Sustainability Assessment of the Aerospace Supply Chain: Stakeholders' Engagement Towards Sustainability

Tomás Figueiredo Diniz de Abreu

Thesis to obtain the Master of Science Degree in

Industrial Engineering and Management

Supervisors: Prof. Ana Isabel Cerqueira de Sousa Gouveia Carvalho
Eng. Carlos Filipe Pinto Malarranha

Examination Committee

Chairperson: Prof. Ana Paula Ferreira Dias Barbosa Póvoa

Supervisor: Prof. Ana Isabel Cerqueira de Sousa Gouveia Carvalho

Member of the Committee: Prof. Amílcar José Martins Arantes

November 2017

Acknowledgments

Firstly, I would like to thank to my supervisor, Professor Ana Carvalho, for believing in me since the beginning and for her tireless guidance during this year, always with a friendly word to say. I would also like to thank the opportunity she provided to develop this dissertation at one of the most prestigious schools of engineering in the world for one month.

I would also like to thank to my co supervisor, Carlos Malarranha, with whom I shared so many ideas, questions and findings, while together we discovered this industry. To him I wish the best success following his path towards his PhD.

I would like to kindly thank to Professor Elsa Olivetti, for her support, guidance and accessibility during the month I spent at MIT developing my dissertation under her supervision.

I would like to thank Professor Ana Póvoa, as the coordinator of the IAMAT-WP4 project, and to every professor and student from IST, MIT, FEUP, UMinho, and engineers at Embraer and Optimal who were involved and contributed in any way with this project.

I would also like to thank my family for their moral and material assistance and invaluable support during all my time at Técnico, particularly during the development of this dissertation. To my grandfather Zé, to whom I especially dedicate this engineering degree; to both my grandmothers, Teresa and Lucinda; to my father and mother; to my brother Francisco and sister Guigas.

I would like to acknowledge my friends with whom I shared the adventure of studying at Técnico: to João Lobo Pires, Francisco Gorjão, Adzan Bonfim and Constança Fernandes, for all the ‘not so good’ and the great moments we lived together, and for those we will certainly continue to live.

Finally, I would like to thank Catarina for her unconditional support and comprehension, for being my best friend and confidant during all these years, for never letting me give up on my dreams, for believing in me like no other. Let this be the beginning of the rest of our lives together!

Abstract

Managing the relations between the organization's stakeholders is one of the most important tasks during strategy making. Nowadays, aerospace manufacturers tend to be integrators of parts, systems and major modules produced by a supply chain with increasing complexity, which must be managed accordingly and in a sustainable way. The efficient management of sustainable supply chain requires decision support tools which can assess sustainability, with the integrated approach of the triple bottom line (3BL) approach.

The increasing complexity of the industry's supply chain and the urgency for correctly managing stakeholders leads to the problem of evaluating the stakeholder's engagement towards sustainability. A complete stakeholders' analysis and performance assessment is therefore needed, working as an integrated decision support tool for the sustainable supply chain management.

The present dissertation starts by contextualising the aerospace manufacturing industry and the commercial aviation sector, followed by the characterisation of the problem to be studied. A state of the art literature review is then conducted, focusing on relevant themes to support the development of a new multimethodology for stakeholders' analysis, that allows the identification of the most relevant stakeholders for the problem in study. Additionally, the stakeholders' engagement towards sustainability is studied and a framework for sustainability performance reporting is suggested as a basis for the measurement of the stakeholders' engagement.

Keywords: sustainability, stakeholders' analysis, stakeholders' engagement, performance indicators, aerospace supply chain

Resumo

A gestão das relações entre os *stakeholders* de uma organização é uma das tarefas mais importantes durante o processo de desenvolvimento de estratégia. Hoje em dia, os grandes fabricantes do ramo aeroespacial tendem a desempenhar o papel de integradores de peças, sistemas e grandes módulos produzidos por uma cadeia de abastecimento cada vez mais complexa, devendo esta ser gerida de uma forma sustentável. Para uma gestão eficiente de cadeias de abastecimento sustentáveis é necessário recorrer a ferramentas de apoio à decisão, capazes de avaliar a sustentabilidade de uma forma integrada utilizando uma abordagem *Triple Bottom Line* (3BL).

A crescente complexidade da cadeia de abastecimento da indústria, e a urgência de uma correta gestão dos *stakeholders* implicam a avaliação do envolvimento desses mesmos *stakeholders* em direção ao conceito de sustentabilidade. São assim necessárias, uma completa análise de *stakeholders*, bem como uma avaliação de desempenho, como ferramentas integradas de apoio à decisão da gestão da cadeia de abastecimento sustentável.

A presente dissertação começa por contextualizar a indústria aeroespacial e o sector da aviação comercial, seguindo-se a caracterização do problema a estudar. Realiza-se ainda uma revisão do estado da arte, com especial enfoque nos temas que pretendem dar suporte ao desenvolvimento de uma nova multi-metodologia de análise de *stakeholders,* capaz de identificar quais os mais relevantes para o problema em estudo. Adicionalmente, sugere-se um *framework* para reporte de desempenho de sustentabilidade, funcionando como base para a medição do seu envolvimento no problema da sustentabilidade da cadeia de abastecimento aerospacial.

Palavras-chave: sustentabilidade, análise de *stakeholders*, envolvimento dos *stakeholders*, indicadores de desempenho, cadeia de abastecimento aerospacial

Table of Contents

List of Figures

List of Tables

List of Acronyms

3BL – Triple Bottom Line

3PL – Third Party Logistics

EASA – European Aviation Safety Agency

EEA – European Environment Agency

GHG – Greenhouse Gas

GRI – Global Reporting Initiative

IATA – International Air Transport Association

ICAO – International Civil Aviation Organisation

ISO – International Standard Organisation

IST – Instituto Superior Técnico

LCA – Life Cycle Assessment

LLC – Lead Logistics Provider

LSSI – Large Scale Systems Integrator

MIT – Massachusetts Institute of Technology

MRO – Maintenance and Repair Operations

NGO – Non-governmental Organisation

OEM – Original Equipment Manufacturer

RPK – Revenue Passenger Kilometre

SC – Supply Chain

SSCM – Sustainable Supply Chain Management

USA – United States of America

US$ – United States dollar

1. Introduction

1.1 Problem Contextualisation

Following the increasing demand for air transportation, the commercial aviation sector is nowadays becoming the main driver of the global aerospace manufacturing industry (Captain & Hussein 2017). The sector is expected to continue to grow, with forecasts for new commercial aircraft until 2035 currently valuated between 5 and 6 trillion US$ (Boeing 2016b).

However, in the last decade, the industry has been dealing with several challenges, from terrorism and natural disasters to global economic instability and record fuel prices. The financial and environmental challenges are nowadays driving fuel efficiency and cost reduction innovations, as well as trying to end monopolies through the supply chain and developing strategies to cut the industry's carbon footprint. Collaboration between stakeholders across the industry is now the vision for the future, and it is believed to be the path for sustainability (IATA 2016).

Today, sustainability is a top concern for most organizations. Managers are now required to concern about the economical, ecological and social pillars of sustainability of the business (Carter & Rogers 2008). In industrial and manufacturing businesses, the sustainability of supply chain (SC) has a major impact on the organisations' performance (Ansari & Kant 2016). The aerospace manufacturing industry is no exception, and all its complexity makes the supply chain impact in sustainability even more relevant.

When discussing supply chain sustainability, the question on the relevancy of stakeholder engagement naturally rises. The management of stakeholders can then become critical for the sustainability across the SC and, consequently, for the organisation's sustainability (Bernhart & Maher 2011).

Several studies about stakeholders' analysis and sustainability performance measurement have been conducted during the past years. However, both the literature and the industry are lacking a tool which integrates these analyses and provides support for management decisions about stakeholder engagement towards sustainability in the aerospace supply chain.

Starting by characterising the aerospace industry, and reviewing the state of the art on the themes above, this dissertation comes as the development of a new multimethodology to address the stakeholders' analysis and sustainability performance measurement, in the context of the aerospace supply chain sustainability.

1.2 Objectives

The main objective of the present dissertation in Industrial Engineering and Management is to conduct a sustainability assessment to the aerospace supply chain, focusing on the stakeholders' engagement theme. This objective can be deconstructed into several intermediate objectives:

- Contextualise and characterise the problem:
  - Contextualisation of the aerospace manufacturing industry;
  - Characterisation and description of the problem to be studied.
- Review the State of the art on:
  - Stakeholders' analysis methodologies and interviewing techniques;
  - Indicators development and validation methodologies;
  - Sustainability indicators.
- Develop and conduct a new methodology for stakeholders' analysis;
- Create indicators to measure the stakeholders' engagement towards sustainability;
- Derive conclusions and suggestions for the future.

1.3 Methodology

The methodology to be implemented during the development of the dissertation is presented in this section. Figure 1 describes the five steps of the methodology.

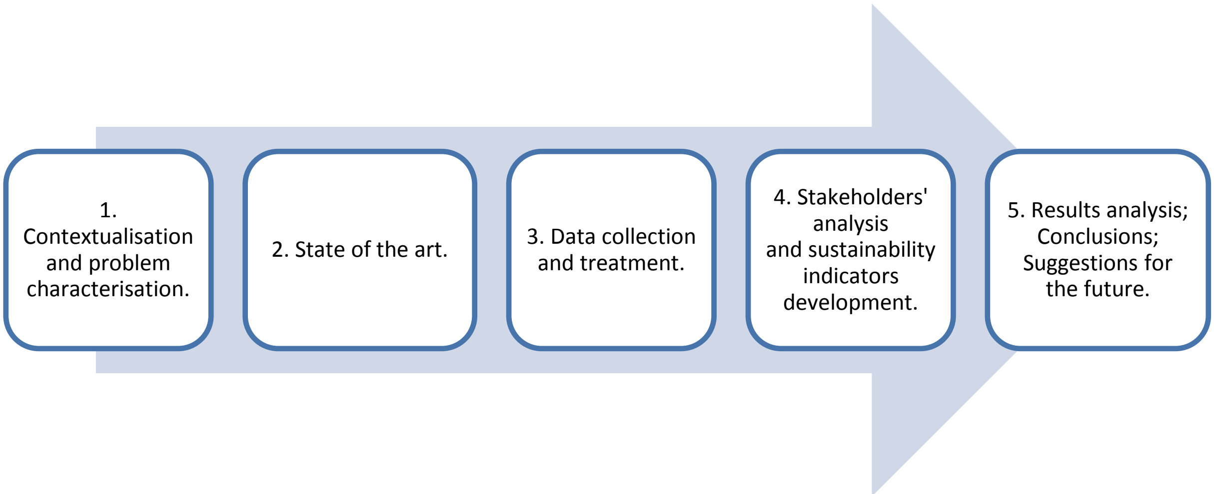


Figure 1 – Methodology to follow in the dissertation.

1. The first step consists on the contextualisation of the commercial aerospace sector, in terms of market and supply chain characterization.

2. In the second step, a literature review on the existing literature on stakeholders' analysis, development and validation of indicators and sustainability indicators.

3. The third step lies on the collection and treatment of the data needed for the analysis required for the dissertation. A survey will be distributed by global aerospace companies.

4. On step four, using the data from step 3 and a combination of the methodologies presented in the literature review from step 2, a novel multimethodology for stakeholders' analysis will be presented and tested, in order to characterise the global aerospace industry's stakeholders in terms of their power, interest, urgency, legitimacy and support towards supply chain sustainability. A set of sustainability indicators to measure the stakeholders' sustainability performance will be developed and validated, using techniques presented in the state of the art and in accordance with the stakeholders' analysis.

5. The fifth and last step is to analyse the results obtained with the application of this new methodology. Conclusions from this work will be drawn and suggestions for the future will be given.

1.4 Structure of the Dissertation

This dissertation is divided into six chapters:

- Chapter 1 – this present chapter presents a brief context to the problem in study, as well as the methodology for the dissertation and its objectives;
- Chapter 2 – this chapter starts with a general overview of the aerospace manufacturing industry, followed by a contextualisation of the commercial aerospace sector, the airplane life cycle, and the industry's supply chain;
- Chapter 3 – in this chapter a literature review is presented. Concepts such as stakeholders' analysis, indicators definition and validation, and sustainability indicators are reviewed, presenting the state of the art regarding these themes;
- Chapter 4 – this chapter presents the methodology used during the development of the dissertation, divided by its main objectives: the stakeholders' analysis and the sustainability performance assessment;
- Chapter 5 – in this chapter the results of the research are presented, as well as the discussion of those results;
- Chapter 6 – in this final chapter, the major conclusions taken from the dissertation are presented, as well as suggestions for future developments.

2. Contextualisation

A brief history of the aerospace manufacturing industry is presented in section 2.1. Section 2.2 gives an overview of the industry, analysing the competitive scenario, characterising the industry's typical supply chain and the aircraft life cycle. The identification of the problem to be studied is described in section 2.3. The chapter ends with section 2.4, in which conclusions from this analysis are presented.

2.1 Brief History of the Aerospace Manufacturing Industry

Few decades after the first flight, both First World War and Second World War proven to be key events with major impact in the evolution of military aircraft and in aviation technology in general. The great technical evolution and expertise acquired especially in Second World War made airplanes capable of flying higher, faster and further, and eventually the demand for air transportation naturally increased.

In the early 1980's, the air transportation industry updated their focus and goals: safety and security were on the top of the agenda, closely followed by financial viability, product and service quality and cost and environmental-friendly standards definition. The aircraft manufacturing industry had to start finding technical solutions and bring complying products to the market. These objectives proved to be very relevant as they still have a role in the industry goals today.

The 21st century brought new and huge challenges throughout the industry, including terrorism, natural disasters, global economic disturbance and unprecedented rise in fuel prices. The previous goals were reinforced during these years, focusing in the environment and financial issues that driven fuel efficiency and cost reduction innovations. The International Air Transportation Association (IATA) leaded a major initiative to reduce costs across the air transport value chain, particularly trying to end monopolies through the suppliers, as well as a long-term strategy to cut the industry's carbon emissions by half in 2050. Partnerships between regulators, airlines, manufacturers, suppliers and across the whole industry are now the vision for the years to come, and it is believed that this is the path for a profitable sustainable future (IATA 2016).

The major role of manufacturers in achieving these goals is undeniable. The following section will give an overview of the global aerospace manufacturing industry, providing a definition of its several subsectors. The current economic scenario will also be explored by analysing the last years, forecasts and the trends in the industry.

2.2 The Global Aerospace Manufacturing Industry

2.2.1 General overview

The Oxford Dictionary of English (2017) defines ‘aerospace’ as ‘the branch of technology and industry concerned with both aviation and space flight’. Using that definition, we can say that the aerospace manufacturing industry is engaged in research, development, production and maintenance of both aircraft and spacecraft.

While aircraft refers to vehicles designed to fly on the Earth’s atmosphere, spacecraft refers to vehicles or machines designed for operation above Earth’s lower atmosphere (Encyclopædia Britannica 2010). This dissertation will not consider the ‘space’ branch of the sector, although most top companies in the industry have businesses and participations in this area.

Regarding the classification of aircraft, there are several approaches. Following a classification based in its purpose, aircraft can be divided into two main categories:

- Military aviation, which includes all combat and supporting aircraft, operated by military forces (Taylor & Guilmartin 2011);
- Civil aviation, which represents all non-military aircraft, both commercial and private (Weiss & Amir 2014);

The classification of civil aviation activities by the International Civil Aviation Organization (ICAO 2009) shows that the segment is also divided in two main categories:

- Commercial aviation, which refers to scheduled and non-scheduled air transportation services;
- General aviation, which includes non-commercial business aviation, aerial work, instructional flying and pleasure flying aircraft.

The definition given above means that, independently of the aircraft type, if a transportation flight is made with commercial purposes it will be considered as commercial aviation. Nowadays, this is the case of several business aircraft, as they operate under commercial charter companies. To further specify the focus of the dissertation, we will consider commercial aviation as all aircraft mainly used for scheduled and non-scheduled transportation services except commercial business aviation.

For several years, the global aerospace industry has shown a revenue expansion with a declining growth trend, mainly driven by budget cuts in the military sector. However, given the large increase in the air transportation demand and global commercial aviation revenues, the last is gaining more and more significance on the global industry numbers (Captain 2016).

Nowadays, the industry’s value chain employs around 1.5 billion high skilled employees around the world, with a wage average 60% higher than general manufacturing industries’ average. The local economic impact of a new aerospace assembly facility is estimated to be as high as US$1 billion a year (World Economic Forum 2016). These numbers show how big the aerospace manufacturing industry is and the major impact it has in various areas of the global and local economy.

2.2.2 Commercial Aviation Market's Characterisation

Commercial aviation, which is defined by passenger and/or cargo transportation (ICAO 2009), is divided in two main segments: 1) mainline aircraft; 2) regional aircraft, where the second is divided in turboprops and jets. As presented in Table 1, these two segments have different competitors, which can be classified as mature or emerging Original Equipment Manufacturers (OEMs) (Bombardier 2015). The regional aircraft segment comprehends aircraft from 60 to 130 seats. Aircraft larger than 130 seats are considered as mainline aircraft. This table considers the single-aisle narrow-bodies mainline jets up to 220 seats. Larger aircraft are usually called wide-bodies (twin-aisle aircraft) and are not considered for this analysis.

For several years, mainline commercial aviation has been a duopoly shared by the United States company Boeing and the European aircraft manufacturer Airbus (Leahy 2016). In the regional aircraft market, the jet segment is dominated by Canadian Bombardier and Brazilian Embraer, while the turboprop segment is divided between Bombardier and Franco-Italian ATR.

The segment where most emerging OEMs are focused is the regional jets segment, with few developments in the mainline jets and turboprops segments. These companies are based in Russia and the Asia-Pacific region, with Chinese AVIC and Comac, Japanese Mitsubishi and Russian Irkut and Sukhoi making this group (Bombardier 2015).

The demand for air transportation is nowadays one of the main drivers of the global aerospace industry growth. Boeing (2016) states that commercial aircraft demand is highly correlated to air transportation demand and identifies its main drivers: a) the ease-of-travel; b) the economic activity; c) local market factors.

Table 1 – Current aircraft of the commercial aviation sector. (Adapted from Bombardier 2015)

		Turboprops	Regional Jets				Medium Range Jets		
Mature OEMs	Airbus						A319	A320	A321
							A319neo	A320neo	A321neo
	ATR	42/72-600							
	Boeing						737-700	737-800	737-900
							737 MAX 7	737 MAX 8	737 MAX 9
	Bombardier	Q400	CRJ700	CRJ900	CRJ1000	CS100	CS300		
	Embraer		E170	E175	E190	E195			
				E170-E2	E190-E2	E-195-E2			
Emerging OEMs	AVIC	MA700							
	Comac			ARJ21-700	ARJ21-900			C919	
	Irkut							MS21-200	MS21-300
	Mitsubishi		MRJ70	MRJ90	MRJ100				
	Shukoi			SSJ100-75	SSJ100-95				

In production
In development
Under studies

Data presented by Captain & Hussein (2017) shows that global airline traffic demand, measured in Revenue Passenger Kilometre (RPK), has been increasing from 1981 to 2016. As we can see in Figure 2, the total number of passengers also increased in the same period and average flight occupancy (load factor) shows the same tendency. Global economic and social events with major impact in the industry, like the Gulf crisis in 1990, 9/11 terrorist attacks in 2001 and the global economic crisis in 2008/2009, can be observed to have slowed or even invert the growth rate trend for a short period. Despite having to deal with multiple market shocks, air-travel industry demand is proven to be resilient to these unexpected events and always return to its historical growth trend in the long term, averaging 5 percent annual growth (Airbus 2016; Boeing 2016b; Embraer 2016).

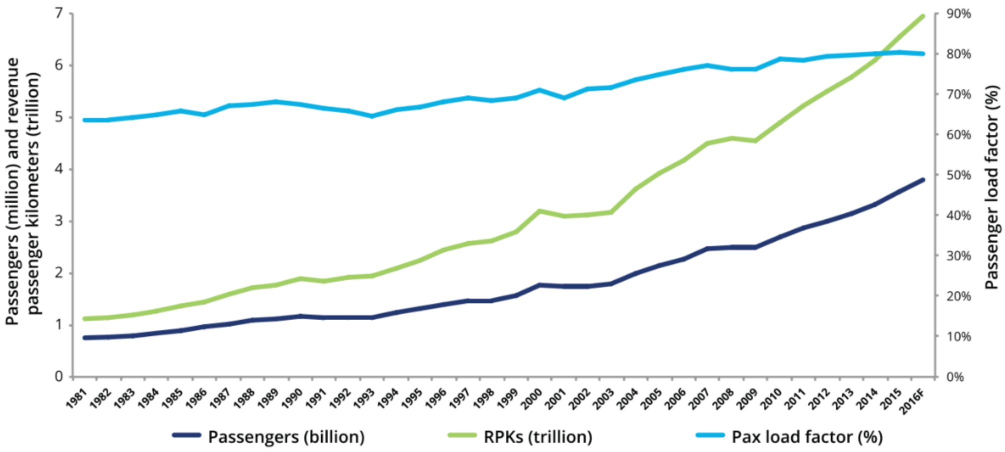


Figure 2 – Global airline traffic evolution from 1981 to 2016. (Captain & Hussein 2017)

Although great variability of the number of orders has been observed in the past years, demand forecasts for new commercial aircraft in the next 20 years are very optimistic. Airbus (2016) forecasted the market's need of around 33000 airplanes until 2035, valuated in US$5.2 trillion, accounting for aircraft with 100 or more seats. By doing so they are leaving most regional airplanes out of their study. Boeing (2016) numbers are even more optimistic, going up to 39600 airplanes, valued in more than US$5.9 trillion for the same period. As opposed to the first forecast, Boeing took regional aircraft in account and, even by forecasting just about 2000 airplanes in this segment, it helped to achieve higher numbers. On the other end, regional aircraft producers like Embraer (2016c) forecasted demand for around 6400 regional jets plus 2000 regional turboprops valuated in US$300 billion. The three forecasts agree the 130-220 seats single-aisle jets segment will be the main driver of the industry's growth, accounting to around 70% of total demand.

Other factors that influence commercial aircraft demand are: 1) Economic growth cycles (Airbus 2017a); 2) the technological innovations (Airbus 2017c); 3) the availability of aircraft financing programs (Airbus 2017a); 4) national and international trade policies (Airbus 2017a; Erdbrink & Clark 2016); 5) the profitability and obsolescence of existing fleets (Boeing 2016b).

As the importance of commercial aviation in the global industry numbers is growing, mostly driven by the increasing demand for air transportation, and therefore for commercial aircraft, the manufacturing supply chain needs to keep up with the demands. The following section will present the airplane life cycle as a starting point for the manufacturing supply chain, which will be presented later.

2.2.3 The Airplane Life Cycle

Airplanes are products with very long life cycles. A typical time frame for an aircraft life cycle is around 30+ years (Beelaerts van Blokland et al. 2010). Design and development are very time-consuming and costly activities, taking from several years or even decades. Production can take several months, depending on the size and complexity of the airplane. The operation is the longest part of the airplane life cycle, being usual to find airframes 25-30 years old still flying daily. During this time, maintenance, repair, retrofit and upgrade activities are preformed to keep the aircraft flying safely and with technology up to date. These activities are essential to make sure the airplane can be in service for so long.

Maintenance, repair and overhaul (MRO) is an important growing segment of the aerospace value chain. Globally, in 2012 the industry spent US$119 billion in MRO and this value is expected to grow up to US$150 billion in 2022 (World Economic Forum 2016).

The MRO supply chain is parallel to the OEMs' supply chain, which will be described in the following section, sharing with it most parts and subassemblies suppliers. Inventory across the supply chain is mandatory with the introduction of MROs, as the production times are long and MRO operations need to be agile. Most of the inventory is held by MRO entities or parts distributors, which have inventory management as one of their core capabilities. This does not mean suppliers and OEMs do not hold inventory. Nowadays, another growing source of parts for MROs is the recycling and recovery phase of the airplane life cycle. After retirement, airplanes are kept in storage and dismantling centres, often including recycling facilities, which take usable parts from old airplanes and re-introduce them through MROs. Unusable parts are sent for material reprocessing. Unrecyclable materials are disposed (Hashemi et al. 2014).

In Figure 3 the airplane life cycle is presented, as well as the position of MROs in the cycle and the spare parts flows. The introduction of recycling and recovery activities in the airplane life cycle can have a major role in reducing environmental impacts of MROs and raw material extraction.

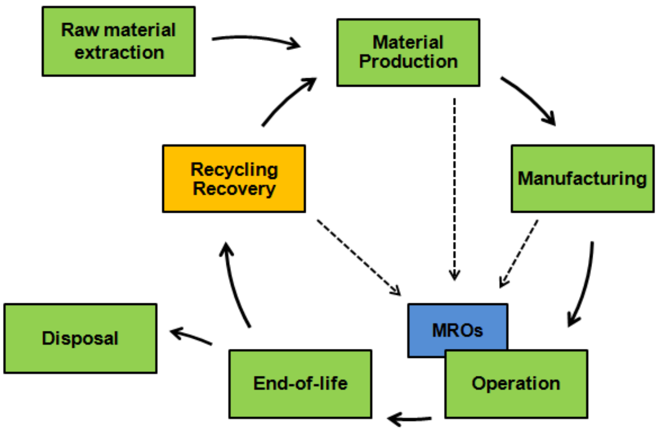


Figure 3 – The aircraft life cycle and MROs spare parts flows. (Adapted from Fraunhofer IBP 2014)

The following section will focus on the raw material extraction, material manufacturing and manufacturing phases of the airplane life cycle, presenting a model for the typical aerospace manufacturing supply chain.

2.2.4 Aerospace Manufacturing Supply Chain

Following the tradition across manufacturing industries, several supply chain models have been applied in aerospace manufacturing though the years. The evolution of the industry's supply chains shows the global trend to apply models based in globalisation and risk-sharing partnerships, evolving from joint ventures, stating that OEM-dominated supply chains are becoming obsolete (Rose-Anderssen et al. 2009). Nowadays, the general aerospace manufacturing supply chain is described as having the OEM as the focal company, with 4 tiers of suppliers upstream and operator downstream, as shown in Figure 4. According to Niosi & Zhegu (2005) and Beelaerts van Blokland et al. (2010), the role of each tier for the generic aerospace supply chain could be:

- Tier-4: raw materials suppliers (extraction and processing of raw materials);
- Tiers-2 and -3: subassemblies and parts suppliers (e.g. electronic components and parts producers; engine components manufacturers);
- Tier-1: module and major assembly suppliers (e.g. airframe structures suppliers; major electric systems suppliers);
- OEMs – Original Equipment Manufacturers: aircraft/engine design and development, final assembly, sales and marketing;

Typically, material flows across the supply chain link all tiers, representing direct flows between entities in every level of the SC.

