitivity Analysis

Sensitivity analysis on the KPIs weights in the KPA scores is one of the outputs of the MACBETH model. This analysis allows observing what changes with the increase or decrease of the weights assigned to each key performance indicator in a pairwise form between years (options). It is possible to perform a sensitivity analysis to all the KPIs, however, for this case study, only five KPIs were chosen to be analysed. The chosen key performance indicators are the most sensitive of each area of activity according to the decision makers judgments. The remaining KPIs not analysed in this chapter can be found in Annex II.

Figure 4-9 shows the sensitivity of the load-factor KPI. The left vertical axis represents the KPA score, and the right vertical axis represents the KPI score for each option (year). The vertical red line positioned at 6.92% accounts for the current weight obtained through the decision makers judgment. It can be seen that the year of 2015 had the best result for the current weight. Also, 2013 had a better result that the year 2010 however, if the weight of this KPI changed from 6.92% to more than 7.2% (orange arrow), 2010 would overcome 2013 rank. On the other hand, if the decision makers decided to decrease the weight to below 5.9% (blue arrow), the year of 2012 would be considered better than 2011, on the contrary to what happens with the current weight.

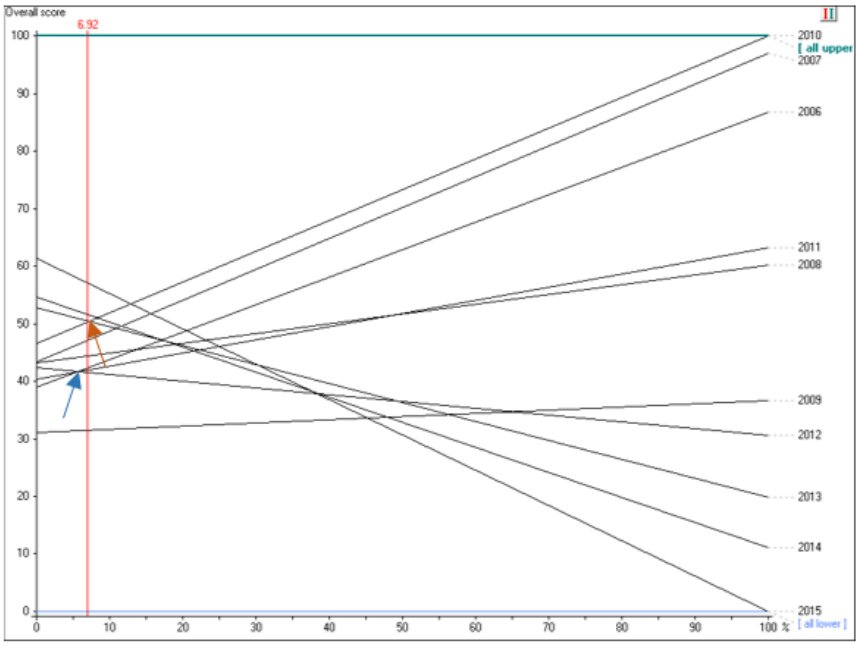


Figure 4-9: Sensitivity analysis on weight for load-factor KPI.

Source: own composition.

Regarding the operational costs KPI, in Figure 4-10 is shown that 2015 had the best result for the current weight (4.16%). Also, the year of 2013 had a better result than 2010, though if the weight of this KPI was changed to more than 4.7% (orange arrow), 2010 would overcome 2013 rank. Alternatively, if the decision makers decided to decrease the weight to below 3.5% (blue arrow), the year of 2011 would be considered better than 2006, on the contrary to what happens with the current weight.

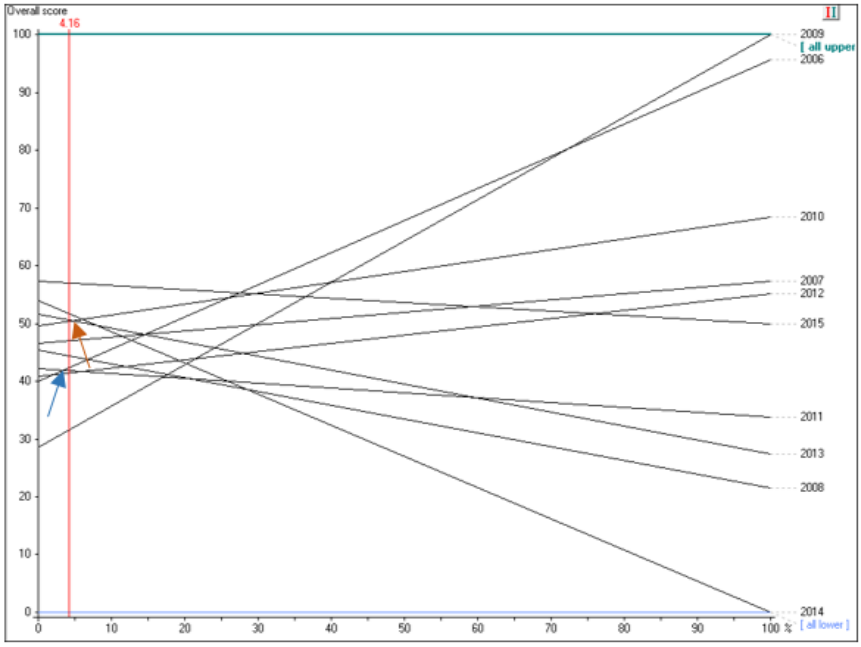


Figure 4-10: Sensitivity analysis on weight for operational costs KPI.
Source: own composition.

Figure 4-11 shows that for the average fleet age KPI the year of 2015 had the best result for the current weight (5.33%). Besides, the year of 2006 had a better result than 2011, but if the weight of this KPI was changed to more than 6.2% (orange arrow), 2011 would overcome 2006 rank. On the contrary, if the decision makers decided to decrease the weight to below 4.9% (blue arrow), the year of 2010 would be considered better than 2013, on the contrary to what happens with the current weight.

Sensitivity analysis on weight for labour cost KPI is shown Figure 4-12. It is possible to conclude that 2015 was the year with the best result for the current weight (4.47%). Moreover, the year of 2013 had a better result than 2010, yet if the weight of this KPI was changed to more than 5.4% (orange arrow), 2010 would overcome 2013 rank. In contrast, if the decision makers decided to decrease the weight to below 4.0% (blue arrow), the year of 2011 would be considered better than 2006, on the contrary to what happens with the current weight.

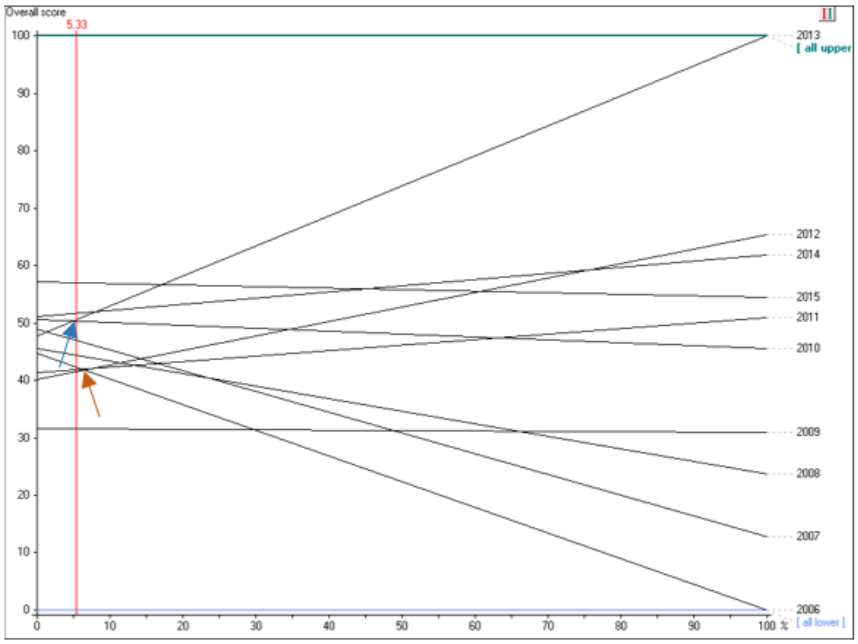


Figure 4-11: Sensitivity analysis on weight for average fleet age KPI.

Source: own composition.

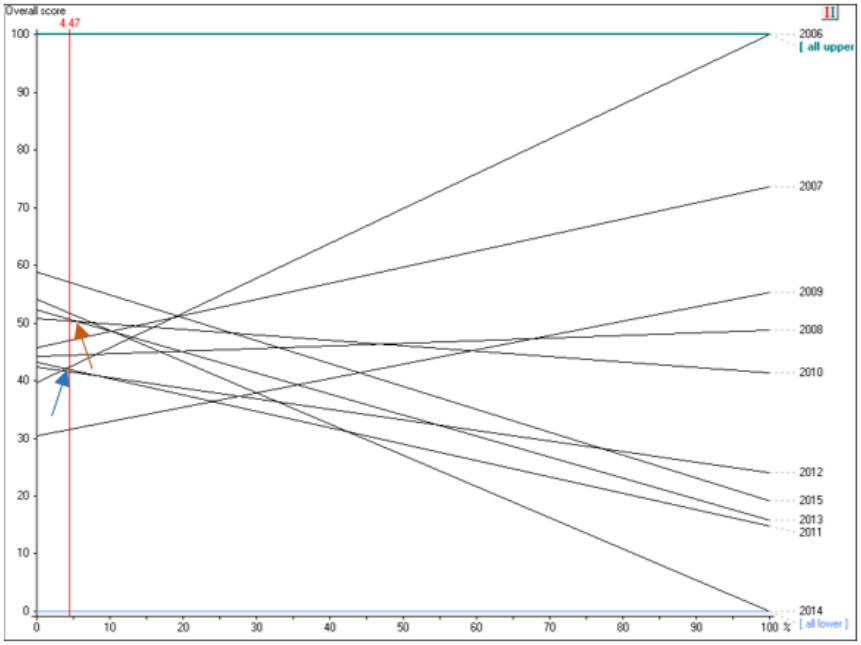


Figure 4-12: Sensitivity analysis on weight for labour cost KPI.

Source: own composition.

Lastly, Figure 4-13 shows that for the CO_2 emissions per transported tonnes KPI the year of 2015 had the best result for the current weight (4.29%). Also, the year of 2011 had a better result than 2012, but if the weight of this KPI was changed to more than 5.0% (orange arrow), 2012 would overcome 2011 rank. On the other hand, if the decision makers decided to decrease the

weight to below 3.2% (blue arrow), the year of 2010 would be considered better than 2013, on the contrary to what happens with the current weight.

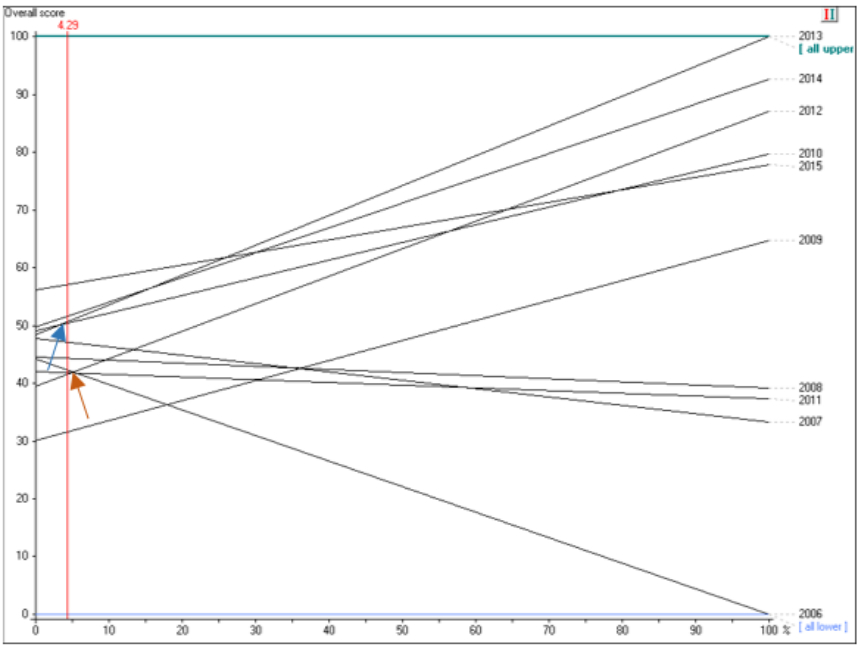


Figure 4-13: Sensitivity analysis on weight for CO_2 emissions per transported tonnes KPI. Source: own composition.

4.2.3.2. Performance Value Profiles

The performance value profiles are another output resulting from the application of the MACBETH approach. Performance value profiles can be traced within and across areas, for every KPA for 2006-2015, to understand which option (year) had the best and the worst profile. Also, It allows understanding if the profile exceeds the good or neutral levels in any area. With this output, it is possible to identify which key performance indicators deserve more attention from the stakeholders. There are 3 zones where the key performance indicator can be positioned:

- Above the good level: no improvement is required;
- Between the good and neutral levels: the KPI meets the requirements;
- Below the neutral level: corrective measures should be implemented.

Figure 4-14 illustrates the performance profiles along the years for operational KPA. From this figure is possible to conclude that the option 2015 is the best profile once that the revenue tonne kilometres, available tonne kilometres and cargo and mail carried KPIs are above the good level, and only the load-factor KPI is below the neutral level under the 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013 and 2014 options. The improvement of load-factor KPI is required to have all the KPIs of the operational KPA in a threshold category of excellent. Contrarily, the 2009 option presents the worst profile, with the revenue tonne kilometres, available tonne kilometres and cargo and mail carried KPIs below the neutral level and only the load-factor KPI between good and neutral levels with a better score than 2012, 2013, 2014 and 2015 options.

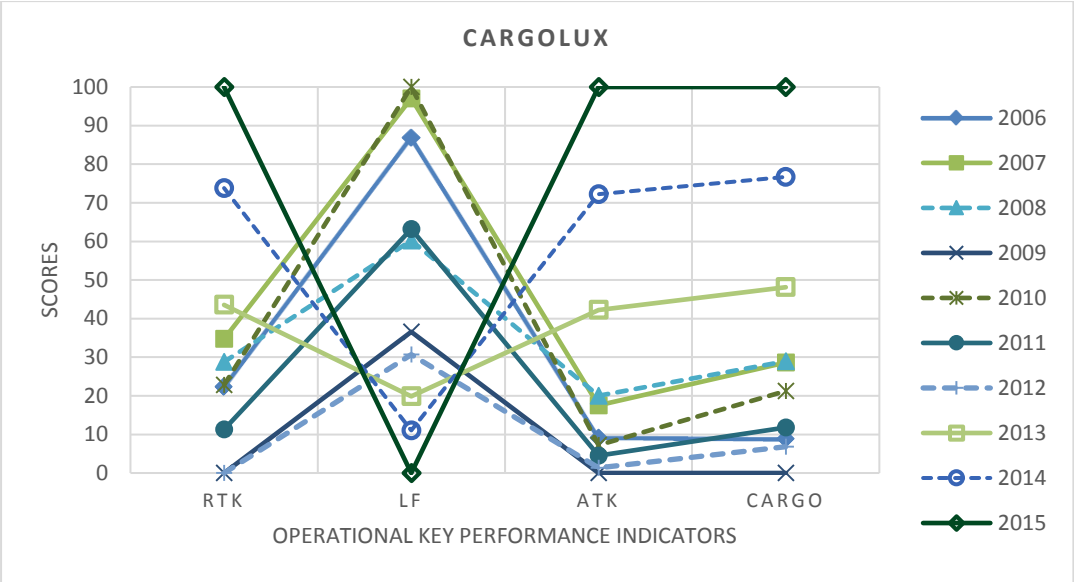


Figure 4-14: Operational value profile for Cargolux.
Source: own elaboration.

Figure 4-15 illustrates the performance profiles along the years for financial KPA. From this figure is possible to conclude that the option 2006 is the best profile once that the operational costs, equity ratio and total liabilities KPIs are above the good level, the operational revenue and operational profit KPIs are between the good and neutral levels, and only the total assets KPI is below the neutral level under the 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014 and 2015 options. To have all the KPIs of the financial KPA in a threshold category of excellent the improvement of operational revenue, operational profit and total assets KPIs is required. Contrarily, the 2009 option presents the worst profile, with the operational revenue and operational profit KPIs below the neutral level, the equity ratio, total assets and total liabilities KPIs between the good and neutral levels, and only the operational costs KPI above the good level with a better score than the 2006, 2007, 2008, 2010, 2011, 2012, 2013, 2014 and 2015 options.

Figure 4-16 illustrates the performance profiles along the years for fleet KPA. From this figure it is possible to conclude that the option 2013 is the best profile once that the average fleet age KPI is above the good level, and the average aircraft utilisation and the number of freighter aircraft in fleet KPIs are between the good and neutral levels. The improvement of average aircraft utilisation and the number of freighter aircraft in fleet KPIs is required to have all the KPIs of the fleet KPA in a threshold category of excellent. Contrarily, the 2009 option presents the worst profile, with the number of freighter aircraft in fleet KPI below the neutral level, the average fleet age and average aircraft utilisation KPIs between the good and neutral levels.

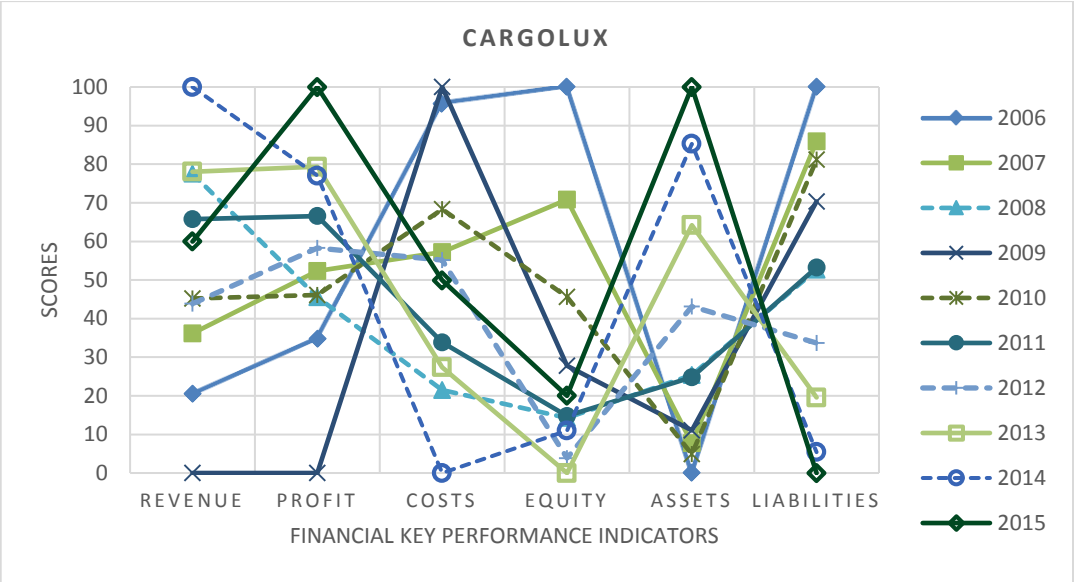


Figure 4-15: Financial value profile for Cargolux.

Source: own elaboration.

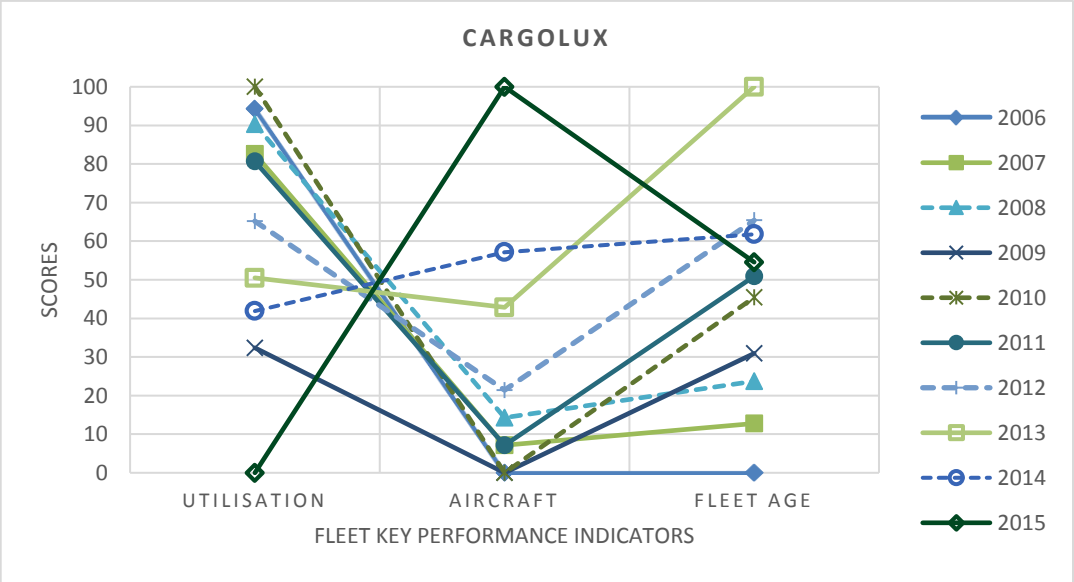


Figure 4-16: Fleet value profile for Cargolux.

Source: own elaboration.

Figure 4-17 illustrates the performance profiles along the years for personnel KPA. From this figure it is possible to conclude that the option 2015 is the best profile once that the number of employees and injury rate KPIs are above the good level, and the revenue per employee and labour cost KPIs are between the good and neutral levels. The improvement of revenue per employee and labour cost KPIs is required to have all the KPIs of the personnel KPA in a threshold category of excellent. Contrarily, the 2009 option presents the worst profile, with the revenue per employee and number of employees KPIs below the neutral level and the labour cost and injury rate KPIs between the good and neutral levels.

