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Systematic Identification of Stakeholder Needs for the Design of Sustainable Long-Range Aircraft of 2050

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Abstract

Designing long-range aircraft for 2050 is a complex, multi-disciplinary challenge requiring integration of technical performance with sustainability objectives, including environmental responsibility, economic viability, circularity, and social acceptance. Existing studies on stakeholder needs in aviation are limited, focusing on specific groups, technical requirements, or individual aircraft concepts, resulting in a fragmented understanding of sustainability-driven needs. This study addresses this gap by systematically identifying stakeholders who influence long-range aircraft development and deriving 191 stakeholder needs, organized into coherent categories spanning manufacturers, operators, passengers, regulators, communities, and energy suppliers. Needs were classified across technical, environmental, economic, circular, and social dimensions, based on a comprehensive review of academic and grey literature, regulatory documents, and industry sources. The resulting framework provides a structured, reproducible approach to support conceptual aircraft design and requirement definition within the European EXAELIA project. By integrating multi-dimensional stakeholder expectations early in the design process, this approach facilitates aircraft development that is technically robust, environmentally sustainable, economically viable, circular, and socially inclusive, demonstrating the value of a stakeholder-driven method for sustainable systems engineering.

Keywords: stakeholder needs; sustainable aircraft; long-range aircraft; holistic sustainability



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1. Introduction

Designing the long-range aircraft that will operate in 2050 presents a profound and multi-disciplinary challenge. Such aircraft refer to concepts expected to enter service around 2050, designed to meet stricter environmental, operational, and economic requirements than current aircraft. They are anticipated to integrate advanced propulsion, higher aerodynamic efficiency, sustainable fuels or alternative energy, and improved lifecycle performance. Operating in a more complex aviation ecosystem with tighter regulations and evolving passenger expectations, these aircraft require a broader consideration of stakeholder needs in early design stages. Therefore, the decision-making process for innovative

aircraft configurations involves multiple stakeholders with diverse needs and interests and spans disciplines beyond aeronautics alone, reflecting the inherently collaborative and multidisciplinary nature of aircraft design [1]. Future aircraft should integrate traditional operational and performance objectives with broader imperatives such as environmental responsibility, economic viability, circular economy principles, and social acceptance [2]. A holistic sustainability-driven perspective is therefore required—one that goes beyond conventional design metrics and embeds long-term value, lifecycle thinking, and stakeholder expectations into the earliest conceptual phases of development [3,4]. Implementing such an approach necessitates identifying stakeholder needs that are comprehensive, encompassing technical, environmental, social, and economic dimensions, to ensure that all relevant perspectives are considered from the outset.

Currently, however, most conceptual design efforts remain heavily weighted toward technical and operational aspects. While conceptual design software provides powerful trade-off analysis and optimization tools [5] it often cannot fully account for holistic needs or evaluation criteria that support sustainability objectives. As a result, innovation may be constrained and evolving societal and environmental demands may not be adequately addressed. Broadening the scope of needs identification early in the process is therefore crucial for shaping aircraft that are both sustainable and competitive. The importance of broadening the scope of needs identification has been recognized, particularly regarding passenger expectations, marketing priorities, safety, and security, which are increasingly incorporated through customer-driven approaches [6,7]; however, this is less common for environmental and other sustainability-related considerations.

Various methodologies have been applied to systematically capture stakeholder needs. Typically, the process involves first identifying stakeholders and classifying them according to type and importance, followed by eliciting their needs through interviews, historical data analysis, and industry information. These include brainstorming, questionnaires, interviews, prototypes, simulations, and Quality Function Deployment (QFD) methods [8]. Structured systems engineering approaches, such as those advocated by the International Council on Systems Engineering (INCOSE), support the elicitation, analysis, and translation of stakeholder needs into aircraft requirements, especially for sustainable air transport system design [9,10].

A notable work in holistic stakeholder needs-identification in the aviation sector includes the FUTPRINT50 project. This project has highlighted the diversity of stakeholders involved in aircraft development. FUTPRINT50 has focused on a regional hybrid-electric aircraft and applied a systems engineering approach to derive needs relating not only to performance and regulations but also to environmental and market considerations [11]. Key stakeholders identified included EU citizens, authorities, operators, airports, air traffic management providers, energy suppliers, and passengers, with EU citizens considered as customers funding sustainable transport initiatives and passengers as primary system users [11].