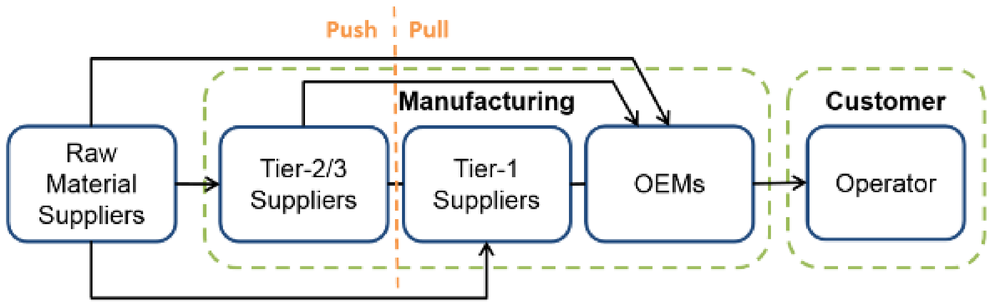


Figure 4 – General aerospace supply chain. (Adapted from Beelaerts van Blokland et al. 2010)

Final assembly starts after the customer confirms the order details and the OEM is ready for final assembly. This means that the industry follows a Push-Pull integration strategy, in which raw material can be transformed into semi-finished products up to a point where the following downstream operations are triggered by customer orders and final assembly rates. The Push-Pull strategy boundary that can move upstream or downstream depending on the part/subassembly/assembly, although it is usually located between tiers-2/3 and 1. The upstream production follows a push-type production, based on forecasts and building inventory, while downstream production controlled by pull-type production (Ghrayeb et al. 2009).

Aircraft lead times are typically long: from several years for new products to a couple years in mature products. This means customers will receive their airplanes several years after putting an order. The main reason for the long lead times is the high complexity of the product with several parts which require special engineering, materials and processes which can rise lead times to several months. Therefore, the global lead time will also be very long (Berson 2015).

The most usual logistics and transportation strategy across the aeroplane manufacturing industry is to develop strategic partnerships with third party logistics (3PLs) or leading logistics providers (LLPs). In some cases, manufacturers develop their own solutions to logistics, to better comply with their specific needs. As an example, Airbus developed a highly-modified cargo airplane, the Beluga, which can transport major assemblies from Tier-1 suppliers to OEMs final assembly facilities very quickly.

Regarding the information flows, it is hard to make a generalisation once there is not a single trend across the global industry. However, as OEM-dominated supply chains became obsolete and joint ventures and risk-sharing partnerships became the main trend, the information flows across the supply chain evolved from single supplier relationships to centralised information systems (Rose-Anderssen et al. 2009).

OEMs

Following this trend, the OEMs' are trying to focus on core competences of designing, assemble and market its products. This is leading these companies to become 'large scale systems integrators' (LSSI). For Beelaerts van Blokland et al. (2010), this is now seen as a requirement for OEMs to be able to maintain a competitive advantage. By adopting the LSSI model, the OEM assumes the role of an integrator of major assemblies that are produced by tier-1 suppliers.

Tier-1

Nowadays, the trend is to increase supplier contribution on the supply chain, involving them by making use of their expertise and knowledge, decreasing global development time and sharing development costs. Following the LSSI theory by Beelaerts van Blokland et al. (2010), the tier concept was redefined, not only implying material flows, but also the functions of the entity. The industry now defines as a Tier-1 a supplier who can design, manufacture, deliver and provide after-market service to a major assembly or system. However, the number of suppliers who can perform all these tasks is still limited and, therefore, the strongest OEMs tend to use all available capacity. Therefore, other OEMs must create their own alternatives, and vertically integrate the production of these major assemblies.

Tier-2/3

This is the tier where most suppliers are located. These suppliers receive raw materials and produce parts and sub-assemblies which will later be assembled by Tier-1 suppliers or by OEMs. Although they are located further up in the supply chain, their activities are closely controlled by OEMs as quality requirements are very high.

Raw materials suppliers

Raw materials suppliers in this industry are closely followed by OEMs. As quality requirements are very exigent, compliance with the norms and previous approval to supply from the OEM is needed, even if they are not supplying directly. The main raw materials used in the industry are aluminium, titanium and, more recently, a variety of composites.

2.3 Problem Characterisation

The supply chain sustainability has been considered as one of the key-themes to achieve corporate sustainability in aerospace manufacturing. Nowadays, companies seek to develop strategies to increase their corporate sustainability, starting by ensuring sustainability across the entire supply chain. However, this is not an easy task as the engagement of all entities is a major requirement, and their management can prove to be an extremely complex task. The following research questions arise when discussing the engagement of stakeholders towards sustainability in the aerospace manufacturing supply chain:

- RQ1: Who are the relevant stakeholders to supply chain sustainability?
- RQ2: How engaged are the relevant stakeholders and how can this engagement be improved?

This dissertation aims to conduct a state of the art, followed by the development of a methodology for stakeholders' analysis and measurement of stakeholder engagement, so that research questions can be answered. A new multimethodology which allows the identification of the most relevant stakeholders, evaluating their engagement towards sustainability will also be developed, and a set of indicators to assess their sustainability performance and their engagement will be suggested.

2.4 Chapter Conclusions

Nowadays, following the increasing demand for air transportation, the commercial aviation sector is becoming the main driver of the global aerospace manufacturing industry. The typical aerospace supply chain currently follows a systems integrator model, where OEMs design, develop, assemble and sell aircraft. Tier-1 suppliers are now expected to design, develop and manufacture major modules and assemblies. However, as capable suppliers are yet not commonly available, the biggest players in the industry tend to use all available capacity. The supply chain is also characterised by high OEM control though the whole chain, and by increasing collaboration. Sustainable supply chain management appears as a key factor for the aerospace development.

Two research questions were derived, regarding supply chain sustainability in the aerospace industry and the stakeholder's engagement. This will be the focus of this dissertation and of the literature review which will be conducted next.

3. State of the Art

This chapter presents a literature review about the theoretical concepts related to this dissertation. A brief literature review about sustainable supply chain management is presented in section 3.1. Section 3.2 presents the concept of Stakeholder Analysis. A literature review of several methodologies related to the previous concept is also presented in this section. In section 3.3, a literature review of indicator development and validation methodologies is presented. Section 3.4 presents a literature review on general sustainability indicators. The chapter ends with section 3.5 presenting the conclusions from this literature review.

3.1 Sustainable Supply Chain Management

Nowadays, increasing globalisation, challenging markets and economic competitiveness allied to the dwindling natural resources is seriously threatening business organisations to sustain their existent supply chains (Gopalakrishnan et al. 2012; Ansari & Kant 2016). According to Ansari & Kant (2016), focusing on internal efficiencies and processes of supply chain is no longer enough to gain a competitive advantage. Today, for companies to achieve a competitive position, it is essential to integrate sustainability concepts and practices in the supply chain. In other words, the sustainable supply chain management (SSCM) is a requirement to the success of business organisations.

Based on the concept of the triple bottom line, Carter & Rogers (2008) defined SSCM as “the strategic, transparent integration and achievement of an organization’s social, environmental, and economic goals in the systemic coordination of key interorganizational business processes for improving the long-term economic performance of the individual company and its supply chains.”

Research on SSCM applied to the aerospace industry, conducted by Gopalakrishnan et al. (2012), identified ten essential elements for deploying sustainability in supply chains, from which we highlight: i) supplier management and integration of supply chain; ii) carbon management across supply chain; iii) review sourcing of raw materials ensuring sustainable procurement; iv) government legislations and external support factors; v) organisational culture and employee involvement.

These elements are in accordance to the findings in Khalid et al. (2015), which established technological integration, long-term relationship development, partner development, joint development, enhanced communication, stakeholder management and innovation as the core SSCM practices. The stakeholders’ engagement relevance in SSCM is therefore undeniable. As a starting point to the study of stakeholders’ engagement, the following section will review methodologies for stakeholders’ analysis.

3.2 Stakeholders’ Analysis

The concept of *stakeholder* was defined by Freeman (1984) in some of the earliest work on stakeholders, as “any group or individual who can affect, or is affected by, the achievement of a corporation's purpose”. During the years, broader and narrower definitions have been presented in stakeholder literature. The first as an attempt to demonstrate the reality that virtually anyone can be affected by an organization's actions; and the latest to face the reality that managers simply cannot attend to all potential or actual claims, and have to prioritise some over the others (Mitchell et al. 1997; Reed et al. 2009). The need for decision makers to understand who is affected by the decisions and actions they take, and who has the power to influence their outcome is becoming increasingly recognized as a critical management tool (Reed et al. 2009). In other words, managing the several and often competing demands and relationships between an organization's different stakeholders is considered one of the most important tasks during strategy making (Ackermann & Eden 2011).

The growing realisation that stakeholders could influence the decision-making process of an organization led to the natural development of approaches for stakeholders analysis (Brugha & Varvasovsky 2000). Although, considered a vital management task, stakeholders are often selected and identified without any specific process or previous planning, leading to the potential marginalisation of important groups and threatening the long-term viability of the process. Therefore, there has been an increasing interest in collecting and defining different methodologies for "stakeholders' analysis" (Reed et al. 2009).

According to Reed et al. (2009), stakeholder's analysis can be characterised as a process that:

1. Defines the issue which will be affected by an action or decision;
2. Identifies the individuals, groups or organizations (i.e. stakeholders) who are affected by or can affect those actions or decisions;
3. Prioritises the stakeholders for involvement in the decision-making process.

Reed et al. (2009) also presented a framework for categorising stakeholders' analysis methodologies based on the purpose each method is used for. Each category is composed by methodologies used for:

1. Identifying stakeholders (section 3.2.2);
2. Differentiating between and categorising stakeholders (section 3.2.3);
3. Investigating relationships between stakeholders (section 3.2.4).

Generally, the majority of the methodologies are used for one purpose only. However, some may be used for more than one – for example, this is the case of Social Network Analysis, which is usually used for identifying relationships between stakeholders, but sometimes can be used for differentiating and categorising them (Reed et al. 2009).

After presenting a few interviewing techniques, the following sections will present several methodologies for stakeholders' analysis, divided using the classification by Reed et al. (2009).

3.2.1 Interviewing techniques for Stakeholders' Analysis

Most Stakeholder's Analysis methodologies involves some type of interviewing to perform tasks such as selecting participants for research, gathering information about stakeholders and their environment, developing scenarios, using stakeholder participation in the analysis, etc. (Wilson 2014).

Three interviewing techniques commonly used for stakeholders' analysis will now be presented. This section comes to an end with a summary of this techniques presented in Table 2.

Focus Groups

A focus group (or group interview) is characterised as a qualitative research method where a facilitator guides a group of five to twelve pre-selected participants in a group interview, with the objective of understanding a wide range of perspectives (Wilson 2014; Lazar et al. 2017). Participants in a focus group are chosen based on the premise they share characteristics relevant for the topic to be discussed (Wilson 2014).

Using as an example the identification of relevant stakeholders, this is done by brainstorming possible stakeholders and trying to find a consensus about the inclusion or exclusion of each identified stakeholder in the analysis. This is typically done by using facilitation materials like flip-charts, post-its, etc., to make the process more visual and therefore easier to follow (Reed et al. 2009).

Although it also comes with expenses, like renting a room for the meeting, food and drink, or high-quality facilitation, this method is considered to be cost-effective as results are typically rapid to obtain. It is also considered to be particularly effective when addressing complex issues that require discussion for knowledge development (Reed et al. 2009). However, depending on the dynamics of individuals or of the group, execution and analysis of the meeting results can become complicated (Lazar et al. 2017).

Semi-structured interviews

A semi-structured interview is characterised by combining predefined questions with open-ended and unstructured questions. The goal of using this method is to gather systematic data about a set of topics, while allowing some exploration of those topics (Wilson 2014).

Interviewers using this approach often use an interview guide which includes and introduction to the purpose and topic of the interview, a list of topics and questions to address, and final comments. However, these interviews are structured in a way that allows the interviewer to change the order and number of predefined questions depending on the answers of the participant (Wilson 2014).

This method is very useful when there is some knowledge about the topic, obtained for example in a focus group, but additional details are still required, given the complexity of the issue or the need for clarification of previous interviews (Reed et al. 2009; Wilson 2014).

The main strengths of this method are uncovering previously unknown information, clarifying complex topics, cross-checking information gathered with other methodologies and providing flexibility for conducting the interview while ensuring a set of topics will be covered. The main weaknesses are the required training and experience of the interviewers to not influence the participant's answers, allowing too much flexibility makes the analysis difficult to make and the fact that the mixture of quantitative and qualitative data is time-consuming to analyse and hence costly (Reed et al. 2009; Wilson 2014).

Structured interviews

Structured interviews are verbal or written questionnaires in which collaboration is limited by a fixed set of questions and minimal deviation. Respondents are usually asked the same questions in the same set of questions in the same order. Closed answers are also used for standardizing responses (Wilson 2014).

This technique is most useful when the objective of the research is to collect standardized information from a large sample of participants. Wilson (2014) recommends the use of structured interviews to obtain general information about demographics, behaviours and relationships, gathering focused information about stakeholders, comparing results across different groups of respondents, or assessing knowledge about a subject.

This kind of interview has as main strengths the advantage of allowing it to be conducted face-to-face or at the distance using phone interviews or collaboration software, the easiness of comparing answers once all the questions and answers are standardised, and less complex interviewer training since they can follow a script (Wilson 2014).

However, there are some disadvantages of using this technique: developing a valid and reliable questionnaire may seem easy, but it is not – you may end up getting detailed answers to the wrong question; the rigid nature of the interview makes the interviewer-respondent connection harder to achieve; the more passive role of participants comes with the risk of highly influencing their answers and ending up not translating their true views about the problem (Wilson 2014).

Table 2 – Interviewing techniques used for Stakeholders' Analysis. (Adapted from Reed et al. 2009)

Technique	References	Description	Strengths	Weaknesses
Focus Groups	Reed et al. (2009); Wilson (2014); Lazar et al. (2017)	A group of 5 to 12 participants brainstorms answers to the problem. Solutions appear following a discussion leaded by a facilitator.	Quick and cost-effective; particularly effective for complex issues which require discussion for developing knowledge.	Execution and analysis can be complicated by the dynamics of individuals working in a group
Semi-structured interviews	Reed et al. (2009); Wilson (2014)	Interviews with a cross-section of themes to check, leaving some flexibility to the conduction of the interview.	Useful to collect data with deeper insight and to cross-check information from focus groups.	Time-consuming and costly. Difficult to generalise the findings.
Structured Interviews	Wilson (2014)	Gathering focused information about stakeholders and their attitudes toward an issue, using a fixed set of questions and sometimes standardized answers.	Very useful to collect uniform data from a large sample. Responses are easily comparable, making data analysis relatively easy. Can be conducted face-to-face, by phone or by collaboration software.	Participants have a more passive role and can be highly influenced. Development of questionnaires may be harder than expected: when done uncarefully there is a high risk of ending up asking the wrong questions.

3.2.2 Stakeholder identification methodologies

Several stakeholders' analysis authors have considered the stakeholder identification process evident and self-constructed, focusing on differentiating and establishing the relationships between them (Reed et al. 2009). However, others say that is necessary to clearly understand and define the issue, so the boundaries of the problem and its reach can be defined, before identifying the stakeholders (Reed et al. 2009). If the boundaries are clearly defined, it is relatively easy to identify the stakeholders, although it is important to remember that the risk of accidentally overlook some stakeholders is real and might have serious consequences for the analysis outcome (Clarkson 1995). On the other hand, the definition of the boundary assumes the exclusion of some stakeholders as a limitation to the research.

From the need to clarify the process of identifying relevant stakeholders, several methodologies were identified or developed. These methodologies usually follow an iterative and participative process, adding more stakeholders to the analysis as it happens (Reed et al. 2009).

Three of these methodologies will be presented next.

Table 3 presents a summary of these methodologies, with references for each method, a brief description of the method, its main strengths and weaknesses.

List evaluation stakeholders

This technique starts with an individual or a small group brainstorming the initial list of individuals, groups or organisations who might affect or be affected by the problem in discussion, i.e. the potential stakeholders (Bryson et al. 2011). This is usually the most basic and initial “back room” work necessary for all other methodologies. The process should never be faced as definitive, being very important to keep in mind that other stakeholders may appear later on (Bryson et al. 2011), but should be faced as an important first step for stakeholders’ analysis.

Radical Transactiveness

Developed by Hart & Sharma (2004), the concept of Radical Transactiveness (RT) seeks to integrate the views of the commonly considered peripheral or “fringe” stakeholders - those who are poor, weak, isolated, non-legitimate, disinterested and non-human - but whose views may provide disruptive change.

Figure 5 shows the difference between “core” and “fringe” stakeholders. Typically, “core” stakeholders are easily identified by other methodologies and are brought into the discussion thanks to their power, legitimacy or urgency. On the other hand, “fringe” stakeholders are often left out as they are invisible, disconnected or just considered too peripheral (Hart & Sharma 2004).

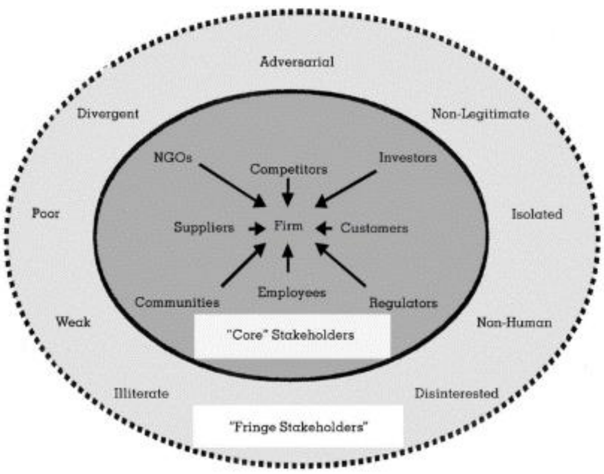


Figure 5 – Core and Fringe Stakeholders. (Hart & Sharma 2004)

The application of this method does not come without the risk of drawing the boundary too far and making the analysis too complex, time-consuming and too costly (Reed et al. 2009). The application of this method also requires additional training to this unusual approach to ensure the engagement of all participants of the analysis (Reed et al. 2009).

Snowball sampling

The concept of snowball sampling has been highly discussed over the years and applied to different procedures (Thompson 2012).

Thompson (2012) highlights the two main network sampling procedures where the term “snowball sampling” has been used:

1. With the purpose of building a sample of a rare population, a few members of that population is asked to identify other members of the population, to contact them and ask to identify more members, and so on (Kalton & Anderson 1986).
2. With the purpose of mathematically estimate the number of social circles or mutual relationships within a population, individuals in the sample are asked to identify a previously fixed number of other individuals, who are then asked to identify other individuals. This process is only repeated for a fixed number of stages (Goodman 1961).

In the stakeholders' analysis context, Reed et al. (2009) proposes to use this method in a simpler way, closer to the process described by Kalton & Anderson (1986): a small set of stakeholders is interviewed and asked to identify more stakeholders or stakeholders categories, providing their contacts. The process is then repeated with the identified stakeholders until all relevant parts are identified.

The main strengths of this method are the easiness of securing interviews, as these are simple, quick and do not require data protection, the capacity to reach stakeholders that are not easily contactable, and the cost-effectiveness of the process (Reed et al. 2009).

As a main weakness of snowball sampling, Reed et al. (2009) highlights the possibility of social networks of earlier participants to influence the final sample.

Table 3 – Methodologies for identification of stakeholders. (Adapted from Reed et al. 2009)

Methodology	References	Description	Strengths	Weaknesses
List evaluation stakeholders	Bryson et al. (2011)	An individual or a small group brainstorms to reveal a broad list of potential stakeholders.	Very basic technique very useful as a starting point to other methodologies.	High risk of not identifying relevant stakeholders.
Radical Transactiveness	Hart & Sharma (2004); Reed et al. (2009)	Identifies weak and fringe stakeholders using a snowball sampling approach.	Identifies stakeholders otherwise left out from analysis, reducing the risk of not taking their stake into account.	Bringing more entities to the analysis makes it more complex, time-consuming and costly.
Snowball Sampling	Goodman (1961); Kalton & Anderson (1986); Reed et al. (2009); Thompson (2012)	An initial group of stakeholders identifies other stakeholders and provide their contacts. Repeat the process with the identified stakeholders.	Easier to secure interviews without data protection. Fewer interviews declined.	Sample might be influenced by the social networks of the first group or individual.

3.2.3 Stakeholders differentiation and categorisation methodologies

The methodologies used for stakeholders' differentiation and categorisation tend to follow two major approaches: i) analytical categorisations and; ii) reconstructive categorisation (Reed et al. 2009).

Analytical categorisations are those methodologies in which the classification is made by the ones conducting the analysis, and therefore with no stakeholders' participation, based on their observation of the issues and previous theoretical knowledge about the problem and its environment (Hare & Pahl-Wostl 2002). These categorisations are often presented in form of matrices or Veen diagrams, graphic ways of presenting the relative evaluation of stakeholders on two or more attributes (Reed et al. 2009).

Reconstructive categorisation methodologies were developed in response to the major limitation of analytical categorisations. Contrary to the last, this set of methodologies allows stakeholders participation during the analysis process by allowing, for example, parameters definition and categorisation to be done by stakeholders themselves. This approach guaranties stakeholders' concerns to be more closely reflected on the analysis (Hare & Pahl-Wostl 2002).

Power-interest grid

This analytical categorisation comes from the early identification by several authors of power and interest as significant dimensions of the stakeholders' analysis (Ackermann & Eden 2011). The plot of this two dimensions in form of a grid, as seen in Figure 6, can provide a tool for managers to better understand their environment or to proactively manage their stakeholders (Ackermann & Eden 2011).

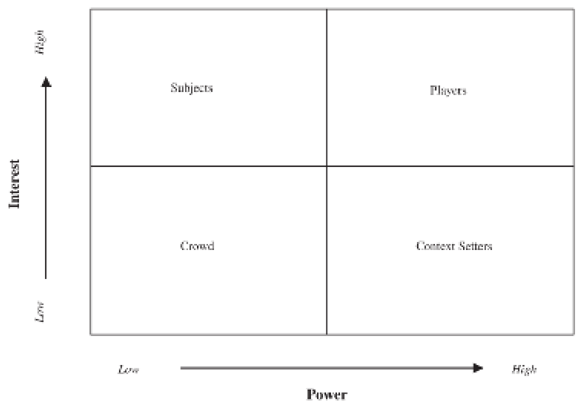


Figure 6 – Power-interest grid. (Eden & Ackermann 1998, p.122 *in* Bryson 2004)

Stakeholder literature has failed in providing a precise and consistent definition to the concept of 'power'. However, as pointed out by Mitchell et al. (1997), most definitions derive from the idea that power is "the probability that one actor within a social relationship would be in a position to carry out his own will despite resistance" (Weber 1947).

Regarding the concept of 'interest', Bryson et al. (2011) points the political stake meaning of the concept, as opposed to the simple inquisitiveness: the concern, the responsibility and the involvement feelings are key to the "interest" definition. Interest can be positive or negative to the project. In other words, high interest can come from strong supporters or from strong opponents (Ackermann & Eden 2011).

The result of this analysis is the categorisation of stakeholders into four groups, as shown in Figure 6, depending on their placement on the grid (Bryson 2004; Ackermann & Eden 2011; Bryson et al. 2011): 1) players; 2) subjects; 3) context steers; 4) crowd.

Power, Urgency and Legitimacy diagram

Presented by Mitchell et al. (1997), this method classifies each stakeholder accordingly to his power, urgency and legitimacy towards the issue in discussion.

While the definition of power can be the same as the one used in the previous method, the concepts of urgency and legitimacy need clarification. Mitchell et al. (1997) defines “urgency” as “the degree to which stakeholder claims for immediate call”, while “legitimacy” is defined as the general perception that the stakeholder’s actions are proper, or appropriate and congruent within the value system of the society in which it operates (Mitchell et al. 1997; Magness 2008).

Following the characterisation of this method by Mitchell et al. (1997), the analytical categorisation provided by this technique places stakeholders in a Venn diagram like the one presented in Figure 7.

Figure 7 – Power, Urgency and Legitimacy diagram. (Mitchell et al. 1997)

The placement of stakeholders on the diagram classifies them into 7 categories: 1) Dormant stakeholders; 2) Discretionary stakeholders; 3) Demanding stakeholders; 4) Dominant stakeholders; 5) Dangerous stakeholders; 6) Dependent Stakeholders; 7) Definitive Stakeholders.

Support versus Opposition Grid

Developed for strategic management planning purposes by Nutt & Backoff (1987) as a “Feasibility assessment”, this technique was later presented by Bryson (2004) as a “Problem-frame stakeholder map” which is useful in helping to develop problem definitions likely to lead to successful partnerships. In Bryson et al. (2011) it is adapted as a method useful to access the viability of evaluation recommendations and presented as an “Evaluation recommendation support versus opposition grids”.

Part of the analytical characterisations, this method relies on the perception and expertise of the evaluation team to rank each stakeholder in terms of their support or opposition towards an issue (Nutt

& Backoff 1987; Bryson 2004) or a recommendation (Bryson et al. 2011), and in terms of the stakeholder power or importance.

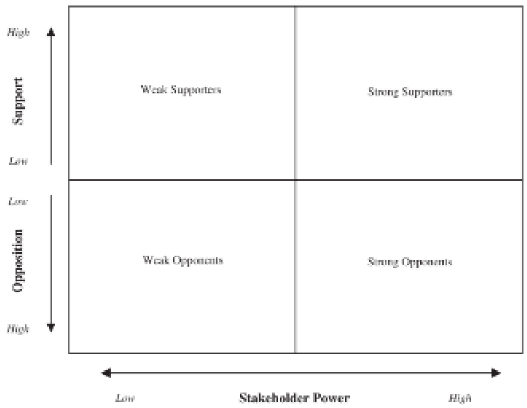


Figure 8 – Support versus Opposition grid. (Bryson 2004)

As a final output of this method, accordingly to their final position on the grid, like the one in Figure 8, stakeholders are classified as problematic, antagonistic, low priority or advocates (Nutt & Backoff 1987) or as weak opponents, strong opponents, weak supporters and strong supporters (Bryson 2004; Bryson et al. 2011).

Table 4 presents a summary of three methodologies used for stakeholder differentiation and categorisation.

Table 4 – Methodologies for stakeholder differentiation and categorisation. (Adapted from Reed et al. 2009)

Methodology	References	Description	Strengths	Weaknesses
Power-interest grid	Bryson (2004); Ackermann & Eden (2011); Bryson et al. (2011)	Stakeholders are placed on a matrix according to their relative power and interest and classified accordingly to their position on the matrix.	Possible to prioritise stakeholders for inclusion; makes power dynamics explicit.	Prioritisation may marginalise certain groups; assumes stakeholder categories based on power-interest are relevant.
Power, Urgency and Legitimacy diagram	Mitchell et al. (1997); Magness (2008)	Stakeholders are evaluated regarding their power, urgency and legitimacy, placed in a Venn diagram and classified accordingly to their position.	Classification of stakeholders is very useful for effort and attention prioritisation.	Miss-comprehension of the attributes can lead to wrongful analysis.
Support versus opposition grid	Nutt & Backoff (1987); Bryson (2004); Bryson et al. (2011)	Rank stakeholders accordingly to their support vs opposition and to their power towards an issue. Plot the results into a matrix.	Provides managers with a classification which tells who is with or against them.	Risk of stakeholder marginalisation. Results can be influenced by the evaluation team.