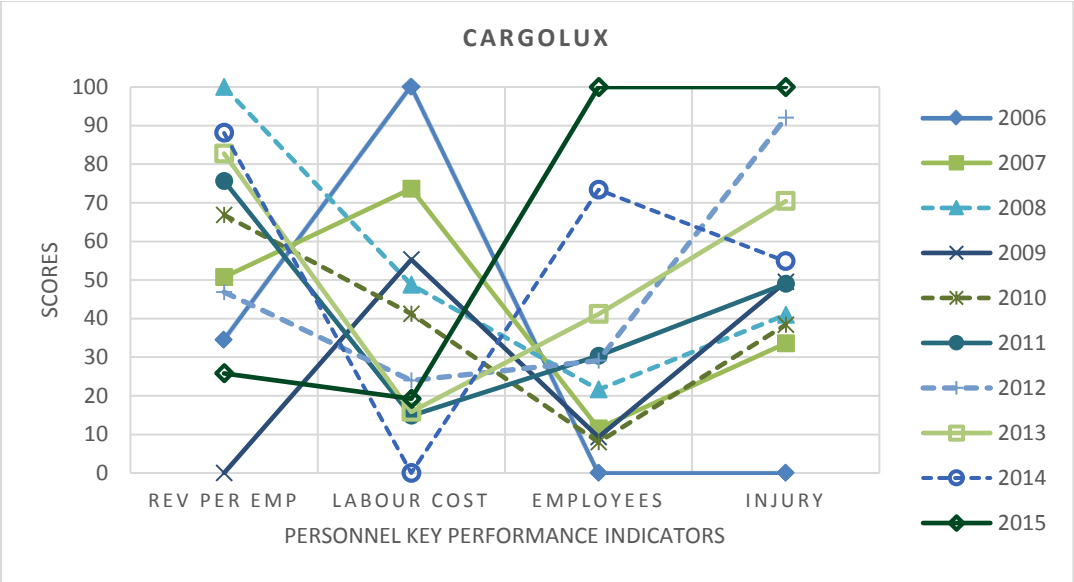


Figure 4-17: Personnel value profile for Cargolux.
Source: own elaboration.

Figure 4-18 illustrates the performance profiles along the years for environment KPA. From this figure it is possible to conclude that the option 2009 is the best profile once that the fuel used, fuel cost and CO_2 emissions KPIs are above the good level, and only the CO_2 emissions per transported tonnes KPI is between the good and neutral levels. The improvement of CO_2 emissions per transported tonnes KPI is required to have all the KPIs of the environment KPA in a threshold category of excellent. Contrarily, the 2014 option presents the worst profile, with the fuel cost KPI below the neutral level, the fuel used and CO_2 emissions KPIs between the good and neutral levels, and only CO_2 emissions per transported tonnes KPI above the good level with a better score than the 2006, 2007, 2008, 2009, 2010, 2011, 2012 and 2015 options.

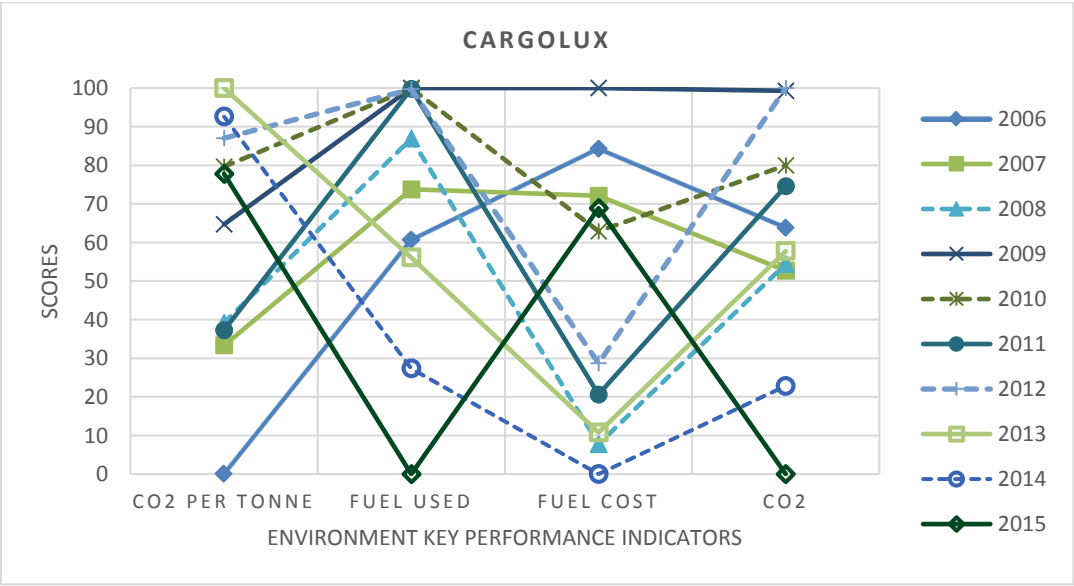


Figure 4-18: Environment value profile for Cargolux.
Source: own elaboration.

4.3. Case Study 2 – Cargolux and Lufthansa Cargo Efficiency

The second case study consists in a peer-benchmarking analysis to evaluate Cargolux and Lufthansa Cargo regarding efficiency over a period of ten years, from 2006 until 2015. According to Table 2-1 Cargolux is a European air cargo carrier based at the Luxembourg Findel Airport established in 1970 and represents almost 5.7% of the air cargo market, in terms of RTK, being the 8th biggest air cargo carrier in the world in 2015. Lufthansa Cargo is also a European air cargo carrier based at the Frankfurt Airport established in 1977 (founded as German Cargo) and represents almost 6% of the air cargo market, in terms of RTK, being the 7th biggest air cargo carrier in the world in 2015, according to Table 2-1 too.

As explained in Sections 3.3, 3.4 and 3.5, it was created a set of key performance areas and key performance indicators to assess air cargo carriers efficiency across the years. After creating this set of KPAs and KPIs, presented in Table 3-4, the next step was to create a value tree in MACBETH, illustrated in Figure 4-19.

Later, it was implemented all the data collected for all the KPIs from 2006 to 2015 and also the data corresponding to the key performance areas and key performance indicators status quo, according to the expert's judgments.

Lastly, with all that information it was possible to obtain the MACBETH outputs which allow the decision makers to understand Cargolux and Lufthansa Cargo efficiency better and to analyse which are the best alternatives they should take to ensure the best assessment over time. Therefore, there are presented the key performance areas and key performance weights, the sensitivity analysis for the most sensitive KPIs and efficiency value profile outputs for the Cargolux and Lufthansa Cargo efficiency case study.

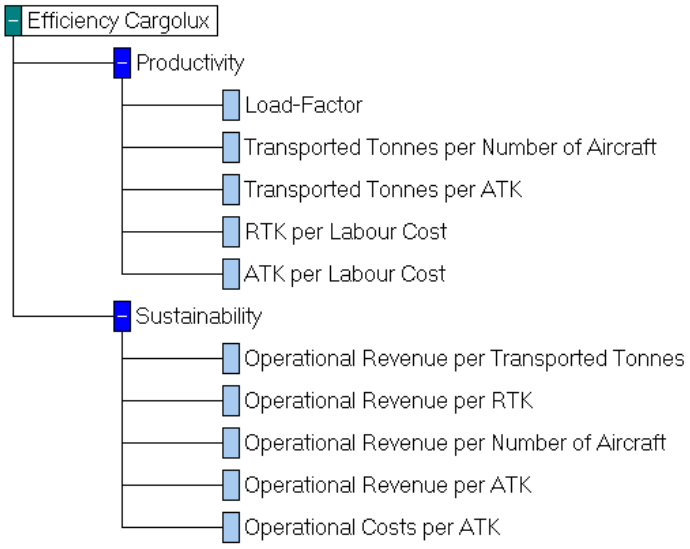


Figure 4-19: MACBETH value tree for the efficiency assessment.

Source: own composition.

4.3.1. Key Performance Areas and Key Performance Indicators Weights

Along with the survey results is possible to obtain the expert's judgments concerning the weight of each area of activity and the respective KPIs in the efficiency assessment. In Figure 4-20, it is possible to observe the weight given to each key performance area. Thus, the productivity KPA is the most relevant regarding efficiency, weighing 55.56%. Sustainability KPA is also very important for the efficiency evaluation, representing a weight of 44.44% in the efficiency assessment.

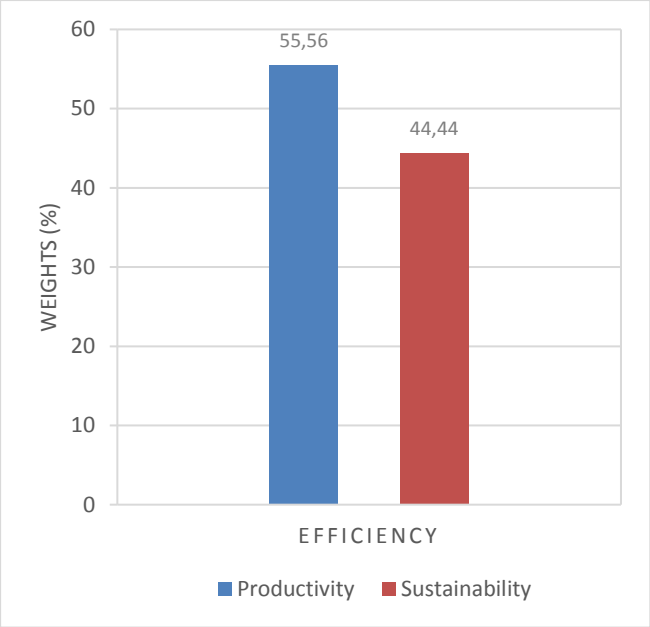


Figure 4-20: Efficiency KPAs weights.

Source: own composition.

Figure 4-21 and Figure 4-22 show the different weights given to each key performance indicator for the two key performance areas of the efficiency assessment. The Figures corresponding to the different areas are placed by order of relevance consistent with the results shown in Figure 4-20. According to Figure 4-21, the most relevant key performance indicator of the productivity KPA is the load-factor, weighing 25.00%. Then, the transported tonnes per aircraft, the transported tonnes per ATK and the RTK per labour cost, reached a weight of 22.50%, 20.00% and 17.50%, respectively. Finally, the KPI related to the ATK per labour cost weighs only 15.00% in the productivity KPA.

Regarding the sustainability key performance area, Figure 4-22 presents the weights for each KPI. The most relevant key performance indicator is the operational revenue per transported tonnes, weighing 24.32%. Then, the operational revenue per RTK reached a weight of 21.62% and the operational revenue per number of aircraft and the operational revenue per ATK reached both a weight of 18.92%, respectively. Finally, the KPI related to the operational costs per ATK weighs only 16.22% in the sustainability KPA.

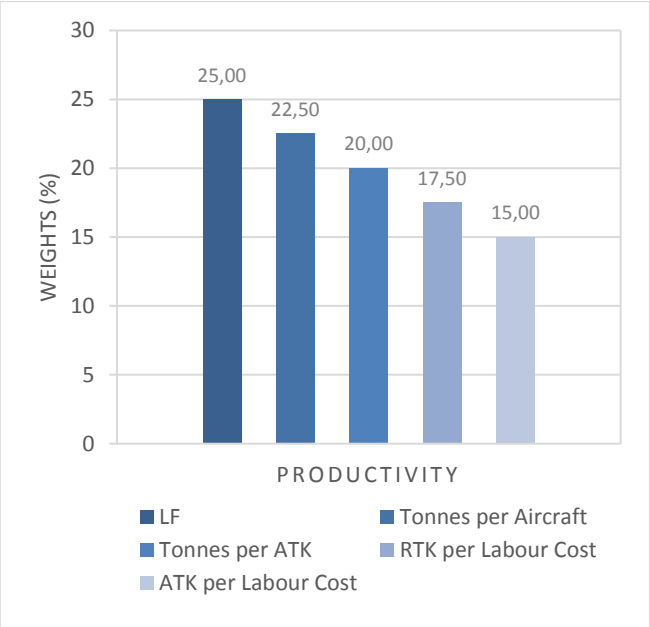


Figure 4-21: Productivity KPIs weights.

Source: own composition.

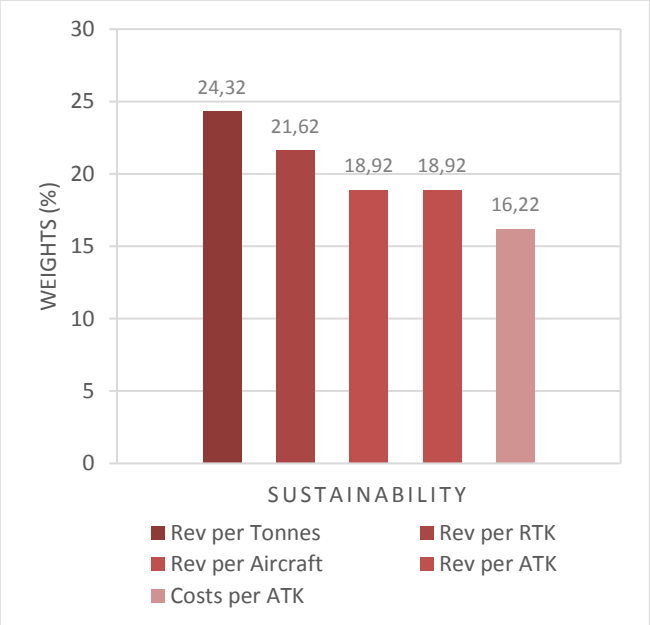


Figure 4-22: Sustainability KPIs weights.

Source: own composition.

4.3.2. Air Cargo Carriers Efficiency Evaluation

With the data implemented in the MACBETH approach, it is also possible to obtain the scores for each KPI and the overall scores of Cargolux and Lufthansa Cargo efficiency for each year of the case study. Table 4-2 and Table 4-3 present the value scores for all the key performance indicators and the overall scores from 2006 to 2015 for the Cargolux and Lufthansa Cargo efficiency case study.

Table 4-2: Cargolux efficiency table of scores.

		2006	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*All Upper*	*All Lower*	*Weights*
Productivity	LF	85.43	96.76	57.20	37.68	100.00	59.63	32.80	21.86	12.15	0.00	100.00	0.00	**0.1389**
	Tonnes per Aircraft	84.13	86.56	66.86	72.81	100.00	66.48	25.81	23.80	23.63	0.00	100.00	0.00	**0.1250**
	Tonnes per ATK	46.41	79.90	70.45	55.19	100.00	78.31	74.53	44.31	23.48	0.00	100.00	0.00	**0.1111**
	RTK per Labour Cost	100.00	71.43	38.09	19.05	28.57	0.00	0.00	28.57	38.09	85.71	100.00	0.00	**0.0972**
	ATK per Labour Cost	74.28	57.14	40.00	22.86	22.86	0.00	5.71	34.28	45.71	100.00	100.00	0.00	**0.0833**
Sustainability	Rev per Tonnes	33.33	35.56	90.77	6.92	53.33	100.00	70.77	63.08	56.67	0.00	100.00	0.00	**0.1081**
	Rev per RTK	24.01	32.85	90.79	12.38	57.70	100.00	86.61	72.97	63.89	0.00	100.00	0.00	**0.0961**
	Rev per Aircraft	67.88	70.68	94.83	38.87	96.56	100.00	50.48	44.65	41.04	0.00	100.00	0.00	**0.0841**
	Rev per ATK	32.82	44.12	90.10	14.70	69.54	100.00	76.84	60.51	48.71	0.00	100.00	0.00	**0.0841**
	Costs per ATK	63.07	35.72	7.06	57.74	35.23	0.00	16.38	34.10	38.74	100.00	100.00	0.00	**0.0721**
	Overall	**62.37**	**64.07**	**65.76**	**34.83**	**70.00**	**62.53**	**44.40**	**41.70**	**37.37**	**23.87**	**100.00**	**0.00**	

Source: own elaboration.

Table 4-2 presents the efficiency scores of Cargolux and Table 4-3 presents the efficiency scores of Lufthansa Cargo. In both cases, it is possible to see that 2009 and 2015 depicted the lowest overall scores in the ten-year period. For the years 2009 and 2015, Lufthansa Cargo presented worst values of overall efficiency (14.98 and 22.32, respectively) than Cargolux (34.83 and 23.87, respectively). The low values of 2009 could be directly connected to the financial crisis, while in 2015, the low scores could be explained due to the low operational revenues and the low number of transported tonnes for both carriers.

Also, according to the results, the best year in terms Cargolux efficiency was 2010, where an overall score of 70.00 was obtained. Lufthansa Cargo obtained the maximum overall score of 73.09 in 2011. Nevertheless, it is possible to say that both carriers followed the same trend across the years.

With the overall scores obtained in Table 4-2 and Table 4-3 is now possible to construct Figure 4-23, where it can be observed and is possible to better understand the evolution of the Cargolux and Lufthansa Cargo efficiency from 2006 to 2015. Also, Figure 4-23 allows observing the trend of the air cargo market across the years.

Table 4-3: Lufthansa Cargo efficiency table of scores.

		2006	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*All Upper*	*All Lower*	*Weights*
Productivity	LF	50.53	70.37	27.16	0.00	100.00	76.95	78.60	83.54	80.25	33.32	100.00	0.00	**0.1389**
	Tonnes per Aircraft	50.99	60.76	37.60	0.00	79.82	100.00	63.90	23.42	14.14	23.58	100.00	0.00	**0.1250**
	Tonnes per ATK	96.93	100.00	30.04	4.06	74.51	48.49	45.41	43.99	31.85	0.00	100.00	0.00	**0.1111**
	RTK per Labour Cost	100.00	57.14	0.00	0.00	100.00	100.00	57.14	0.00	0.00	28.57	100.00	0.00	**0.0972**
	ATK per Labour Cost	100.00	57.14	28.57	57.14	78.57	78.57	57.14	14.29	0.00	57.14	100.00	0.00	**0.0833**
Sustainability	Rev per Tonnes	41.61	44.52	100.00	18.39	44.52	55.16	38.71	28.06	32.90	0.00	100.00	0.00	**0.1081**
	Rev per RTK	62.82	62.63	100.00	26.37	50.32	58.11	40.70	28.89	30.58	0.00	100.00	0.00	**0.0961**
	Rev per Aircraft	50.86	60.75	97.67	4.75	72.66	100.00	55.57	20.62	20.02	0.00	100.00	0.00	**0.0841**
	Rev per ATK	64.64	69.50	100.00	14.44	61.14	65.74	45.21	31.82	33.24	0.00	100.00	0.00	**0.0841**
	Costs per ATK	26.05	26.31	0.00	50.41	46.42	38.33	46.50	54.14	55.94	100.00	100.00	0.00	**0.0721**
	Overall	**64.34**	**62.48**	**51.23**	**14.98**	**72.66**	**73.09**	**54.19**	**34.73**	**31.46**	**22.32**	**100.00**	**0.00**	

Source: own elaboration.

As observed, both Cargolux and Lufthansa Cargo follow the same trend over the years, meaning that both carriers may have followed the same procedures, practices and strategies over the years.

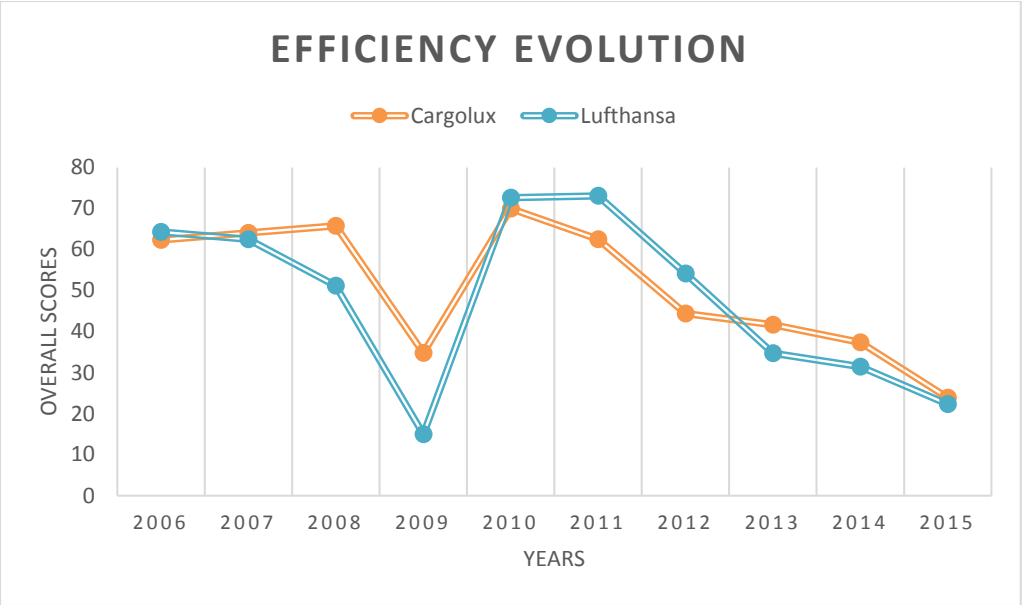


Figure 4-23: Cargolux and Lufthansa Cargo efficiency evolution.

Source: own elaboration.

4.3.3. MACBETH Outputs

4.3.3.1. Sensitivity Analysis

Sensitivity analysis on the KPIs weights in the KPA scores is another output of the MACBETH model. This analysis allows observing what changes with the increase or decrease of the weights assigned to each key performance indicator in a pairwise form between years (options). It is possible to perform a sensitivity analysis to all the KPIs, however, for this case study, only two KPIs were chosen to be analysed. The chosen key performance indicators are the most sensitive of each air cargo carrier meaning that it was selected the most sensitive key performance indicator of Cargolux and the most sensitive key performance indicator of Lufthansa Cargo according to the decision makers judgments of each key performance area. The remaining KPIs not analysed in this chapter can be found in Annex II.

Figure 4-24 shows the sensitivity of the ATK per labour cost KPI for Cargolux. The left vertical axis represents the KPA score, and the right vertical axis represents the KPI score for each option (year). The vertical red line positioned at 8.33% accounts for the current weight obtained through the decision makers judgment. It can be realised that the year of 2010 had the best result for the current weight. Also, 2011 had a better result that the year 2006 however, if the weight of this KPI changed from 8.33% to more than 8.5% (orange arrow), 2006 would overcome 2011 rank. On the other hand, if the decision makers decided to decrease the weight to below 5.8% (blue arrow), the year of 2011 would be considered better than 2007, on the contrary to what happens with the current weight.

Regarding the operational revenue per number of aircraft KPI for Lufthansa Cargo, in Figure 4-25 is shown that 2011 had the best result for the current weight (8.41%). Also, the year of 2012 had a better result than 2008, though if the weight of this KPI was changed to more than 14.4% (orange arrow), 2008 would overcome 2012 rank. Alternatively, if the decision makers decided to decrease the weight to below 6.9% (blue arrow), the year of 2010 would be considered better than 2011, on the contrary to what happens with the current weight.