Other studies have further emphasized the integration of stakeholder needs into early design processes. For instance, multi-day visits to Airbus, Rolls-Royce, and GKN Aerospace Engine Systems Sweden allowed researchers to gather data through semi-structured interviews with managers, engineers, and IT experts, capturing requirements related to hardware, software, and service development [12]. Similar investigations in regional aircraft programs have identified key stakeholders such as OEMs, airlines, engine manufacturers, certification authorities, MRO providers, passengers, and the market, with a number of about 25 needs being typically catalogued [13]. These studies illustrate that a structured, holistic approach—taking into account broader sustainability objectives as seen

in policy frameworks such as the Fly the Green Deal [14]—is essential for identifying the full range of stakeholder needs that will inform the design of future long-range aircraft [9].

Despite the insights provided by the afore-mentioned works, several gaps remain since they tend to focus on a limited subset of stakeholders or emphasize technical and operational requirements, while broader environmental, economic, circular economy, and social dimensions are only partially addressed. Existing methodologies often capture stakeholder needs in isolation or without a systematic classification, which limits their usefulness for guiding the conceptual design of sustainable long-range aircraft.

This study addresses these gaps by systematically identifying stakeholders that directly or indirectly influence the development of the future long-range aircraft and deriving their needs. Stakeholder identification is conducted through a comprehensive review of academic and grey literature, regulatory documents, industry sources, and relevant research projects. Once identified, stakeholders are grouped into meaningful categories and subgroups, to provide a clear and systematic representation of the stakeholder landscape relevant to long-range aircraft development. In this context, a stakeholder need is defined as a qualitative expression of an expectation, concern, or desired outcome articulated by an actor who influences or is affected by the aircraft lifecycle. Stakeholder needs are solution-neutral and may span technical, operational, environmental, economic, or social dimensions. In contrast, requirements are formal, measurable, and verifiable specifications derived from these needs during subsequent systems engineering processes. While requirement development lies beyond the scope of this paper, establishing a structured and comprehensive understanding of stakeholder needs is a prerequisite for informing conceptual design and requirement definition.

The systematically captured needs offer a solid foundation for the next phase, where they will guide the design and evaluation criteria for future long-range aircraft. These requirements are being studied within the EXAELIA project [15], which focuses on developing the next generation of long-range aircraft by exploring innovative technologies, optimizing performance, and ensuring sustainability for future aviation.

In large-scale systems such as future aircraft, systematically identifying stakeholder needs is an important step that informs requirement definition, system architecture development, and early design decisions. While the case study focuses on future long-range aircraft concepts, the main contribution of this work is a structured framework for identifying and organizing stakeholder needs across multiple sustainability dimensions, supporting the integration of stakeholder perspectives into early-stage aircraft design.

The current paper is structured as follows: following the introduction (Section 1), Section 2 discusses the methodology used to identify and classify the relevant stakeholders and their needs. Section 3 presents the actual needs and analyzes them based on their classification. Section 4 provides a discussion on the implications of these needs for requirements development, which will inform conceptual design, as well as the associated challenges and limitations. Section 5 presents the conclusions and main findings.

2. Methodology

This work focuses on the systematic elicitation, filtering, and structuring of stakeholder needs relevant to the conceptual design phase of long-range aircraft targeting service entry around 2050. The study does not include quantitative requirement prioritization, detailed aircraft configuration design, or full trade-off optimization, which are addressed in subsequent phases of the EXAELIA project. The presented stakeholder analysis should therefore be interpreted as a foundational and extensible basis for future design and assessment activities rather than a final or exhaustive definition of all possible stakeholder expectations.

The stakeholder-driven methodology adopted in this study follows a structured, two-layered and multi-step approach designed to ensure comprehensive coverage of all actors and needs relevant to the conceptual design of future long-range aircraft (FLRA) targeting entry into service around 2050. The methodology, as illustrated in Figure 1, is structured into four sequential phases to ensure a comprehensive and systematic approach to stakeholder-driven aircraft design:

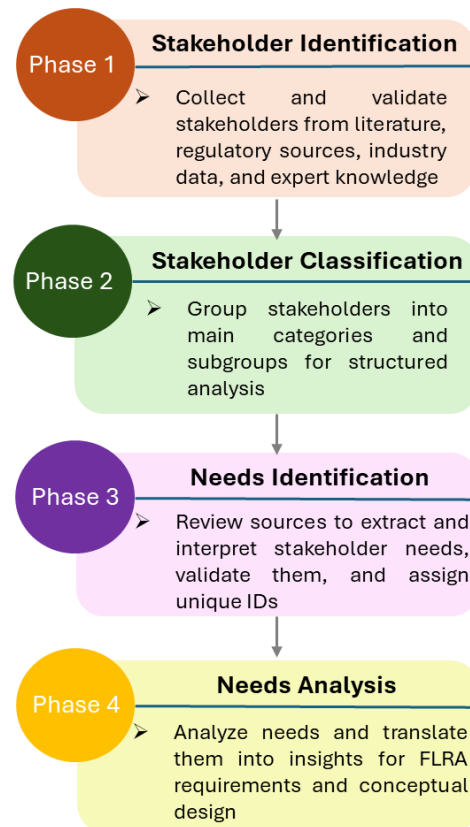


Figure 1. Methodology workflow for identifying and analyzing stakeholder needs for the FLRA.

Stakeholder Identification (Phase 1): All actors who are directly involved in, or indirectly affected by, the aircraft lifecycle are systematically recognized. Relevant literature and background information are also collected to inform the identification process.

Stakeholder Classification (Phase 2): Identified stakeholders are organized using a two-layer hierarchical structure. The primary layer defines the main stakeholder categories associated with each need, while the secondary layer introduces sub-categories that refine stakeholder groupings within each main category.

Stakeholder Needs Identification (Phase 3): Building on the structured stakeholder foundation, needs are systematically derived from literature, regulatory documents, industry standards, and project-specific sources.

Needs Analysis (Phase 4): Retained needs undergo a structured analysis to support their translation into aircraft requirements, evaluation criteria, and design implications for subsequent conceptual design phases.

2.1. Stakeholder Identification and Classification

The identification of stakeholders (Phase 1) is a critical step in the development of future long-range aircraft, aiming to systematically recognize all actors who are directly involved in or indirectly affected by the aircraft lifecycle. Early identification enables the

systematic collection and analysis of stakeholder needs, expectations, and constraints, forming the foundation for defining comprehensive system requirements.

The stakeholder identification process combined the authors' domain expertise and long-term engagement within the EXAELIA project with evidence gathered from academic literature, regulatory frameworks, industry reports, and prior research initiatives. Expert knowledge was operationalized through iterative stakeholder mapping and cross-checking against documented stakeholder groups reported in the literature and relevant aviation projects. Stakeholders were categorized according to their direct or indirect influence on long-range aircraft development, operation, regulation, and societal impact. This triangulated approach reduced subjectivity and supported the completeness of the stakeholder set, ensuring that both prominent and less-visible actors—including manufacturers, operators, passengers, regulators, communities, and energy suppliers—were systematically captured, thereby providing a robust foundation for subsequent needs elicitation.

Stakeholder selection was guided by the objective of capturing a broad and representative spectrum of perspectives and expertise relevant to sustainable aircraft development. Identification criteria included involvement in aircraft design and manufacturing, interaction with aircraft operations and lifecycle processes, exposure to environmental or social impacts, regulatory or financial influence, and contribution to enabling technologies or infrastructure. Based on these criteria, stakeholders were organized into structured categories (Phase 2) reflecting their roles and influence. The principal stakeholder categories considered in this study are summarized in Table 1.

Table 1. Main stakeholder categories.

Stakeholder Type	Description/Role
Aviation Industry Stakeholders	Primary actors directly involved in aircraft manufacturing, operation, and lifecycle, including manufacturers, operators, suppliers, and regulatory authorities. Central to design, compliance, and operational decisions.
Societal Stakeholders	Passengers, local communities, and workforce groups who are significantly affected by aircraft operations and deployment.
Technology and Innovation Stakeholders	Entities advancing emerging technologies, including digital systems, sustainable fuels, and automation, which are critical to the evolution of future aircraft.
Finance and Investment Stakeholders	Actors responsible for assessing economic viability, providing funding, and influencing investment decisions to ensure long-term project sustainability.
Academic and Research Stakeholders	Organizations contributing scientific knowledge, technological innovation, and independent analysis to support evidence-based decision making.
Regulatory and Policy Stakeholders	Public policy bodies, NGOs, and community organizations that ensure broader sustainability, social responsibility, and public interest objectives are addressed.