3.2.4 Methodologies for investigating relationships between stakeholders

As a final step for the stakeholders' analysis, methodologies for investigating relationships between stakeholders regarding a particular issue have been developed. Most of these methodologies require previous categorisation of stakeholders, while some provide a complete analysis like the SSM method.

Actor-linkage matrices

This method is used to describe stakeholders' relationships by building a matrix with their names in the rows and columns and classifying each of their relationships with keywords such as "conflict", "complementary" or "cooperation" (Reed et al. 2009).

The methodology is very simple an cheap to apply, making it very useful for analysis where, due to resources limitations, research may be need to be done without the use of computers (Reed et al. 2009). However, it does not provide an in-depth analysis of the relations and therefore should not be faced as very meaningful.

Participation Planning Matrix

Presented by Bryson (2004) and further explored by Bryson et al. (2011), the participation planning matrix appears as a specific method for planning stakeholder participation in the strategic management process. Participation levels range from non-participants (Bryson et al. 2011) to empowering roles such as final-decision authority (Bryson 2004). To implement this method, a matrix with tasks in the rows and functions – such as *inform, consult, involve, collaborate* and *empower* – in the columns is built, followed by the placement of stakeholders' names across the matrix, specifying who has each role in each task (Bryson 2004; Bryson et al. 2011). This method is presented in a very similar way to the Responsibility Assignment Matrix (RACI Matrix), made famous by the PMBOCK Guide from the Project Management Institute. The main difference between the two matrices is the position of stakeholders and their functions. The RACI Matrix is presented with the stakeholders in columns and their function towards a task specified in the matrix body, providing a better picture of all functions each stakeholder has regarding all tasks.

Social Network Analysis (SNA)

Similar to the actor-linkage matrices, the Social Network Analysis, as described by Reed et al. (2009), uses similar matrices to establish relationship ties between stakeholders. The concept was created based on the idea that "social environment can be expressed as patterns or regularities in relationships among interacting units" (Wasserman & Faust 1994). Therefore, those ties are characterised by numbers (instead of keywords) which represent the existence or absence of a relationship and the relative strength of the relationship. The analysis comprehends several matrices, each representing a relationship such as communication, friendship, advice, trust, etc. (Reed et al. 2009). To conduct the SNA, data is typically obtained via structured interviews, questionnaires or observation (Wasserman & Faust 1994). Although the methodology is very useful to gain insight of the stakeholder network, identifying and quantifying their connections and establishing influential and peripheral stakeholders' categorisation, it is also time-consuming and hence costly, needs a specialist to conduct the analysis and the questionnaire can become tedious for the respondents.

Stakeholder Influence Network

Ackermann & Eden (2011) present this technique as a natural evolution of the power-interest grid (section 3.2.3), as a need for exploring interactions between stakeholders on this broadly used representation. The stakeholder influence network represents influence relationships by linking stakeholders with arrows to indicate the direction of their influence (Bryson et al. 2011). Although two-way influences are possible, an effort should be made to characterise the main direction of influence between two stakeholders (Bryson 2004). This analysis brings a new perspective on how to manage stakeholders' power and interest since it is possible, for example, to find extremely well connected stakeholders which were classified as having low power and interest, or powerful and highly interested stakeholders who lack connections (Ackermann & Eden 2011).

The process of building this network, as represented in Figure 9, starts with a previously defined power-interest grid. The evaluation group used to build the power-interest grid should then suggest and discuss influence connections between stakeholders, as well as their direction, while a facilitator draws the arrows. When final agreement is reached, a network which includes all stakeholders should be achieved (Bryson 2004; Ackermann & Eden 2011).

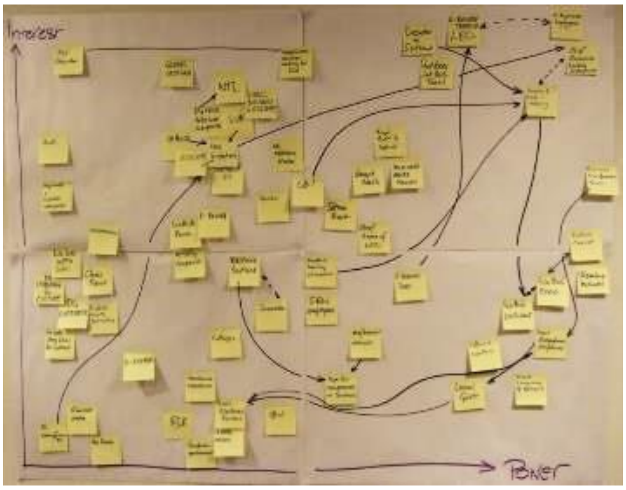


Figure 9 - Early stages of the stakeholder influence network. (Ackermann & Eden 2011)

<u>Value Flow Mapping</u>

Developed by Cameron et al. (2008), this method is characterised by identifying, grouping and mapping complex relationships between stakeholders, based on their added value to the problem resolution.

It starts by grouping stakeholders into categories and then identifying the inputs and outputs each category requires to add value during the problem resolution. After modelling each category, the next step it to connect stakeholders using the previously identified inputs and outputs. Resulting flows are classified regarding the nature of the relationship they represent (Cameron et al. 2008). As an example of the final map, Figure 10 presents the simplified value flow map of a stakeholders' analysis of a large government program.

It is important to refer that depending on the number of nodes (stakeholders' categories) or level of detail of the model, the analysis can identify a few to hundreds of connections between stakeholders (Cameron et al. 2008), possibly making the analysis too complex to be used in a practical way.

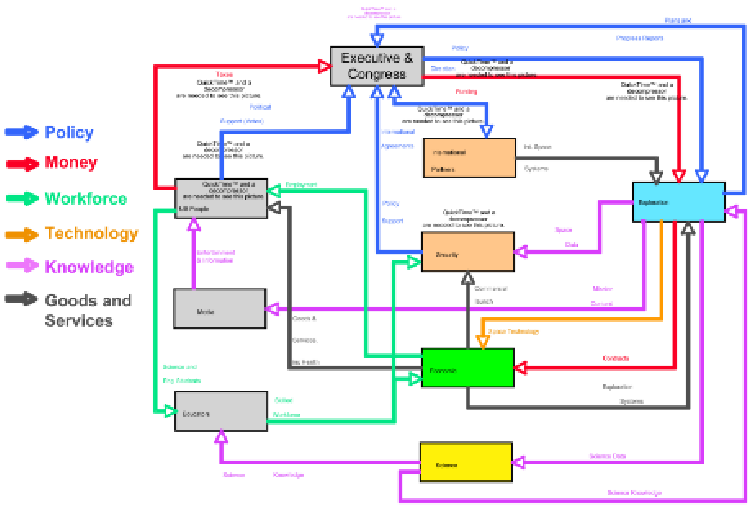


Figure 10 – Example of a Value Flow Map. (Cameron et al. 2008)

In this section, a collection of four methodologies developed to investigate stakeholders' relationships was presented. Table 5 presents a summary of those methodologies.

Table 5 – Methodologies for investigating relationships between stakeholders. (Adapted from Reed et al. 2009)

Methodology	References	Description	Strengths	Weaknesses
Actor-linkage Matrices	Reed et al. (2009)	Describes stakeholders' relationships on a matrix with using keywords.	Simplicity of use and flexibility. Very low cost.	Lack of complexity. Analysis might be too simple.
Participation Planning Matrix	Bryson (2004); Bryson et al. (2011)	Matrix with stakeholders in the columns and tasks in the rows. Specifies the level of participation of each stakeholder in each task.	Visual representation of stakeholder participation in tasks makes it easy to understand their involvement.	Complex relationships can be hard to understand from this information alone.
Social Network Analysis	Wasserman & Faust (1994); Reed et al. (2009)	Used to identify the network of stakeholders and measuring relational ties between stakeholders through use of structured interview/ questionnaire.	Gain insight into the boundary of stakeholder network; the structure of the network; identifies influential stakeholders and peripheral stakeholders.	Time-consuming; questionnaire is a bit tedious for respondents; need specialist in the method.
Stakeholder Influence Network	Bryson (2004); Bryson et al. (2011); Ackermann & Eden (2011);	Based on the power-interest grid, establishes influence connections and direction between stakeholders.	Brings connections to the discussion, giving a new perspective about how to manage stakeholders' power and interest.	Time-consuming. Analysis can be influenced by the evaluation team.
Value Flow Mapping	Cameron et al. (2008)	Identifies and represents complex relationships between stakeholders' categories, based on their added value to the problem.	Captures stakeholders needs and relates them to the outcomes required to create value to the organisation or problem.	Can become too complex and time-consuming to be easily used in a practical way.

After a complete stakeholders' analysis, composed by methodologies like the ones presented before, there is the need to measure the stakeholders' performance to solve the given issue. The following section will review methodologies to develop and validate indicators, as these are the most common tool to measure stakeholder performance.

3.3 Indicator Development and Validation Methodologies

Indicators are quantitative or qualitative measures used to interpret the complex world around us, in such a way that makes it easily understood, when a direct measurement is not possible for financial or technical reasons (Mitchell et al. 1995). The use of indicators in business management is tightly related to the need of tracking the organisation's progress in a measurable way as a tool to help the decision-making process and achieve success. Popova & Sharpanskykh (2010) defines these indicators as *Performance Indicators*. The definition by Parmenter (2015) goes further, presenting the performance indicators as well established measures of business performance which allow managers to identify problems and to directly act to significantly increase performance. However, Parmenter (2015) alerts to the fact that many companies have been using these measures in the wrong way. Unfortunately, performance indicators often fail to represent performance, but instead highlight problems of performance measurement. Clarification regarding the development and validation processes of performance indicators is therefore needed.

3.3.1 Indicators development process

Regarding the development process, Kueng (2000) identifies two approaches to produce appropriate performance indicators: i) using a generic set of indicators and choose the relevant ones; ii) start building indicators from scratch. While starting with a generic set of indicators seems to be more efficient, there are some issues regarding this method: 1) there is no generally accepted list of indicators and the available indicators are often built with imprecise definitions or related to processes incongruent with the one, which is being measured; 2) the process of choosing and selecting indicators from a list requires well-established and sufficiently discriminative selection criteria that can be hard to define; 3) achieving acceptance and ownership of the chosen indicators is quite difficult (Kueng 2000).

The second alternative – building from scratch – tends to be preferable since the indicators are custom-made and, therefore, highly adapted to the process to be measured. The personal involvement in the process of building appropriate performance indicators also plays a major role when looking to the level of acceptance and ownership (Kueng 2000). To develop performance indicators, Kueng (2000) presents a four step process presented in Figure 11. This process relies on the construction of a goal tree in which a performance indicator is developed to and connected to each goal. Steps 2, 3 and 4 should be repeated as many times as needed until a clear set of goals and performance indicators is developed.

As a way to set the direction and clearly defining goals, Kueng (2000) highlights the need to set target values to each performance indicator. Simulation experiments, stakeholder participation, competitive benchmarking or research institutions can be an input source to set these numbers.

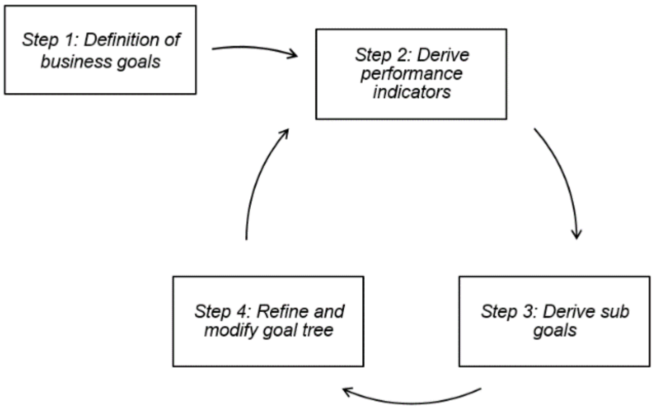


Figure 11 – Performance indicators development process.

Mitchell et al. (1995) presented the methodological framework 'PICABUE' for the development of sustainability indicators. The 'PICABUE' method gained its name from its seven steps:

1. Principles – defines the objectives of the performance indicators programme (business goals);
2. Issues – identifies the issues of concern;
3. Construct – select or build indicators of the issues of concern;
4. Augment – expand the set of indicators by relating them to the objectives identified in step 1;
5. Boundary – modify indicators from step 4 to address boundary issues (e.g. measuring cross-boundary flows);
6. Uncertainty – develop or modify indicators from step 4 to account with uncertainty;
7. Evaluate – review the final performance indicators.

Mitchell et al. (1995) also identified three approaches regarding the construction of indicators and the available data: i) many specific indicators; ii) a few composite indicators; iii) key and simple composite indicators. There are advantages and disadvantages of using each approach. For example, while using the first approach, very specific indicators will be developed at the cost of having an often too large set of indicators to evaluate.

Although having different levels of detail regarding the process of developing indicators, the methodologies presented by Mitchell et al. (1995) and by Kueng (2000) agree on the early definition of goals and objectives, the constant reviewing process of constructing indicators and on the need to evaluate and validate indicators. The process of validating indicators will be presented next.

3.3.2 Indicators validation process

The indicator validation process usually comes to the validation of indicators proprieties (Roubtsova & Michell 2013). This phase of the indicator development process is often postponed until the implementation of indicators, using the real data to validate indicators' proprieties. However, leaving validation for the implementation phase can result in creating ineffective indicators (Roubtsova & Michell 2013), leading to wrongful analysis or, if the inefficiency is identified, the need to come back to the design phase.

To avoid additional costs and wrong decisions based in inefficient indicators, Roubtsova & Michell (2013) suggest the creation of an abstract business process to allow the validation of performance indicators during the design phase.

A simple approach is to validate proprieties for every indicator developed. By critically evaluating and testing each propriety, performance indicators can be considered effective or ineffective. Some authors defend the use of mathematical and computer models to perform this evaluation (e.g. Roubtsova & Michell 2013). If the indicator is considered inefficient, problems can be linked to a single or several proprieties. As an example, Kueng (2000) presents six proprieties of performance indicators, which are described in Table 6, and should be fulfilled to ensure relevant and efficient indicators are built. Table 6 also presents an example of validation techniques regarding each propriety.

Table 6 – Example of performance indicators proprieties and validation techniques.

Propriety	Description	Validation Technique
Quantifiability	Indicators must be presented as a number. Qualitative concepts must be transformed into numbers.	The process of derivation of numbers from qualitative concepts validates itself (just make sure every indicator is presented as a number).
Sensitivity	Minor performance changes should be detected by the indicator.	Using fictional values, test if minor argument changes are perceived in the result.
Linearity	Linear dependency between performance change and indicator change is preferred.	Using fictional values, test if minor argument changes result in minor results changes. Do the same with high values.
Reliability	The results must be free of systematic errors and correctly calculate performance in normal and unexpected circumstances.	Empty set of assumptions needed to derive the indicator prove reliability.
Efficiency	Indicators must be cost-effective to produce and measure.	Critically evaluate if the benefit of producing and measuring the indicator is higher than its cost.
Improvement-oriented	Indicators should provide improvement directions instead of evaluating conformity to the plans.	Empty set of scenarios allowing indicator manipulation to meet planed values.

Since the main subject to be studied in this dissertation is related to the sustainability theme, the following section will present a literature review about sustainability performance indicators.

3.4 Sustainability Indicators

The sustainability performance measurement has been considered an emerging topic both in academia and in practice (Piotrowicz & Cuthbertson 2015; Antolín-López et al. 2016). Following the process to develop metrics, the goals and dimensions of sustainability to be considered must be precisely defined. Therefore, in this section, the sustainability indicators will be presented by establishing usual goals and sub-dimensions of sustainability rather than presenting ratios and formulas. Among the literature, there is a general consensus of using the three pillars of sustainability (economic, environmental and social) as a starting point for defining sub-dimensions. This section will present a literature review on general sustainability indicators, derived from the dimensions and sub-dimensions.

3.4.1 Economic Pillar

The economical pillar of sustainability is the representation of the organization's competitiveness in the markets, both in the short and long terms. It is also measures the creation of value by the organization and its stakeholders (Rodrigues et al. 2016). The standards by GRI (2015) refer the importance of measuring economic performance at the local, national and global levels. The importance of this pillar for global sustainability is confirmed by the fact that environmental and social pillars of sustainability can only be a concern for an organisation if economical sustainability is guaranteed (Carvalho 2016). Furthermore, Antolín-López et al. (2016) describes the close relation between the economic and social pillars, presenting the concept of socio-economic sustainability, and stating that economic prosperity is the major driver for raising the living standards of the society and, therefore, providing social sustainability. A list of economic sub-dimensions of sustainability is presented on Table 7, providing references in the literature. These are divided into three areas of economical sustainability assessment, suggested by Carvalho (2016): i) Supply Chain Assessment; ii) Operational Process Assessment; and iii) Investment Process Assessment.

Table 7 – Economic sub-dimensions of sustainability. (Adapted from Antolín-López et al. 2016)

Economic sub-dimensions		**Verfaillie & Bidwell (2000)**	**ISO 26000 (2010)**	**Piotrowicz & Cuthbertson (2015)**	**GRI (2015)**	**Antolín-López et al. (2016)**	**Rodrigues et al. (2016)**
Supply Chain Assessment	Financial support from government		x		x	x	
	Future Liabilities	x			x		
	Market Presence	x	x		x	x	
	Indirect Economic Impacts				x		
	Procurement Practices		x		x	x	x
	Product Value			x			
Operational Process Assessment	Profit and Revenue	x			x	x	x
	Efficiency and costs	x			x	x	
	Employee Compensation		x		x	x	
	Quality			x			
	Risk and Crisis Management		x	x	x	x	x
Investment Process Assessment	Investment and innovation			x		x	x
	Investors relationship						x

If these sub-dimensions/goals of sustainability are in the same direction as the organisation's values and objectives, indicators which can measure them should be developed, following the processes presented in 3.3 Indicator Development and Validation Methodologies.

3.4.2 Environmental Pillar

There is a general agreement about environmental pillar of sustainability representing the "organisation's impacts on living and non-living natural systems, including ecosystems, land, air, and waters" (GRI 2015, p.52). While the boundaries between the economic and social pillars are often hard to establish, the boundaries for the environmental pillar of sustainability are well defined (Antolín-López et al. 2016). Following the previous approach, Table 8 presents an extensive list of environmental impact classes and categories, rather than actual indicators. These impact categories are usually converted into indicators and measured by using the life cycle assessment (LCA) approach and its several methodologies, as presented by Carvalho et al. (2014), who also proposed the categorisation of impact classes into: i) ecological impacts; ii) human health impacts; iii) resources impacts; and iv) other impacts.

Table 8 – Environmental impact classes and categories. (Adapted from Carvalho et al. 2014)

Ecological	Human Health	Resources	Other
• Acidification	• Carcinogenic	• Abiotic resources	• Damage to build structures
• Acidification/ eutrophication	• Causalities	• Base cation capacity	• Noise
• Air pollution	• Human health	• Biotic resources	• Product specific emissions
• Bioaccumulation	• Human health-other effects	• Crop production capacity	• Green product & packaging
• Damage to flora	• Human toxicity	• Element reserves	• Green suppliers
• Ecotoxicity	• Ionising Radiation	• Energy	• Environmental reporting
• Eutrophication	• Life expectancy	• Fish & meat production capacity	• Environmental compliance
• Extinction of species	• Morbidity	• Gravel execution	• Environmental risk
• Fish toxicity	• Non-carcinogenic	• Land use	
• Global warming	• Nuisance	• Mineral resources	
• Hazard substances	• Respiratory effects	• Natural resources	
• Heavy metals		• Non-renewable energy	
• Hydrosphere pollution		• Non-renewable, fossil	
• Impairment of soil fertility		• Non-renewable, metals	
• Malodorous air		• Non-renewable, nuclear	
• Oxygen consumption		• Non-renewable, primary forest	
• Ozone Layer depletion		• Production capacity for water	
• Particulate matter		• Raw material consumption	
• Persistent organic pollutants		• Recycling effect	
• Photochemical oxidation		• Renewable energy	
• Volatile organic compounds		• Renewable, biomass	
• Waste		• Renewable, geothermal	
• Waste heat		• Renewable, solar	
		• Renewable, wind	
		• Resources consumption	
		• Water	
		• Wood production capacity	

3.4.3 Social Pillar

The social pillar of sustainability is defined by GRI (2015) as the organisation's impacts on the social systems in which it operates. Social indicators are related to a variety of societal impacts, about which the evaluation is highly dependent of human intuition and expertise. They are mainly related to qualitative criteria and are, therefore, hard to quantify (Carvalho 2016). Subsequently, several indicators have been developed to assess different social impacts (Shokrian et al. 2015). Following the same approach as in the previous sections, Table 9 presents a list of goals/sub-dimensions for social sustainability, rather than the indicators themselves. These sub-dimensions are divided into three categories, as proposed by Carvalho (2016): i) social life cycle; ii) health and safety; and iii) labour conditions.

Table 9 – Social sub-dimensions of sustainability. (Adapted from Antolín-López et al. 2016)

Social sub-dimensions		ISO 26000 (2010)	Piotrowicz & Cuthbertson (2015)	GRI (2015)	Antolín-López et al. (2016)	Carvalho (2016)	Rodrigues et al. (2016)
Social Life Cycle	Corporate citizenship				x	x	
	Local commitment			x	x		
	Bottom of the Pyramid				x		
	Anti-corruption			x		x	x
	Fair business and competition	x		x		x	x
	Human Rights	x		x	x	x	
	Quality Management				x		
	Consumer health and safety	x		x	x	x	
	Marketing Communications			x			
	Customer privacy			x			
	Customer satisfaction					x	
	Stakeholder involvement	x				x	x
	Supplier/partner development			x			x
Health and Safety	Type and rates of Injuries/accidents		x	x		x	
	Heat of Reaction					x	
	Flammability Index					x	
	Toxic Exposure Index					x	
	Explosively Index					x	
	Temperature index					x	
	Pressure Index					x	
	Corrodibility Index					x	
	Equipment Safety Index					x	
	Noise Exposure Index		x				
	Layout					x	
Labour Conditions	Job creation			x		x	x
	Talent attraction and retention		x	x			x
	Diversity and equal opportunity			x			
	Benefits/promotions			x		x	
	Employee training and development		x	x	x	x	x
	Employee satisfaction		x				
	Supplier conditions assessment			x			

3.5 Chapter Conclusions

Nowadays, the relation between Sustainable Supply Chain Management and Stakeholder Engagement is undeniable. The level to which stakeholders are involved and integrated in the strategy of the supply chain is critical to the success of organisations and to achieve sustainability. To evaluate the stakeholder engagement, an in depth and integrated stakeholders' analysis is needed. Although several methodologies have suggested different approaches to the stakeholders' analysis, the literature is lacking a single methodology which can assess all phases of the analysis in a systematic way: 1) identifying stakeholders; 2) differentiating between and categorising stakeholders; 3) identifying relationships between stakeholders. Several interviewing methodologies can be used during stakeholders' analysis to ensure stakeholder participation. While focus groups are good for gaining knowledge about a theme which requires discussion, semi-structured interviews are useful to gain a deep insight on individual opinions, and structured interviews very useful to collect uniform data from a large sample.

The development and validation of indicators processes are essential to ensure the efficiency and quality of indicators. Although commonly used, the development of indicators starting with a general list of indicators can prove to be a wrongful and inefficient process. The development of indicators must start by clearly establish the organisation's goals, sub-goals and dimensions of concern, and developing metrics which are capable of measuring performance regarding those goals. The indicator validation process comes to verifying if the indicator respects a certain set of rules, such as the ones presented by Kueng (2000).

To assess sustainability performance, sustainability indicators must be developed to each of the pillars of the 3BL, based on the goals and sub-dimensions of impact that are considered most relevant in the context of study.

4. Methodology

This chapter presents the methodology which has been followed during the development of the dissertation. Section 4.1 presents a new multimethodology for an integrated stakeholders' analysis. The methodology followed to measure the stakeholders' engagement towards sustainability, based on a sustainability performance assessment, is presented in section 4.2. The chapter ends with section 4.3 presenting the conclusions.

4.1 Stakeholders' Analysis

To answer the first research question, "Who are the relevant stakeholders to supply chain sustainability?", a compete stakeholders' analysis will be conducted.

The Stakeholders' Analysis methodology used in this dissertation is mainly inspired in the work presented by Reed et al. (2009), who described the process has having three main steps: (1) defining the issue; (2) identifying the stakeholders; (3) prioritising the stakeholders for involvement in the decision-making process. However, these authors present several stakeholders' analysis methodologies which are typically focused on steps 2 and 3 and are used for one of the following purposes: i) identifying stakeholders; ii) differentiating between and categorising stakeholders; iii) investigating relationships between stakeholders.

The methodology for Stakeholders' Analysis to be used in this dissertation, is significantly different and follows a novel approach, presenting an integrated multimethodology for a complete analysis. This approach is based in the suggestions presented by Mingers & Gill (1997), which described the benefits of using more than one methodology in management sciences. The proposed multimethodology comprehends the application of three tasks (A, B, and C) and six steps (1 to 6). The multimethodology for the Stakeholders' Analysis is represented in Figure 12.

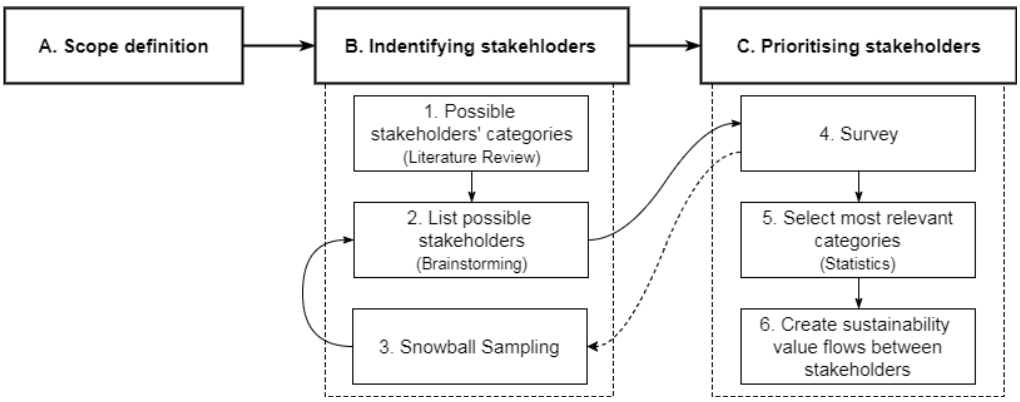


Figure 12 – Multimethodology for the Stakeholders' Analysis

The following sections describe in detail the methodologies that were used during the development of the dissertation, which originated this novel multimethodology approach to the stakeholders' analysis.

4.1.1 Task A – Scope Definition

The objective of task A is to define the scope of the study by clearly defining its boundaries. The boundaries are established by defining the industry/sector, the context/stage and the main subject. In this case, the scope of the stakeholders' analysis is defined by the boundaries presented in Table 10.