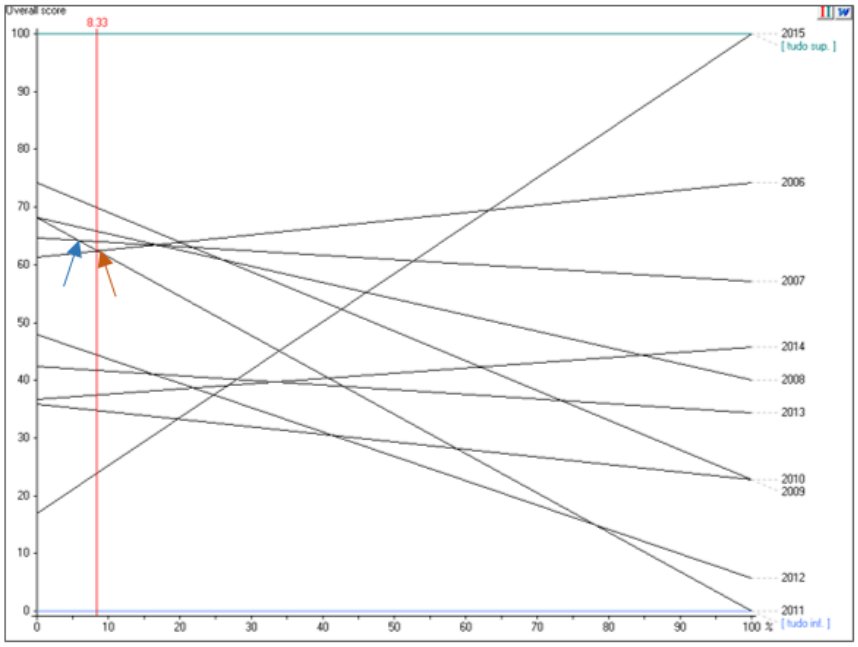


Figure 4-24: Sensitivity analysis on weight for ATK per labour cost KPI (Cargolux).

Source: own composition.

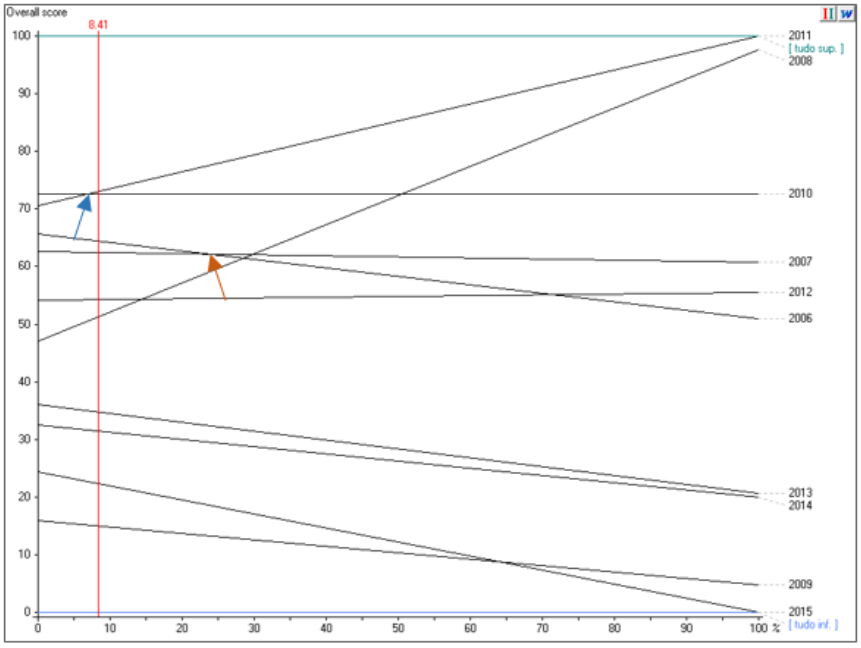


Figure 4-25: Sensitivity analysis on weight for operational revenue per number of aircraft KPI (Lufthansa Cargo).

Source: own composition.

4.3.3.2. Efficiency Value Profiles

The efficiency value profiles are another output resulting from the application of the MACBETH approach. Efficiency value profiles can be traced within and across areas, for every KPA for 2006-2015, to understand which option (year) had the best and the worst profile. Also, It allows understanding if the profile exceeds the good or neutral levels in any area. With this output, it is possible to identify which key performance indicators deserve more attention from the stakeholders. There are 3 zones where the key performance indicator can be positioned:

- Above the good level: no improvement is required;
- Between the good and neutral levels: the KPI meets the requirements;
- Below the neutral level: corrective measures should be implemented.

Figure 4-26 illustrates the efficiency profiles along the years for productivity KPA for Cargolux. From this figure it is possible to conclude that the option 2007 is the best profile once that the load-factor, transported tonnes per aircraft and transported tonnes per ATK KPIs are above the good level and the RTK per labour cost and ATK per labour cost KPI is between the good and neutral levels. To have all the KPIs of the productivity KPA in a threshold category of excellent the improvement of RTK per labour cost and ATK per labour cost KPIs is required. Contrarily, the 2012 option presents the worst profile, with the RTK per labour cost and ATK per labour, cost KPIs below the neutral level and the load-factor, transported tonnes per aircraft and transported tonnes per ATK KPIs between good and neutral levels.

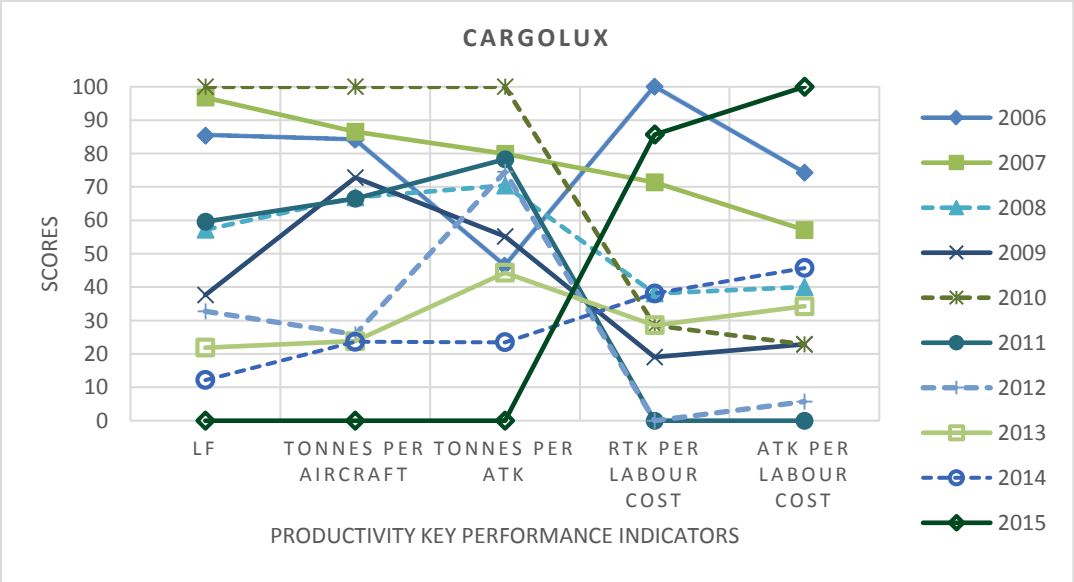


Figure 4-26: Productivity value profile for Cargolux.

Source: own elaboration.

Figure 4-27 illustrates the efficiency profiles along the years for sustainability KPA for Cargolux. From this figure it is possible to conclude that the option 2011 is the best profile once that the operational revenue per transported tonnes, operational revenue per RTK, operational revenue

per number of aircraft and operational revenue per ATK KPIs are above the good level, and only the operational costs per ATK KPI is below the neutral level under the 2006, 2007, 2008, 2009, 2010, 2012, 2013, 2014 and 2015 options. The improvement of operational costs per ATK KPI is required to have all the KPIs of the sustainability KPA in a threshold category of excellent. Contrarily, the 2015 option presents the worst profile, with the operational revenue per transported tonnes, operational revenue per RTK, operational revenue per number of aircraft and operational revenue per ATK KPIs below the neutral level, and only the operational costs per ATK KPI above the good level with a better score than the 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013 and 2014 options.

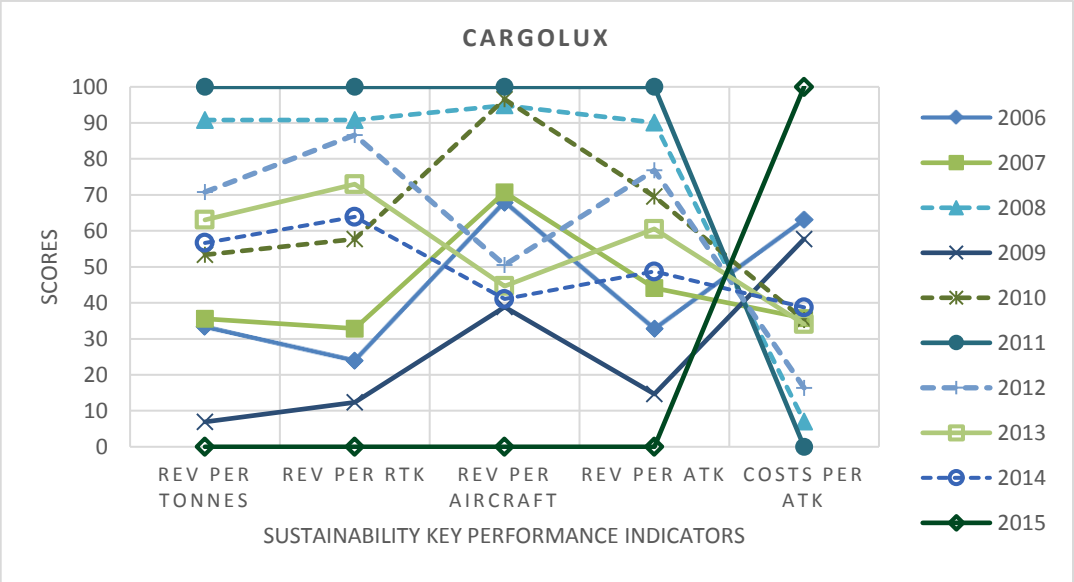


Figure 4-27: Sustainability value profile for Cargolux.
Source: own elaboration.

Figure 4-28 illustrates the performance profiles along the years for productivity KPA for Lufthansa Cargo. From this figure it is possible to conclude that the option 2010 is the best profile once that the load-factor and RTK per labour cost KPIs are above the good level, and the transported tonnes per aircraft, transported tonnes per ATK and ATK per labour cost KPIs are between the good and neutral levels. To have all the KPIs of the productivity KPA in a threshold category of excellent the improvement of transported tonnes per aircraft, transported tonnes per ATK and ATK per labour cost KPIs is required. Contrarily, the 2009 option presents the worst profile, with the load-factor, transported tonnes per number of aircraft, transported tonnes per ATK and RTK per labour cost KPIs below the neutral level and the ATK per Labour cost KPI between the good and neutral levels.

Figure 4-29 illustrates the performance profiles along the years for sustainability KPA for Lufthansa Cargo. From this figure it is possible to conclude that the option 2008 is the best profile once that the operational revenue per transported tonnes, operational revenue per RTK,

operational revenue per number of aircraft and operational revenue per ATK KPIs are above the good level, and only the operational costs per ATK KPI is below the neutral level under the 2006, 2007, 2009, 2010, 2011, 2012, 2013, 2014 and 2015 options. The improvement of operational costs per ATK KPI is required to have all the KPIs of the sustainability KPA in a threshold category of excellent. Contrarily, the 2015 option presents the worst profile, with the operational revenue per transported tonnes, operational revenue per RTK, operational revenue per number of aircraft and operational revenue per ATK KPIs below the neutral level, and only the operational costs per ATK KPI above the good level with a better score than the 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013 and 2014 options.

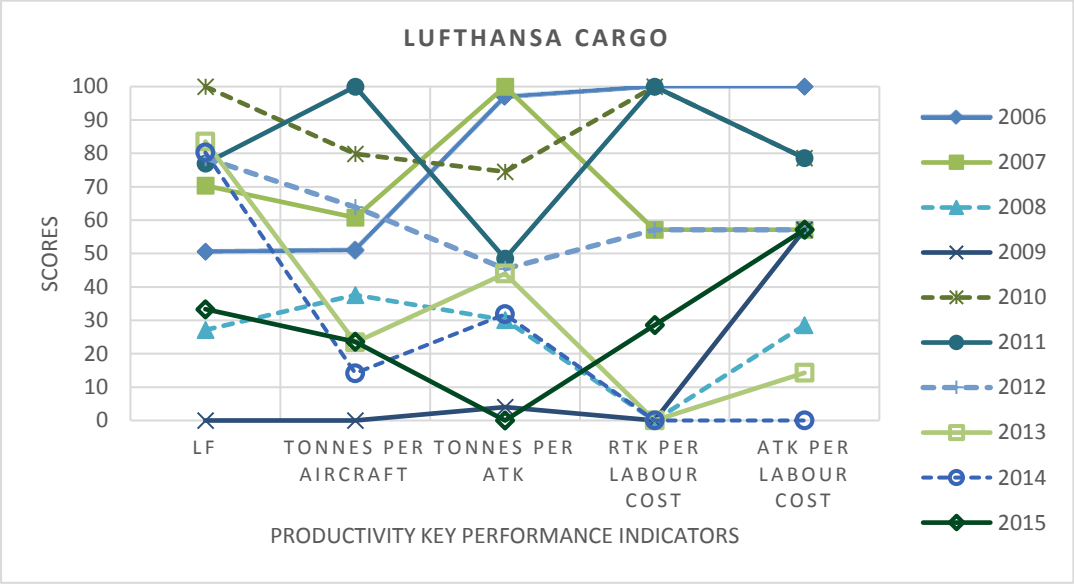


Figure 4-28: Productivity value profile for Lufthansa Cargo.

Source: own elaboration.

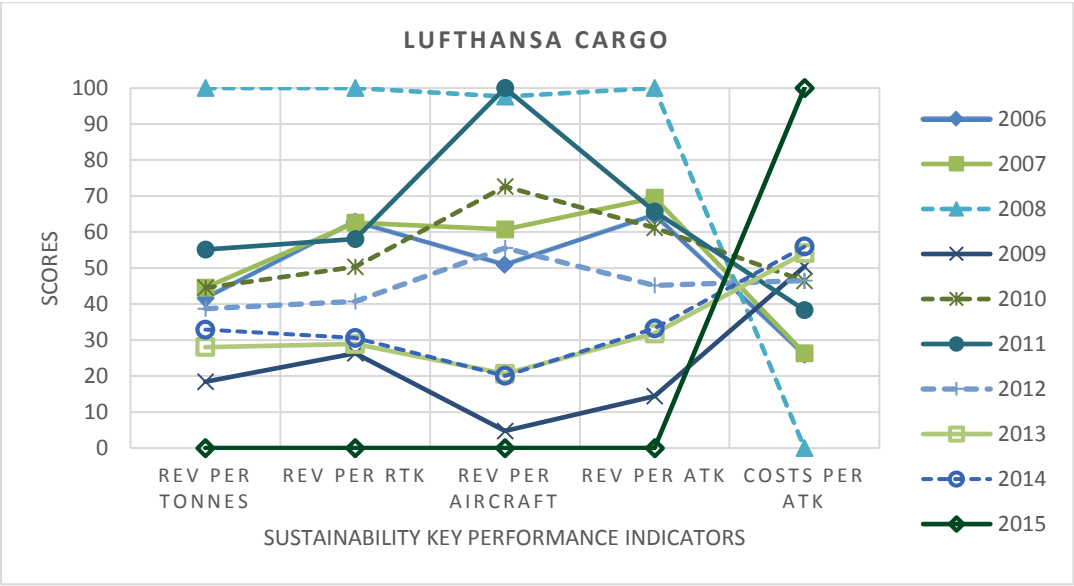


Figure 4-29: Sustainability value profile for Lufthansa Cargo.

Source: own elaboration.

4.3.3.3. Overall Scores Quadrant Analysis

The overall scores quadrant analysis allows observing the relationship between the two air cargo carriers studied and to analyse the evolution of the air cargo market in general, according to the air cargo carriers efficiency overall scores. In this analysis, shown in Figure 4-30, is shown the relation and evolution of Cargolux and Lufthansa Cargo overall efficiency from 2006 until 2015. The x axis represents the overall scores of Cargolux while the y axis represents the overall scores of Lufthansa Cargo. Figure 4-30 was built based on the overall scores presented in Table 4-2 regarding Cargolux and in Table 4-3 regarding Lufthansa Cargo.

As observed, Figure 4-30 is divided into four quadrants to group the options under evaluation as follows:

- Quadrant 1 (Q1): years with a low Cargolux overall scores and low Lufthansa Cargo overall scores: 2009, 2013, 2014 and 2015;
- Quadrant 2 (Q2): years with a low Cargolux overall scores and high Lufthansa Cargo overall scores: 2012;
- Quadrant 3 (Q3): years with a high Cargolux overall scores and high Lufthansa Cargo overall scores: 2006, 2007, 2008, 2010 and 2011;
- Quadrant 4 (Q4): years with a high Cargolux overall scores and low Lufthansa Cargo overall scores: none.

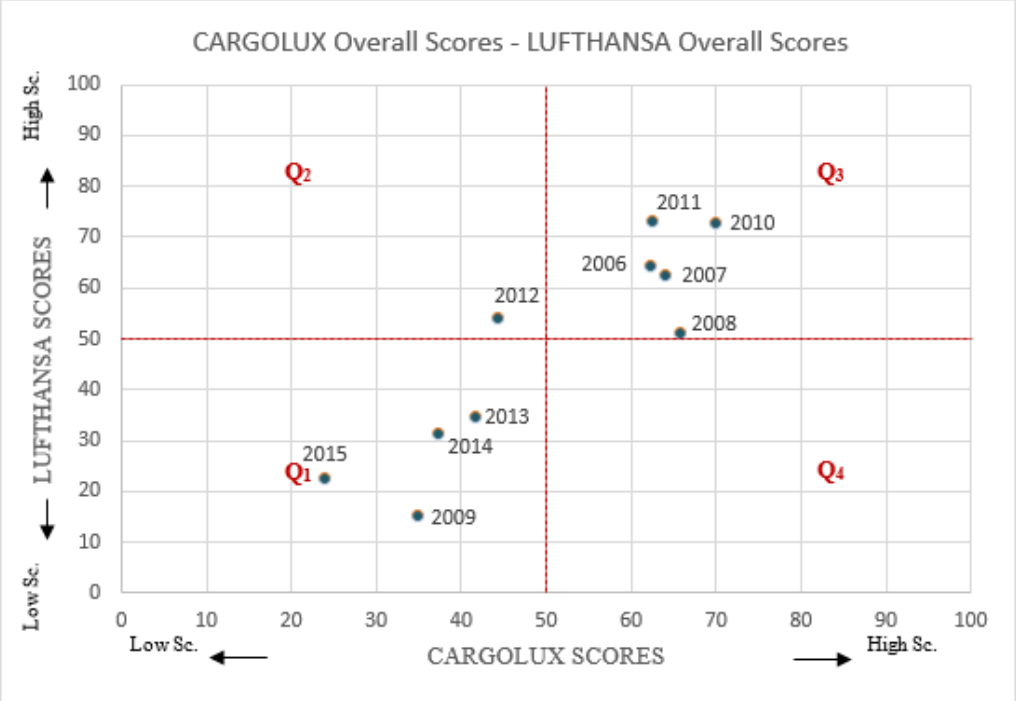


Figure 4-30: Cargolux and Lufthansa Cargo overall scores.
Source: own elaboration.

Except for the 2012 year in Q2 where Lufthansa score is high compared to Cargolux, all other options (years) from both air cargo carriers follow unsurprisingly the same score trend, when Cargolux has a low score so as Lufthansa (Q1), and when scores are high both air cargo carriers also follow the same score trend too (Q3). Also, as expected, the year of 2009 presents one of the lowest scores once that was the year when the global financial crisis hit the air cargo market.

4.4. Conclusion

In this chapter were presented the two case studies of this dissertation, the self-benchmarking and the peer-benchmarking analysis. The ten-year period analysed it is one that encompasses the industry downturn due to the financial crisis, the recovery from the crisis and a period of a strong air traffic growth as well. Likewise, are presented the results of the key performance areas and key performance indicators weights, overall scores, sensitivity analysis and value profiles for both case studies, obtained with the air cargo carriers data implemented in the MACBETH approach.

Regarding the Cargolux performance case study, the results show that operational KPA is the most relevant of the five regarding performance. Also, analysing the overall scores is possible to conclude that the financial crisis from 2009 had a significant impact on Cargolux performance and, on the contrary, the best results were achieved in the last three years studied. In addition, the sensitivity analysis results show that 2015 was the best year for every KPI presented in this case study, and the value profiles results indicate that 2015 was the best year for the operational and personnel KPAs; however, for the financial, fleet and environment KPAs the best profiles were obtained in 2006, 2013 and 2009, respectively.

Regarding the Cargolux and Lufthansa efficiency case study, the results show that productivity KPA is the most relevant of both. Also, analysing the overall scores is possible to conclude that both carriers followed the same trend and, such as occurred in the performance assessment, the financial crisis from 2009 had a significant impact on both carriers efficiency; however, despite the recovery from the crisis, both show a downward trend until 2015. Regarding the sensitivity analysis and value profiles results is not possible to define the best or the worst years regarding efficiency, while it is possible to conclude that 2010 was the best year for Cargolux for the ATK per labour cost KPI, and 2011 was the best year for Lufthansa Cargo operational revenue per number of aircraft. The value profiles results indicate that the best levels of productivity were achieved in 2007 by Cargolux, and in 2010 by Lufthansa Cargo, while the best levels of sustainability were reached in 2011 by Cargolux, and in 2008 by Lufthansa Cargo.

Therefore, it is possible to conclude that Cargolux and Lufthansa Cargo presented a downturn during the financial crisis that hit the air transport industry which started in 2008. The effects

of this global crisis were felt until the year of 2010 where is possible to observe a recovery in the overall performance and efficiency in both air cargo carriers.

Chapter 5 – Conclusions

5.1. Dissertation Synthesis

This dissertation is structured in five chapters. In the first chapter is presented the motivation where is given a brief introduction about the air cargo carriers activities and the evolution of the air cargo market. Moreover, are defined the object and the main objectives of this study. It has as object to assess air cargo carriers performance and efficiency performing a self and peer benchmarking analysis in a ten year period, and as objectives to create a set of KPAs and KPIs that could relate all the air cargo carriers operations, to collect data for the defined key performance indicators for the ten year period, and to analyze and discuss the obtain results of the two case studies. Also, are presented the methodology and the dissertation structure.

The second chapter deals with the evolution of the air cargo industry, where is given an overview of the air cargo industry and it is shown the developments in the world air traffic. It is explained how the air cargo market is affected by the course of global events once that this is a very vulnerable industry, but at the same time, is shown how the same industry recovers from this period of crisis. Also, are explained the different business models adopted by the air cargo carriers, there are presented the main players involved in the various phases of the air cargo supply chain, and it is showed the importance of each player in the supply chain. Later it is defined the benchmarking process, and it is justified why this is a useful tool in the airline industry once it could make them improve their operating levels and thus leading to an improved organisational performance and efficiency.

In Chapter 3 are identified the main approaches used to evaluate different air transportation actors performance and efficiency. To assess air cargo carriers performance and efficiency it was necessary to identify the best methodology for the case studies, so it is justified the use of a MCDA tool, the Measuring Attractiveness by a Categorized Based Evaluation Technique (MACBETH). The mathematical foundations of MACBETH are also presented in Chapter 3. Besides, in this chapter is presented the set of KPAs and KPIs for the performance and efficiency and are explained the five steps necessary to evaluate air cargo carriers regarding overall performance and efficiency with MACBETH.

The fourth chapter presents the two case studies of this research: evaluation of the overall performance of Cargolux, under the process of self-benchmarking, and evaluation of the overall efficiency of Cargolux and Lufthansa Cargo, under the process of peer-benchmarking, both over the course of ten years. In this chapter is presented the resulting order of relevance of the several KPAs and KPIs subsequent to the experts' judgment and the outputs obtained with the MACBETH approach, namely, sensitivity analysis and value profiles.

In Chapter 5 is presented the dissertation synthesis and are given the concluding remarks and the prospects for future work.

5.2. Concluding Remarks

The airline industry is a complex, dynamic and, at the same, a vulnerable industry subject to seasonal changes, economic cycles and external events. In the past years, the air cargo market experienced some challenges like terrorist attacks or financial crisis that made it essential to carry out a global evaluation of the air cargo carriers performance and efficiency.

The dissertation results evidence the importance of this type of evaluation to understand how air cargo carriers deal with performance and efficiency issues and to understand how is possible to achieve better results regarding overall performance and efficiency. With the MACBETH approach, it is possible to evaluate any air cargo carrier, comprising its particularities and complexities, once that the KPIs data is collected.

Based on the decision makers' opinions, this study shows that operational is the most relevant and environment is the less significantrelevant areas regarding performance while productivity is the most relevant and sustainability the less relevant areas in the air cargo carrier efficiency. Also, according to the overall scores obtained through the data collected it is possible to conclude that both Cargolux and Lufthansa Cargo followed the same trend, regarding efficiency, in the period studied.

Concerning the results of the sensitivity analysis, in the Cargolux performance case study, it can be seen that 2015 was the best year for all the key performance indicators, representing that Cargolux is following a positive progression in all aspects of performance, conversely to what occurs to the KPIs presented in the second case study.

The major obstacles in completing this study arise especially from the difficulty to obtain the data for the ten years and for the selected carriers. In fact, in the case of the average fleet age and the fuel used of Cargolux was used a trend line to fulfil the data gap in the years 2011-2006. Moreover, a third air cargo carrier (FedEx Express) was initially supposed to be studied along with Cargolux and Lufthansa Cargo in the peer-benchmarking analysis; however, due to the difficulty to obtain data for the selected key performance indicators, FedEx Express was excluded from this study.

Finally, it can be said that the main objectives proposed were achieved; however, they could go further if it was possible to collect more data related to the defined key performance indicators from more air cargo carriers.

5.3. Prospects for Future Work

The air cargo industry faces many challenges and this study allowed to identify several investigation lines for future research. Thus, future research work concerning the sector should focus on the following items:

1. To develop and implement a new robust and flexible multidimensional tool that can be used in a user-friendly environment;
2. To extend the research of self-benchmarking and peer-benchmarking analysis to more air cargo carries (all-cargo, combination and integrators);
3. To enlarge the developed set of key performance areas and key performance indicators to implement some new activity areas in the evaluation, such as service quality, promptness, and safety;
4. To apply the performance and efficiency evaluation not only to air cargo carriers but to all the actors present in the air cargo supply chain;
5. To focus on the development of forecasts for the air cargo market so that air cargo carriers could anticipate some management measures to ensure better results for overall performance and efficiency.

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Annex I – Survey Results

Table I-1: Ranking of performance KPAs.

Rank	Very Weak (1)	Weak (2)	Moderate (3)	Strong (4)	Very Strong (5)	Extreme (6)	Average	Result
Fleet	0	0	2	4	13	4	4.83	Strong-Very Strong
Financial	0	0	0	8	9	6	4.91	Strong-Very Strong
Operational	0	0	1	5	9	8	5.04	Very Strong
Personnel	0	0	4	5	12	2	4.52	Strong-Very Strong
Environment	0	7	4	6	4	2	3.56	Moderate-Strong
Productivity	0	0	1	2	9	11	5.30	Very Strong
Sustainability	0	0	1	8	9	5	4.78	Strong-Very Strong

Source: own composition.

Table I-2: Ranking of fleet KPIs.

Rank	Very Weak (1)	Weak (2)	Moderate (3)	Strong (4)	Very Strong (5)	Extreme (6)	Average	Result
Number of Freighter Aircraft in Fleet	0	0	3	6	3	2	4.29	Strong
Average Fleet Age	0	2	2	5	4	1	4.00	Strong
Average Aircraft Utilisation	0	0	0	0	10	4	5.29	Very Strong

Source: own composition.

Table I-3: Number of freighter aircraft in the fleet KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	3	4	4	2	4.14	Strong
Question 2 AC	0	0	2	6	5	1	0	3.36	Moderate
Question 3 BD	0	0	3	5	6	0	0	3.21	Moderate
Question 4 AB	0	1	3	7	1	1	1	3.07	Moderate
Question 5 BC	0	2	5	3	2	2	0	2.79	Weak-Moderate
Question 6 CD	0	3	4	4	2	1	0	2.57	Weak-Moderate

Source: own composition.

Table I-4: Average fleet age KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	2	1	3	6	1	4.00	Strong
Question 2 AC	0	1	3	3	6	1	0	3.21	Moderate

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 3 BD	0	1	3	3	6	1	0	3.21	Moderate
Question 4 AB	1	1	3	5	2	1	1	2.93	Weak-Moderate
Question 5 BC	1	1	4	5	1	2	0	2.71	Weak-Moderate
Question 6 CD	1	1	6	3	3	0	0	2.43	Weak

Source: own composition.

Table I-5: Average aircraft utilisation KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	0	3	5	5	4.86	Strong-Very Strong
Question 2 AC	0	0	1	2	5	4	2	4.29	Strong
Question 3 BD	0	0	1	3	7	2	1	3.93	Moderate-Strong
Question 4 AB	0	0	1	5	2	4	2	4.07	Strong
Question 5 BC	0	0	3	4	2	4	1	3.71	Moderate-Strong
Question 6 CD	0	0	3	6	1	3	1	3.50	Moderate

Source: own composition.

Table I-6: Ranking of financial KPIs.

Rank	Very Weak (1)	Weak (2)	Moderate (3)	Strong (4)	Very Strong (5)	Extreme (6)	Average	Result
Operational Revenue	0	0	0	1	5	3	5.22	Very Strong
Operational Costs	0	0	0	3	3	3	5.00	Very Strong
Operational Profit (Loss)	0	0	0	2	3	4	5.22	Very Strong
Equity Ratio	0	1	0	3	5	0	4.33	Strong
Total Assets	0	0	2	5	2	0	4	Strong
Total Liabilities	1	0	0	6	2	0	3.89	Moderate-Strong

Source: own composition.

Table I-7: Operational revenue KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	0	0	5	3	4.89	Strong-Very Strong
Question 2 AC	0	0	1	0	0	6	2	4.89	Strong-Very Strong
Question 3 BD	0	0	0	1	2	5	1	4.67	Strong-Very Strong

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 4 AB	0	0	0	1	5	1	2	4.44	Strong
Question 5 BC	0	0	0	2	4	2	1	4.22	Strong
Question 6 CD	0	0	0	3	5	0	1	3.89	Moderate-Strong

Source: own composition.

Table I-8: Operational costs KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	0	0	3	5	5.11	Very Strong
Question 2 AC	0	0	1	0	1	5	2	4.78	Strong-Very Strong
Question 3 BD	0	0	0	1	2	5	1	4.67	Strong-Very Strong
Question 4 AB	0	0	0	1	4	2	2	4.55	Strong-Very Strong
Question 5 BC	0	0	0	2	4	2	1	4.22	Strong
Question 6 CD	0	0	0	3	4	1	1	4.00	Strong

Source: own composition.

Table I-9: Operational profit (loss) KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	0	0	2	6	5.22	Very Strong
Question 2 AC	0	0	1	0	1	3	4	5.00	Very Strong
Question 3 BD	0	0	0	1	1	6	1	4.78	Strong-Very Strong
Question 4 AB	0	0	0	1	4	2	2	4.56	Strong-Very Strong
Question 5 BC	0	0	0	1	3	4	1	4.56	Strong-Very Strong
Question 6 CD	0	0	0	3	4	1	1	4.00	Strong

Source: own composition.

Table I-10: Equity ratio KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	1	3	4	0	4.00	Strong
Question 2 AC	0	0	1	0	7	1	0	3.89	Moderate-Strong
Question 3 BD	0	0	0	4	5	0	0	3.56	Moderate-Strong
Question 4 AB	0	0	0	6	2	0	1	3.56	Moderate-Strong

Question 5 BC	0	0	3	3	2	1	0	3.11	Moderate
Question 6 CD	0	0	3	4	2	0	0	2.88	Weak-Moderate

Source: own composition.

Table I-11: Total assets KPI variation.

Rank	*No Difference*	*Very Weak*	*Weak*	*Moderate*	*Strong*	*Very Strong*	*Extreme*	*Average*	*Result*
Question 1 AD	0	1	0	1	2	4	1	4.22	Strong
Question 2 AC	0	0	1	0	4	3	1	4.33	Strong
Question 3 BD	0	0	0	2	6	1	0	3.89	Moderate-Strong
Question 4 AB	0	0	0	4	3	1	1	3.89	Moderate-Strong
Question 5 BC	0	0	1	5	1	2	0	3.44	Moderate
Question 6 CD	0	0	2	4	2	1	0	3.22	Moderate

Source: own composition.

Table I-12: Total liabilities KPI variation.

Rank	*No Difference*	*Very Weak*	*Weak*	*Moderate*	*Strong*	*Very Strong*	*Extreme*	*Average*	*Result*
Question 1 AD	0	1	0	1	1	4	2	4.44	Strong
Question 2 AC	0	0	1	0	4	3	1	4.33	Strong
Question 3 BD	0	0	0	2	6	0	1	4.00	Strong
Question 4 AB	0	0	0	2	5	1	1	4.11	Strong
Question 5 BC	0	0	1	5	1	2	0	3.44	Moderate
Question 6 CD	0	0	1	5	2	1	0	3.33	Moderate

Source: own composition.

Table I-13: Ranking of operational KPIs.

Rank	*Very Weak (1)*	*Weak (2)*	*Moderate (3)*	*Strong (4)*	*Very Strong (5)*	*Extreme (6)*	*Average*	*Result*
Revenue Tonne Kilometres	0	0	0	0	9	5	5.36	Very Strong
Available Tonne Kilometres	0	0	0	9	4	1	4.43	Strong
Load-Factor	0	0	0	1	9	4	5.21	Very Strong
Cargo and Mail Carried	0	0	3	7	3	1	4.14	Strong

Source: own composition.

Table I-14: Revenue tonne kilometres KPI variation.

Rank	*No Difference*	*Very Weak*	*Weak*	*Moderate*	*Strong*	*Very Strong*	*Extreme*	*Average*	*Result*
Question 1 AD	0	1	0	0	3	8	2	4.64	Strong-Very Strong
Question 2 AC	0	0	1	2	5	5	1	4.21	Strong
Question 3 BD	0	0	1	3	6	2	2	4.07	Strong
Question 4 AB	0	0	0	7	3	2	2	3.93	Moderate-Strong
Question 5 BC	0	0	2	5	4	2	1	3.64	Moderate-Strong
Question 6 CD	0	0	2	8	2	1	1	3.36	Moderate

Source: own composition.

Table I-15:Available tonne kilometres KPI variation.

Rank	*No Difference*	*Very Weak*	*Weak*	*Moderate*	*Strong*	*Very Strong*	*Extreme*	*Average*	*Result*
Question 1 AD	0	1	0	1	6	4	2	4.29	Strong
Question 2 AC	0	0	2	3	3	6	0	3.93	Moderate-Strong
Question 3 BD	0	0	2	4	4	4	0	3.71	Moderate-Strong
Question 4 AB	0	0	2	5	4	2	1	3.64	Moderate-Strong
Question 5 BC	0	0	3	7	2	2	0	3.21	Moderate
Question 6 CD	0	0	4	7	1	2	0	3.07	Moderate

Source: own composition.

Table I-16: Load-factor KPI variation.

Rank	*No Difference*	*Very Weak*	*Weak*	*Moderate*	*Strong*	*Very Strong*	*Extreme*	*Average*	*Result*
Question 1 AD	0	1	0	0	3	5	5	4.86	Strong-Very Strong
Question 2 AC	0	0	1	1	4	6	2	4.50	Strong
Question 3 BD	0	0	1	2	2	8	1	4.43	Strong
Question 4 AB	0	0	0	5	1	7	1	4.29	Strong
Question 5 BC	0	0	1	3	4	5	1	4.14	Strong
Question 6 CD	0	0	2	3	5	4	0	3.79	Moderate-Strong

Source: own composition.

Table I-17: Cargo and mail carried KPI variation.

Rank	*No Difference*	*Very Weak*	*Weak*	*Moderate*	*Strong*	*Very Strong*	*Extreme*	*Average*	*Result*
Question 1 AD	0	1	2	1	2	5	3	4.21	Strong

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 2 AC	0	0	2	4	5	3	0	3.64	Moderate-Strong
Question 3 BD	0	0	3	4	3	4	0	3.57	Moderate-Strong
Question 4 AB	0	0	3	5	4	0	2	3.50	Moderate
Question 5 BC	0	1	3	4	4	1	1	3.29	Moderate
Question 6 CD	0	1	4	4	3	2	0	3.07	Moderate

Source: own composition.

Table I-18: Ranking of personnel KPIs.

Rank	Very Weak (1)	Weak (2)	Moderate (3)	Strong (4)	Very Strong (5)	Extreme (6)	Average	Result
Number of Employees	0	0	2	5	3	0	4.10	Strong
Injury Rate	1	1	2	1	2	3	4.10	Strong
Revenue per Employee	0	0	2	3	2	3	4.60	Strong-Very Strong
Labour Cost	0	1	1	2	4	2	4.50	Strong

Source: own composition.

Table I-19: Number of employees KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	0	5	3	1	4.20	Strong
Question 2 AC	0	0	1	3	5	1	0	3.60	Moderate-Strong
Question 3 BD	0	0	0	6	4	0	0	3.40	Moderate
Question 4 AB	0	0	2	4	3	0	1	3.40	Moderate
Question 5 BC	0	1	3	4	1	1	0	2.80	Weak-Moderate
Question 6 CD	0	2	3	2	3	0	0	2.60	Weak-Moderate

Source: own composition.

Table I-20: Injury rate KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	1	3	2	3	4.40	Strong
Question 2 AC	0	0	2	2	2	3	1	3.90	Moderate-Strong
Question 3 BD	0	0	1	4	3	1	1	3.70	Moderate-Strong
Question 4 AB	0	0	4	1	3	0	2	3.50	Moderate
Question 5 BC	0	2	3	1	2	2	0	2.90	Weak-Moderate

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 6 CD	0	4	1	3	1	1	0	2.40	Weak

Source: own composition.

Table I-21: Revenue per employee KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	1	0	2	4	3	4.45	Strong
Question 2 AC	0	0	2	0	3	3	2	4.30	Strong
Question 3 BD	0	0	1	3	3	3	0	3.80	Moderate-Strong
Question 4 AB	0	0	1	3	5	0	1	3.70	Moderate-Strong
Question 5 BC	0	2	1	2	4	1	0	3.10	Moderate
Question 6 CD	0	2	2	3	3	0	0	2.70	Weak-Moderate

Source: own composition.

Table I-22: Labour cost KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	2	2	5	0	4.00	Strong
Question 2 AC	0	0	2	2	2	4	0	3.80	Moderate-Strong
Question 3 BD	0	0	2	2	4	2	0	3.60	Moderate-Strong
Question 4 AB	0	1	1	3	3	1	1	3.50	Moderate
Question 5 BC	0	1	1	5	1	2	0	3.20	Moderate
Question 6 CD	0	2	1	5	1	1	0	2.80	Weak-Moderate

Source: own composition.

Table I-23: Ranking environment KPIs.

Rank	Very Weak (1)	Weak (2)	Moderate (3)	Strong (4)	Very Strong (5)	Extreme (6)	Average	Result
CO2 Emissions	0	0	1	3	5	3	4.83	Strong-Very Strong
CO2 Emissions per Transported Tonne	0	0	0	2	6	4	5.17	Very Strong
Fuel Used	0	0	1	1	6	4	5.08	Very Strong
Fuel Cost	0	0	0	3	6	3	5.00	Very Strong

Source: own composition.

Table I-24: CO_2 emissions KPI variation.

Rank	*No Difference*	*Very Weak*	*Weak*	*Moderate*	*Strong*	*Very Strong*	*Extreme*	*Average*	*Result*
Question 1 AD	0	1	0	0	3	5	3	4.67	Strong-Very Strong
Question 2 AC	0	0	1	1	4	5	1	4.33	Strong
Question 3 BD	0	0	1	2	5	4	0	4.00	Strong
Question 4 AB	0	0	2	5	4	0	1	3.41	Moderate
Question 5 BC	0	2	1	4	3	2	0	3.17	Moderate
Question 6 CD	1	2	1	3	5	0	0	2.75	Weak-Moderate

Source: own composition.

Table I-25: CO_2 emissions per transported tonne KPI variation.

Rank	*No Difference*	*Very Weak*	*Weak*	*Moderate*	*Strong*	*Very Strong*	*Extreme*	*Average*	*Result*
Question 1 AD	0	1	0	0	3	3	5	4.83	Strong-Very Strong
Question 2 AC	0	0	1	1	6	4	0	4.08	Strong
Question 3 BD	0	0	1	3	4	4	0	3.92	Moderate-Strong
Question 4 AB	0	0	2	3	4	1	2	3.83	Moderate-Strong
Question 5 BC	0	2	1	2	4	3	0	3.41	Moderate
Question 6 CD	1	1	1	2	6	1	0	3.17	Moderate

Source: own composition.

Table I-26: Fuel used KPI variation.

Rank	*No Difference*	*Very Weak*	*Weak*	*Moderate*	*Strong*	*Very Strong*	*Extreme*	*Average*	*Result*
Question 1 AD	0	1	0	0	0	8	3	4.91	Strong-Very Strong
Question 2 AC	0	0	1	0	4	5	2	4.58	Strong-Very Strong
Question 3 BD	0	0	0	1	6	4	1	4.41	Strong
Question 4 AB	0	0	0	2	6	3	1	4.25	Strong
Question 5 BC	0	0	0	5	4	2	1	3.92	Moderate-Strong
Question 6 CD	0	0	2	5	3	2	0	3.42	Moderate

Source: own composition.

Table I-27: Fuel cost KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	0	1	5	5	5.00	Very Strong
Question 2 AC	0	0	1	0	5	4	2	4.50	Strong
Question 3 BD	0	0	0	1	8	1	2	4.33	Strong
Question 4 AB	0	0	0	5	2	4	1	4.08	Strong
Question 5 BC	0	0	1	4	2	5	0	3.91	Moderate-Strong
Question 6 CD	0	1	2	2	5	2	0	3.42	Moderate

Source: own composition.

Table I-28: Ranking of productivity KPIs.

Rank	Very Weak (1)	Weak (2)	Moderate (3)	Strong (4)	Very Strong (5)	Extreme (6)	Average	Result
Load-Factor	0	0	0	4	11	8	5.17	Very Strong
Transported Tonnes per Number of Aircraft	0	1	1	3	13	5	4.87	Strong-Very Strong
Transported Tonnes per ATK	0	1	3	5	10	4	4.57	Strong-Very Strong
ATK per Labour Cost	0	0	5	9	9	0	4.17	Strong
RTK per Labour Cost	0	1	2	6	13	1	4.48	Strong

Source: own composition.

Table I-29: Load-factor KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	0	4	10	8	5.00	Very Strong
Question 2 AC	0	0	1	2	6	12	2	4.52	Strong-Very Strong
Question 3 BD	0	0	1	2	10	9	1	4.30	Strong
Question 4 AB	0	0	1	7	9	5	1	3.91	Moderate-Strong
Question 5 BC	0	0	4	7	6	6	0	3.61	Moderate-Strong
Question 6 CD	0	1	3	8	7	4	0	3.43	Moderate

Source: own composition.

Table I-30: Transported tonnes per number of aircraft KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	1	1	6	7	7	4.65	Strong-Very Strong

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 2 AC	0	1	1	4	7	9	1	4.09	Strong
Question 3 BD	0	1	2	3	10	7	0	3.87	Moderate-Strong
Question 4 AB	1	0	0	10	6	5	1	3.70	Moderate-Strong
Question 5 BC	1	0	2	8	10	2	0	3.39	Moderate
Question 6 CD	1	1	3	9	7	2	0	3.13	Moderate

Source: own composition.

Table I-31: Transported tonnes per ATK KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	1	3	5	9	4	4.93	Strong
Question 2 AC	0	1	2	5	4	11	0	3.96	Moderate-Strong
Question 3 BD	0	1	4	4	8	5	1	3.65	Moderate-Strong
Question 4 AB	0	2	2	8	7	3	1	3.43	Moderate
Question 5 BC	1	1	3	9	6	3	0	3.17	Moderate
Question 6 CD	1	1	4	10	5	2	0	3.00	Moderate

Source: own composition.

Table I-32: ATK per labour cost KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	4	9	8	1	4.13	Strong
Question 2 AC	0	0	3	8	7	5	0	3.61	Moderate-Strong
Question 3 BD	0	0	6	7	6	4	0	3.35	Moderate
Question 4 AB	0	3	4	8	6	1	1	3.04	Moderate
Question 5 BC	1	4	5	8	3	2	0	2.61	Weak-Moderate
Question 6 CD	1	5	6	6	4	1	0	2.43	Weak

Source: own composition.

Table I-33: RTK per labour cost KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	4	8	8	2	4.22	Strong
Question 2 AC	0	0	2	5	10	5	1	3.91	Moderate-Strong
Question 3 BD	0	0	5	5	11	2	0	3.43	Moderate

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 4 AB	0	3	1	10	5	3	1	3.30	Moderate
Question 5 BC	0	4	2	10	5	2	0	2.96	Weak-Moderate
Question 6 CD	1	3	7	7	5	0	0	2.52	Weak-Moderate

Source: own composition.