Table 10 – Boundaries for the stakeholders' analysis

Industry/Sector	Context/Stage	Main Subject
Aerospace Industry/ Commercial Aviation	Sustainable supply chains	Identifying relevant stakeholders and their engagement

4.1.2 Task B – Identifying Stakeholders

Task B consists on the identification of the stakeholders. It comes as a variation of the List evaluation stakeholders method, as presented by Bryson et al. (2011), where the brainstorming is supported by a previous literature review and definition of stakeholders' categories (e.g. suppliers, customers, etc.). This task comprehends steps 1, 2 and 3 of the multimethodology, which are described next.

Step 1 – Possible stakeholders' categories

In step 1, a list of possible stakeholders' categories is built based on a literature review. The classic work by Freeman (1984) presents several stakeholders categories in the definition of the 'stakeholder view of the firm' and for 'very large organisations'. Only the "core" stakeholders suggested by these authors were considered. Freeman et al. (2007) presented a basic two-tier stakeholder map, where primary and secondary stakeholders' categories are differentiated. Primary and secondary supply chain stakeholders' categories are suggested by Cetinkaya et al. (2011). The categories suggested by each work are presented in Table 11.

Table 11 – Stakeholders' categories literature review

Stakeholders' Categories	Freeman (1984)	Hart & Sharma (2004)	Freeman et al. (2007)	Cetinkaya et al. (2011)
Activist Groups	x			
Competitors	x	x	x	x
Consumer Advocate Groups	x		x	
Consumers				x
Customers	x	x	x	x
Employees	x	x	x	x
Governments	x		x	x
Infra-structure Operators				x
Interest Groups			x	x
Investors and Financial Institutions	x	x	x	x
Local Communities	x	x	x	x

Table 11 – Stakeholders' categories literature review (cont.)

Stakeholders' Categories	Freeman (1984)	Hart & Sharma (2004)	Freeman et al. (2007)	Cetinkaya et al. (2011)
Management Board				x
Media	x		x	x
NGOs	x	x		x
Regulators		x		
Scientific Community				x
Services Providers				x
Shareholders	x			x
Society at large				x
Suppliers	x	x	X	x
Trade Associations	x			
Unions	x			

Step 2 – List possible stakeholders

In step 2, using the list of stakeholders' categories created in the previous step as a starting point, a group of experts brainstorms and researches possible stakeholders (specific companies, organisations or individuals). The research was mainly done online, using 'aerospace industry' and the categories as search words. These possible stakeholders' contacts are also listed during this step. The identified possible stakeholders are then invited to participate in a survey (task C, step 4).

Step 3 – Snowball Sampling

The last step from this task, step 3, is the application of the snowball sampling method, using approach presented by Kalton & Anderson (1986) and Reed et al. (2009). A section of the survey asked the respondents to identify other possible stakeholders, which were then added to the possible stakeholders' list, and invited to participate in the study. It is important to notice that step 3 is only possible by applying the survey, which is the step 4 of the multimethodology stakeholders' analysis.

4.1.3 Task C – Prioritising Stakeholders

The objective of task C is to prioritise stakeholders regarding their relevance to the sustainability of the supply chain and map their relations. This step is divided into three steps: (4) survey; (5) selecting most relevant categories; (6) creating sustainability value flows between stakeholders. These steps are presented next.

Step 4 - Survey

A survey was developed as step 4 of the multimethodology stakeholders' analysis. This survey was designed to be answered by the possible stakeholders, previously identified in step 2 and later identified in step 3. Therefore, it considers a stakeholder-led evaluation. This method was chosen as it allows to collect standardized information from a large sample of participants, in a very cost-effective way. As recommended by Wilson (2014), surveys are very useful to gather focused information about stakeholders and comparing results across different groups of respondents.

The survey based research is a long and complex process which requires a theoretical model. Figure 13 presents the process of the survey based research and the activities which compose it.

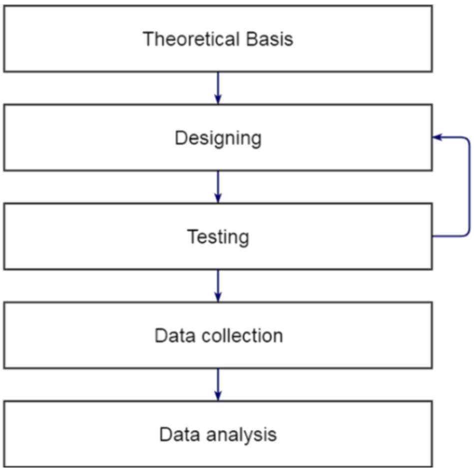


Figure 13 – Survey based research process (Adapted from Cardoso 2012)

The theoretical basis for the survey was developed based in the following stakeholders' analysis: Power-interest matrix (Bryson 2004; Ackermann & Eden 2011; Bryson et al. 2011); Power, urgency and legitimacy diagram (Mitchell et al. 1997; Magness 2008); Support vs opposition grid (Nutt & Backoff 1987; Bryson 2004).

The survey design phase is characterised by the definition of its main characteristics, the information to be researched, the sample and the collection technique. The surveys were created in electronic format, using the *Google Forms* and the *eSurvey Creator* platforms.

An introductory text was used to explain the study and its context, and the survey structure. The survey was composed by 16 questions, divided into 4 sections. The first section was dedicated to identify the respondents and characterising the sample. In the second section, the respondents were asked to evaluate themselves or their organisations regarding the attributes *Power*, *Interest*, *Urgency*, *Legitimacy* and *Support* towards the problem in study.

It was very important to clearly define each attribute and to include these definitions in the survey. This helped respondents during their evaluations. The definitions used were:

- **Power:** the probability that an actor within a social relationship would be in a position to carry out his own will despite resistance. It is the ability of those who possess power to bring about the outcomes they desire (Mitchell et al. 1997; Bryson 2004; Ackermann & Eden 2011);
- **Interest:** the feeling that a subject concerns, draws the attention, the responsibility, the involvement or the curiosity of a person, group or organization (Bryson 2004; Ackermann & Eden 2011);
- **Urgency:** the degree to which a stakeholder claims call for immediate attention to a given problem and is time-sensitive to the actions he classifies as critical or highly important (Mitchell et al. 1997; Magness 2008);

- **Legitimacy: "**a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (Mitchell et al. 1997, p. 869);
- **Support:** to be actively interested in and concerned for the success of the project, as opposed to provide resistance or dissent, expressed in action or argument (Nutt & Backoff 1987).

The evaluation regarding the attributes preformed in the survey used a score system from 1 to 5 points, where 1 represents low and 5 high (e.g. low power/high power).

The third section asked to evaluate all stakeholders' categories regarding the same five attributes using a comparative approach. In the fourth and last section respondents were invited to identify more possible stakeholders to be included in the study, i.e. the application of the snowball sampling methodology. These were also invited to participate in the survey.

The complete survey used in this step is presented next.

START

---Please read carefully before you start---

Thank you for your interest in answering this survey. It should take you approximately 15 minutes to complete.

This survey will support a Master Thesis titled "Sustainability Assessment of the Aerospace Supply Chain – Stakeholders' engagement towards sustainability" being pursued at Instituto Superior Técnico – University of Lisbon (Portugal), in collaboration with MIT.

The definition of 'stakeholder' used in this work includes any person, group or organization that can affect or be affected by an organization's strategy.

We are focusing on the aerospace supply chain with a Commercial Aerospace OEM (airframe or engine manufacturer) as the focal company.

We consider the triple bottom line framing of sustainability, which includes the economic, the environmental and social aspects of sustainability.

The survey you are about to start is divided into four sections: 1. Identification; 2. Self-evaluation; 3. Evaluating stakeholders' categories; 4. Identifying other stakeholders.

*Required

I – Identification

In this section you are asked to identify yourself and the company, organization or group you represent.

1. Which company, organization or group do you represent? *

(n/a if you are answering as an individual)

____

2. What is your function within that company, organization or group? *

- ☐ CEO
- ☐ Top Management
- ☐ Middle Management
- ☐ Team Leader/Supervisor
- ☐ Staff/Employee
- ☐ Leader (non-business organization - e.g. NGOs, Community group, etc.)
- ☐ Member (non-business organization - e.g. NGOs, Community group, etc.)
- ☐ Individual (not part of an organization)

3. Do you work in sustainability? *

- ☐ yes
- ☐ no

4. How many employees/members does your company, organization or group have? *

- ☐ 1 to 250
- ☐ 251 to 500
- ☐ 501 to 1000
- ☐ 1001 to 5000
- ☐ more than 5000
- ☐ n/a

5. In the aerospace supply chain context, in which of the following stakeholder categories does your company, organization or group fit? *

- ☐ Management Board (of the OEMs airframe or engine makers)
- ☐ Customers (Airlines, Leasing companies)
- ☐ Suppliers
- ☐ Services Providers (Logistics, Recycling, Disposers, etc.)
- ☐ NGOs
- ☐ Scientific Community
- ☐ Employees
- ☐ Investors and Financial Institutions
- ☐ Media
- ☐ Consumers (Passengers & Cargo)
- ☐ Shareholders
- ☐ Governments
- ☐ Local Communities
- ☐ Regulators
- ☐ Other: _________________________

II – Self-evaluation

In this section you will evaluate your organization in five attributes. We ask you to classify each of these attributes on a scale from 1 to 5, where 1 means low and 5 means high.

6. What is the level of power that your organization holds in the development of a sustainable supply chain in the aerospace industry? *

Power: the probability that an actor within a social relationship would be in a position to carry out his own will despite resistance. It is the ability of those who possess power to bring about the outcomes they desire.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

7. How would you classify the interest of your organization in developing a sustainable supply chain for the aerospace industry? *

Interest: the feeling that a subject (such as supply chain sustainability) concerns, draws the attention, the responsibility, the involvement or the curiosity of a person, group or organization.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

8. How urgent is the 'sustainability in the supply chain' theme for your organization? *

Urgency: the degree to which a stakeholder claims call for immediate attention to a given problem (such as supply chain sustainability) and is time-sensitive to the actions he classifies as critical or highly important.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

9. Do you consider your organization's actions legitimate in the context of the supply chain sustainability? *

Legitimacy: a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

10. Regarding the support of a sustainable supply chain, how would you classify your organization? *

Support: to be actively interested in and concerned for the success of the project, as opposed to provide resistance or dissent, expressed in action or argument.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

III – Evaluating stakeholders' categories

In this section we ask you to evaluate the same 5 attributes in all the stakeholder's categories, by comparing them with each other. The scale used in here is the same as in the previous page.

11. POWER *

Power: the probability that an actor within a social relationship would be in a position to carry out his own will despite resistance. It is the ability of those who possess power to bring about the outcomes they desire.

	1	2	3	4	5
Management Board (of the OEMs)	☐	☐	☐	☐	☐
Customers (Airlines, Leasing Companies)	☐	☐	☐	☐	☐
Suppliers	☐	☐	☐	☐	☐
Services providers (logistics, recycling, etc.)	☐	☐	☐	☐	☐
NGOs	☐	☐	☐	☐	☐
Scientific Community	☐	☐	☐	☐	☐
Employees	☐	☐	☐	☐	☐
Investors and Financial Institutions	☐	☐	☐	☐	☐
Media	☐	☐	☐	☐	☐
Consumers (passengers & cargo)	☐	☐	☐	☐	☐
Shareholders	☐	☐	☐	☐	☐
Governments	☐	☐	☐	☐	☐
Local Communities	☐	☐	☐	☐	☐
Regulators	☐	☐	☐	☐	☐

12. INTEREST *

Interest: the feeling that a subject (such as supply chain sustainability) concerns, draws the attention, the responsibility, the involvement or the curiosity of a person, group or organization.

	1	2	3	4	5
Management Board (of the OEMs)	☐	☐	☐	☐	☐
Customers (Airlines, Leasing Companies)	☐	☐	☐	☐	☐
Suppliers	☐	☐	☐	☐	☐
Services providers (logistics, recycling, etc.)	☐	☐	☐	☐	☐
NGOs	☐	☐	☐	☐	☐
Scientific Community	☐	☐	☐	☐	☐
Employees	☐	☐	☐	☐	☐
Investors and Financial Institutions	☐	☐	☐	☐	☐
Media	☐	☐	☐	☐	☐
Consumers (passengers & cargo)	☐	☐	☐	☐	☐
Shareholders	☐	☐	☐	☐	☐
Governments	☐	☐	☐	☐	☐
Local Communities	☐	☐	☐	☐	☐
Regulators	☐	☐	☐	☐	☐

13. URGENCY *

Urgency: the degree to which a stakeholder claims call for immediate attention to a given problem (such as supply chain sustainability) and is time-sensitive to the actions he classifies as critical or highly important.

	1	2	3	4	5
Management Board (of the OEMs)	☐	☐	☐	☐	☐
Customers (Airlines, Leasing Companies)	☐	☐	☐	☐	☐
Suppliers	☐	☐	☐	☐	☐
Services providers (logistics, recycling, etc.)	☐	☐	☐	☐	☐
NGOs	☐	☐	☐	☐	☐
Scientific Community	☐	☐	☐	☐	☐
Employees	☐	☐	☐	☐	☐
Investors and Financial Institutions	☐	☐	☐	☐	☐
Media	☐	☐	☐	☐	☐
Consumers (passengers & cargo)	☐	☐	☐	☐	☐
Shareholders	☐	☐	☐	☐	☐
Governments	☐	☐	☐	☐	☐
Local Communities	☐	☐	☐	☐	☐
Regulators	☐	☐	☐	☐	☐

14. LEGITIMACY *

Legitimacy: a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions.

	1	2	3	4	5
Management Board (of the OEMs)	☐	☐	☐	☐	☐
Customers (Airlines, Leasing Companies)	☐	☐	☐	☐	☐
Suppliers	☐	☐	☐	☐	☐
Services providers (logistics, recycling, etc.)	☐	☐	☐	☐	☐
NGOs	☐	☐	☐	☐	☐
Scientific Community	☐	☐	☐	☐	☐
Employees	☐	☐	☐	☐	☐
Investors and Financial Institutions	☐	☐	☐	☐	☐
Media	☐	☐	☐	☐	☐
Consumers (passengers & cargo)	☐	☐	☐	☐	☐
Shareholders	☐	☐	☐	☐	☐
Governments	☐	☐	☐	☐	☐
Local Communities	☐	☐	☐	☐	☐
Regulators	☐	☐	☐	☐	☐

15. SUPPORT *

Support: to be actively interested in and concerned for the success of the project, as opposed to provide resistance or dissent, expressed in action or argument.

	1	2	3	4	5
Management Board (of the OEMs)	☐	☐	☐	☐	☐
Customers (Airlines, Leasing Companies)	☐	☐	☐	☐	☐
Suppliers	☐	☐	☐	☐	☐
Services providers (logistics, recycling, etc.)	☐	☐	☐	☐	☐
NGOs	☐	☐	☐	☐	☐
Scientific Community	☐	☐	☐	☐	☐
Employees	☐	☐	☐	☐	☐
Investors and Financial Institutions	☐	☐	☐	☐	☐
Media	☐	☐	☐	☐	☐
Consumers (passengers & cargo)	☐	☐	☐	☐	☐
Shareholders	☐	☐	☐	☐	☐
Governments	☐	☐	☐	☐	☐
Local Communities	☐	☐	☐	☐	☐
Regulators	☐	☐	☐	☐	☐

IV – Identifying other stakeholders

16. Finally, we ask you to name some companies, organizations or groups that you think would fit in each of the stakeholders' categories. This method is called snowball sampling and is used to identify more stakeholders, which will be included in this study.

Management Board (of the OEMs)	
Customers (Airlines, Leasing Companies)	
Suppliers	
Services providers (logistics, recycling, etc.)	
NGOs	
Scientific Community	
Employees	
Investors and Financial Institutions	
Media	
Consumers (passengers & cargo)	
Shareholders	
Governments	
Local Communities	
Regulators	

END

The survey development, more specifically the question's definition, was based on the literature review of the several methodologies. The references supporting each question, the type of question and the questions' objectives are schematised in Table 12.

Table 12 – Structured Interview Questions' references, type and objectives

Question	References	Type of Question	Objectives
I – Identification			
1	Wilson (2014)	Short open answer	Identifying the company/organisation/group
2	Wilson (2014)	Multiple choice	Function within the company/organisation/group
3	Wilson (2014)	Yes/No	Do you work in sustainability
4	Wilson (2014)	Multiple choice	Number of employees
5	Freeman (1984); Hart & Sharma (2004); Freeman et al. (2007); Cetinkaya et al. (2011)	Multiple choice	Stakeholder category
II – Self-evaluation			
6	Mitchell et al. (1997); Bryson (2004); Magness (2008); Ackermann & Eden (2011); Bryson et al. (2011)	1 to 5 scale	To evaluate the respondent's organisation "Power" attribute towards the issue in study.
7	Bryson (2004); Ackermann & Eden (2011); Bryson et al. (2011)	1 to 5 scale	To evaluate the respondent's organisation "Interest" attribute towards the issue in study.
8	Mitchell et al. (1997); Magness (2008)	1 to 5 scale	To evaluate the respondent's organisation "Urgency" attribute towards the issue in study.
9	Mitchell et al. (1997); Magness (2008)	1 to 5 scale	To evaluate the respondent's organisation "Legitimacy" attribute towards the issue in study.
10	Nutt & Backoff (1987); Bryson (2004); Bryson et al. (2011)	1 to 5 scale	To evaluate the respondent's organisation "Support" attribute towards the issue in study.
III – Differentiating between stakeholders' categories			
11	Mitchell et al. (1997); Bryson (2004); Magness (2008); Ackermann & Eden (2011); Bryson et al. (2011)	1 to 5 scale matrix	To evaluate the attribute "Power" across the stakeholders' categories using a comparative approach.
12	Bryson (2004); Ackermann & Eden (2011); Bryson et al. (2011)	1 to 5 scale matrix	To evaluate the attribute "Interest" across the stakeholders' categories using a comparative approach.
13	Mitchell et al. (1997); Magness (2008)	1 to 5 scale matrix	To evaluate the attribute "Urgency" across the stakeholders' categories using a comparative approach.
14	Mitchell et al. (1997); Magness (2008)	1 to 5 scale matrix	To evaluate the attribute "Legitimacy" across the stakeholders' categories using a comparative approach.
15	Nutt & Backoff (1987); Bryson (2004); Bryson et al. (2011)	1 to 5 scale matrix	To evaluate the attribute "Support" across the stakeholders' categories using a comparative approach.
IV – Identifying other stakeholders			
16	Kalton & Anderson (1986); Reed et al. (2009); Thompson (2012)	Short open answer matrix	Identifying more stakeholders to be included in the study: Snowball Sampling.

A validation of the survey was performed, following the process represented in Figure 14. The survey was reviewed and validated by the dissertation supervisor and co-supervisor, Professor Ana Carvalho and MSc Carlos Malarranha from Instituto Superior Técnico (IST), and by Professor Elsa Olivetti form the Massachusetts Institute of Technology (MIT). The survey was then reviewed and validated by a survey research specialist from the MIT through Prof. Olivetti.

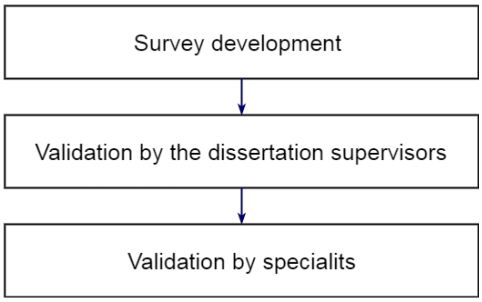


Figure 14 – Survey validation process (Adapted from Cardoso 2012)

After validating the survey, the data collection phase was conducted. During this phase, the survey was sent to all identified possible stakeholders by email and the answers were collected online.

Step 5 – Select most relevant categories

By preforming a statistical analysis on the data from the survey, the most relevant stakeholder categories for the issue in study are selected with the application of this step.

1. First, to score each pair stakeholder-category/attribute, the mean value from the scores attributed by respondents is calculated.
2. Then, an analysis to the results of each attribute is made separately. Justifications and conclusions for the scores in each *power*, *interest*, *urgency*, *legitimacy* and s*upport* attributes are driven in an individual way, without considering the score of each other.
3. After gathering all scores from all attributes, to facilitate the analysis by spreading the scores along the complete evaluation scale, a normalisation of the scores is performed by applying the linear interpolation equation (1). The highest score assumes the highest value in the scale ($y_1 = 5$), and the lowest score assumes the lowest value in the scale ($y_0 = 1$).

$$y = y_0 + (y_1 - y_0)\frac{x-x_0}{x_1-x_0} \quad (1)$$

In this case, y is the normalised score, x is the original score, x_0 is the original minimum score and x_1 is the original maximum score, therefore originating equation (2), which was used for the normalisation of scores.

$$y = 1 + (5-1)\frac{x-x_0}{x_1-x_0} \quad (2)$$

4. Using the normalised scores, the original Power-Interest Matrix and Support vs Opposition Grid methodologies were applied as early indicators of the final results of the multimethodology stakeholders' analysis.
5. After preforming these analysis, there is the need to create an aggregated score for each stakeholder category, so that the most relevant ones are identified. Based on the fact that attributes do not hold the same importance regarding the problem, there is the need to weight each of their contributions to the final score. The final aggregated score for each stakeholder category can then be calculated by applying equation (3).

$$S_j = \sum_{i=1}^{5} w_i \, s_{ij}, \forall\, j = 1, \dots, 14 \qquad (3)$$

Where,

- S_j = final score of the stakeholder category j;
- w_i = the weight of the attribute i;
- s_{ij} = score of the stakeholder category j regarding the attribute i.

The weighted final scores for each stakeholder category are then used to order them in terms of relevance towards the problem in study, from the highest to the lowest score. By comparing the final scores, the top categories are then selected as the most relevant.

6. A radar chart for each of the most relevant stakeholders' category is also created to illustrate their scores in the 5 attributes in the same graph.

The method used for the weighting in point 5 is presented next.

The Swing Weighting Method

When trying to solve problems which require the evaluation of multiple criteria in several options, a multi-criteria analysis is required. The multiple criteria evaluated during problems rarely has the same weights in the analysis and, therefore, in the solution.

There are several weighting methods to deal with the different relevancies given to the different criteria, from which two were analysed: the Swing Weighting Method (Goodwin & Wright 2014) and the MACBETH approach (Bana e Costa & Vansnick 1994).

Although the MACBETH approach presents results with less error comparatively to the Swing Weighting method (Goodwin & Wright 2014), the fact that it constitutes a non-numerical elicitation technique, based on a qualitative scale, was the main reason to not be considered the as the best method to apply. Since this study is based in quantitative evaluations, the numerical elicitation technique Swing Weighting was considered more adequate in the context of this analysis.

The Swing Weighting method is based on the inputs by one or more decision makers, who present their preferences by applying a questioning protocol. The application of this methodology requires three steps:

1. The method starts by creating a neutral performance scenario for every criterion. The decision makers are then asked to choose in which criterion a swing from neutral to good performance is more relevant. This question is repeated until all criteria is ordinated.
2. Then, 100 points are given to the most important swing, and the decision makers are asked to score the next criterion in comparison to the first. This process is repeated until all criteria is given a score. However, it is important to refer that scores must be smaller than the score attributed to the previous criterion. This step produces a list of ordinated criteria and scores in terms of their relevance to the decision makers.
3. To generate the weights for the criteria, the scores then are normalised so that the sum of all weights is equal to one (Goodwin & Wright 2014). This is achieved by applying equation (3).

$$w_i = \frac{s_i}{\sum_{i=1}^{n} s_i}, \forall\ i = 1,2,3,4,5 \tag{3}$$

Where,

- s_i = the swing score (non-normalised) of the attribute i ($i = 1,2,3,4,5$);
- w_i = the normalised weight of the attribute i.

<u>Step 6 - Creating sustainability value flows between stakeholders</u>

Based on the Value Flow Mapping methodology presented by Cameron et al. (2008), this last step of the stakeholders' analysis comes as the integration of the stakeholders' engagement concept in the analysis. A description of the application of this method is done next.

For each one of the most relevant stakeholders' categories, the inputs and outputs required to add sustainable value to the problem are brainstormed by a small group of experts, taking into consideration the inputs and outputs from the other categories. To discover the inputs, the same group of experts was asked the question "Which inputs are required by this stakeholder category to generate sustainability value?". To discover the outputs, question "What are the outputs of sustainability value created by the stakeholder category and who they are provided to?" is asked. These sustainable value inputs and outputs must consider the economic, the environmental and the social nature of sustainability, following a 3BL approach.

The following step it to connect stakeholders' categories using the previously identified inputs and outputs, resulting in a flow map, which provides the visual conceptualisation of the ideal stakeholders' engagement towards sustainability.

As advised by Cameron et al. (2008), the complexity of this process is highly influenced by the number of stakeholders' categories considered, possibly making the analysis too complex to be used in a practical way. In the previous step the most relevant stakeholders' categories were selected. Our analysis will only consider those as a way of reducing the complexity of this step.

4.2 Sustainability Performance: Measuring Stakeholders' Engagement

Following the stakeholders' analysis and the definition of the most relevant stakeholders' categories for the supply chain sustainability problem, the stakeholders' performance regarding sustainability must be assessed applying sustainability indicators. This section comes as the answer to the second research question (RQ2: How engaged are the relevant stakeholders and how can this engagement be improved?).

One of the crucial activities for the stakeholders' engagement towards sustainability is the sustainability reporting, which demonstrate interest and transparency regarding the subject. This practices help organisations in general to set objectives, measure performance and manage change in order to become more sustainable (GRI 2015).

Sustainability reports must cover all of the organisation's impacts on the economy, the environment and in society, whether these are positive or negative. Nowadays, one of the most widely used standards to report sustainability is the GRI-G4, as these guidelines are designed to be universally applicable to all organizations, large and small, independently of the geography.

The standardisation of sustainability reporting in the context of SC sustainability performance evaluation is also of the most importance, since only this way it is possible to aggregate and compare performances from different entities in the same supply chain.

The sustainability assessment presented here is based in a qualitative analysis of the information reported by a sample of stakeholders of the aerospace supply chain. Only stakeholders from the most relevant categories are considered in this assessment. The methodology used in this assessment has 4 steps:

1. Create a representative sample. When possible, a few representative stakeholders from each one of the 'most relevant' categories must be selected.
2. Analyse published information related to their sustainability performance. The GRI-G4 guidelines were chosen as the standard to allow comparisons between reported data. The data reported by the stakeholders was associated to GRI indicators to allow comparisons.
3. Identify the GRI sustainability aspects that are reported by the stakeholders.
4. Based on the results from the previous step, suggest the most relevant themes to be reported and present a framework for the assessment of stakeholders' sustainability performance, as a measure of stakeholders' engagement towards sustainability in the aerospace supply chain. The results from this step are presented as a participation planning matrix, where the function of each stakeholder regarding every particular indicator is defined.

4.3 Chapter Conclusions

The present chapter proposed the methodology to follow in the development of this dissertation. The dissertation is mainly divided into two analysis: (1) a stakeholders' analysis; (2) a sustainability performance assessment as a measurement of stakeholders' engagement.

A novel multimethodology for Stakeholders' Analysis was developed to collect, treat and analyse data during the development of the dissertation. As proposed by Mingers & Gill (1997), the combination of two or more management science methodologies in the same process is likely to produce a richer picture for understanding the complex relationships and connections, just like the ones on the aerospace industry. This likely leads to better decisions by managers and stakeholders in general (Mingers & Gill 1997). Therefore, the development of this multimethodology comes as an important scientific contribution to the area of the Stakeholders' Analysis in the context of sustainability.

The data for the stakeholders' analysis was collected based on a survey, which considers a stakeholder-led evaluation. The survey was developed and validated following the methodology described in this chapter. The testing and validation phases were crucial during the development of the survey. The complete survey, its structure and the objectives for each question were also described in this chapter.

The Swing Weighting method was considered as the best to lead with the multi-criteria nature of this multimethodology analysis.

The sustainability performance assessment as a measurement of stakeholders' engagement is addressed in a qualitative analysis. By researching the standards and the reported data, suggestions to the aerospace supply chain sustainability performance measurement are drawn.

5. Results and Discussion

This chapter presents the data obtained with the application of methodologies used during the development of the thesis. Additionally, the discussion of the results will be performed in this chapter. The results and discussion regarding the stakeholders' analysis is presented in section 5.1. Section 5.2 presents the results and discussion of the sustainability performance assessment. In section 5.3, the chapter conclusions are presented.

5.1 Stakeholders' Analysis

5.1.1 Identifying Stakeholders

Considering the problem to be studied and the methodology to follow in the data acquisition, 14 out of the 22 researched stakeholders' categories were chosen. The possible stakeholders' categories applied in the study, in no particular order are:

- Management Board (of the OEMs);
- Customers (airlines);
- Suppliers;
- Services providers;
- NGOs;
- Scientific Community;
- Employees;
- Investors and Financial Institutions;
- Media;
- Consumers (passengers);
- Shareholders;
- Governments;
- Local Communities;
- Regulators

Contrarily to most authors, we chose not to classify these categories as primary or secondary stakeholders, as these could affect the results and the identification of the most relevant stakeholders' categories. Based on this list, the group of experts, which in this case was composed by three academics from IST and one from the MIT, brainstormed possible stakeholders (i.e. companies, organisations, groups, individuals) and listed 350 contacts. These contacts were then invited to participate in the survey. An additional 47 contacts were later identified, through the application of the snowball sampling method, and invited to participate in the survey. A total of 397 contacts were invited.

5.1.2 Survey – Sample Characterisation

A total of 36 answers were received. This represents a total response rate of 9,1%. However, 5 respondents did not complete the survey and, therefore, their answers were manually removed and were not analysed further. A total of 31 surveys were competed, which represents an effective response rate of 7,8%. The results presented next consider the data collected from the 31 completed surveys, which were then exported to Excel and analysed. Descriptive analysis and graphical presentation tools are applied next.

The first section of the survey was meant to characterise the sample for this study.

The answers to the first question – identifying the company/organisation/group – were not considered in our analysis, as the participation in the survey was anonymous. This data was only used to keep track of which organisations had already participated. Although invitations were sent to more than one person within the same organisation, curiously, all received answers came from different organisations.

As shown in Figure 15, the sample can be characterised by the position of the respondent within the organisation he/she represents. Employees represent 25,8% of the sample (8 answers), as well as Individuals – those who are not representing an organisation (8 answers). CEO, Middle Management and Team Leader functions represent 12,9% of the sample each (4 answers).

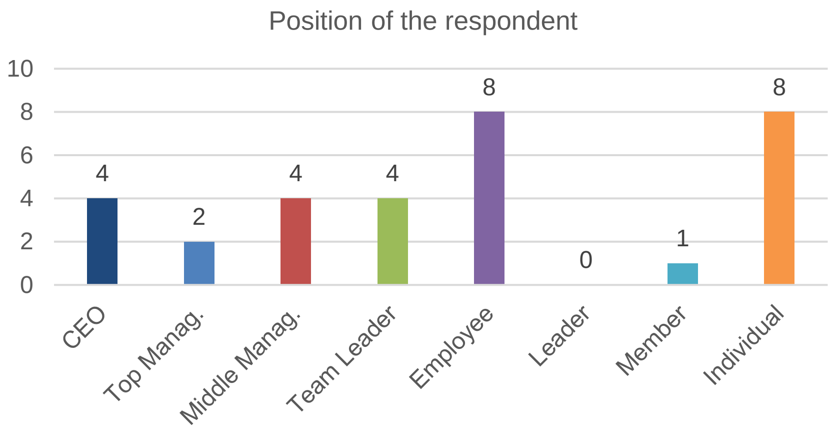


Figure 15 – Position of the respondent within the organisation he is representing

The sample was also characterised by differentiating respondents regarding their direct work with sustainability. Most respondents do not work directly with sustainability, accounting for 61,3% of the sample (19 answers). Respondents who work directly with sustainability represent 38,7% of the sample (12 answers). This data is shown in Figure 16.

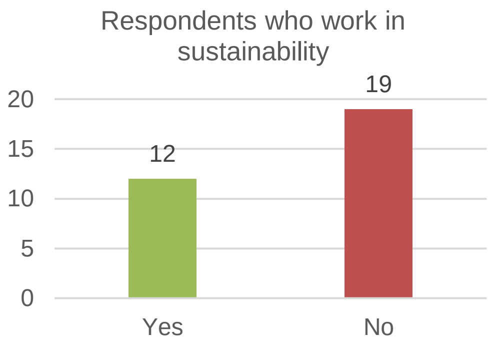


Figure 16 – Distribution of respondents regarding the direct work with sustainability

Regarding the dimension of the organisations represented by the respondents, as shown in Figure 17, the sample is manly composed by small organisations, with 1 to 250 employees (8 answers). This represents 36,4% of the sample. Major organisations, with more than 5000 employees, represent 27,3% of the sample (6 answers). Medium/major organisations represent 18,2% of the sample (4 answers), Medium organisations 13,6% (3 answers) and Medium/small organisations 4,5% (1 answer). It is important to notice that this analysis excludes individuals, who were not representing any organisation and to whom this question did not apply (9 answers).

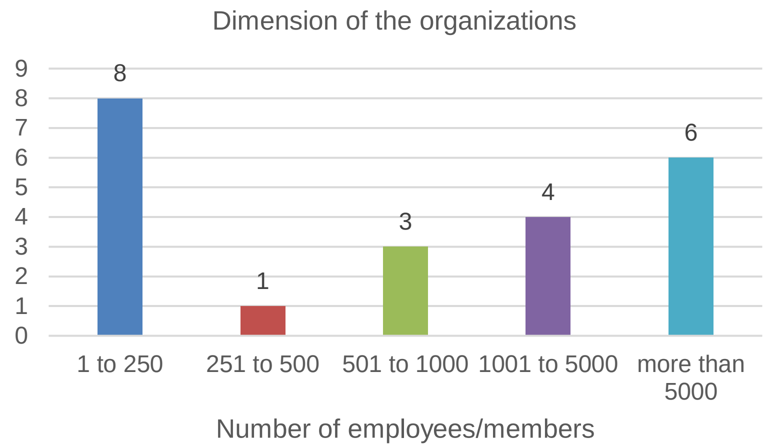


Figure 17 – Dimension of the organisations

The last relevant factor for the characterisation of the sample is the stakeholder category in which the respondent fitted the best. Every category account for at least one answer, except the NGOs and the Shareholders categories, which were not represented. The most represented categories were Suppliers with 32,3% (10 answers), Scientific Community with 16,1% (5 answers), and Consumers and Local Communities, both with 12,9% (4 answers). The data regarding this characterisation is represented in Figure 18.

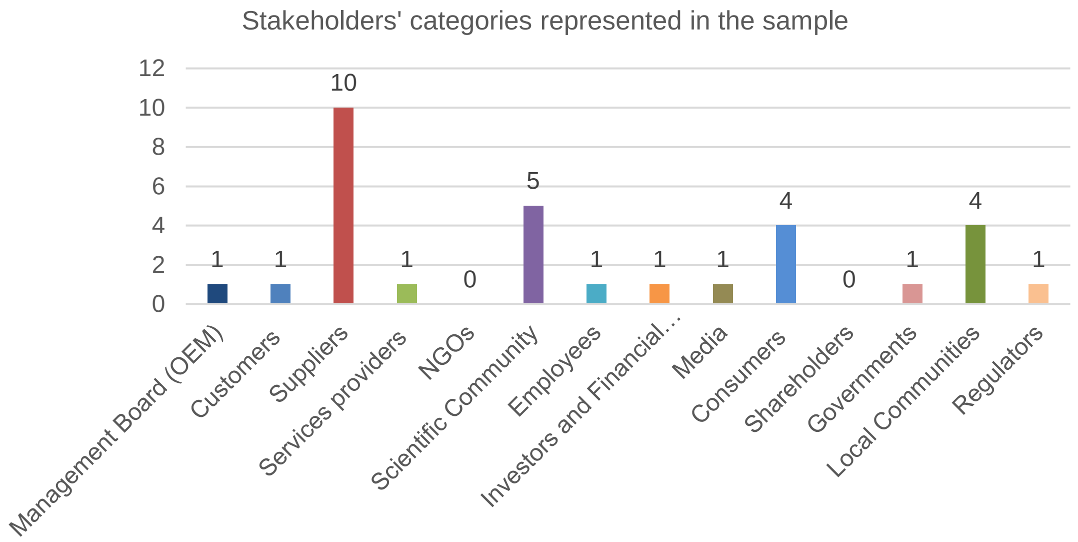


Figure 18 – Stakeholders’ categories represented in the sample

Summarizing, the sample is composed by 31 answers, representing 7,8% of answers. Most respondents hold an Employee function within their organisations (25,8%) or answered as Individuals not representing any organisation (25,8%). Most respondents do not work directly with the theme of sustainability, accounting for 61,3% of the sample. However, those who do work directly with sustainability represent a relevant 38,7% of the sample. Most respondents were not representing any organisation and answered as individuals. However, when excluding those, the sample is mainly composed by small organisations, with 1 to 250 employees (36,4%), followed by major organisations with more than 5000 employees (27,3%). The most represented stakeholders’ categories in the sample were Suppliers (32,3%), Scientific Community (16,1%), Consumers (12,9%) and Local Communities (12,9%). The categories NGOs and Shareholders are the only with no representation. Once the sample is characterised, it is possible to analyse the data collected using the primary methodology, the survey.

5.1.3 Selecting the most relevant categories

The differentiation of the stakeholders' categories was done by evaluating five attributes: *power*, *interest*, *urgency*, *legitimacy* and *support*. This evaluation used the data from the third section of the survey and, since the respondents are the stakeholders, this is a stakeholder-led evaluation.

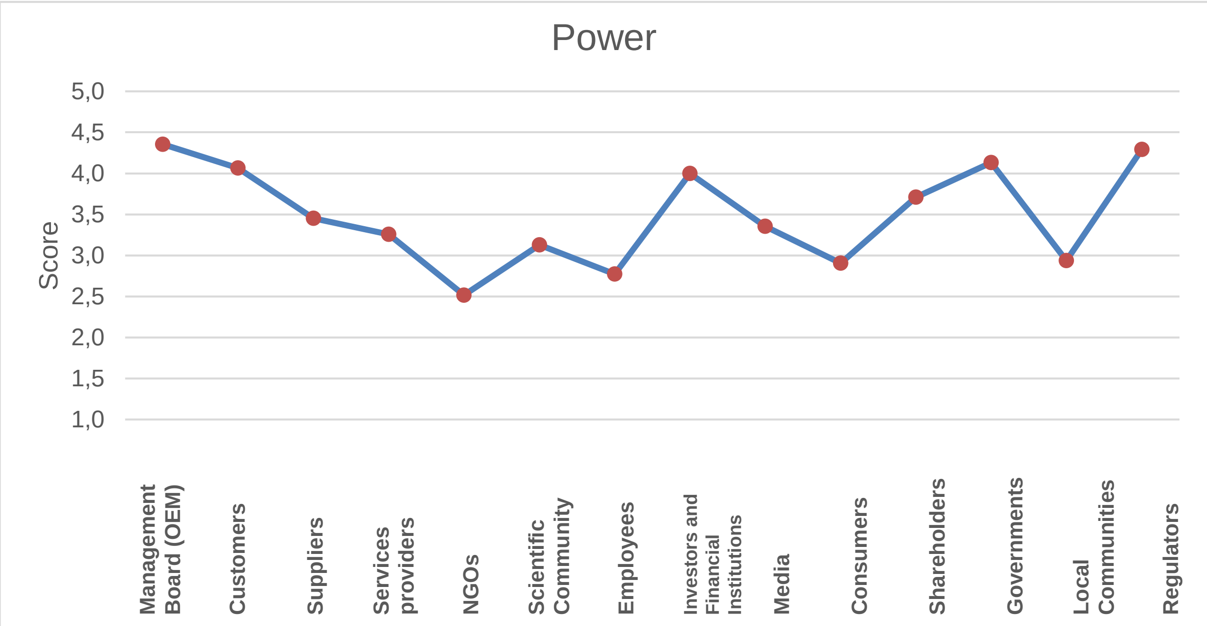
The evaluation used a score system from 1 to 5 points, where 1 means low and 5 means high. Using this score system, three types of values were calculated:

1. The scores of each stakeholder category in each attribute were calculated using the mean value (μ) of the evaluations conducted by the respondents.
2. The standard deviation (σ), which is used to quantify the dispersion of the set of values used to calculate the mean. A low standard deviation indicates that the points tend to be closer to the mean, while a high standard deviation value indicates a greater dispersion.
3. The coefficient of variation (C_V), which is defined as the ratio between the standard deviation and the average, indicating the extend of the variation between the data and the mean value.

The results and the respective discussion for each attribute are presented next.

Power

The results of the analysis regarding the attribute *power* are presented in Figure 19.



	Management Board (OEM)	Customers	Suppliers	Services providers	NGOs	Scientific Community	Employees	Investors and Financial Institutions	Media	Consumers	Shareholders	Governments	Local Communities	Regulators
Score	4,35	4,06	3,45	3,26	2,52	3,13	2,77	4,00	3,35	2,90	3,71	4,13	2,94	4,29
σ	0,61	1,00	0,93	0,93	0,93	1,15	1,09	0,97	0,80	1,08	0,97	0,88	1,12	0,86
c_V	0,14	0,25	0,27	0,29	0,37	0,37	0,39	0,24	0,24	0,37	0,26	0,21	0,38	0,20

Figure 19 – Scores regarding the attribute "power".

The most relevant stakeholders' categories regarding the *power* attribute are:

- Management Board of the OEMs (4,35 points): These stakeholders are recognised as the most powerful, as they are in control of the OEMs, which are the focal companies of the aerospace manufacturing supply chain. In this context, this kind of companies establish an oligopoly, and possess the highest bargaining power in the supply chain. Furthermore, due to the constant media coverage and public interest in the OEMs, this group can be more recognisable than other stakeholders;
- Regulators and Governments (4,29 and 4,13 points): These stakeholders' categories are classified as very powerful in terms of the sustainability of the aerospace supply chain as their main function is to legislate and ensure compliance with the legislation. By "dictating the rules", these stakeholders end up in a very powerful position;
- Customers (4,06 points): The customers of the aerospace supply chain are also considered very powerful in what concerns to the sustainability in the supply chain. The constant pressures for cost-effective, environmentally friendly and safer aircraft are some of the factors that make these stakeholders very powerful. The public exposure of these stakeholders also has a part in their definition as very powerful;
- Investors and Financial Institutions (4,00 points): These category of stakeholders is considered to be very powerful as they hold most of the economic power in the supply chain and decide where to invest or not.

On the other end, the least relevant category regarding this attribute is:

- NGOs (2,52 points): Although this kind of stakeholders possess high influencing power in other industries, this might not the be case in the aerospace manufacturing supply chain. The respondents were not indifferent to this fact and recognised the low power the NGOs hold in the context of aerospace supply chain sustainability.

Regarding the coefficients of variation, we can observe that:

- The lowest coefficient of variation is held by the Management Board of the OEMs, accounting for 14%. This low value indicates that most stakeholders agree in considering this category the most relevant;
- All other categories have coefficients of variation of 20% or higher, reaching to values as high as 39%. These results show more disagreement between the respondents when evaluating these categories. One of the main reasons of such high variation can be explained through the way respondents have interpreted the term "sustainability" when answering to the survey. Respondents were asked to follow an integrated 3BL approach to sustainability, however:
    - Some respondents did not follow this instruction and answered focusing only in the economic or environmental pillar of sustainability, since they don't have the knowledge on the integrated vision;
    - In various cases, focusing only in one pillar leads to contrary evaluations by the stakeholders. As an example, the Investors usually have high power when considering

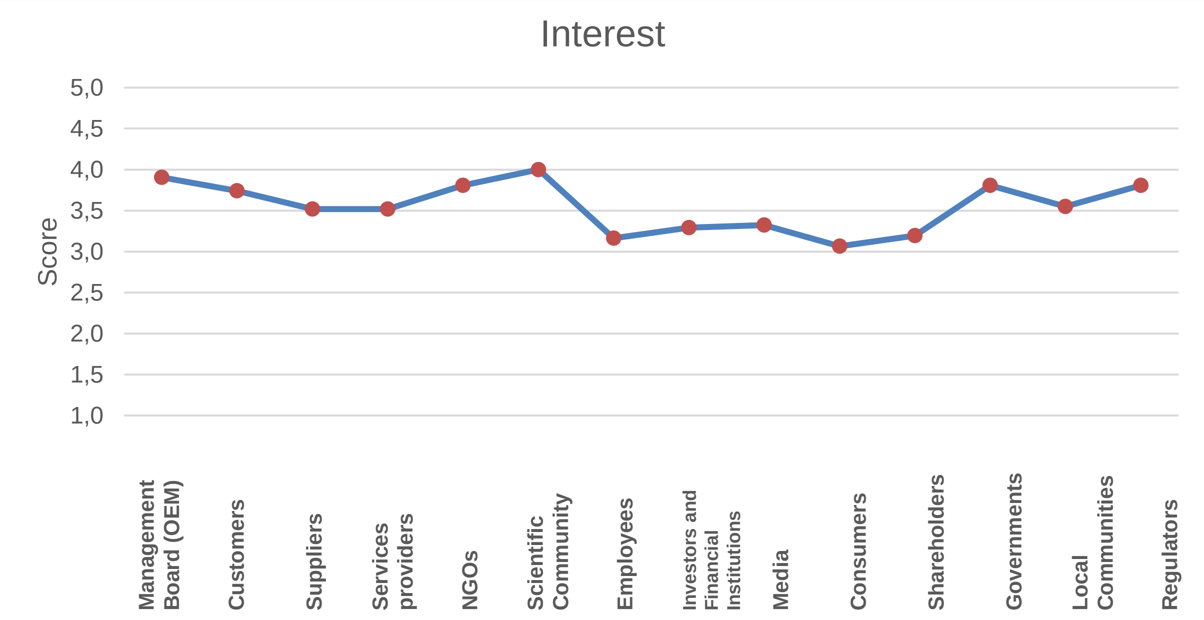
the economic pillar and can be classified as having low power when considering the environmental pillar;

- ○ A higher participation of respondents who work directly in sustainability, and therefore are better informed, would most likely reduce the high coefficients of variation problem to insignificant levels, as currently these respondents only account for 40% of the sample, approximately.

High coefficients of variation in the following attributes can also be explained by the same reasons explained above, since these problems could affect the entire evaluation.

<u>Interest</u>

The results regarding the attribute *interest* are presented in Figure 20.



	Management Board (OEM)	Customers	Suppliers	Services providers	NGOs	Scientific Community	Employees	Investors and Financial Institutions	Media	Consumers	Shareholders	Governments	Local Communities	Regulators
Score	3,90	3,74	3,52	3,52	3,81	4,00	3,16	3,29	3,32	3,06	3,19	3,81	3,55	3,81
σ	0,94	0,89	0,89	0,96	1,17	0,82	0,90	0,74	0,91	0,81	1,01	0,91	0,93	0,95
c_v	0,24	0,24	0,25	0,27	0,31	0,20	0,28	0,22	0,27	0,27	0,32	0,24	0,26	0,25

Figure 20 – Scores regarding the attribute 'interest'.

Although the differences between stakeholders' scores are much subtle than in the previous attribute, in a general way, the most relevant stakeholders' categories regarding the *interest* are the same as in the previous analysis. However, we highlight the inclusion of some stakeholders in the most relevant categories, such as:

- <u>Scientific Community</u> (4,00 points): This category of stakeholders is responsible for the scientific and technological developments which propel sustainability across the aerospace supply chain. Although they do not hold enough power to be considered relevant, the high interest in the theme is usually what moves the progress;
- <u>NGOs</u> (3,81 points): Although they cannot develop significant power in this industry, the NGOs interest in the sustainability theme is transversal to all industries.

We also highlight the exclusion of the following category from the most relevant group:

- Investors and Financial Institutions (3,29 points): when evaluating their interest in developing a sustainable supply chain for the aerospace industry, the Investors are not recognised as most interested by the other stakeholders, as they tend to be focused in the economic pillar of sustainability, disregarding the environmental and social pillars.

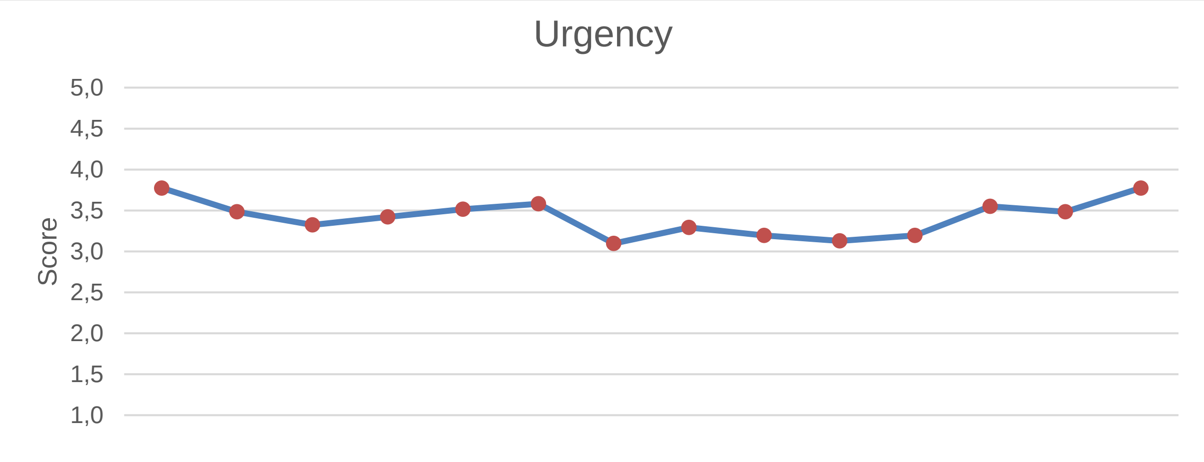
It is also interesting commenting about the category with the lowest score regarding the *interest*:

- Consumers (3,06 points): Nowadays, the passengers' consumer habits seem to be moved almost exclusively by the ticket prices. Therefore, the sustainability of the aerospace SC can be just one more theme these stakeholders are not very interested in, as they are primarily concerned about flying for a low fare.

The coefficients of variation in this attribute vary from 20% to 32%. As explained before, the reasons presented for this kind of values in the attribute *power* can also be applied to these results.

Urgency

The results regarding the attribute *urgency* are presented in Figure 21.



	Management Board (OEM)	Customers	Suppliers	Services providers	NGOs	Scientific Community	Employees	Investors and Financial Institutions	Media	Consumers	Shareholders	Governments	Local Communities	Regulators
Score	3,77	3,48	3,32	3,42	3,52	3,58	3,10	3,29	3,19	3,13	3,19	3,55	3,48	3,77
σ	0,84	0,89	0,91	0,85	1,26	1,12	0,94	0,94	0,87	0,85	1,08	0,99	0,93	0,92
c_v	0,22	0,26	0,27	0,25	0,36	0,31	0,30	0,29	0,27	0,27	0,34	0,28	0,27	0,24

Figure 21 – Scores regarding the attribute 'urgency'.

The evaluation of this attribute by the stakeholders revealed that:

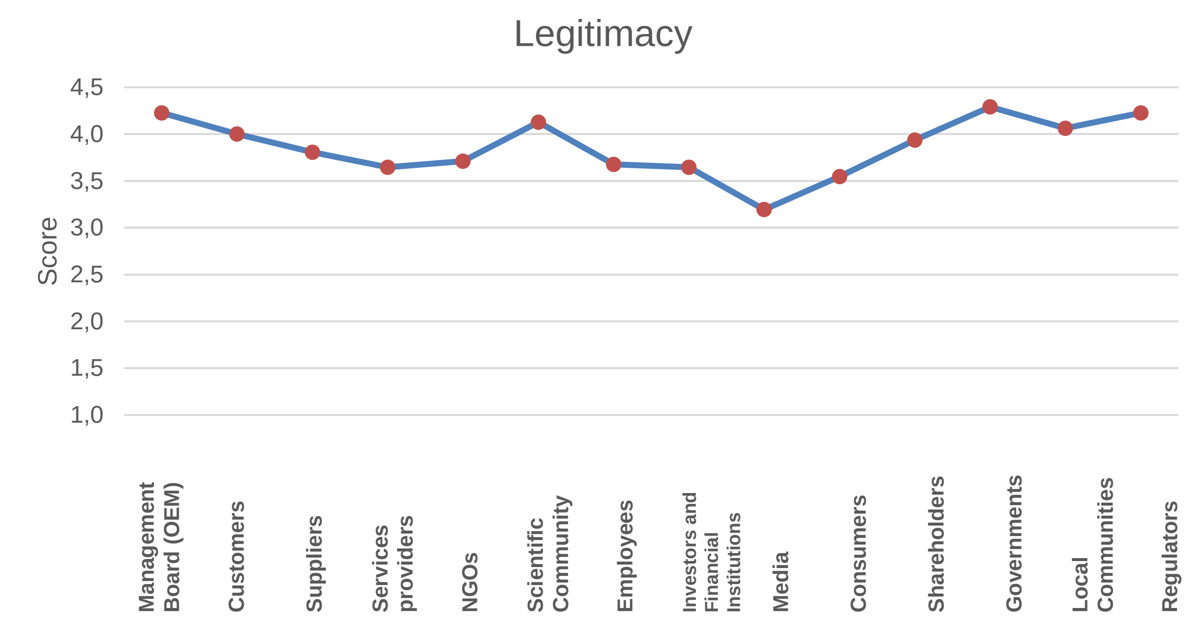
- All stakeholders' categories hold roughly the same level of urgency towards the problem of sustainability in the aerospace supply chain, as the lowest score is 3,10 points and the highest is 3,77 points;

- In a general way, most stakeholders across the aerospace industry hold a medium urgency towards developing a sustainable supply chain.

Once more, the relatively high coefficients of variation (from 22% to 36%) can be explained by the same reasons.