Table I-34: Raking of sustainability KPIs.

Rank	Very Weak (1)	Weak (2)	Moderate (3)	Strong (4)	Very Strong (5)	Extreme (6)	Average	Result
Operational Revenue per RTK	0	0	4	5	8	6	4.70	Strong-Very Strong
Operational Revenue per ATK	0	0	3	8	10	2	4.48	Strong
Operational Costs per ATK	0	2	2	7	8	4	4.43	Strong
Operational Revenue per Transported Tonnes	0	0	1	6	12	4	4.83	Strong-Very Strong
Operational Revenue per Number of Aircraft	0	0	3	9	7	4	4.52	Strong-Very Strong

Source: own composition.

Table I-35: Operational revenue per RTK KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	1	0	6	11	4	4.61	Strong-Very Strong
Question 2 AC	0	0	2	4	8	9	0	4.04	Strong
Question 3 BD	0	1	1	4	10	7	0	3.91	Moderate-Strong
Question 4 AB	0	1	2	7	8	4	1	3.65	Moderate-Strong
Question 5 BC	1	1	2	9	6	4	0	3.30	Moderate
Question 6 CD	1	1	4	8	7	2	0	3.09	Moderate

Source: own composition.

Table I-36: Operational revenue per ATK KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	3	6	8	5	4.52	Strong-Very Strong
Question 2 AC	0	0	4	3	7	9	0	3.91	Moderate-Strong
Question 3 BD	0	0	4	4	8	7	0	3.78	Moderate-Strong
Question 4 AB	0	2	2	9	6	3	1	3.39	Moderate

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 5 BC	0	2	4	6	9	2	0	3.22	Moderate
Question 6 CD	1	2	4	7	8	1	0	2.96	Weak-Moderate

Source: own composition.

Table I-37: Operational costs per ATK KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	1	7	6	8	4.78	Strong-Very Strong
Question 2 AC	0	0	2	4	4	12	1	4.26	Strong
Question 3 BD	0	0	3	4	5	11	0	4.04	Strong
Question 4 AB	0	1	2	7	9	3	1	3.61	Moderate-Strong
Question 5 BC	0	2	3	6	9	3	0	3.35	Moderate
Question 6 CD	0	3	3	7	9	1	0	3.09	Moderate

Source: own composition.

Table I-38: Operational revenue per transported tonnes KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	0	7	9	6	4.78	Strong-Very Strong
Question 2 AC	0	0	1	3	9	9	1	4.26	Strong
Question 3 BD	0	0	1	4	9	9	0	4.13	Strong
Question 4 AB	0	0	1	11	8	2	1	3.61	Moderate-Strong
Question 5 BC	0	0	4	8	9	2	0	3.39	Moderate
Question 6 CD	0	1	5	7	8	2	0	3.22	Moderate

Source: own composition.

Table I-39: Operational revenue per number of aircraft KPI variation.

Rank	No Difference	Very Weak	Weak	Moderate	Strong	Very Strong	Extreme	Average	Result
Question 1 AD	0	1	0	1	6	11	4	4.65	Strong-Very Strong
Question 2 AC	0	0	1	5	12	4	1	3.96	Moderate-Strong
Question 3 BD	0	0	2	6	10	5	0	3.78	Moderate-Strong
Question 4 AB	0	0	5	8	7	2	1	3.39	Moderate
Question 5 BC	0	1	6	9	6	1	0	3.00	Moderate

Rank	*No Difference*	*Very Weak*	*Weak*	*Moderate*	*Strong*	*Very Strong*	*Extreme*	*Average*	*Result*
Question 6 CD	0	1	7	10	3	2	0	2.91	Weak-Moderate

Source: own composition.

Annex II – Sensitivity Analysis

Cargolux Performance:

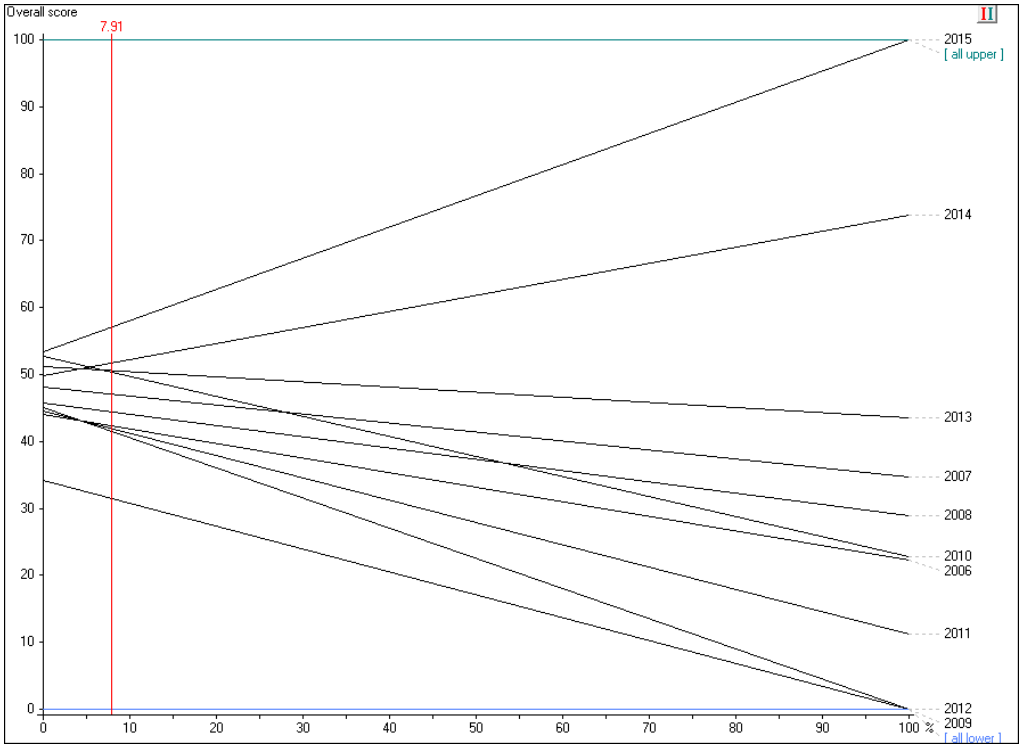

Figure II-1: Sensitivity analysis on weight for revenue tonne kilometres KPI.

Source: own composition.

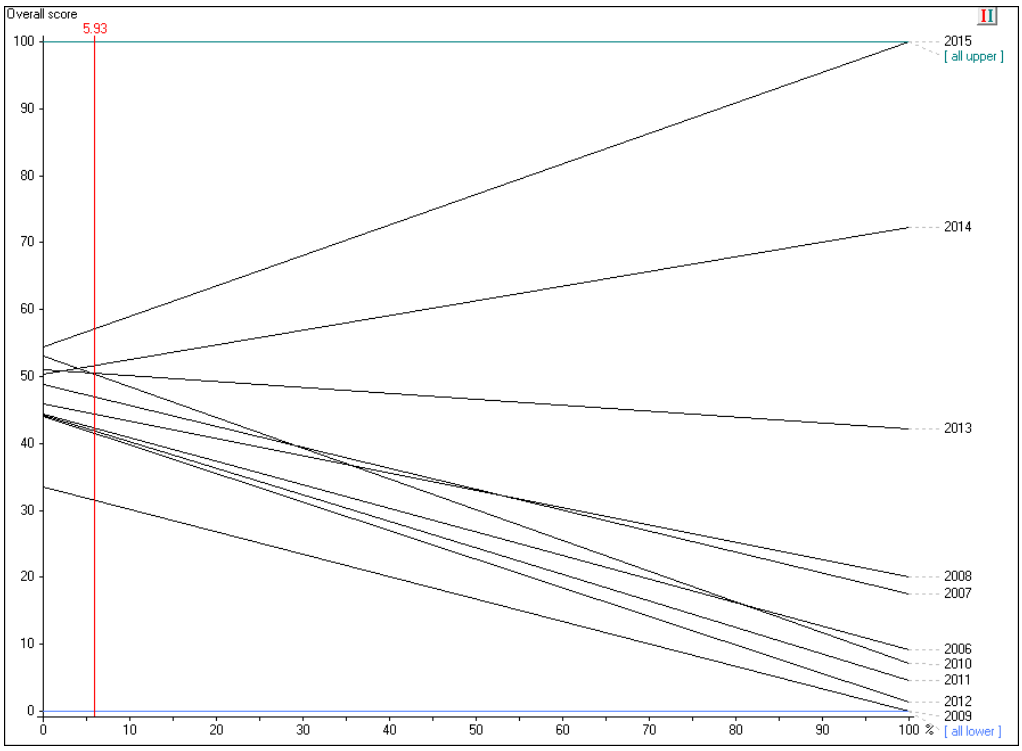

Figure II-2: Sensitivity analysis on weight for available tonne kilometres KPI.

Source: own composition.

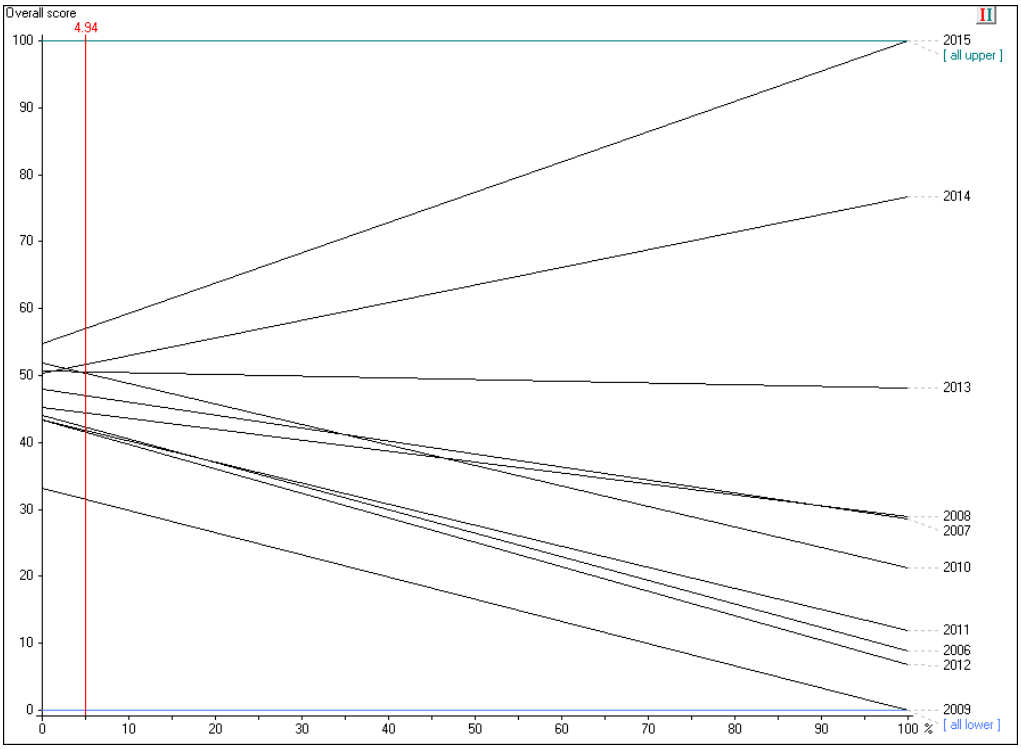

Figure II-3: Sensitivity analysis on weight for cargo and mail carried KPI.

Source: own composition.

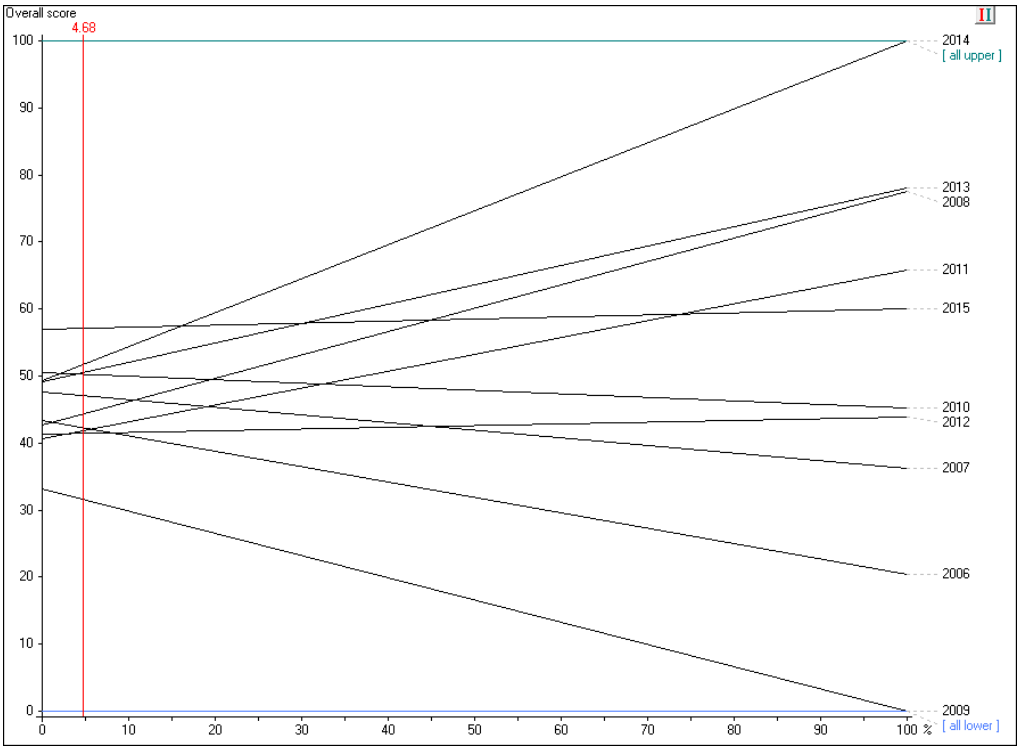

Figure II-4: Sensitivity analysis on weight for operational revenue KPI.

Source: own composition.

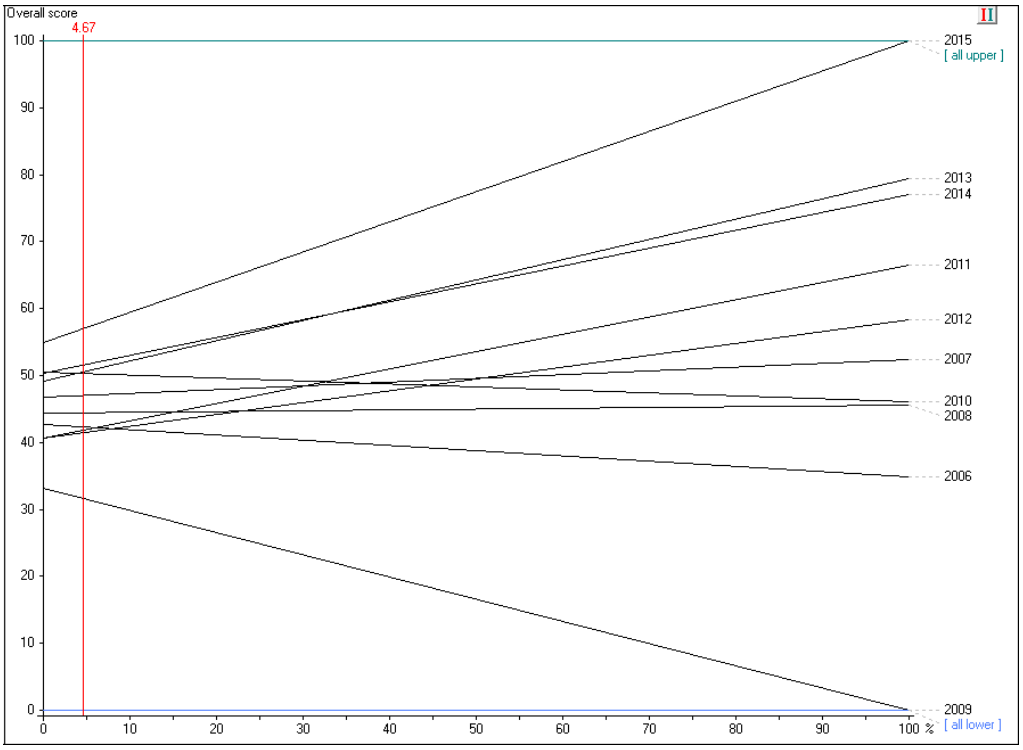

Figure II-5: Sensitivity analysis on weight for operational profit (loss) KPI.

Source: own composition.

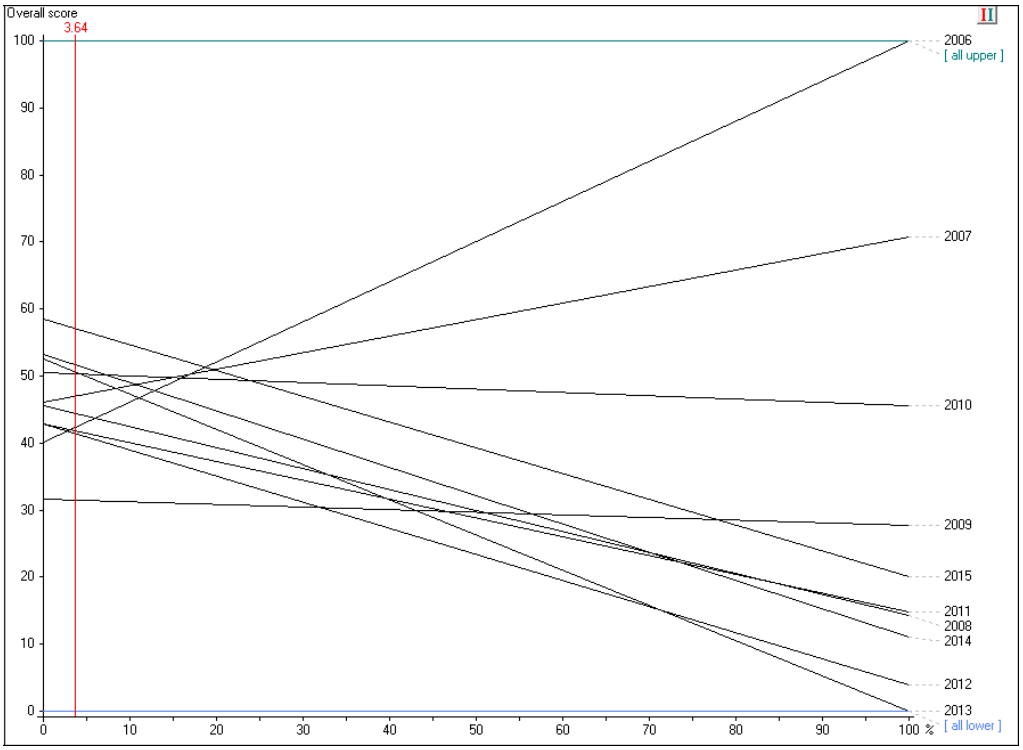

Figure II-6: Sensitivity analysis on weight for equity ratio KPI.

Source: own composition.

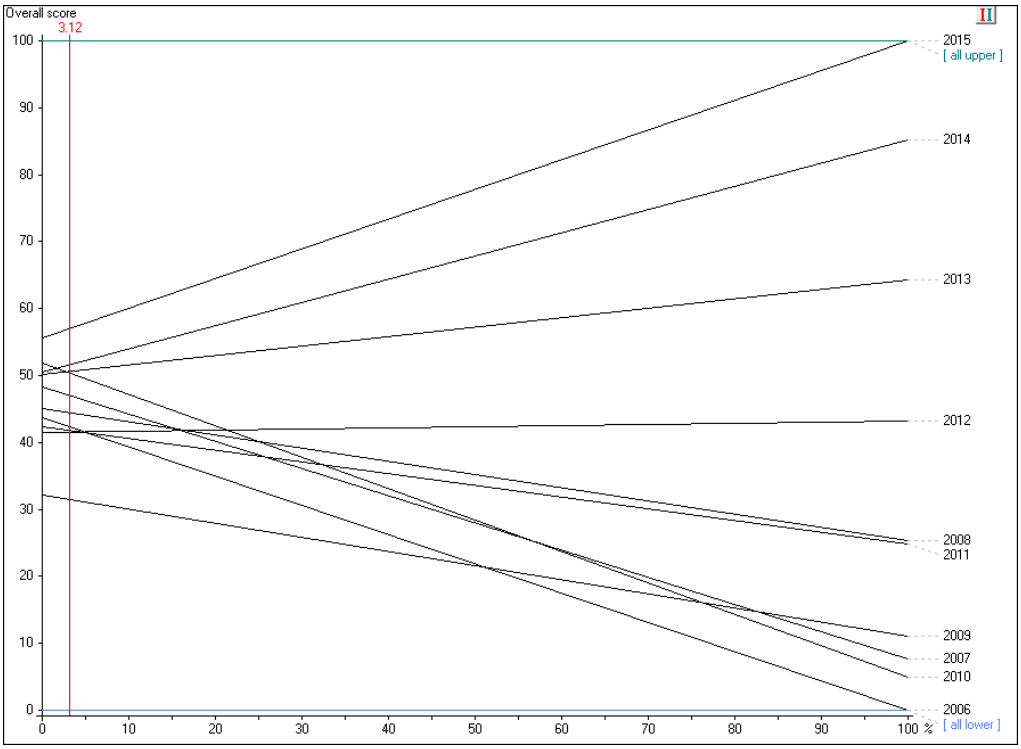

Figure II-7: Sensitivity analysis on weight for total assets KPI.

Source: own composition.