<u>Legitimacy</u>

The results from the analysis of the attribute *legitimacy* are presented in Figure 22.



	Management Board (OEM)	Customers	Suppliers	Services providers	NGOs	Scientific Community	Employees	Investors and Financial Institutions	Media	Consumers	Shareholders	Governments	Local Communities	Regulators
Score	4,23	4,00	3,81	3,65	3,71	4,13	3,68	3,65	3,19	3,55	3,94	4,29	4,06	4,23
σ	0,88	0,93	0,83	1,02	1,01	0,85	0,75	1,05	0,95	0,89	0,96	0,82	1,00	0,88
c_v	0,21	0,23	0,22	0,28	0,27	0,20	0,20	0,29	0,30	0,25	0,24	0,19	0,25	0,21

Figure 22 – Scores regarding the attribute 'legitimacy'.

From the most relevant categories in terms of *legitimacy* when acting in the theme of supply chain sustainability, we highlight the:

- <u>Governments</u> (4,29 points): the main role of most governments in the aerospace supply chain is to legislate – in the context of sustainability – the economic, environmental and social matters. Most respondents feel that the actions taken by governments are highly acceptable within the societies where they operate;
- <u>Management Board</u> (4,23 points): The stakeholders of the aerospace supply chain also consider the actions of the OEMs' Management Boards towards the sustainability to be very legitimate.
- <u>Scientific Community</u> (4,13 points): Known by their constant pursue for scientific and technological development that improves sustainability in general, the actions of the Scientific Community in the development of a sustainable aerospace SC are considered by the other stakeholders to be very legitimate.

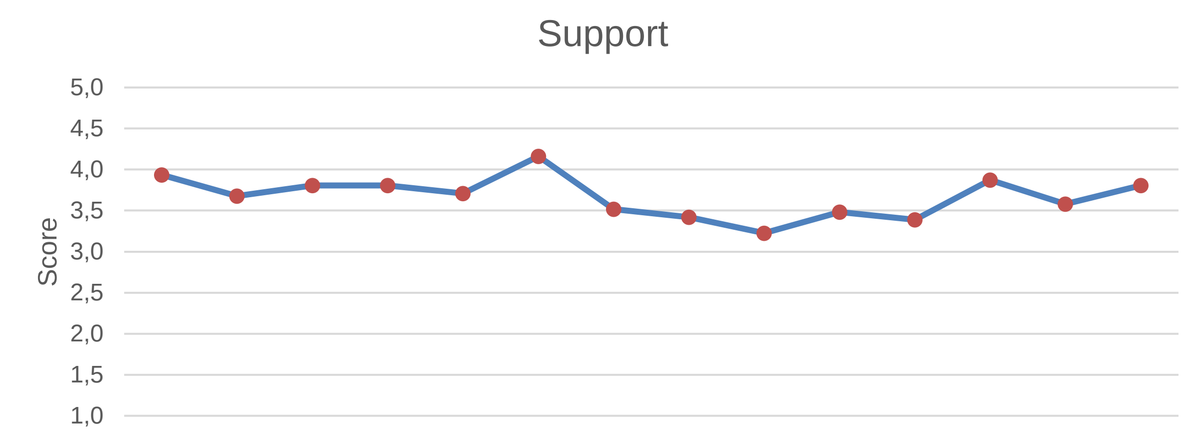
On the other side, the least legitimate stakeholders belong to:

- Media (3,19 points): The SC stakeholders considered the actions of the media to be the least legitimate of all stakeholders' categories. This could be justified by a general perception of low credibility. These are often seen as "noise making" stakeholders, which do not hold enough power to significantly interfere.

In this analysis, the coefficients of variation are between 19% and 30%. The reasons presented before to explain the higher values in this measure are valid for this analysis as well.

Support

The results from the analysis to the attribute *support* are presented in Figure 23.



	Management Board (OEM)	Customers	Suppliers	Services providers	NGOs	Scientific Community	Employees	Investors and Financial Institutions	Media	Consumers	Shareholders	Governments	Local Communities	Regulators
Score	3,94	3,68	3,81	3,81	3,71	4,16	3,52	3,42	3,23	3,48	3,39	3,87	3,58	3,81
σ	0,85	1,11	0,79	0,79	1,04	0,78	0,77	0,92	0,84	0,85	0,88	0,99	1,09	0,98
c_v	0,22	0,30	0,21	0,21	0,28	0,19	0,22	0,27	0,26	0,24	0,26	0,26	0,30	0,26

Figure 23 – Scores regarding the attribute 'support'.

The main conclusions taken from the analysis of this attribute are:

- In the same way as the attribute *urgency*, most stakeholders hold roughly the same level of support regarding the sustainability of the aerospace supply chain;
- Although the scores are, on average, slightly higher than in the *urgency* attribute, the level of support is also considered medium;
- An exception has to be made regarding the score of the Scientific Community (4,16 points), which is clearly recognised as the most supportive stakeholders' category regarding the theme of sustainability in the industry. The scientific and technological progresses accomplished by these stakeholders have been clearly supporting the sustainability across the aerospace SC.

The coefficients of variation regarding this attribute vary from 19% to 30%.

A compilation of the previous results is presented in Table 13, where all scores are presented for every stakeholder category.

Table 13 – Scores of stakeholders' categories per attribute (original scores)

	Management Board (OEM)	Customers	Suppliers	Services providers	NGOs	Scientific Community	Employees	Investors and Financial Institutions	Media	Consumers	Shareholders	Governments	Local Communities	Regulators
Power	4,35	4,06	3,45	3,26	2,52	3,13	2,77	4,00	3,35	2,90	3,71	4,13	2,94	4,29
Interest	3,90	3,74	3,52	3,52	3,81	4,00	3,16	3,29	3,32	3,06	3,19	3,81	3,55	3,81
Urgency	3,77	3,48	3,32	3,42	3,52	3,58	3,10	3,29	3,19	3,13	3,19	3,55	3,48	3,77
Legitimacy	4,23	4,00	3,81	3,65	3,71	4,13	3,68	3,65	3,19	3,55	3,94	4,29	4,06	4,23
Support	3,94	3,68	3,81	3,81	3,71	4,16	3,52	3,42	3,23	3,48	3,39	3,87	3,58	3,81

In our multimethodology, the step after calculating the scores for each pair attribute/stakeholder category was to normalise these values, following the methodology explained in chapter 4. As the previous values are very close to each other it would be quite difficult to detect the scores' differences when analysing the results. By linearly expanding the scores through the entire evaluation scale, it is much easier to detect these differences, therefore facilitating the analysis. The normalised scores are presented in Table 14.

Table 14 – Scores of stakeholders' categories per attribute (normalised scores)

	Management Board (OEM)	Customers	Suppliers	Services providers	NGOs	Scientific Community	Employees	Investors and Financial Institutions	Media	Consumers	Shareholders	Governments	Local Communities	Regulators
Power	5,00	4,37	3,04	2,61	1,00	2,33	1,56	4,23	2,82	1,84	3,60	4,51	1,91	4,86
Interest	4,02	3,67	3,18	3,18	3,81	4,23	2,40	2,68	2,75	2,19	2,47	3,81	3,25	3,81
Urgency	3,74	3,11	2,75	2,96	3,18	3,32	2,26	2,68	2,47	2,33	2,47	3,25	3,11	3,74
Legitimacy	4,72	4,23	3,81	3,46	3,60	4,51	3,53	3,46	2,47	3,25	4,09	4,86	4,37	4,72
Support	4,09	3,53	3,81	3,81	3,60	4,58	3,18	2,96	2,54	3,11	2,89	3,95	3,32	3,81

The normalisation applied a transformation in which the highest score became 5 (highest value of the scale) and the lowest score became 1 (lowest value of the scale). This allowed for a greater dispersion of the scores through the evaluation scale, using a linear transformation, and therefore facilitating the differentiation between the categories during the analysis. From this step on, only the normalised scores were used to conduct the analysis and further calculations.

The scores calculated before allowed to apply some of the original methodologies which compose our multimethodology, as early indicators of the final results. The application of two of those original methodologies is presented next.

Power-Interest Matrix

The first of original methodologies to be applied was the Power-Interest Matrix, as suggested by Bryson (2004), Ackermann & Eden (2011) and Bryson et al. (2011), is presented in Figure 24.

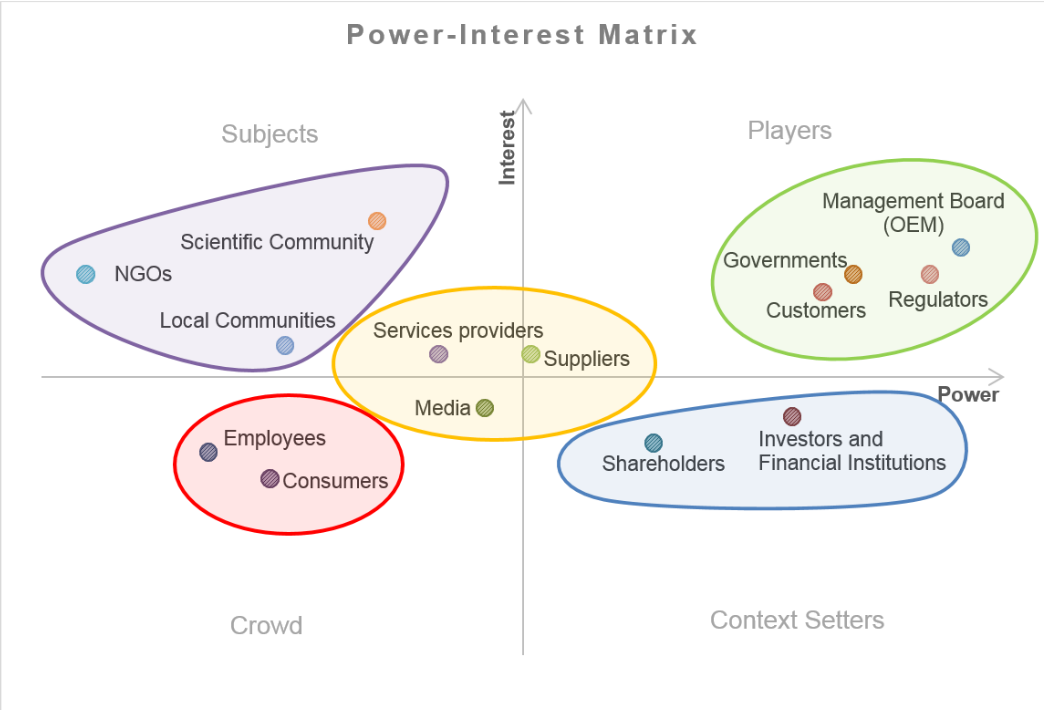


Figure 24 – Power-Interest Matrix

By analysing the placement of the stakeholders' categories in the power-interest matrix, it was possible to establish five clusters, which are represented by different colours.

- The green cluster, characterised as 'Players' is placed in the first quadrant of the matrix, where both power and interest are high. Stakeholders in this cluster are considered the most relevant stakeholders. Two types of stakeholders' categories are placed in this cluster:
    - Entities on the physical SC – Management Board of the OEMs and Customers. As the most powerful constituents of the physical supply chain, the Management Board of the OEMs (which are the representatives of the focal company) and the Customers are also highly interested in the sustainability theme. Therefore, they are considered some of the most relevant categories;
    - Governmental entities – Governments and Regulators. These are the stakeholders who legislate and regulate regarding the sustainability of the supply chain – they are the "law". Holding a high level of power and interest in the theme, these are considered as most relevant stakeholders.

- The purple cluster is characterised as ‘Subjects’. This is where stakeholders with low power and high interest are placed. If empowered these stakeholders can easily become ‘Players’. It is interesting to observe that:
    - The Scientific Community, which is formed by the most interested stakeholders, is the most prone category to become one of the most relevant, if empowered. If they become powerful enough to bring about their desires, mostly regarding the scientific and technological advancements, they will certainty become ‘players’;
    - The NGOs, although present a medium to high interest, are very unlikely to become very relevant in this industry, as commented before;
    - The Local Communities tend to have a lower interest level than the other two categories. If their interest in the sustainability of the supply chain lowers, they end up becoming almost irrelevant. However, as this industry usually has a large socio-economic impact in the areas of its operation, the tendency of its local communities is to become more interested.
- The red cluster is characterised as ‘Crowd’. These are the stakeholders who present low levels of power and interest. Two categories were considered as ‘crowd’:
    - Consumers: as commented before, the most typical consumer behaviour of passengers in this industry is highly driven by the low prices. The relevance of sustainability issues for these stakeholders is usually very low;
    - Employees: several authors consider the employees as primary stakeholders. In this case, we can explain this result as the current low engagement of this stakeholders' category in the sustainability of the aerospace SC. A long-term objective regarding these stakeholders' actions in the supply chain could be to empower and improve their interest in the sustainability matters so that they become truly engaged.
- The blue cluster is named as ‘Context Setters’. These stakeholders hold high power while having low interest, often meaning these stakeholders can highly influence the outcomes, but not always in the best interest. In this cluster, the represented stakeholders' categories are:
    - Investors and Financial Institutions, which are the primary financial support of the supply chain, but to whom integrated sustainability is not always a priority;
    - Shareholders, to whom the environmental and social performances of the supply chain are not very important, but to whom the economic performance is crucial.
- The yellow cluster was added to the original methodology and was named ‘Undecided’. These stakeholders are placed almost in the middle of the matrix, meaning that small changes in both their power or interest levels can make them to be included in any other cluster. The stakeholders' categories in this situation are:
    - the Media, tending to become irrelevant;
    - the Suppliers, requiring empowerment to fully engage on sustainability and becoming main ‘players’;
    - the Services Providers, which do not hold a lot of power, but could be influenced to become more interested and pursue better sustainability performances.

A summary of the analysis of the Power-Interest Matrix is presented in Table 15. In this table we also presents the general strategies suggested by Bryson (2004), Ackermann & Eden (2011) and Bryson et al. (2011).

Table 15 – Power-Interest Matrix analysis summary

Characterisation	*Power*	*Interest*	Stakeholders' Categories	General Strategy
Players	High	High	• Management Board • Regulators • Governments • Customers	Most significant stakeholders who deserve sustained management attention.
Subjects	Low	High	• Scientific Community • NGOs • Local Communities	Empower positively interested ones to become Players and neutralise the negatively interested ones.
Undecided	Medium	Medium	• Suppliers • Services Providers • Media	As these stakeholders can easily transfer to other categories, efforts should be made to positively influence them.
Crowd	Low	Low	• Employees • Consumers	Efforts should be made to engage this stakeholders by raising their interest and/or power
Context Setters	High	Low	• Investors and Financial Institutions • Shareholders	Seek to raise awareness as these stakeholders can change the overall context.

<u>Support vs Opposition Grid</u>

The power-interest matrix authors alert for the fact that interest in a subject is not always positive. The differentiation of positive and negative interests is crucial when drawing a strategy to deal with stakeholders. As a complement to the previous analysis, the support vs opposition grid, as presented by Nutt & Backoff (1987), Bryson (2004) and Bryson et al. (2011), comes as an indicator of the kind of interest held by the stakeholders.

Before analysing the results, it is important to clarify that:

- In the original methodology, stakeholders are typically characterised as strong or weak supporters and strong or weak opponents.;
- the scale used to evaluate support in the original method assumes positive values to express support and negative values to express opposition;
- However, in this case we cannot consider real opponents, as stakeholders were evaluated only in terms of support (from low to high) and not in terms of opposition - a low level of support does not imply any level of opposition.

The results from this methodology are presented in Figure 25.

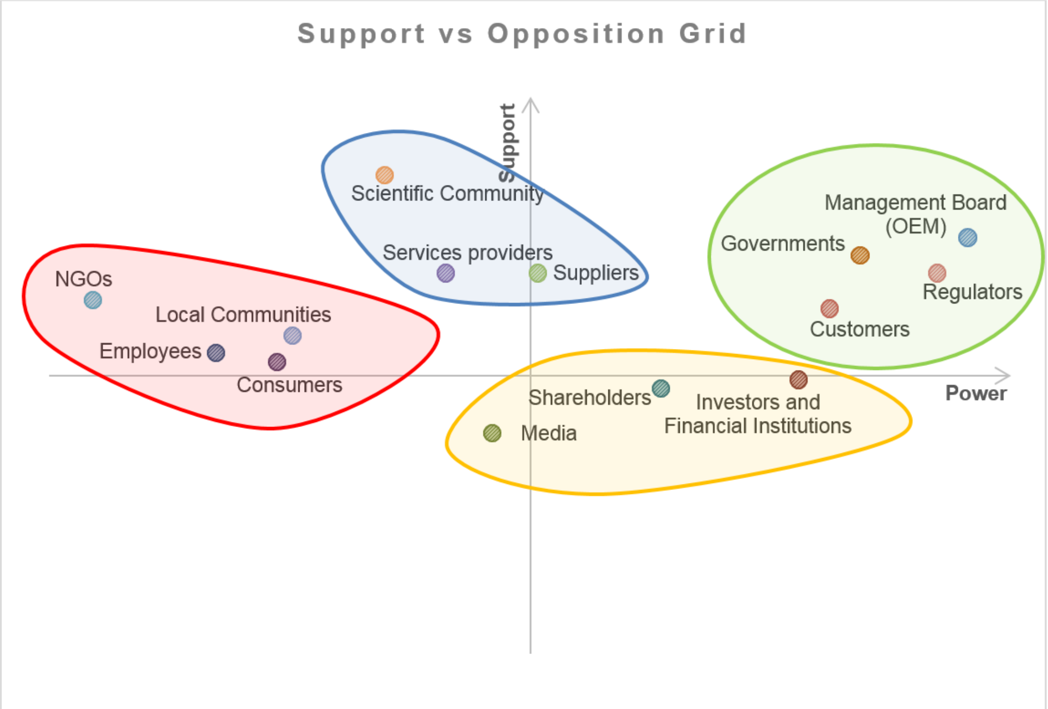


Figure 25 – Support vs Opposition Grid

Regarding the results from the support vs opposition grid we can verify that:

- Most stakeholders hold a medium to high level of support, meaning that their interest in the sustainability of the supply chain is mostly positive;
- Four clusters can be identified:
    - The green cluster, comprehending the high power and high support stakeholders, and therefore the most relevant. This cluster is composed by the same four stakeholders' categories previously identified as most relevant;
    - The blue cluster, composed by highly supportive stakeholders with medium power. These are the stakeholders who are more subject to become most relevant, if empowered. It includes the Scientific Community, as the most supportive category in terms of sustainability, and the Suppliers and the Service Providers, as entities of the physical supply who must be engaged;
    - The red cluster holds the medium supportive and low power stakeholders. Consequently, the Local Communities, the Consumers, the Employees and the NGOs are the least relevant stakeholders' categories. Following the same analysis as before, while the local communities and employees' engagement is often considered very important, the NGOs are very unlikely to gain a lot of power in this industry. If the support of sustainability by consumers was improved, their interest in this issue could also rise and eventually become a significant stakeholders' group;
    - The yellow cluster is composed by the least supportive stakeholders, even though they hold a medium level of support, while possessing high power. The financial moved Shareholders and Investors, and the Media are the categories among this cluster. It is

important to manage the increase of support from these stakeholders, as they are also among the least interested ones and are powerful enough to impact the sustainability of the supply chain. As discussed before, the media's actions in this industry are often questionable, making it harder to become one of the most relevant stakeholders' categories.

Although each one of these two methodologies only applies two of the five evaluated attributes, they can provide us with an indication of the final results regarding who are the most relevant stakeholders' categories for the aerospace sustainable supply chain. In this case, these methodologies clearly indicated as most relevant the following categories:

- Management Board of the OEMs;
- Regulators;
- Governments;
- Customers.

However, our multimethodology stakeholders' analysis is based on the simultaneous evaluation of five attributes. Therefore, a final score is required to order the categories. The application of the weighting methodology is presented next.

Swing Weighting

To calculate a final score for each stakeholder category, as this is a multi-criteria analysis, there is the need to differentiate the contributions of each attribute score. The swing weighting methodology was applied. This methodology was conducted by the same group of experts, who gave the inputs regarding their perception of the attributes. The attributes were ordered as follows: (1) *Power*; (2) *Legitimacy*; (3) *Interest*; (4) *Support*; (5) *Urgency*.

The group of experts then scored the swings from neutral to good performance in each attribute, in comparison to the most relevant attribute.

The results from the application of the Swing Weighting Method are schematised in Table 16.

Table 16 – Swing Weighting

Attribute	Swing Score	Weights
Power	s_1=100	w_1=0,294
Legitimacy	s_2=90	w_2=0,265
Interest	s_3=80	w_3=0,235
Support	s_4=40	w_4=0,118
Urgency	s_5=30	w_5=0,088
Total	$\sum s_i = 340$	$\sum w_i = 1$

Final Scores

The final scores and the ordinated list of stakeholders' categories accordingly to their relevance is presented in Table 17.

Table 17 – Stakeholders Categories' Final Scores and Final Relevance Order

Stakeholder Category	Final Score	Final Order
Management Board (OEM)	**4,48**	**1st**
Regulators	**4,35**	**2nd**
Governments	**4,26**	**3rd**
Customers	**3,96**	**4th**
Scientific Community	**3,71**	**5th**
Investors and Financial Institutions	**3,38**	**6th**
Suppliers	**3,34**	**7th**
Shareholders	**3,28**	**8th**
Local Communities	**3,15**	**9th**
Services providers	**3,14**	**10th**
NGOs	**2,85**	**11th**
Media	**2,65**	**12th**
Employees	**2,53**	**13th**
Consumers	**2,49**	**14th**

The selection of the most relevant categories was done by plotting the final scores, as shown in Figure 26, and evaluating the differences between scores. We can observe three tendency lines: from the 1st to the 5th categories, from the 6th to the 10th and from the 11th to the 14th. The group of experts suggested to continue the analysis considering the five most relevant categories, which are marked in green in Figure 26.

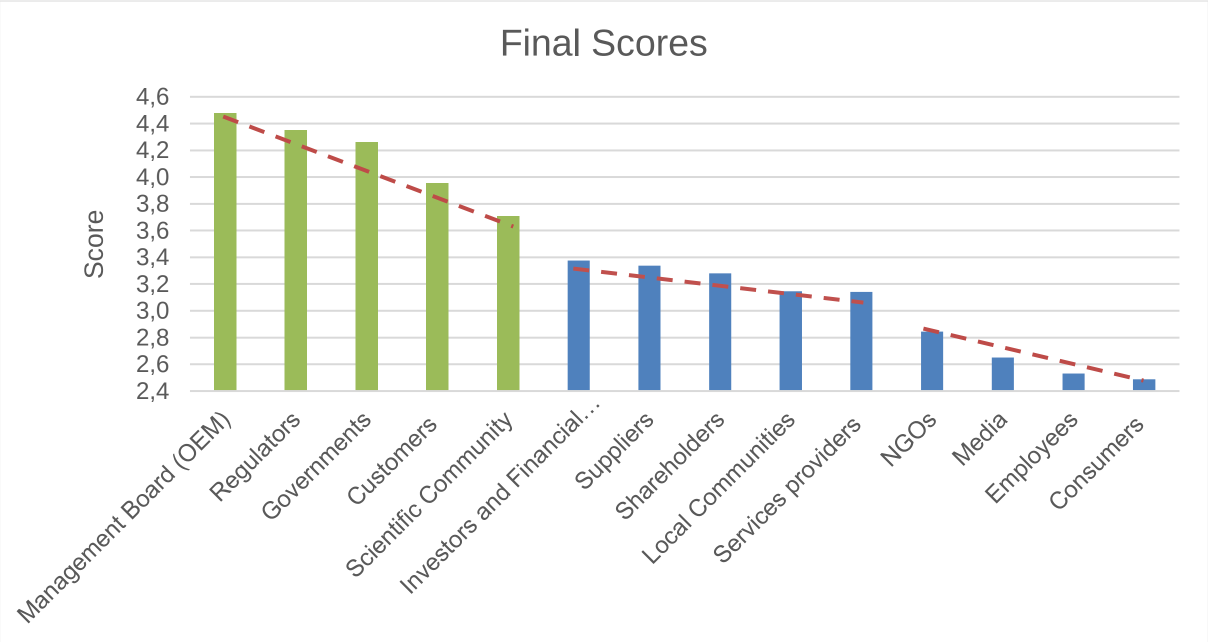


Figure 26 – Final scores of the stakeholders' categories

As one of the main results from our multimethodology stakeholders' analysis, the most relevant stakeholders' categories for the sustainability of the aerospace supply chain are:

1º. Management Board of the OEMs;
2º. Regulators;
3º. Governments;
4º. Customers;
5º. Scientific Community.

The score profile of the five most relevant stakeholders' categories is presented in Figure 27, using a radar chart and plotting the five attributes at the same time.

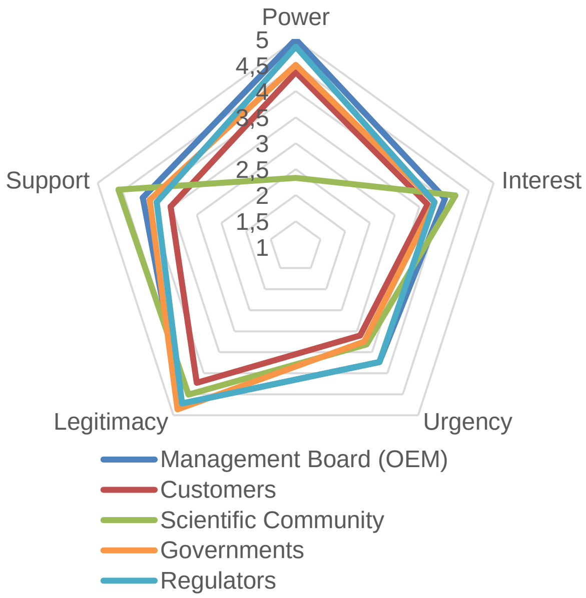


Figure 27 – Radar chart for the five most relevant stakeholders' categories

It is very interesting to compare these results to the ones from the power-interest matrix, presented in, Figure 24 and the support vs opposition grid presented in Figure 25, as:

- The most relevant categories in those analysis (green clusters in Figure 24 and Figure 25) are also considered most relevant in our stakeholders' analysis multimethodology;
- The only category which was not considered as most relevant before was the Scientific Community. As we can see in Figure 27, the only attribute where this category is considered less relevant than the other categories is the Power. In every other attribute it is considered to have a high performance. Regarding the Support and the Interest, the Scientific Community is even considered the most relevant category. The very good performance in all other attributes ends up balancing the low performance in power, allowing the good overall score.
- This means that, although incomplete, the analysis performed with the power-interest matrix (Figure 24) and in the support vs opposition grid (Figure 25) are reliable indicators to the most relevant stakeholders' categories.

Sensitivity Analysis

To evaluate the robustness of the stakeholders' analysis multimethodology, a sensitivity analysis was performed by creating various scenarios and analyse their impacts on the final score. As represented in Figure 28, three types of scenarios were considered when conducting the sensitivity analysis:

(S1) using the same weights for the final score calculation;

(S2) filtering the sample regarding the direct work with sustainability (question 3 on the survey);

(S3) filtering the data regarding the most represented stakeholders' categories (question 5 on the survey).