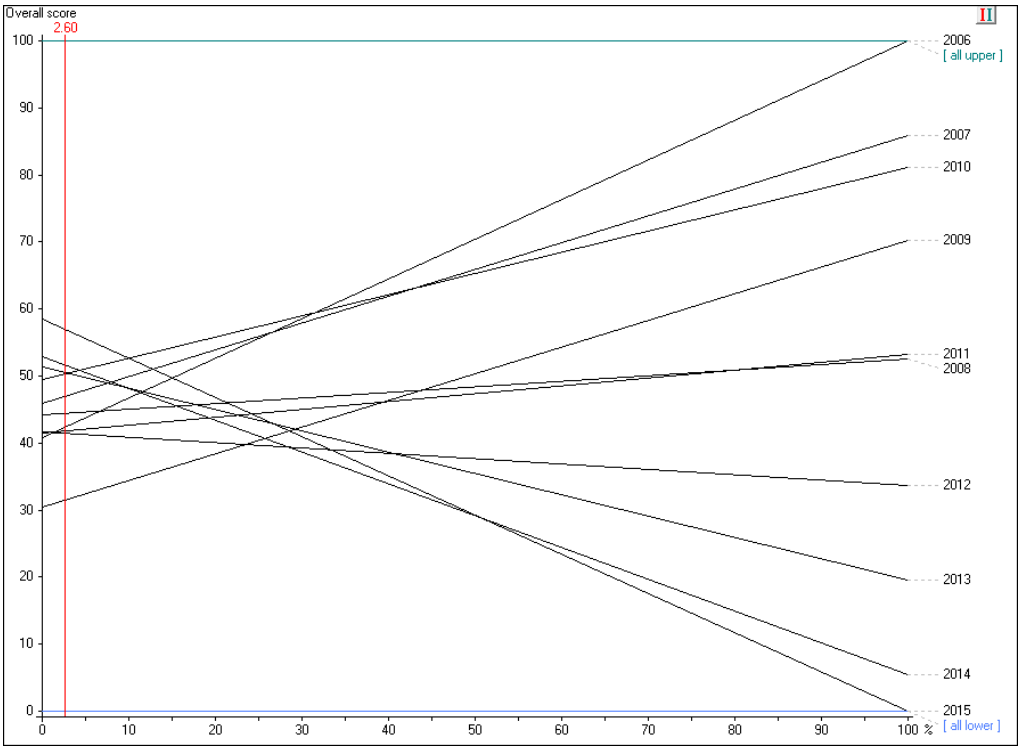

Figure II-8: Sensitivity analysis on weight for total liabilities KPI.

Source: own composition.

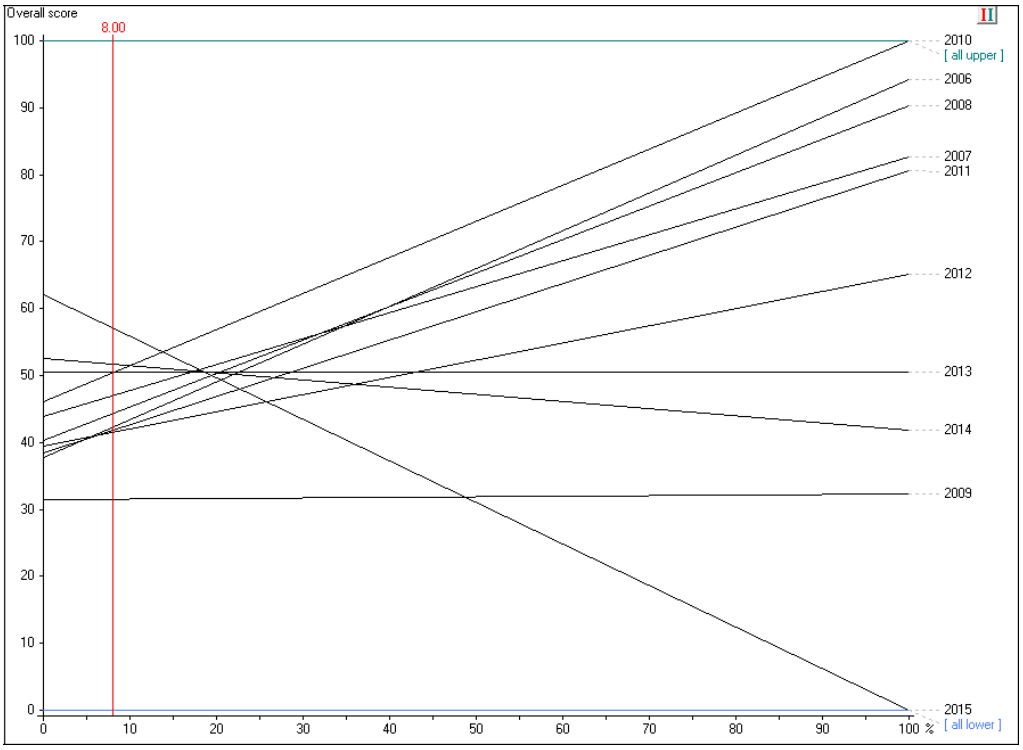

Figure II-9: Sensitivity analysis on weight for average aircraft utilisation KPI.

Source: own composition.

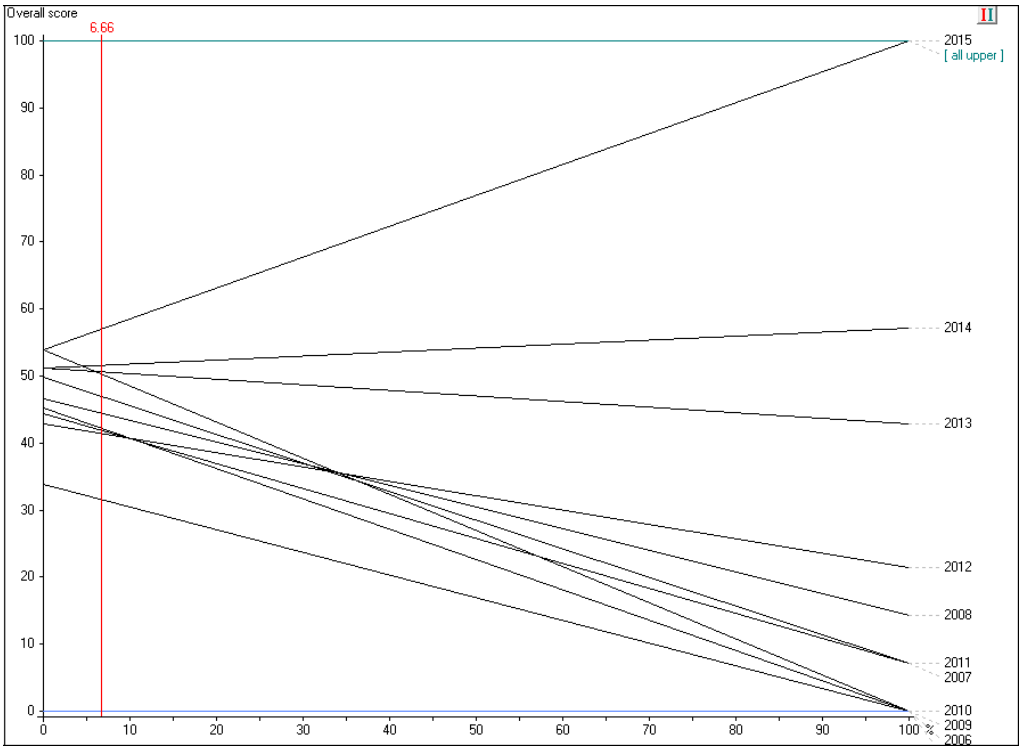

Figure II-10: Sensitivity analysis on weight for a number of freighter aircraft in the fleet KPI.

Source: own composition.

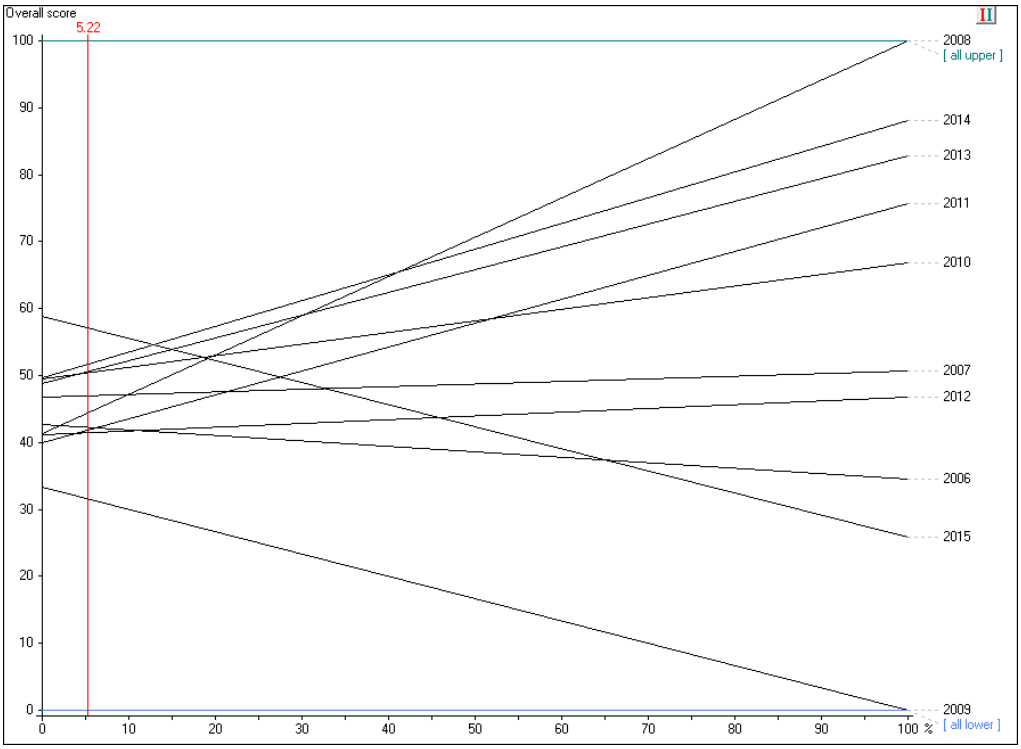

Figure II-11: Sensitivity analysis on weight for revenue per employee KPI.

Source: own composition.

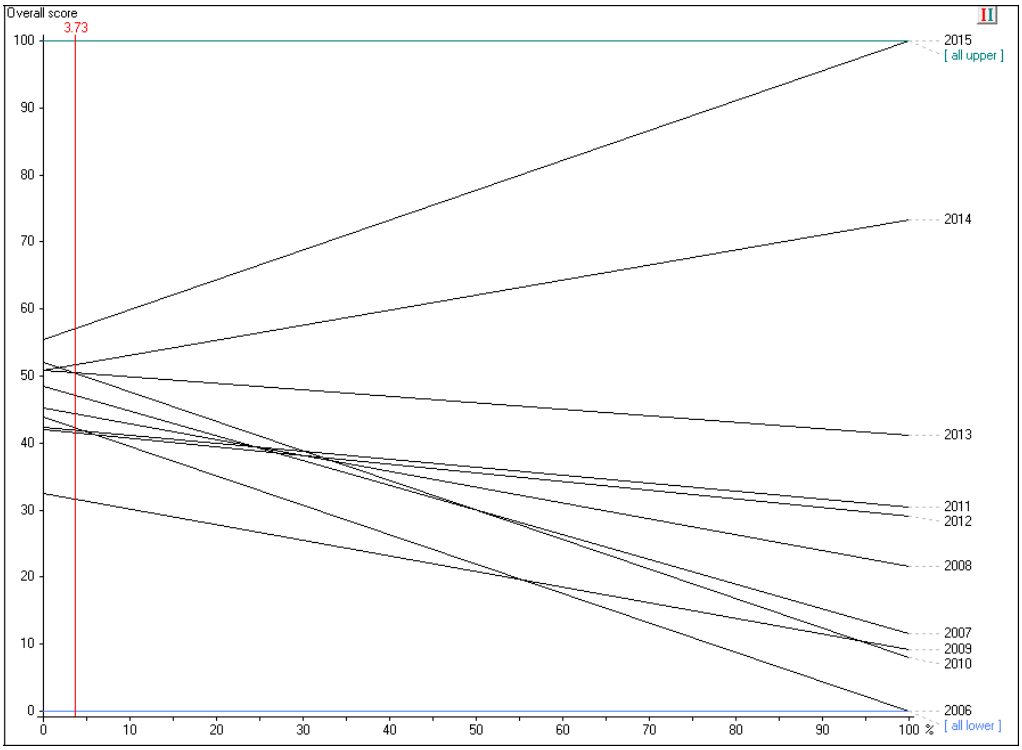

Figure II-12: Sensitivity analysis on weight for a number of employees KPI.

Source: own composition.

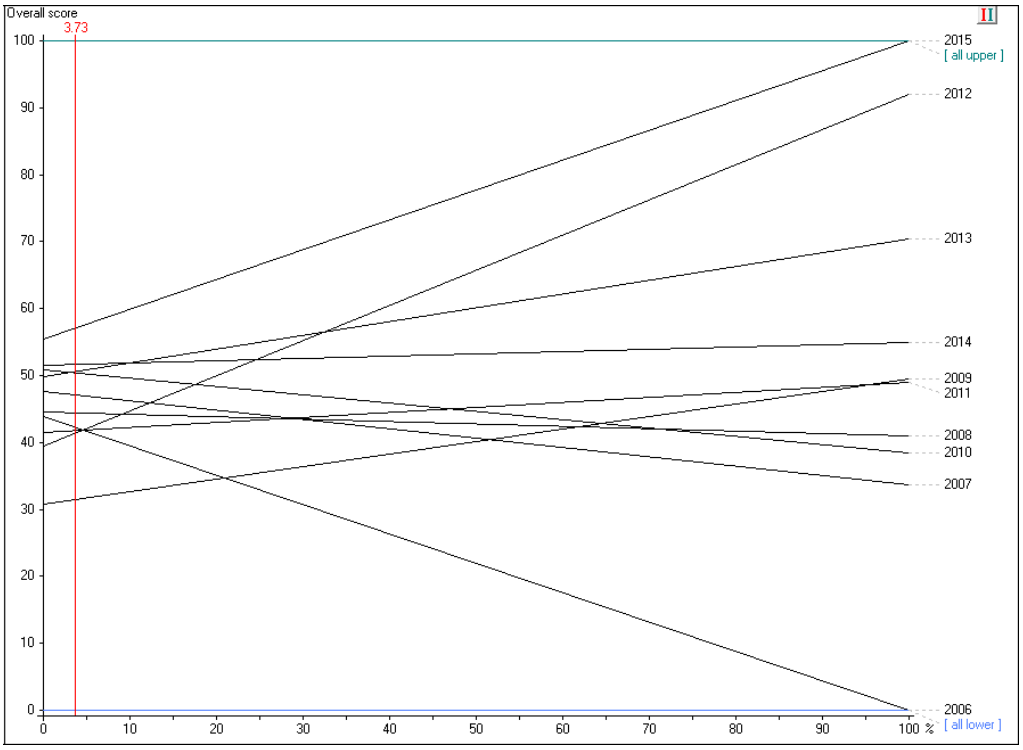

Figure II-13: Sensitivity analysis on weight for injury rate KPI.

Source: own composition.

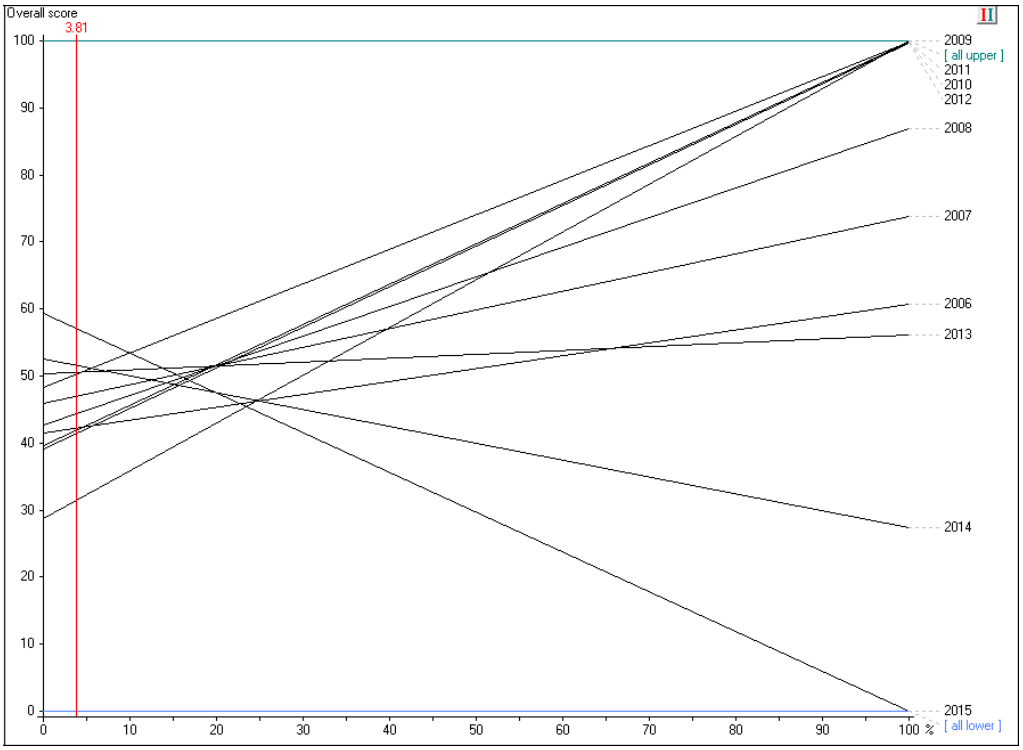

Figure II-14: Sensitivity analysis on weight for fuel used KPI.

Source: own composition.

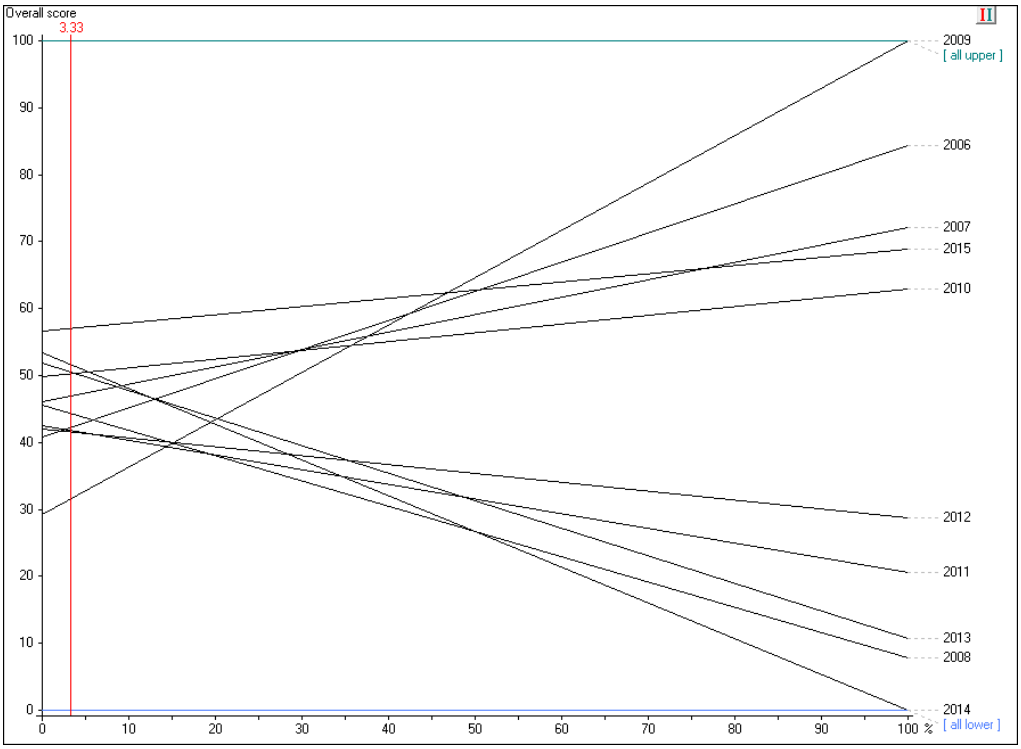

Figure II-15: Sensitivity analysis on weight for fuel cost KPI.

Source: own composition.

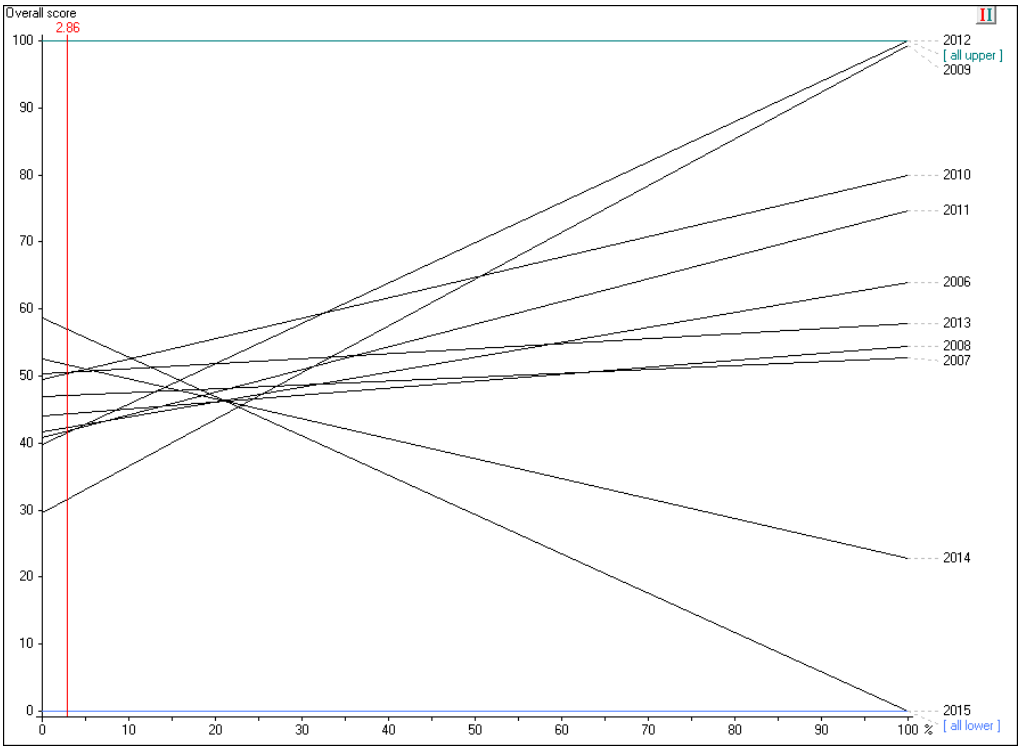

Figure I-16: Sensitivity analysis on weight for CO_2 emissions KPI.

Source: own composition.