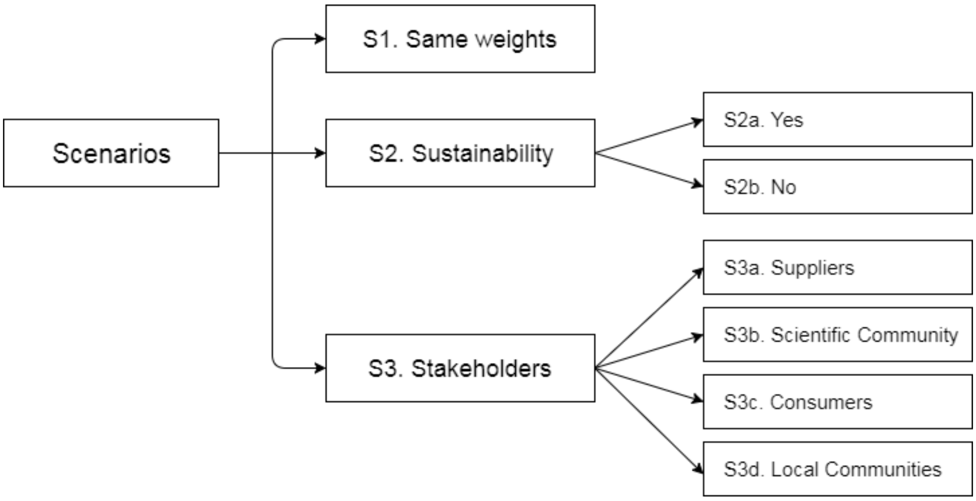


Figure 28 – Scenarios for the Sensitivity Analysis

- Scenario S1. assumed all attributes had the same relevancy, and therefore the swing weighting methodology was not considered. The same weight was given to all attributes ($w_i = \frac{1}{5} = 0{,}2$) (n=31).
- Scenario S2. considered the answers from respondents who do/do not work directly with the sustainability:
    - S2a. Yes (n=12);
    - S2b. No (n=19).
- Scenario S3 considered only the answers from respondents who considered themselves as:
    - S3a. Suppliers (n=10);
    - S3b. Scientific Community (n=5);
    - S3c. Customers (n=4);
    - S3d. Local Communities (n=4).

After performing the multimethodology analysis considering these scenarios, the order of relevance of the original top five stakeholders' categories was compared in each of the scenarios. This analysis is represented in Table 18. The complete final scores in each scenario are presented in Appendix I.

Table 18 – Sensitivity Analysis: Comparison of relevance orders

Stakeholder Category	Original Order	Scenario						
		S1	S2a	S2b	S3a	S3b	S3c	S3d
Management Board (OEM)	1st	1st	2nd	1st	1st	3rd	7th	2nd
Regulators	2nd	2nd	1st	4th	2nd	1st	2nd	5th
Governments	3rd	3rd	3rd	3rd	5th	2nd	1st	1st
Customers	4th	5th	4th	2nd	4th	4th	4th	4th
Scientific Community	5th	4th	5th	6th	3rd	5th	8th	6th

When analysing these results, we can conclude that:

- In a general way, when considering the various scenarios, the top five categories remain the same;
- The inclusion of the Scientific Community in the top five categories is not very robust, as it is not considered as most relevant in three different scenarios. However, more responses to the survey could provide more robustness to this result;
- The only three scenarios where some of the original top categories were not considered in the top five are S2a, S3c and S3d. These scenarios share the fact that the data is prevenient from the less informed stakeholders: non-sustainability practitioners (S2b), consumers (S3c) and local communities (S3d).
- If we only consider the scenarios with data from well-informed stakeholders (S1, S2a, S3a and S3b) the robustness of the model is proven.
- As a suggestion for the future, allied to the inclusion of more data in the model (more responses), it would be very interesting to conduct this analysis considering more scenarios.

5.1.4 Creating Sustainability Value Flows Between Stakeholders' Categories

The last step of the Stakeholders' Analysis, step 6, was to create sustainability value flows between stakeholders' categories as a way to map the engagement of stakeholders towards sustainability.

This step was based on the work by Cameron et al. (2008), which presented the Value Flow Mapping Methodology. In our analysis, we chose to address the value not just in its economic pillar, but in its environmental and social pillars. Therefore, the value, as studied in this step, can acquire an economic, environmental, social or even 3BL nature.

The first step in this method was to discover the sustainability value creation inputs and outputs by the stakeholders' categories previously identified as most relevant to the aerospace SC. This step was performed based in the opinions and knowledge of the same group of experts that were consulted during the previous steps of the multimethodology stakeholders' analysis. The results from this step are presented in Figure 29.

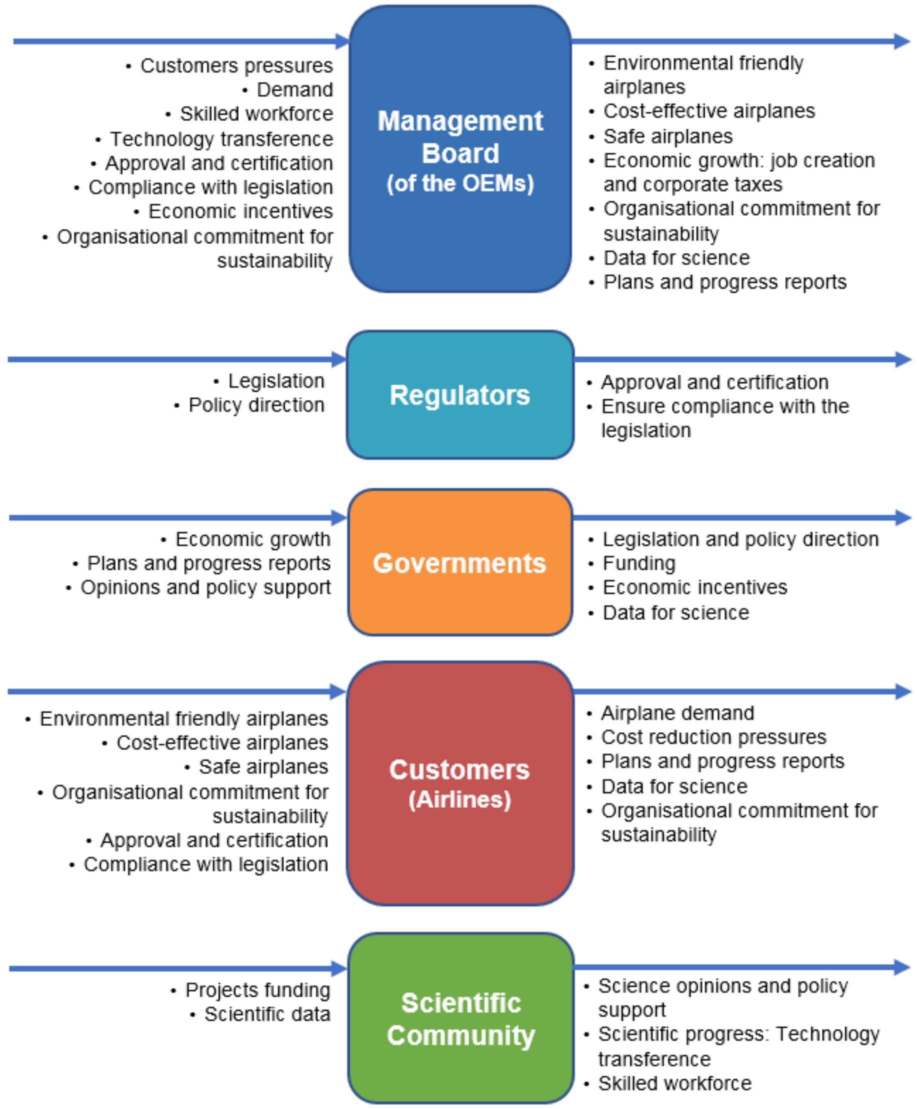


Figure 29 – Sustainability value inputs and outputs for the top five stakeholders' categories

The main conclusions taken from the analysis of this figure are:

- The categories in which more inputs and outputs were identified were the ones which are part of the physical supply chain – the Management Board of the OEMs and the Customers. These are also the only two categories which contemplate material inputs or outputs, in this case the products of the SC (airplanes), since these are the only stakeholders' categories were materials transferences occur in reality;
- Pure economical value inputs and outputs were identified, such as 'projects funding' or 'economic incentives', in all stakeholders' categories but the Regulators, since their function is not directly related to economic value creation;
- Most inputs and outputs describe intangible value such as 'scientific progress', 'legislation and policy direction' or 'cost reduction pressures', meaning the analysis is focused primarily in conceptual value other than physical or monetary value;

- Both the Management Board of OEMs and the Customers presented 'organisational commitment' as inputs and outputs. These flows were then considered internal value flows, in which the company commits itself to become more sustainable and that way generates sustainability value;
- The inputs and outputs considered for this analysis took into account the particular relations between these five stakeholders' categories only. For example, inputs and outputs such as 'wages' which would link the Management Board of the OEMs to Employees were not considered, as the analysis did not consider the second. This means that probably hundreds of other value flows could be established if more stakeholders were considered.

For the second step, the previously identified inputs and outputs were linked between stakeholders' categories. This links created sustainability value flows, which were then and classified by the group of experts regarding the nature of their value (economic, environmental, social or integrated - 3BL). The result from this step is presented as a map in Figure 30, where the flows colours represent the nature of the value.

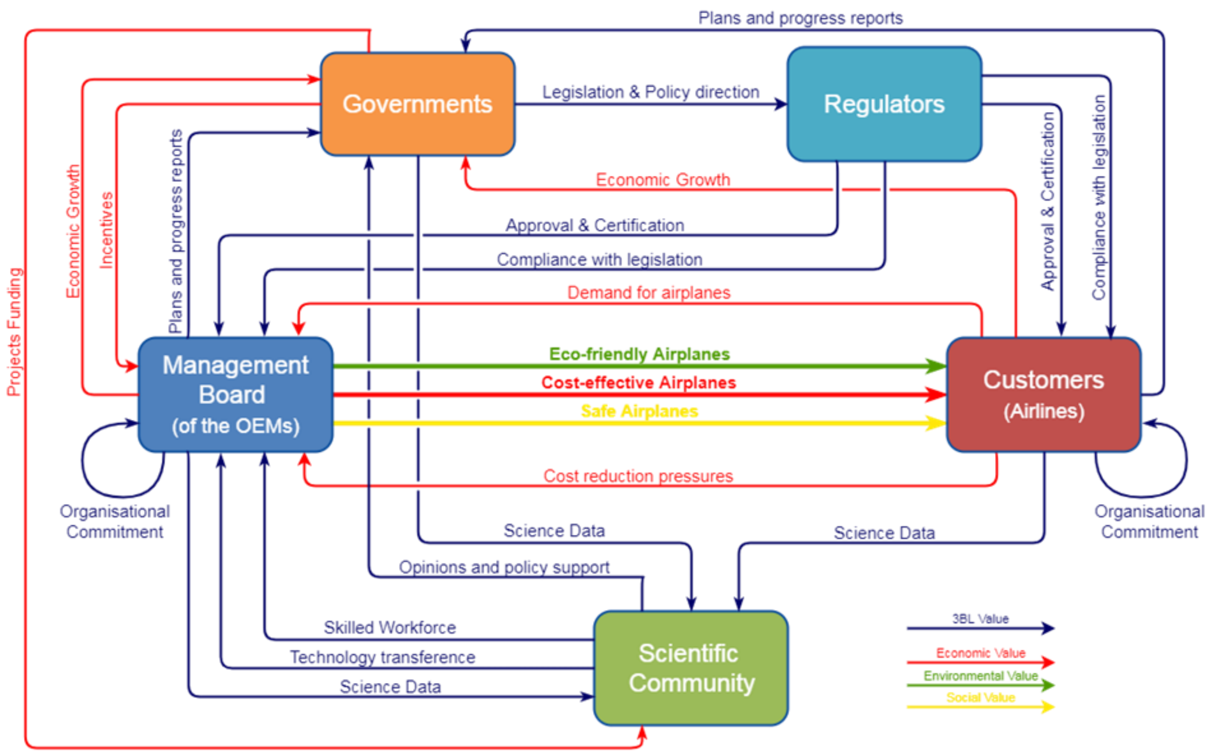


Figure 30 – Sustainability Value Flow Map

This map establishes a novel framework to the stakeholders' engagement towards sustainability in aerospace supply chains, by mapping the stakeholders' relations which create sustainable value for the supply chain.

Regarding the classification of the value flows, we noticed that:

- Economic value flows are easier to categorise than environmental and social flows because monetary and economic value is typically very easy to recognise with the common sense. In this case, these flows are:
    - The projects funding from the Governments to the Scientific Community;
    - The economic incentives given by the Governments to the OEMs;
    - The economic growth generated by the OEMs and Airlines which affect directly the Governments;
    - The demand for airplanes and the cost reduction pressures from the Airlines to the OEMs.
- On a general way and if not clearly identified as economic value, the sustainability flows usually acquire an integrated 3BL value. This happens as most flows end up generating positive impacts in all three pillars of sustainability. This is the case of the sustainable value created by:
    - Legislation and policy direction;
    - Compliance with the legislation;
    - Approval and certification of OEMs and Airlines activities;
    - Science data shared with the Scientific Community;
    - Technology transference and development of skilled workforce from the Scientific community to the OEMs;
    - Sharing plans and progress reports (Management Boards of OEMs and Customers), as well as opinions and policy support (Scientific Communities) with the Government, as a basis to the creation of legislation;
    - Organisational commitment for sustainability within the OEMs and the Airlines.
- The three flows from the Management Board to the Customers represented the contribution for each pillar of sustainability from the products of the supply chain: airplanes. To be distinguished from the other flows, these are represented with thicker lines, as they are the only ones representing physical value.
- Although considered very relevant for the sustainability of the supply chain, the sustainability value created by the Regulators is exclusive to their action as they approve and certificate the actions of the supply chain and ensure compliance with the legislation created by the Governments.

From this analysis we conclude that:

- Nowadays, the sustainability value flows tend to adopt the 3BL nature, therefore proving the importance and benefits of integrated sustainability.
- Furthermore, the numerous loops that can be established within the sustainability value map often include more than one type of sustainability value, proving once more the integrated nature of sustainability.

- The decision-making process led by these stakeholders has, more than ever, to consider the tradeoffs between economic, environmental a social value to achieve an effective stakeholders' engagement towards sustainability, throughout the supply chain.

This analysis came as the last step of the multimethodology for Stakeholders' Analysis. The following section is dedicated to measuring the stakeholders' engagement towards sustainability by developing a sustainability performance assessment framework.

5.2 Sustainability Performance: Measuring Stakeholders' Engagement

In this section, a sustainability performance reporting framework is presented as a way of measuring the stakeholders' engagement towards sustainability. This analysis is based on: (1) the results from the previously conducted multimethodology stakeholders' analysis; (2) sustainability reporting practices from representative stakeholders; and (3) adopted the GRI-G4 standards for sustainability reporting (GRI 2015).

As a starting point to develop the framework, we analysed the GRI-G4 standards which present a set of aspects and indicators directly related to supply chains in general, as presented in Table 19.

Table 19 – Supply chain related standard aspects (Adapted from GRI 2015)

Aspects	GRI-G4 indicators
Economic	
Procurement Practices	G4-EC9
Environmental	
Energy	G4-EN4
Emissions	G4-EN17
Supplier Environmental Assessment	G4-EN32
	G4-EN33
Social	
Sub-category: Labour Practices and Decent Work	
Occupational Health and Safety	G4-LA6
Supplier Assessment for Labour Practices	G4-LA14
	G4-LA15
Sub-category: Human Rights	
Freedom of Association and Collective Bargaining	G4-HR4
Child Labour	G4-HR5
Forced or Compulsory Labour	G4-HR6
Supplier Human Rights Assessment	G4-HR10
	G4-HR11
Sub-category: Society	
Supplier Assessment for Impacts on Society	G4-SO9
	G4-SO10

However, these indicators take a much narrower approach to the supply chain than the one used in our study, as it is very focused in the relationship between the focal company and its suppliers.

By analysing the content of the sustainability reports from organisations which are representative of the five most relevant stakeholders' categories, previously identified in this study, a set of aspects and indicators are suggested to measure the aerospace SC sustainability performance, and therefore, the stakeholders' engagement towards sustainability.

The same group of experts that performed the decisions in the Stakeholders' Analysis selected the companies/organisations to be studied in this assessment, which are presented in Table 20. The principal data reference used for each one and their reporting type are also presented in this table.

Table 20 – Representative companies, principal data references and reporting type

Stakeholder Category	Company	Principal data reference	Reporting type
Management Board of the OEMs	Airbus Group	Airbus (2017a); Airbus (2017b)	GRI-G4
	The Boeing Company	Boeing (2016a); Boeing (2017)	Non-GRI
	Bombardier	Bombardier (2016)	Citing GRI
	Embraer	Embraer (2017)	GRI-G4
Regulators	EASA	EASA (2015); EASA et al. (2016)	Non-GRI
Governments	City of Chicago	City of Chicago (2013)	GRI-G3.1
Customers	Finnair	Finnair (2017)	GRI-G4
	Lufthansa Group	Lufthansa Group (2017)	GRI-G4
	TAP Group	TAP Group (2016)	GRI-G4
Scientific Community	University of Minho	University of Minho (2016)	GRI-G4

The motives which leaded the group of experts to select these organisations were:

- In the case of the Management Board of the OEMs the top players of the industry were selected, whether presenting the best practices or not: Airbus, Boeing, Bombardier and Embraer.
- For the Regulators category, EASA – the major European regulator – was selected.
- For Governments categories, the City of Chicago, where Boeing Headquarters are located, was selected as representative of governmental entities.
- For the Customers category, three European GRI-G4 reporting airlines or airlines groups were selected: Finnair from Finland, Lufthansa Group from Germany and TAP Group from Portugal.
- As representative of the best practices in reporting sustainability in the Scientific Community, University of Minho, the only GRI-G4 reporting higher education entity in Portugal, was selected.

Then, by analysing the content of the sustainability reporting by these representative organisations and the information contained in them, it was possible to map which aspects of sustainability were reported by each company. The results from this analysis are presented in Table 21. The companies in which equivalent aspects where considered are marked with (*) and the reported themes are marked with (▲).

Table 21 – Reported GRI aspects or equivalent by the representative companies

Aspects	Management Board of the OEMs				Reg	Gov.	Customers			Sci Com
	Airbus	Boeing*	Bombardier*	Embraer	EASA*	City of Chicago	Finnair	Lufthansa Group	TAP Group	Uni. Minho
Economic										
Economic Performance	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Market Presence		▲		▲				▲	▲	▲
Indirect Economic Impacts		▲	▲	▲		▲	▲		▲	▲
Procurement Practices		▲	▲		▲		▲		▲	▲
Environmental										
Materials									▲	▲
Energy	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Water	▲	▲	▲	▲		▲		▲	▲	▲
Biodiversity		▲				▲	▲	▲		
Emissions	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Effluents and Waste	▲	▲	▲	▲		▲	▲		▲	▲
Products and Services				▲				▲		
Compliance		▲					▲			
Transport						▲				
Overall						▲			▲	
Supplier Environmental Assessment				▲				▲		
Environmental Grievance Mechanisms				▲					▲	
Social: Labour Practices and Decent Work Aspect										
Employment	▲	▲	▲	▲	▲		▲	▲	▲	▲
Labour/Management Relations							▲	▲	▲	
Occupational Health and Safety	▲	▲	▲	▲			▲	▲	▲	▲
Training and Education	▲			▲	▲		▲	▲	▲	▲
Diversity and Equal Opportunity	▲	▲	▲				▲	▲	▲	▲
Equal Remuneration for Women and Men			▲				▲	▲	▲	▲
Supplier Assessment for Labour Practices				▲				▲		
Labour Practices Grievance Mechanisms				▲						▲

▲ Reported; *non-GRI reporting – equivalent aspects reported

Table 21 – Reported GRI aspects or equivalent by the representative companies (cont.)

Aspects	Management Board of the OEMs				Reg	Gov	Customers			Sci Com
	Airbus	Boeing*	Bombardier*	Embraer	EASA*	City of Chicago	Finnair	Lufthansa Group	TAP Group	Uni. Minho
Social: Human Rights										
Investment				▲				▲		▲
Non-discrimination		▲		▲				▲		▲
Freedom of Association and Collective Bargaining		▲	▲	▲				▲	▲	
Child Labour		▲		▲					▲	
Forced or Compulsory Labour		▲	▲	▲					▲	
Security Practices			▲						▲	
Indigenous Rights										
Assessment							▲	▲		
Supplier Human Rights Assessment				▲			▲	▲		
Human Rights Grievance Mechanisms				▲				▲		
Social: Society										
Local Communities	▲	▲		▲						▲
Anti-corruption	▲		▲	▲		▲	▲	▲	▲	▲
Public Policy						▲	▲			
Anti-competitive Behaviour			▲				▲			
Compliance							▲			
Supplier Assessment for Impacts on Society				▲				▲		
Grievance Mechanisms for Impacts on Society				▲						
Social: Product Responsibility										
Customer Health and Safety							▲	▲		
Product and Service Labelling	▲			▲			▲	▲		
Marketing Communications							▲			
Customer Privacy							▲	▲		
Compliance							▲			

▲ Reported; *non-GRI reporting – equivalent aspects reported

By observing the previous table, we can conclude that:

- In this representative sample there is at least one organisation reporting each aspect, except for one (Indigenous Rights).;
- Some aspects, such as Economic Performance, 'Energy' and 'Emissions' are reported by all companies/organisations;
- In a general way, some aspects are extensively reported throughout the stakeholders, such as
  - All Economic aspects, which have been being reported in many years;
  - 'Energy';
  - 'Water';
  - 'Emissions';
  - 'Effluents and Waste', as the reporting of quantifiable environmental impacts more related to air pollution and resources and waste management are becoming a standard in several industries.
- The Customers (airlines) are very focused in reporting their labour practices and decent work aspects, as these companies are typically subject to high pressures from their employees and unions;
- The most relevant labour aspects in the industry are:
  - 'Employment', as this is an industry which employs a very large number of people;
  - 'Occupational Health and Safety', which evaluates the safety and incidents among the employees;
  - 'Diversity and Equal Opportunity', which is closely related to the basic human rights.
- Regarding the human rights aspects, as these aspects were themes reported very seriously by some OEMs and Airlines, the group of experts understood that the most relevant aspects were:
  - the 'Freedom of Association and Collective Bargaining';
  - the 'Child Labour';
  - the 'Forced or Compulsory Labour';
- When addressing the society aspects, the most reported theme is:
  - 'Anti-corruption'. The industry has had some problems with corruption scandals in its history, therefore the need to report this aspect;
- The Product Responsibility aspect which is most reported is:
  - the 'Product and service labelling' aspect, which is closely related to the high standards of product safety in the aerospace industry.

Based in the supply chain related aspects suggested by GRI-G4, presented in Table 19, and in the previous analysis of the actual reported information by these organisations, the group of experts suggested a set of sustainability matters as most relevant. These matters were associated to GRI standard aspects and GRI-G4 indicators to construct a Sustainability Performance Assessment methodology. The proposed framework ultimately allows the evaluation of the engagement of the several stakeholders towards the sustainability of the aerospace supply chain.

Using some of the performance indicators validation proprieties suggested by Kueng (2000), presented in section 3.3.2, a few characteristics were used to further select or adapt GRI-G4 indicators. We selected indicators which possessed the following characteristics:

- Quantifiable: consider only quantifiable indicators;
- Improvement-orientated: consider only indicators which provide improvement directions instead of evaluating conformity to the plans.

The selected indicators, separated by the sustainability pillar to which they are related, are presented next. The indicators suggested by GRI as supply chain related are marked with (º), while the adapted indicators are marked with (*):

Economic Performance Assessment:

- G4-EC1: direct economic value generated and distributed;
- G4-EC4: financial assistance received from government;
- G4-EC8: significant indirect economic impacts, including the extent of impacts;
- G4-EC9º: proportion of spending on local suppliers at significant locations of operation.

Environmental Performance Assessment:

- G4-EN3: energy consumption within the organization;
- G4-EN6: reduction of energy consumption;
- G4-EN8: total water withdrawal by source;
- G4-EN10: percentage and total volume of water recycled and reused;
- G4-EN16/17/18: greenhouse gas (GHG) emissions (scope 1/2/3);
- G4-EN19: reduction of greenhouse gas (GHG) emissions;
- G4-EN22: total water discharge by quality and destination;
- G4-EN23: total weight of waste by type and disposal method;
- G4-EN32: percentage of new suppliers that were screened using environmental criteria.

Social Performance Assessment:

- G4-LA1: total number and rates of new employee hires and employee turnover by age group, gender and region;
- G4-LA6º: type of injury and rates of injury, occupational diseases, lost days, and absenteeism, and total number of work-related fatalities, by region and by gender;
- G4-LA12: composition of governance bodies and breakdown of employees per employee category according to gender, age group, minority group membership, and other indicators of diversity;
- G4-LA14º: percentage of new suppliers that were screened using labour practices criteria;

- G4-HR4º*: total number of operations and suppliers identified in which the right to exercise freedom of association and collective bargaining may be violated or at significant risk
- G4-HR5º*: total number of operations and suppliers identified as having significant risk for incidents of child labour;
- G4-HR6º*: total number of operations and suppliers identified as having significant risk for incidents of forced or compulsory labour;
- G4-HR10º: percentage of new suppliers that were screened using human rights criteria;
- G4-SO1: percentage of operations with implemented local community engagement, impact assessments, and development programs;
- G4-SO3: total number and percentage of operations assessed for risks related to corruption and the significant risks identified;
- G4-SO5: confirmed incidents of corruption and actions taken;
- G4-SO9º: percentage of new suppliers that were screened using criteria for impacts on society
- G4-PR4: total number of incidents of non-compliance with regulations and voluntary codes concerning product and service information and labelling, by type of outcomes;
- G4-PR5: results of surveys measuring customer satisfaction.

As the final framework for sustainability performance assessment, a participation planning matrix was then created to map the functions of each stakeholder category in the sustainability reporting process. Usually, in this type of matrix, the tasks (rows) are linked to the stakeholders (columns) by defining their responsibility towards that concrete task. In our framework, for each indicator (rows) the group of experts defined the responsibility of each stakeholders' category (columns). Four types of responsibilities were considered:

1. Audit, marked as (♦);
2. Legislate, marked as (■);
3. Report, marked as (▲);
4. Research, marked as (●).

Each sustainability matter, GRI aspect and its corresponding GRI-G4 indicators previously identified as the most relevant to this assessment were listed. The responsibilities of each stakeholder category, regarding these indicators, were defined and mapped in the matrix.

The framework is presented in Table 22.