Cargolux Efficiency:

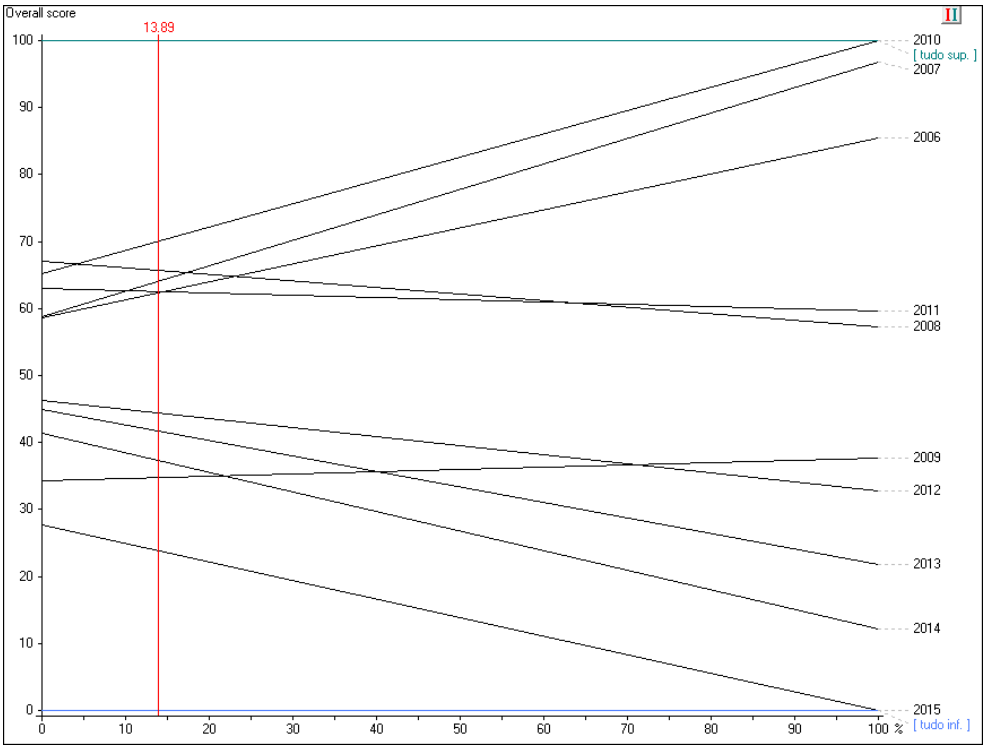

Figure II-17: Sensitivity analysis on weight for load-factor KPI (Cargolux).

Source: own composition.

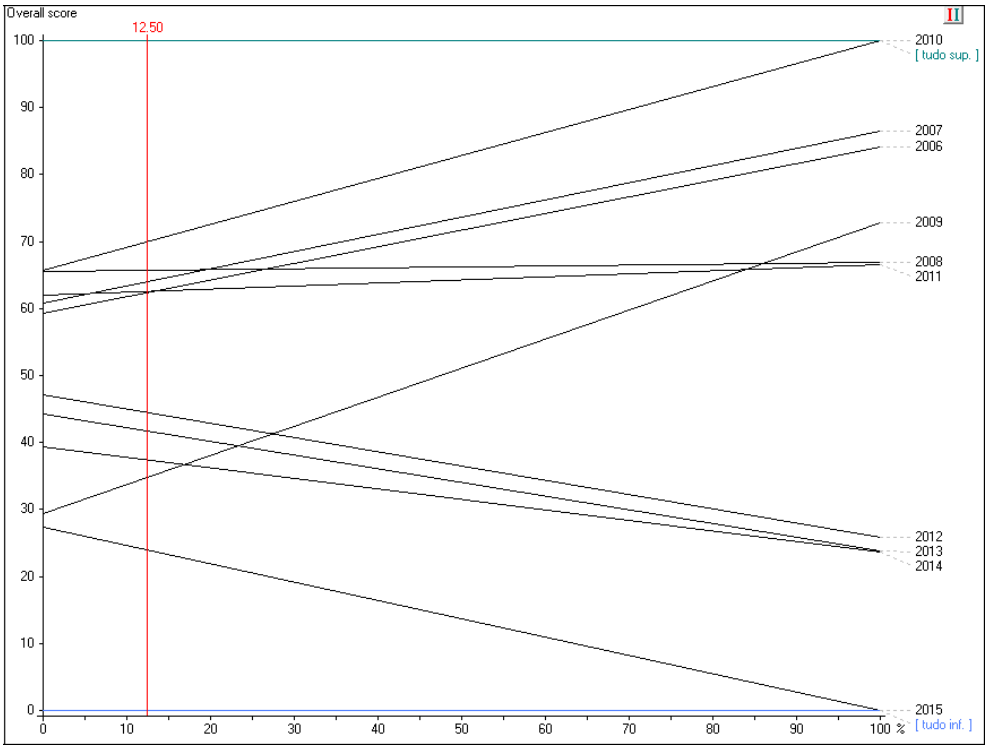

Figure II-18: Sensitivity analysis on weight for transported tonnes per number of aircraft KPI (Cargolux).

Source: own composition.

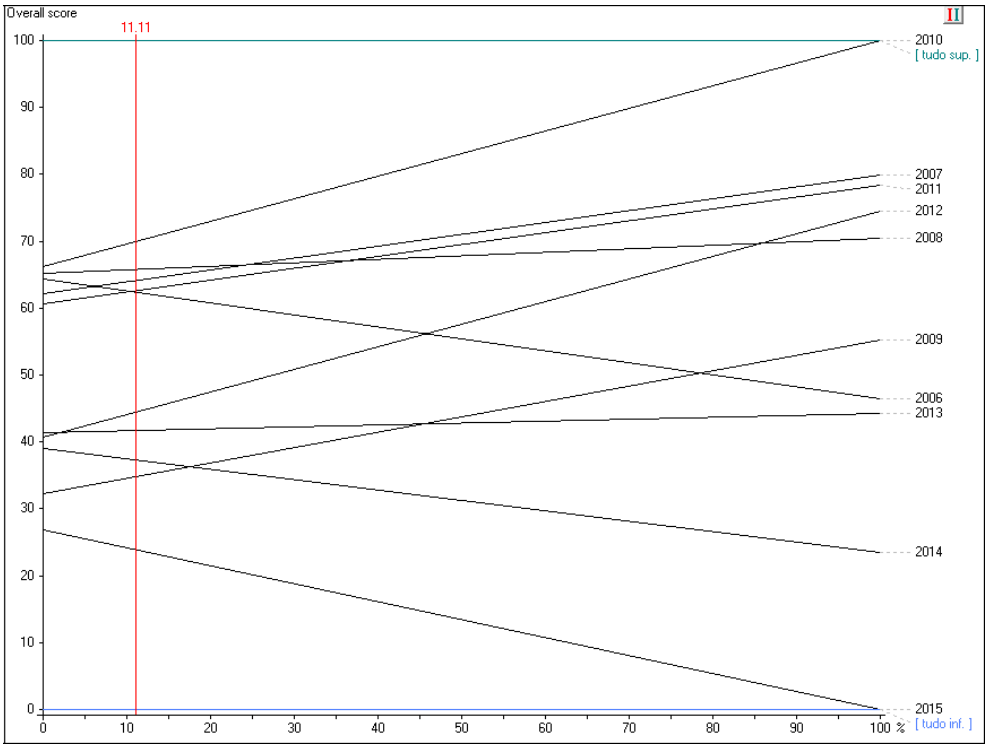

Figure II-19: Sensitivity analysis on weight for transported tonnes per ATK KPI (Cargolux).

Source: own composition.

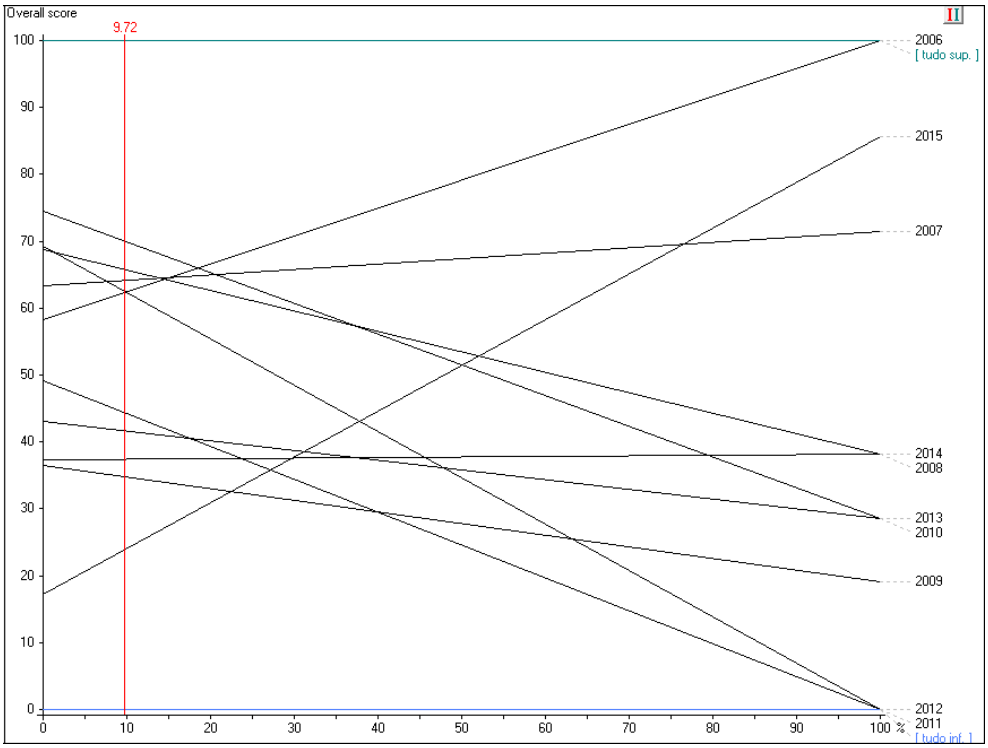

Figure II-20: Sensitivity analysis on weight for RTK per labour cost KPI (Cargolux).

Source: own composition.

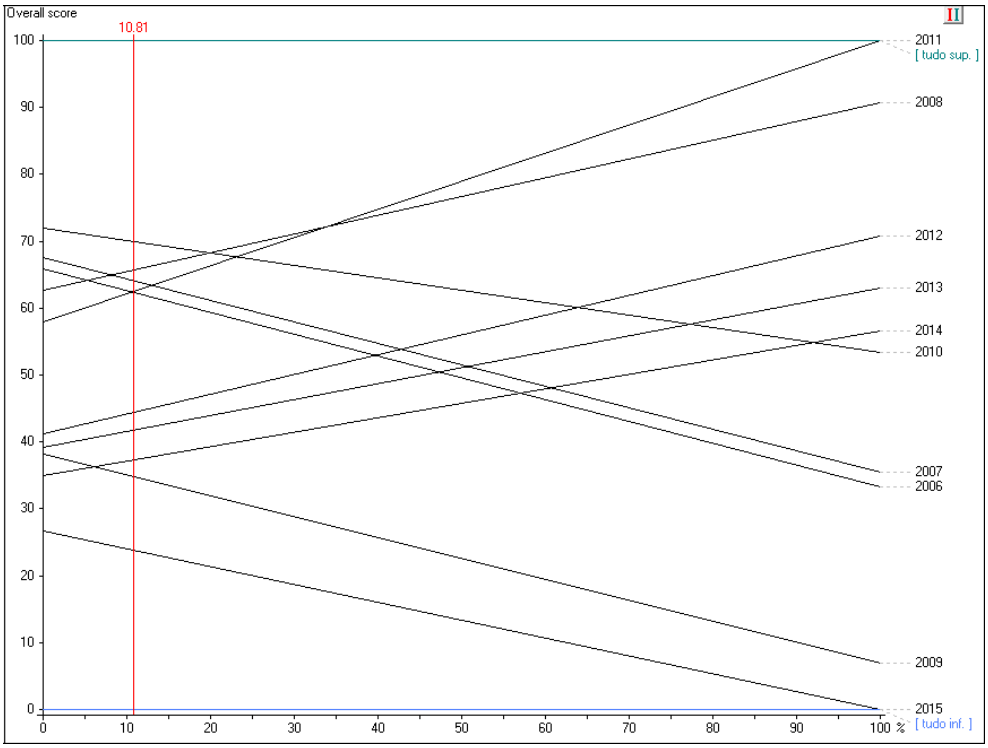

Figure II-21: Sensitivity analysis on weight for operational revenue per transported tonnes KPI (Cargolux).

Source: own composition.

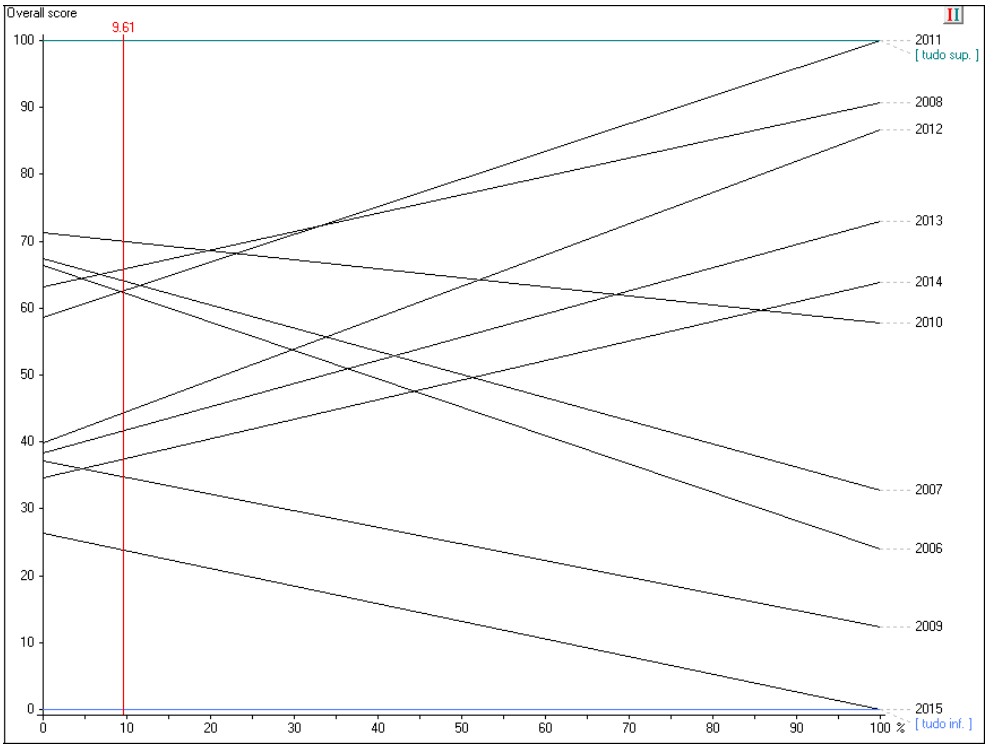

Figure II-22: Sensitivity analysis on weight for operational revenue per RTK KPI (Cargolux).

Source: own composition.

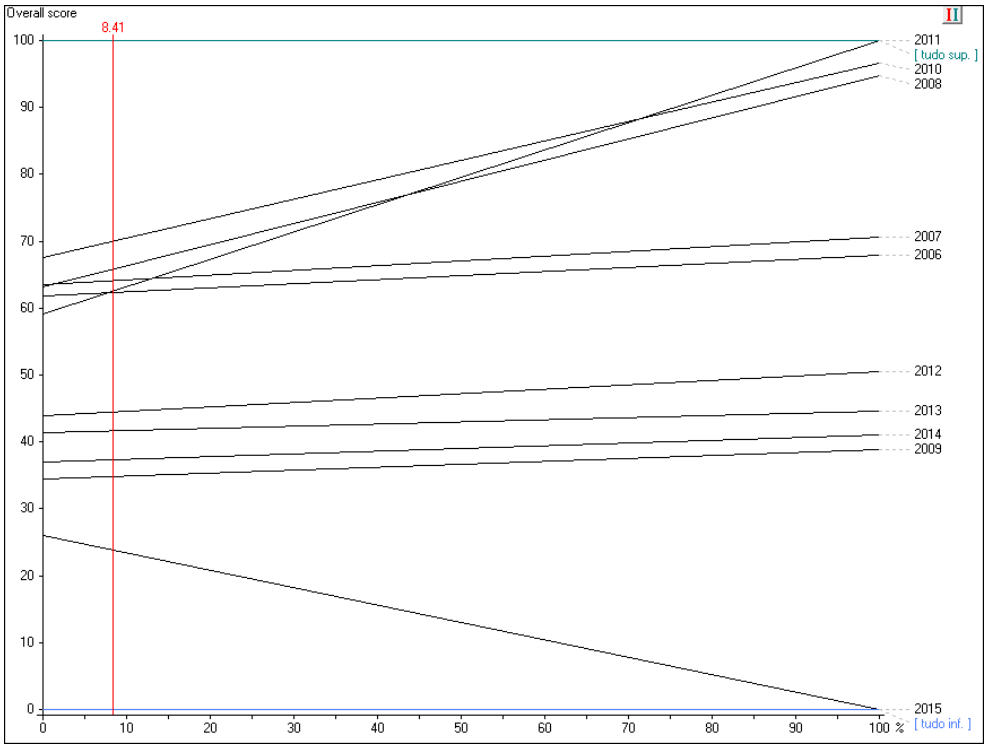

Figure II-23: Sensitivity analysis on weight for operational revenue per number of aircraft KPI (Cargolux).

Source: own composition.

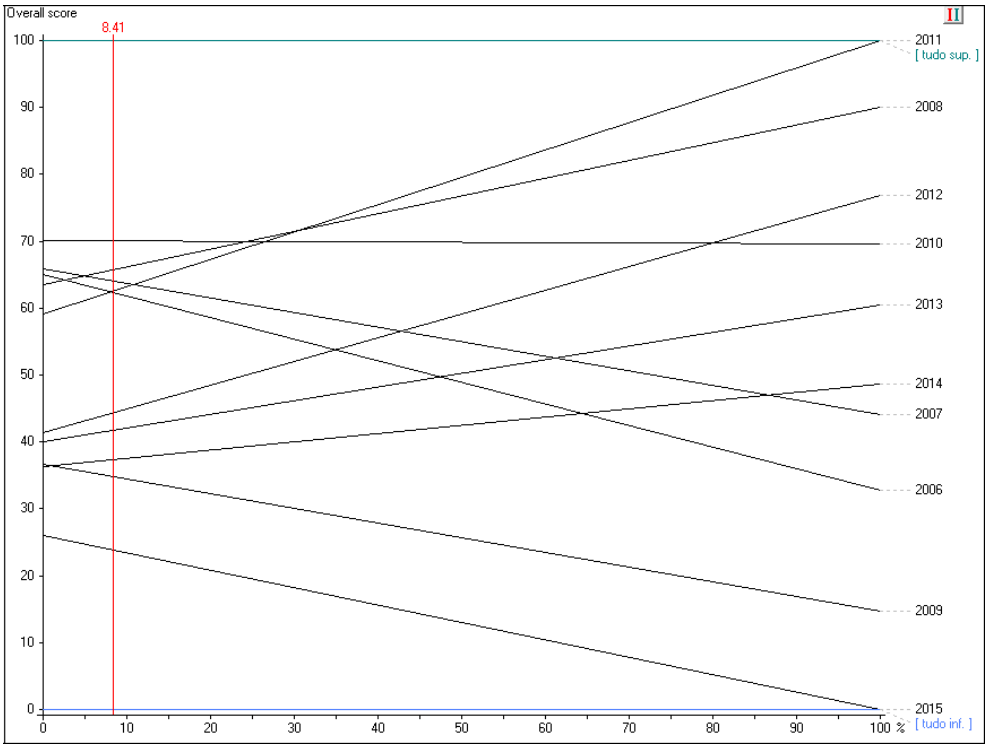

Figure II-24: Sensitivity analysis on weight for operational revenue per ATK KPI (Cargolux).

Source: own composition.

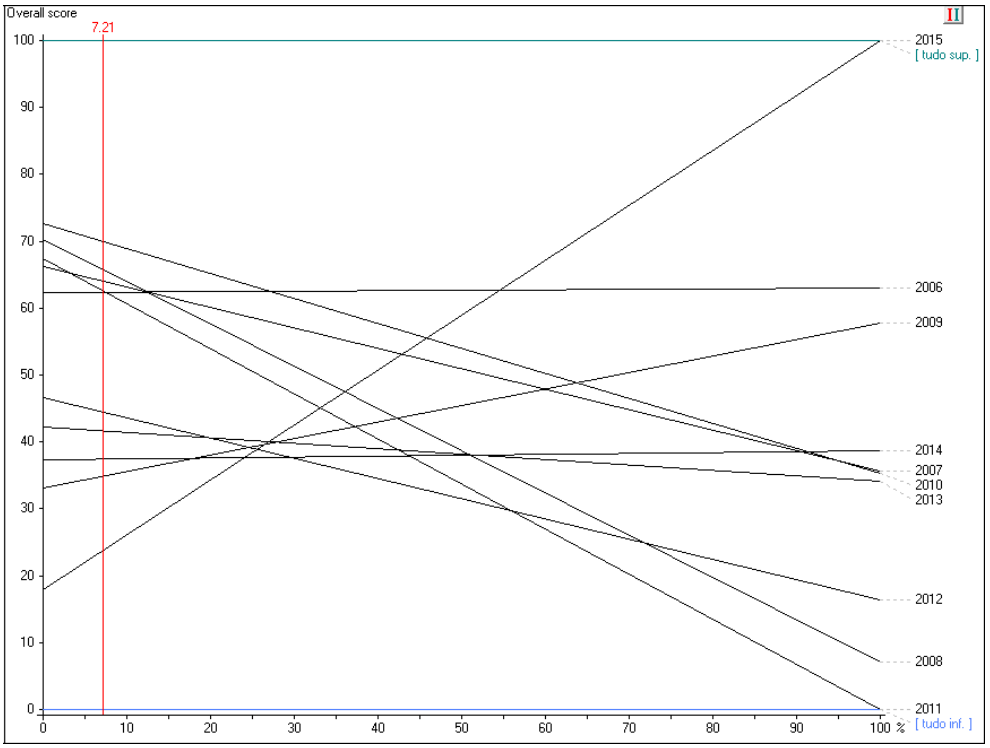

Figure II-25: Sensitivity analysis on weight for operational costs per ATK KPI (Cargolux).

Source: own composition.