Table 22 – Framework for Sustainability Reporting in the Aerospace Supply Chain

	Sustainability Matter	GRI Aspect	GRI-G4 Indicators	Management Board (OEM)	Regulators	Governments	Customers	Scientific Community
Economic	Economic performance and impacts	Economic Performance	G4-EC1 G4-EC4	▲	▲♦	▲■	▲	▲
	Local socio-economic development	Indirect Economic Impacts	G4-EC8	▲	-	▲	▲	▲
	Management of supply chain	Procurement Practices	G4-EC9^{o}	▲	-	-	▲	-
Environment	Management of natural resources and waste	Energy	G4-EN3 G4-EN6	▲	♦	▲■	▲	▲●
		Water	G4-EN8 G4-EN10	▲	♦	▲■	▲	▲●
		Effluents and Waste	G4-EN22 G4-EN23	▲	♦	▲■	▲	▲●
	Atmospheric emissions & climate change	Emissions	G4-EN15/16/17 G4-EN19	▲	♦	▲■	▲	▲●
	Management of supply chain	Supplier Environmental Assessment	G4-EN32	▲	-	-	▲	●
Social	**Sub-category: Labour Practices and Decent Work**							
	Attraction, development and retention of human resources	Employment	G4-LA1	▲	▲♦	▲■	▲	▲
		Diversity and Equal Opportunity	G4-LA12	▲	♦	▲■	▲	▲
	Employee health and safety	Occupational Health and Safety	G4-LA6^{o}	▲	♦	▲■	▲	▲
	Management of supply chain	Supplier Assessment for Labour Practices	G4-LA14^{o}	▲	-	-	▲	●
	Sub-category: Human Rights							
	Human and labour rights	Freedom of Association and Collective Bargaining	G4-HR4^{o*}	▲	♦	■	▲	▲
	Management of supply chain	Child Labour	G4-HR5^{o*}	▲	♦	■	▲	-
		Forced or Compulsory Labour	G4-HR6^{o*}	▲	♦	■	▲	-
		Supplier Human Rights Assessment	G4-HR10^{o}	▲	-	-	▲	●
	Sub-category: Society							
	Local socio-economic development	Local Communities	G4-SO1	▲	-	♦	▲	▲●
	Ethics	Anti-corruption	G4-SO3 G4-SO5	▲	♦	■	▲	▲●
	Management of supply chain	Supplier Assessment for Impacts on Society	G4-SO9^{o}	▲	-	-	▲	●
	Sub-category: Society							
	Product safety	Labelling products and services	G4-PR4 G4-PR5	▲●	♦	■	▲●	●

♦ Audit; ■ Legislate; ▲ Report; ● Research

In this framework, we clearly suggest preference roles for each stakeholder category when participating in the aerospace supply chain sustainability reporting process:

- The Management Board of the OEMs, as well as the Customers must adopt a reporting role;
- Regulators must adopt an auditing role;
- Governments must adopt a legislating role;
- The Scientific Community must adopt researching role.

As a future development of this framework, when developing concrete indicators it is important to follow the other validation characteristics presented by Kueng (2000):

- Sensitivity: minor performance changes should be detected by the indicator;
- Linearity: linear dependency between performance change and indicator change is preferred;
- Reliability: the results must be free of systematic errors and correctly calculate performance in normal and unexpected circumstances;
- Efficiency: indicators must be cost-effective to produce and measure.

To compare sustainability performances of stakeholders as a way to measure their engagement towards sustainability in the aerospace supply chain, the implementation of standardised reporting across the supply chain's stakeholders is of the most interest. The presented framework could be used as the basis for the development of a standard for this industry. Furthermore, it is crucial that sustainability reporting evolves from an exceptional activity undertaken by a minority of organisations to a standard practice.

5.3 Chapter Conclusions

In the present chapter the results obtained from the multimethodology for Stakeholders' Analysis and of the Sustainability Performance Assessment were presented. The discussion of these results was also presented in this chapter.

The novel multimethodology developed to perform the Stakeholders' Analysis produced a richer picture for understanding the complex aerospace supply chain and the relations between its stakeholders. This new approach is considered an important contribution for the science of stakeholders' analysis as it can be applied to other industries and contexts.

The data collection in this new methodology was based in an online survey and included the participation of stakeholders from the entire aerospace supply chain at a global scale. Although a low response rate was verified (7,8%, n=31), the results allowed to conduct the entire analysis, using descriptive and graphical tools. The diversity of the sample in every evaluated aspect (function, direct work with sustainability, organisation dimension, stakeholders' categories) enriched this study by providing various points of view. However, due to the small sample size, it was not possible to introduce the self-evaluation data in the model.

Although the usual stakeholders' analysis methodologies 'power-interest matrix' and 'support vs opposition grid' only consider two attributes each, they can be useful as an indicator of the complete multimethodology analysis' results. However, they do not substitute the complete analysis and must be seen as mere indicators. Our multimethodology considered the *power*, the *interest*, the *urgency*, the *legitimacy* and the *support* as relevant attributes to be studied, and from which better results can be derived. Although evaluating five attributes in the same analysis creates complexity, it is the only way to truly manage the high complexity of the aerospace industry.

One of the main results of the multimethodology stakeholders' analysis was to identify the five most relevant stakeholders' categories, in the context of the aerospace supply chain sustainability. These were:

- the Management Board of the OEMs;
- the Regulators;
- the Governments;
- the Customers;
- the Scientific Community.

The sensitivity analysis demonstrated the reliability of the model, when considering the evaluations by well-informed stakeholders' groups.

The sustainability value flow map presented the most relevant flows between stakeholders' categories which improve sustainability across the aerospace supply chain in an integrated way. Most flows present an integrated sustainable value (3BL value), leading to the conclusion that the decision-making process led by these stakeholders has, more than ever, to consider the tradeoffs between economic, environmental and social value to achieve an effective stakeholders' engagement towards sustainability throughout the supply chain.

A framework for sustainability performance reporting was presented as a way of measuring the stakeholders' engagement towards sustainability in the aerospace supply chain. The GRI-G4 standards were used as the basis for sustainability reporting.

The main conclusion regarding to this assessment, which can be used as indicator of the stakeholders' engagement towards sustainability in the aerospace supply chain, is the necessity of reporting standardisation across all entities. Only by doing so, it is possible to compare performances from individual organisations and to aggregate the supply chain's global impacts. In the future, the presented framework could be used as a basis for the development of a sustainability reporting standard for the aerospace supply chain.

6. Conclusions and Future Work

The commercial aviation sector's relevance in the global aerospace manufacturing industry has been growing during the last years, mainly due to the increase in air transportation demand. However, aerospace is a complex global industry with equally complex sustainability challenges and, therefore, proper supply chain management is needed to make this a sustainable growth, in its economic, environmental and social dimensions.

During this dissertation, the state of the art on relevant themes was presented, therefore achieving the objective of performing a literature review on several different approaches to stakeholders' analysis, interviewing techniques, indicators development and validation methodologies and sustainability indicators.

One of the main objectives of this dissertation was to develop and conduct a new methodology for stakeholders' analysis. Based in an innovative and challenging process, with the collaboration of several academic and industrial institutions, it resulted in the collection of interesting data and in the definition of a novel multimethodology for stakeholders' analysis, coming as a significant contribution for this area of science, as it can be adapted to other contexts and produce richer results than the existent methodologies.

The complete analysis resulted in the definition of the five most relevant stakeholders' categories, in the context of the aerospace supply chain sustainability, using a score system from 1 to 5 points: (1) Management Board of the OEMs (4,48 points); (2) Regulators (4,35 points); (3) Governments (4,26 points); (4) Customers (3,96 points); (5) Scientific Community (3,71 points). These were considered to be the stakeholders which must be primarily engaged when addressing the issue of sustainability in the aerospace supply chain, as they are the most powerful, interested, legitimate, supportive and with the most sense of urgency regarding this theme. Therefore, these stakeholders are the ones who are in the best position of driving change and which can more effectively have a positive impact the sustainability in the industry.

The sustainability value flow map presented the most relevant flows between stakeholders' categories which improve sustainability across the aerospace supply chain in an integrated way. This was also a new approach to the assessment of stakeholders' engagement, in this case by creating an intuitive map of how sustainability value can be created between them.

As recommendations following this analysis, we consider that establishing positive relations and shared strategies between all stakeholders in the aerospace supply chain are critical to achieve the integrated economic, environmental and social sustainability. Although the definition of the most relevant stakeholders is needed as a tool to reduce the complexity of the system to a manageable level, the engagement of all stakeholders is crucial.

The last main objective for this dissertation was to create indicators to measure the stakeholders' engagement towards sustainability in the aerospace supply chain. Despite this objective was not fully achieved, a framework for sustainability performance reporting was presented as a basis for the development of a standard. The main limitation observed regarding this objective were related to the low standardisation in reporting practices across the industry, which is closely linked its high complexity. The main conclusion related to this problem is, therefore, the need of reporting standardisation across all entities, since only by using the same measures and techniques, it is possible to compare companies' performances and to evaluate the supply chain performance. The creation of a sustainability performance reporting standard for the aerospace industry and its stakeholders would have a major impact in how this theme is addressed by the industry. By allowing more accurate comparisons between the organisations, competition regarding their sustainability performance would increase and could become a major driver sustainability. Given the high importance of this analysis and its implications for this assessment, a more detailed and time-consuming approach is needed.

As future work, first we recommend increasing the size of the sample, to produce more robust results, as well as the introduction of semi-structured interviews and focus groups as data collection techniques. It would also be interesting to test this novel multimethodology for stakeholders' analysis in other contexts, industries, issues and use case studies to take the analysis to the particular level. Regarding the sustainability performance assessment, we recommend starting with the development of concrete indicators based in the presented framework, followed by testing its application in a case study.

7. References

Ackermann, F. & Eden, C., 2011. Strategic Management of Stakeholders: Theory and Practice. *Long Range Planning*, 44(3), pp.179–196.

Airbus, 2017a. *Annual Report 2016*, Toulouse.

Airbus, 2017b. CSR Reporting and Data. *company.airbus.com*. Available at: http://company.airbus.com/responsibility/csr-reporting.html [Accessed October 4, 2017].

Airbus, 2017c. Future by Airbus. *airbus.com*. Available at: http://www.airbus.com/innovation/future-by-airbus/ [Accessed January 13, 2017].

Airbus, 2016. *Mapping Demand*, Toulouse.

Ansari, Z. & Kant, R., 2016. A state-of-art literature review reflecting 15 years of focus on sustainable supply chain management. *Journal of Cleaner Production*, 142(4), pp.2524–2543.

Antolín-López, R., Delgado-Ceballos, J. & Montiel, I., 2016. Deconstructing corporate sustainability: A comparison of different stakeholder metrics. *Journal of Cleaner Production*, 136(A), pp.5–17.

Bana e Costa, C. & Vansnick, J., 1994. MACBETH — An interactive path towards the construction of cardinal value functions. *International Transactions in Operational Research*, 1(4), pp.489–500.

Beelaerts van Blokland, W., Santema, S. & Curran, R., 2010. Lean Supply Chain Management in Aerospace. In *Encyclopedia of Aerospace Engineering*. Chichester: Wiley, pp. 3855–3865.

Bernhart, M. & Maher, F., 2011. *ISO 26000 in Practice: A User Guide*, Milwaukee, WI: AQS Quality Press.

Berson, J., 2015. How long does it take to construct an airliner (e.g. Boeing 747, Airbus)? *quora.com*. Available at: https://www.quora.com/How-long-does-it-take-to-construct-an-airliner-e-g-Boeing-747-Airbus [Accessed February 7, 2017].

Boeing, 2016a. *Build Something Cleaner - The Boeing Company 2016 Environmental Report*, Chicago.

Boeing, 2016b. *Current Market Outlook 2016-2035*, Chicago.

Boeing, 2017. Our Principles. *boeing.com*. Available at: http://www.boeing.com/principles/ [Accessed October 9, 2017].

Bombardier, 2016. *2015 Activity Report*, Montreal.

Bombardier, 2015. *Market Forecast 2015-2034*, Montreal.

Brugha, R. & Varvasovsky, Z., 2000. Stakeholder analysis: a review. *Health Policy and Planning*, 15(3), pp.239–246.

Bryson, J., 2004. What to do when Stakeholders matter. *Public Management Review*, 6(1), pp.21–53.

Bryson, J., Patton, M. & Bowman, R., 2011. Working with evaluation stakeholders: A rationale, step-wise approach and toolkit. *Evaluation and Program Planning*, 34(1), pp.1–12.

Cameron, B., Crawley, E., Loureiro, G. & Rebentisch, E., 2008. Value flow mapping: Using networks to inform stakeholder analysis. *Acta Astronautica*, 62(4–5), pp.324–333.

Captain, T., 2016. *2016 Global aerospace and defense sector outlook*, Washington, D.C.

Captain, T. & Hussain, A., 2017. *2017 Global aerospace and defense sector outlook*, Washington, D.C.

Cardoso, M., 2012. *Outsourcing Logístico em Portugal: O Caso da SLOG – Serviços e Logística , S.A.,* Instituto Superior Técnico.

Carter, C. & Rogers, D., 2008. A framework of sustainable supply chain management: moving toward new theory. *International Journal of Physical Distribution & Logistics Management*, 38(5), pp.360–387.

Carvalho, A., Mimoso, A., Mendes, A. & Matos, H., 2014. From a literature review to a framework for environmental process impact assessment index. *Journal of Cleaner Production*, 64(1), pp.36–62.

Carvalho, A., 2016. Strategic Sustainable Assessment of Retrofit Design for Process Performance Evaluation. In *Sustainability in the Design, Synthesis and Analysis of Chemical Engineering Processes*. Butterworth-Heinemann, pp. 249–273.

Cetinkaya, B., Cuthbertson, R., Ewer, G., Klaas-Wissing, T. Piotrowicz, W. & Tyssen, C., 2011. *Sustainable Supply Chain Management - Pratical Ideas for Moving Towards Best Practice*, New York: Springer.

City of Chicago, 2013. *Sustainable Chicago 2015*, Chicago.

Clarkson, M., 1995. A Stakeholder Framework for Analyzing and Evaluating Corporate Social Performance. *The Academy of Management*, 20(1), pp.92–117.

EASA - European Aviation Safety Agency, 2015. *Annual Activity Report 2014*, Cologne.

EASA, EEA & EUROCONTROL, 2016. *European Aviation Environmental Report 2016*, Brussels.

Eden, C. & Ackermann, F., 1998. *Making Strategy*, Thousand Oaks, CA: Sage.

Embraer, 2017. *Annual Report 2016*, São José dos Campos.

Embraer, 2016. *Market Outlook 2016*, São José dos Campos.

Encyclopædia Britannica, 2010. Spacecraf. *Encyclopædia Britannica Online*. Available at: https://www.britannica.com/topic/spacecraft [Accessed January 16, 2017].

Erdbrink, T. & Clark, N., 2016. U.S. Allows Boeing and Airbus to Sell Planes to Iran. *The New York Times*. Available at: http://www.nytimes.com/2016/09/22/world/middleeast/iran-airbus-boeing-aircraft.html?_r=0 [Accessed October 28, 2016].

Finnair, 2017. *Finnair Annual Report 2016*, Helsinki.

Fraunhofer IBP, 2014. Actio et reactio. *ibp.fraunhofer.de*. Available at: https://www.ibp.fraunhofer.de/en/Press/Research_in_focus/Archives/Mai_2014_actioetreactio.html [Accessed November 12, 2016].

Freeman, R., 1984. *Strategic Management: a Stakeholder Approach*, Marshfield, Massachusetts: Pitman Publishing.

Freeman, R., Harrison, J. & Wicks, A., 2007. *Managing for Stakeholders*, New Haven & London: Yale University Press.

Ghrayeb, O., Phojanamongkolkij, N. & Tan, B.A., 2009. A hybrid push/pull system in assemble-to-order manufacturing environment. *J Intell Manuf*, 20(4), pp.379–387.

Goodman, L., 1961. Snowball Sampling. *The Annals of Mathematical Statistics*, 32(1), pp.148–170.

Goodwin, P. & Wright, G., 2014. *Decision Analysis for Management Judgment* Fifth Edit., Chichester: Wiley.

Gopalakrishnan, K., Yusuf, Y.,Musa, A., Abubakar, T. & Ambursa, H., 2012. Sustainable supply chain management: A case study of British Aerospace (BAe) Systems. *International Journal of Production Economics*, 140(1), pp.193–203.

GRI-Global Reporting Initiative, 2015. *G4 Sustainability Reporting Guidelines - Reporting Principles and Standard Disclosures*, Amsterdam.

Hare, M. & Pahl-Wostl, C., 2002. Stakeholder Categorisation in Participatory Integrated Assessment Processes. *Integrated Assessment*, 3(1), pp.50–62.

Hart, S. & Sharma, S., 2004. Engaging fringe stakeholders for competitive imagination. *Academy of Management Executive*, 18(1), pp.7–18.

Hashemi, V., Chen, M. & Fang, L., 2014. Process planning for closed-loop aerospace manufacturing supply chain and environmental impact reduction. *Computers & Industrial Engineering*, 75, pp.87–95.

IATA - International Air Transport Association, 2016. IATA - History. *iata.org*. Available at: http://www.iata.org/about/Pages/history_2.aspx [Accessed October 15, 2016].

ICAO - International Civil Aviation Organization, 2009. Review of the Classification and Defenitions Used for Civil Aviation Activities. In *Tenth Session of the Statistics Division*. Montréal: ICAO.

ISO - International Standard, 2010. *ISO 26000 - Guidance on social responsibility*, Geneva.

Kalton, G. & Anderson, D., 1986. Sampling Rare Populations. *Journal of the Royal Statistical Society*, 149(1), pp.65–82.

Khalid, R., Seuring, S., Beske, P., Land, A., Yawar, S. & Wagner, R., 2015. Putting sustainable supply chain management into base of the pyramid research. *Supply Chain Management: An International Journal*, 20(6), pp.681–696.

Kueng, P., 2000. Process performance measurement system: A tool to support process-based organizations. *Total Quality Management*, 11(1), pp.67–85.

Lazar, J., Feng, J.H.F. & Hochheiser, H., 2017. Interviews and focus groups. In T. Green, ed. *Research Methods in Human Computer Interaction*. Cambridge, MA: Morgan Kaufmann, pp. 187–228.

Leahy, J., 2016. *2015 commercial review*, Airbus. Available at: http://www.airbus.com/presscentre/hot-topics/annual-press-conference-2016/?eID=maglisting_push&tx_maglisting_pi1%5BdocID%5D=104646 [Accessed January 17, 2017].

Lufthansa Group, 2017. *Balance*, Cologne.

Magness, V., 2008. Who are the stakeholders now? An empirical examination of the Mitchell, Agle, and Wood theory of stakeholder salience. *Journal of Business Ethics*, 83(2), pp.177–192.

Mingers, J. & Gill, A., 1997. *Multimethodology: Towards Theory and Practice and Mixing and Matching Methodologies*, New York: Wiley.

Mitchell, G., May, A. & McDonald, A., 1995. PICABUE : a methodological framework for the development of indicators of sustainable development. *International Journal of Sustainable Development & World Ecology*, 2(2), pp.104–123.

Mitchell, R., Agle, B. & Wood, D., 1997. Toward a Theory of Stakeholder Identification and Salience : Defining the Principle of Who and What Really Counts. *Academy of Management Review*, 22(4), pp.853–886.

Niosi, J. & Zhegu, M., 2005. Aerospace Clusters: Local or Global Knowledge Spillovers? *Industry & Innovation*, 12(1), pp.5–29.

Nutt, P. & Backoff, R., 1987. A Strategic Management Process for Public and Third-Sector Organizations. *Journal of the American Planning Association*, 53(1), pp.44–57.

Parmenter, D., 2015. *Key Performance Indicators: Developing, Implementing, ans Using Winning KPIs* 3rd ed., Hoboken, NJ: Wiley.

Piotrowicz, W. & Cuthbertson, R., 2015. Performance measurement and metrics in supply chains: an exploratory study. *International Journal of Productivity and Performance Management*, 64(8), pp.1068–1091.

Popova, V. & Sharpanskykh, A., 2010. Modeling organizational performance indicators. *Information Systems*, 35(4), pp.505–527.

Reed, M., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C. & Stringer, L., 2009. Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*, 90(5), pp.1933–1949.

Rodrigues, V., Pigosso, D. & McAloone, T., 2016. Process-related key performance indicators for measuring sustainability performance of ecodesign implementation into product development. *Journal of Cleaner Production*, 139(15), pp.416–428.

Rose-Anderssen, C., Baldwin, J., Ridgway, K., Allen, P., Varga, L. & Strathern, M., 2009. A cladistic classification of commercial aerospace supply chain evolution. *Journal of Manufacturing Technology Management*, 20(2), pp.235–257.

Roubtsova, E. & Michell, V., 2013. Modelling and Validation of KPIs. , (July 2014). Available at: https://www.researchgate.net/profile/Ella_Roubtsova2/publication/258999189_Modelling_and_Validation_of_KPIs/links/53d229000cf2a7fbb2e975f2/Modelling-and-Validation-of-KPIs.pdf [Accessed June 15, 2017].

Shokrian, M., High, K. & Sheffert, Z., 2015. Screening of process alternatives based on sustainability metrics: comparison of two decision-making approaches. *International Journal of Sustainable Engineering*, 8(1), pp.26–39.

TAP Group, 2016. *Sustainability Report 2015*, Lisbon.

Taylor, J. & Guilmartin, J., 2011. Military aircraft. *Encyclopædia Britannica Online*. Available at: https://www.britannica.com/technology/military-aircraft [Accessed January 11, 2017].

The Oxford Dictionary of English, 2017. Aerospace. *Oxford Dictionaries Online*. Available at: https://en.oxforddictionaries.com/definition/aerospace [Accessed January 11, 2017].

Thompson, S., 2012. *Sampling* 3rd ed., Hoboken, NJ: Wiley.

University of Minho, 2016. Sustainability Report 2015. Braga.

Verfaillie, H. & Bidwell, R., 2000. *Measuring eco-efficiency - a guide to reporting company performance*, Available at: http://www.bcsd.org.tw/sites/default/files/node/domain_tool/110.file.128.pdf [Accessed May 22, 2017].

Wasserman, S. & Faust, K., 1994. *Social network analysis : methods and applications*, Cambridge: Cambridge University Press.

Weber, M., 1947. *The Theory of Social and Economic Organization*, New York: Free Press.

Weiss, S. & Amir, R., 2014. Aerospace industry. *Encyclopædia Britannica Online*. Available at: https://www.britannica.com/topic/aerospace-industry [Accessed January 11, 2017].

Wilson, C., 2014. *Interview Techniques for Ux Practitioners: A User-Centered Design Method* 1st ed. M. Dunkerley & H. Scherer, eds., Waltham, MA: Morgan Kaufmann.

Winkler, I., 2009. Stakeholder salience in corporate codes of ethics: Using legitimacy, power, and urgency to explain stakeholder relevance in ethical codes of German blue chip companies. *Electronic Journal of Business Ethics and Organization Studies*, 14(1), pp.4–13.

World Economic Forum, 2016. Manufacturing Growth Reports - Aerospace Industry Infographics. *reports.weforum.org*. Available at: http://reports.weforum.org/manufacturing-growth/aerospace-industry-infographics/ [Accessed October 23, 2016].

Appendix I – Sensitivity Analysis

Scenario S1 – Final Scores and Order using the same weights for every attribute

Stakeholder Category	Final score	Original Order
Management Board (OEM)	4,31	1st
Regulators	4,19	2nd
Governments	4,07	3rd
Scientific Community	3,79	5th
Customers	3,78	4th
Suppliers	3,32	7th
Investors and Financial Institutions	3,20	6th
Services providers	3,20	10th
Local Communities	3,19	9th
Shareholders	3,11	8th
NGOs	3,04	11th
Media	2,61	12th
Employees	2,59	13th
Consumers	2,54	14th

Scenario S2a – Final Scores and Order considering only the answers from respondents who work directly with sustainability

Stakeholders' Categories	Final Score	Original Order
Regulators	4,61	2nd
Management Board	4,48	1st
Governments	4,40	3rd
Customers	3,94	4th
Scientific Community	3,86	5th
Suppliers	3,72	7th
Services providers	3,59	10th
Shareholders	3,40	8th
Investors and Financial Institutions	3,36	6th
Local Communities	3,36	9th
NGOs	3,09	11th
Media	3,04	12th
Employees	2,61	13th
Consumers	2,60	14th

Scenario 2b – Final Scores and Order considering only the answers from respondents who do not work directly with sustainability

Stakeholders' Categories	Final Score	Original Order
Management Board	4,47	1st
Customers	3,99	4th
Governments	3,97	3rd
Regulators	3,80	2nd
Investors and Financial Institutions	3,41	6th
Scientific Community	3,37	5th
Shareholders	3,02	8th
Local Communities	2,68	9th
Suppliers	2,50	7th
Employees	2,35	13th
NGOs	2,31	11th
Consumers	2,25	14th
Services providers	2,16	10th
Media	1,81	12th

Scenario 3a – Final Scores and Order considering the Suppliers answers only

Stakeholders' Categories	Final Score	Original Order
Management Board	4,23	1st
Regulators	3,75	2nd
Scientific Community	3,68	5th
Customers	3,49	4th
Governments	3,33	3rd
Suppliers	3,25	7th
Local Communities	3,09	9th
Investors and Financial Institutions	3,08	6th
Employees	2,97	13th
Shareholders	2,81	8th
Media	2,29	12th
Consumers	2,16	14th
Services providers	2,03	10th
NGOs	1,85	11th

Scenario 3b – Final Scores and Order considering the Scientific Community answers only

Stakeholders' Categories	Final Score	Original Order
Regulators	4,09	2nd
Governments	4,00	3rd
Management Board	3,98	1st
Customers	3,64	4th
Scientific Community	3,29	5th
Investors and Financial Institutions	3,20	6th
Suppliers	3,05	7th
Services providers	2,89	10th
Shareholders	2,81	8th
NGOs	2,57	11th
Local Communities	2,55	9th
Media	2,29	12th
Consumers	2,25	14th
Employees	2,22	13th

Scenario 3c – Final Scores and Order considering the Consumers answers only

Stakeholders' Categories	Final Score	Original Order
Governments	3,92	3rd
Regulators	3,76	2nd
Shareholders	3,71	8th
Customers	3,22	4th
Services providers	3,19	10th
Investors and Financial Institutions	3,10	6th
Management Board	2,93	1st
Scientific Community	2,53	5th
Consumers	2,41	14th
Suppliers	2,28	7th
Media	1,84	12th
NGOs	1,79	11th
Local Communities	1,67	9th
Employees	1,35	13th

Sce3nario 3d – Final Scores and Order considering the Local Communities answers only

Stakeholders' Categories	Final Score	Original Order
Governments	4,39	3rd
Management Board	4,39	1st
Media	4,07	12th
Customers	3,95	4th
Regulators	3,92	2nd
Scientific Community	3,87	5th
Investors and Financial Institutions	3,71	6th
Services providers	3,60	10th
Suppliers	3,55	7th
Consumers	3,44	14th
Shareholders	3,21	8th
Local Communities	3,13	9th
Employees	2,77	13th
NGOs	2,26	11th