Lufthansa Cargo Efficiency:

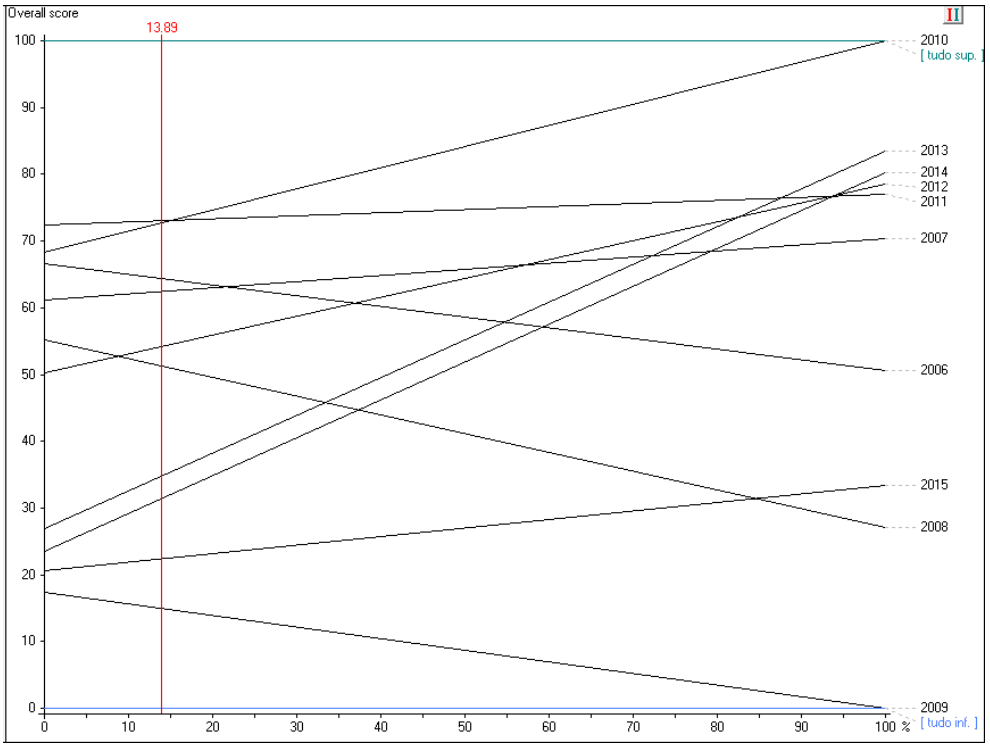

Figure II-26: Sensitivity analysis on weight for load-factor KPI (Lufthansa Cargo).

Source: own composition.

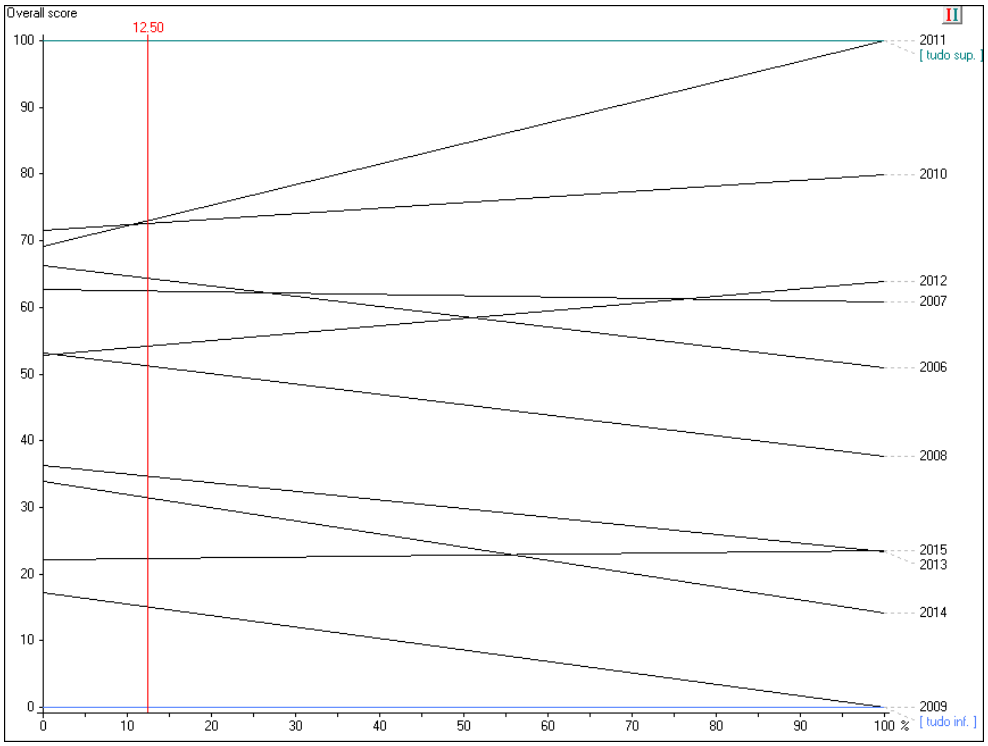

Figure II-27: Sensitivity analysis on weight for transported tonnes per number of aircraft KPI (Lufthansa Cargo).

Source: own composition.

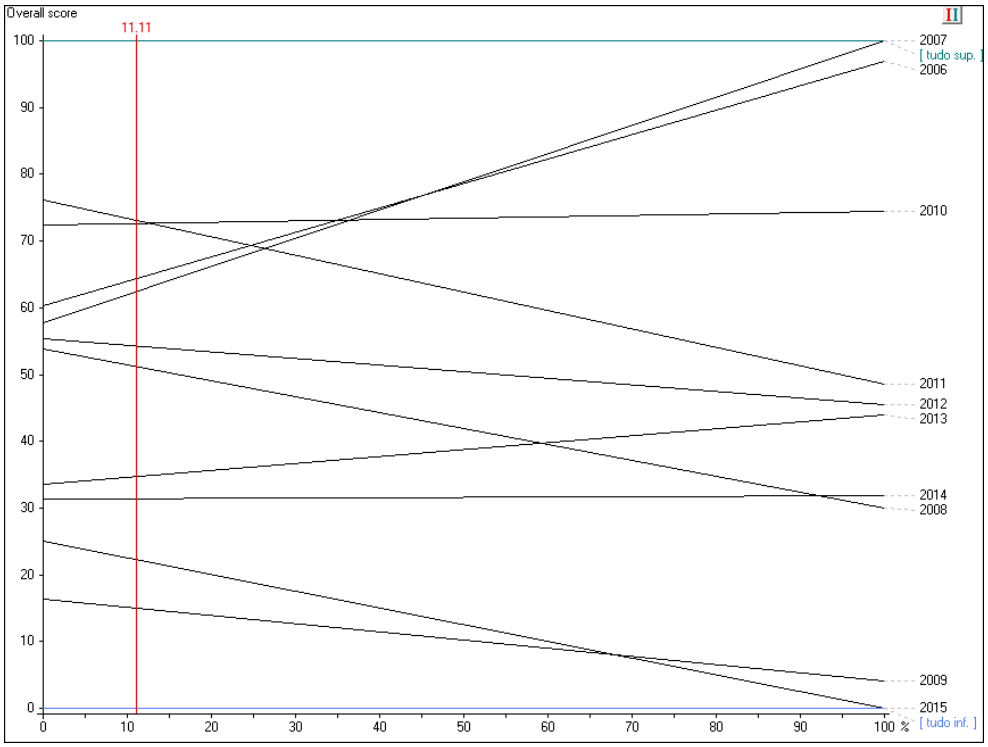

Figure II-28: Sensitivity analysis on weight for transported tonnes per ATK KPI (Lufthansa Cargo).

Source: own composition.

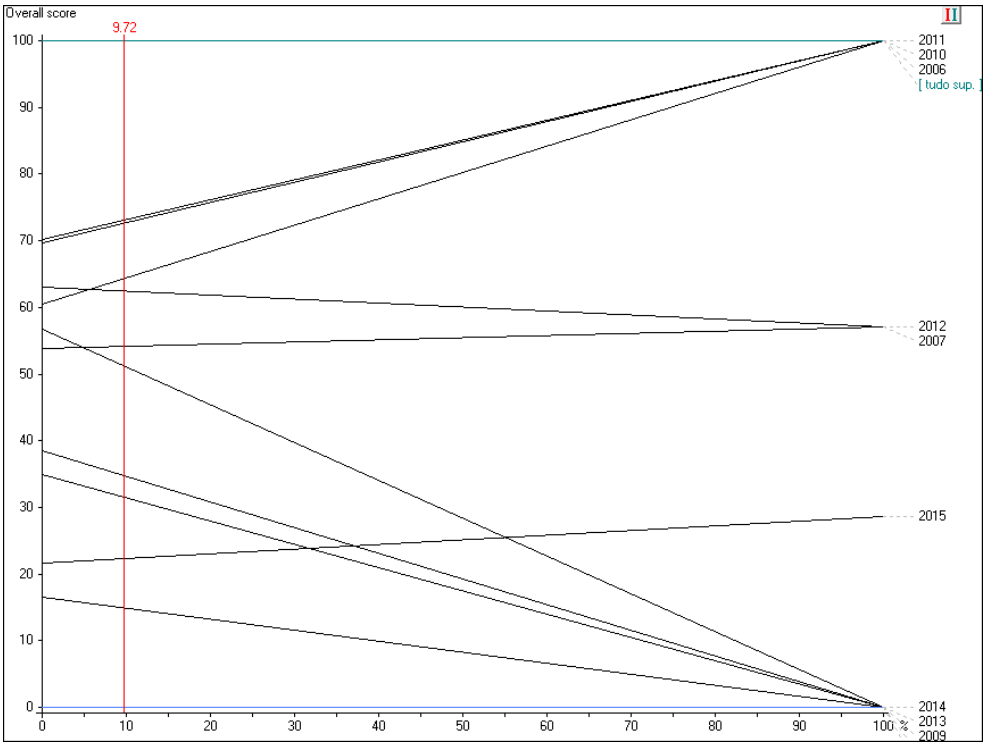

Figure II-29: Sensitivity analysis on weight for RTK per labour cost KPI (Lufthansa Cargo). Source: own composition.

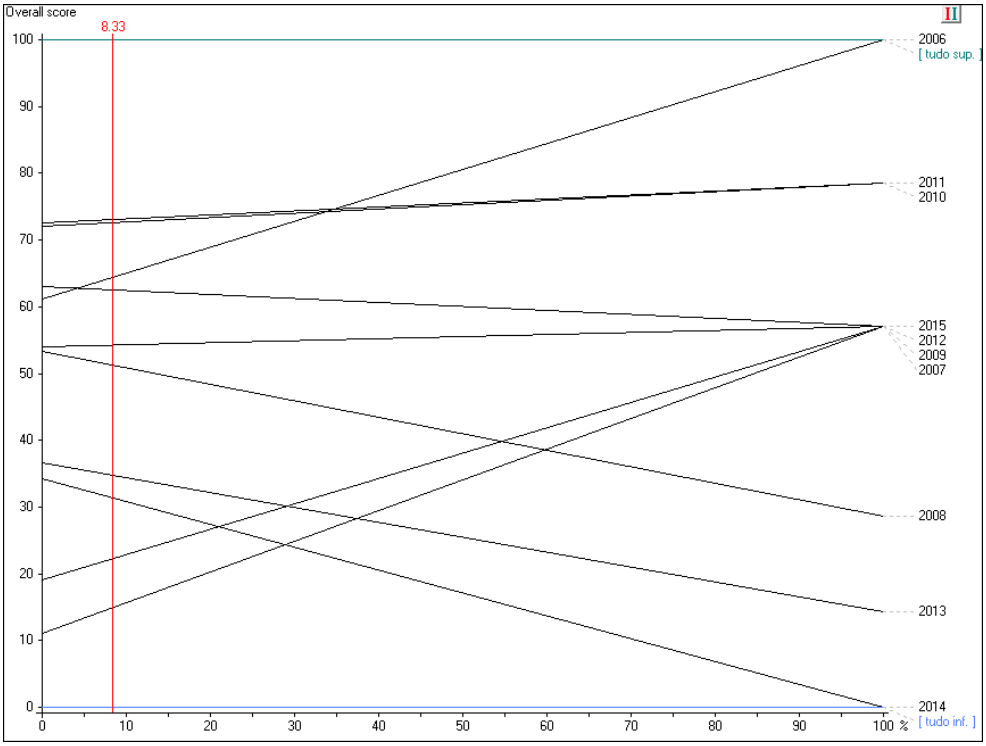

Figure II-30: Sensitivity analysis on weight for ATK per labour cost KPI (Lufthansa Cargo). Source: own composition.

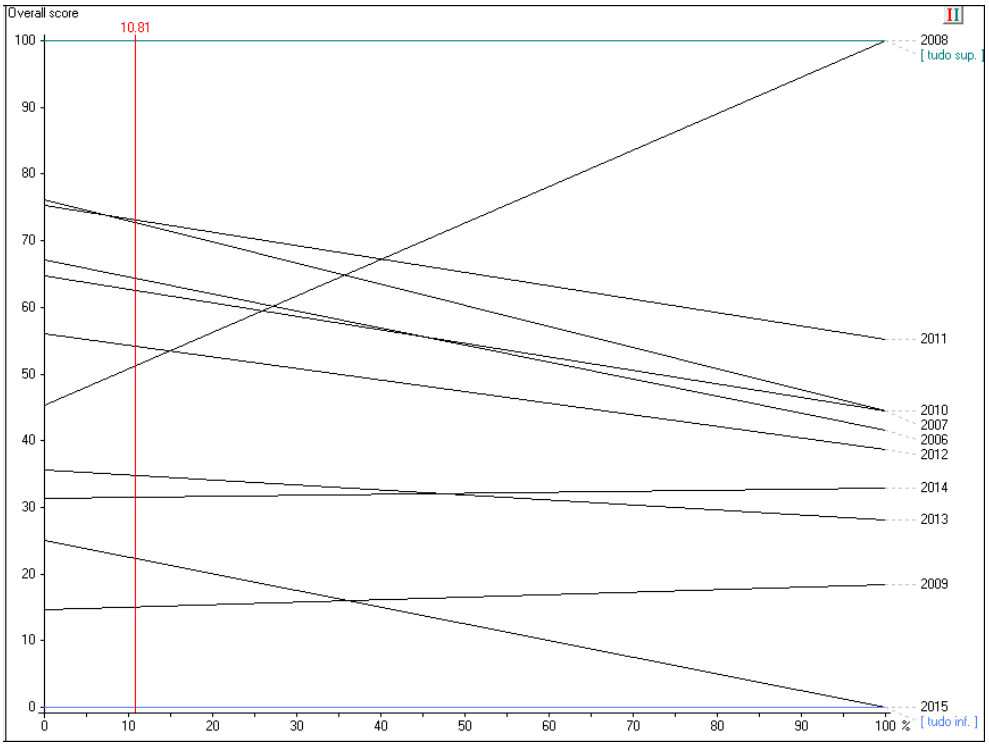

Figure II-31: Sensitivity analysis on weight for operational revenue per transported tonnes KPI (Lufthansa Cargo).

Source: own composition.

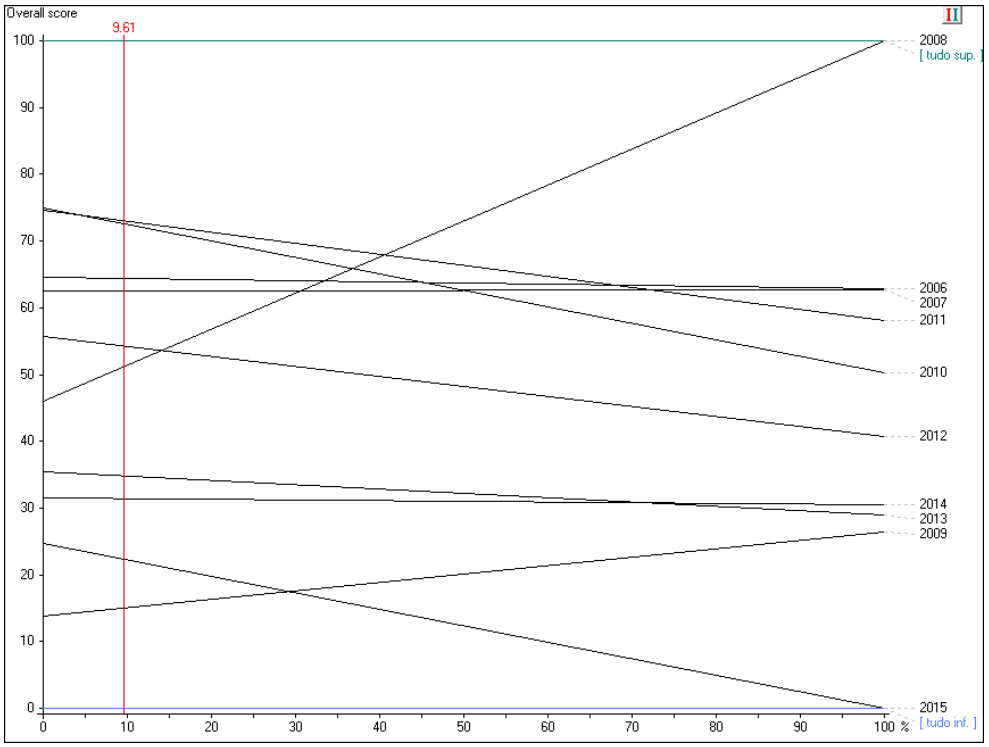

Figure II-32: Sensitivity analysis on weight for operational revenue per RTK KPI (Lufthansa Cargo).

Source: own composition.

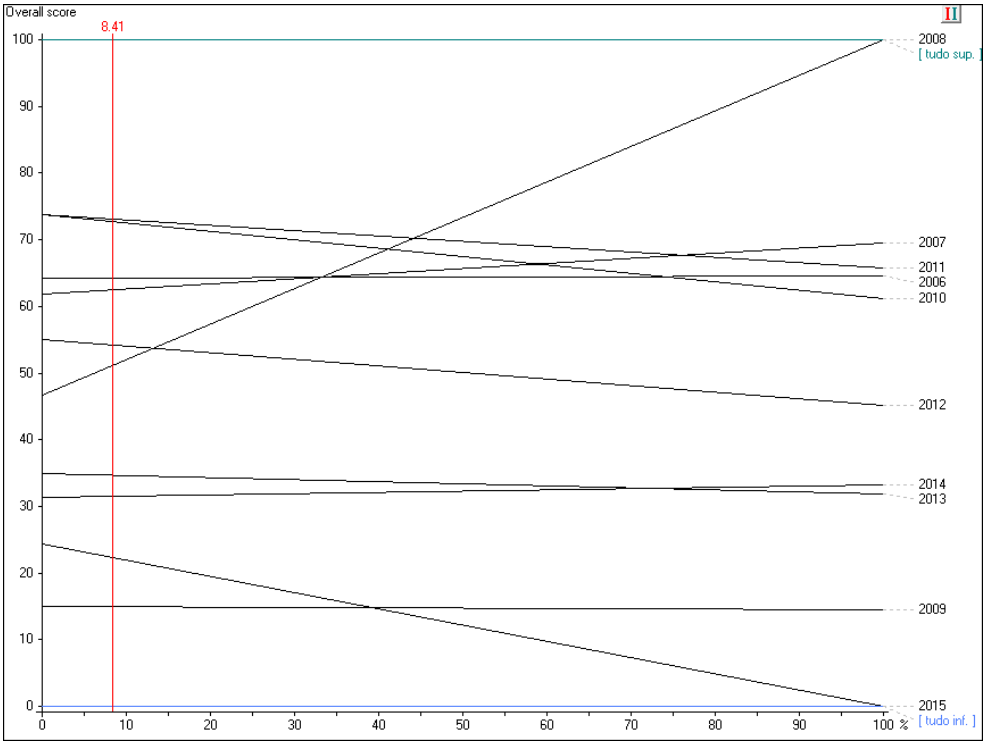

Figure II-33: Sensitivity analysis on weight for operational revenue per ATK KPI (Lufthansa Cargo).

Source: own composition.

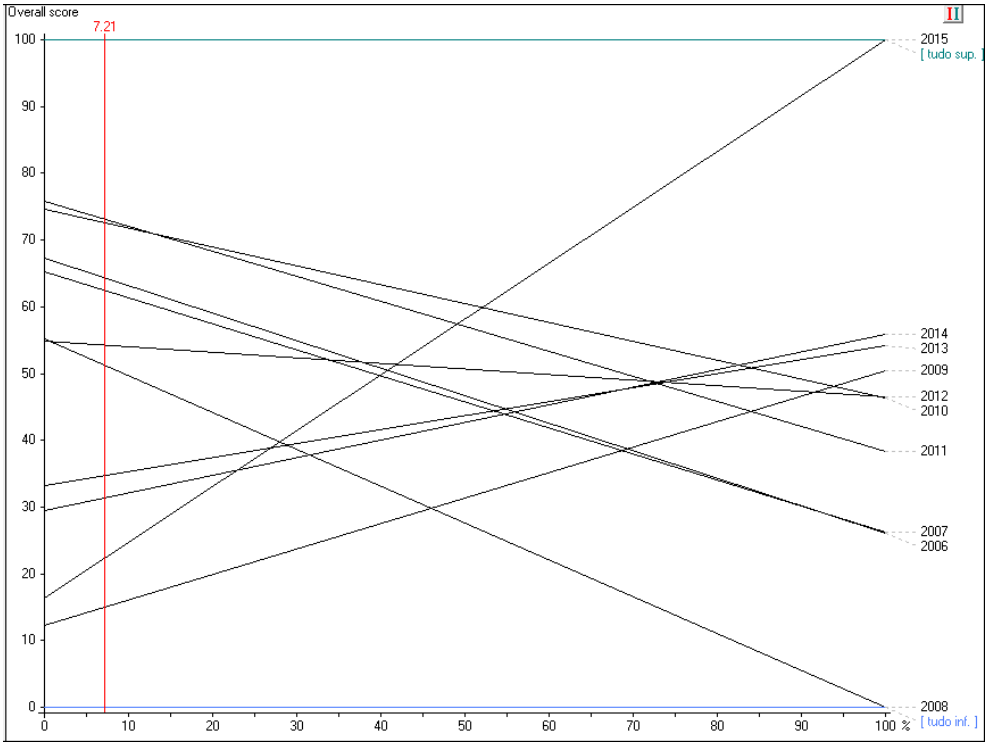

Figure II-34: Sensitivity analysis on weight for operational costs per ATK KPI (Lufthansa Cargo).

Source: own composition.

Annex III – Scientific Article accepted for publication at the 21th ATRS World Conference

21TH ATRS WORLD CONFERENCE

AIR CARGO CARRIERS PERFORMANCE AND EFFICIENCY ANALYSIS USING A MCDA METHODOLOGY

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Abstract

The air cargo became a very competitive and dynamic industry. Traditional passenger airlines already noticed the importance and profitability of the cargo market and that all-cargo carriers are considerably growing due to the high demand. Although, this industry is very vulnerable to diverse factors. This study aims to understand which are the Key Performance Areas (KPAs) and Key Performance Indicators (KPIs) that contribute for the air cargo carrier's success in order to help decision makers to select the best alternatives to ensure the best assessment in terms of performance and efficiency of several air cargo carriers. It finds that the most relevant key performance areas are the operational and financial ones. PESA–ACCGB (Performance Efficiency Support Analysis – Air Cargo Carriers Global Benchmarking), based on MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique), is the MCDA (Multi Criteria Decision Analyses) methodology tool used for that purpose. This research evaluates several air cargo carriers, in terms of performance and efficiency, over a course of ten years (2006 - 2015). Based on the survey results, this research finds that the most relevant key performance areas are the operational and financial ones.

Keywords: Air cargo, Benchmarking, Efficiency, MCDA, MACBETH, Performance