The applied approach captures the diversity of stakeholder perspectives across technical, economic, social, and environmental dimensions, supporting the development of next-generation aircraft that are sustainable, competitive, and socially responsible. For effective management and analysis, stakeholders are grouped based on their roles, interests, and influence on aircraft development. Such categorization facilitates communication, prioritization of requirements, and targeted engagement with specific stakeholder groups, ensuring that all relevant perspectives are considered throughout the design and development process.

2.2. Stakeholders Needs Identification

Building upon the stakeholder grouping established in Section 2.1, stakeholder needs for the Future Long-Range Aircraft (FLRA) were identified through a structured qualitative synthesis (Phase 3). This approach combined needs explicitly extracted from the literature and documentary sources with additional needs inferred through expert interpretation within the EXAELIA context. Literature-derived needs were systematically compiled and traceable to their sources, while expert-inferred needs were formulated to consolidate overlapping statements, address gaps not explicitly documented, and ensure completeness across technical, environmental, economic, circular, and social dimensions. Agreement among contributing experts was achieved through iterative review and consensus discussions, thereby reducing subjectivity and enhancing reproducibility.

The supporting literature review followed a mixed and iterative approach. An initial body of sources informed stakeholder identification and validation, while a second, more targeted review focused on extracting stakeholder-specific needs. To improve transparency and reproducibility, searches were conducted using keywords such as “aircraft stakeholders,” “aviation sustainability,” “stakeholder needs,” “stakeholder expectations,” “passenger expectations,” “aircraft conceptual design,” “aircraft design requirements,” “future aviation 2050,” “long-range aircraft,” “sustainable air transport requirements,” “circular economy aviation,” “environmental impact aviation,” “societal impact aviation,” and “eco-efficient aircraft” across academic databases, regulatory publications, industry reports, and European research project outputs. All sources were iteratively screened and cross-checked to ensure comprehensive coverage of both stakeholder groups and their associated needs. Specifically, each source was reviewed to identify which stakeholder groups were addressed and which needs were reported. The identified needs were then cross-compared across all sources to verify that each stakeholder group had been represented and that recurring needs were consistently captured. When discrepancies or gaps were found—such as a stakeholder group mentioned in one source but not others—additional sources were consulted. This iterative process ensured that all relevant stakeholder groups and their associated needs were systematically captured, minimizing the risk of omission and providing a robust foundation for subsequent requirement derivation.

The literature review encompassed seventy peer-reviewed journal articles, seventeen technical reports from research and regulatory bodies (e.g., Flightpath 2050, DESTINATION 2050, Fly the Green Deal, ICAO), and seventeen online sources, including industry reports, white papers, and other relevant publications. These sources were published primarily between 2010 and 2025, a period reflecting the increasing research focus on aviation sustainability and future aircraft concepts. The selection criteria were based on relevance to aviation sustainability, aircraft design, stakeholder analysis, or future aviation system development. This approach ensured that the collected literature represented a balanced combination of academic research, regulatory perspectives, industry insights, and research project outcomes, providing a comprehensive foundation for identifying stakeholder needs.

During this process, it was observed that the same stakeholder needs were frequently identified across multiple sources, reinforcing their significance and providing confidence in their inclusion. Each extracted need was systematically documented and assigned a unique identification (ID) number to ensure clarity, traceability, and reproducibility.

This methodology captures a broad and multidimensional spectrum of stakeholder needs, providing a robust, evidence-based foundation to support the development of design requirements, including top-level aircraft requirements (TLARs). While the direct impact on TLARs will be determined during subsequent requirement engineering and conceptual design phases, the structured capture of stakeholder needs ensures that all relevant perspectives are systematically considered, establishing a comprehensive baseline

for the future long-range aircraft. Moreover, while additional needs may emerge as the aviation ecosystem evolves, the current process establishes a comprehensive and solid baseline for informing the top-level requirements and conceptual design of a future long-range aircraft

It should be also noted that while the full set of 191 needs captures the broad spectrum of stakeholder expectations, only those directly relevant to the overall aircraft design—rather than aspects related to the wider air transport system—were selected for the next phase, where they inform the derivation of top-level and sustainability-related aircraft requirements.

3. Results

3.1. Stakeholder Overview

The stakeholders identified in this study have been grouped into distinct categories based on their roles, interests, and influence on the development of future long-range aircraft (FLRA), as schematically illustrated in Figure 2. The main stakeholder categories are as follows:

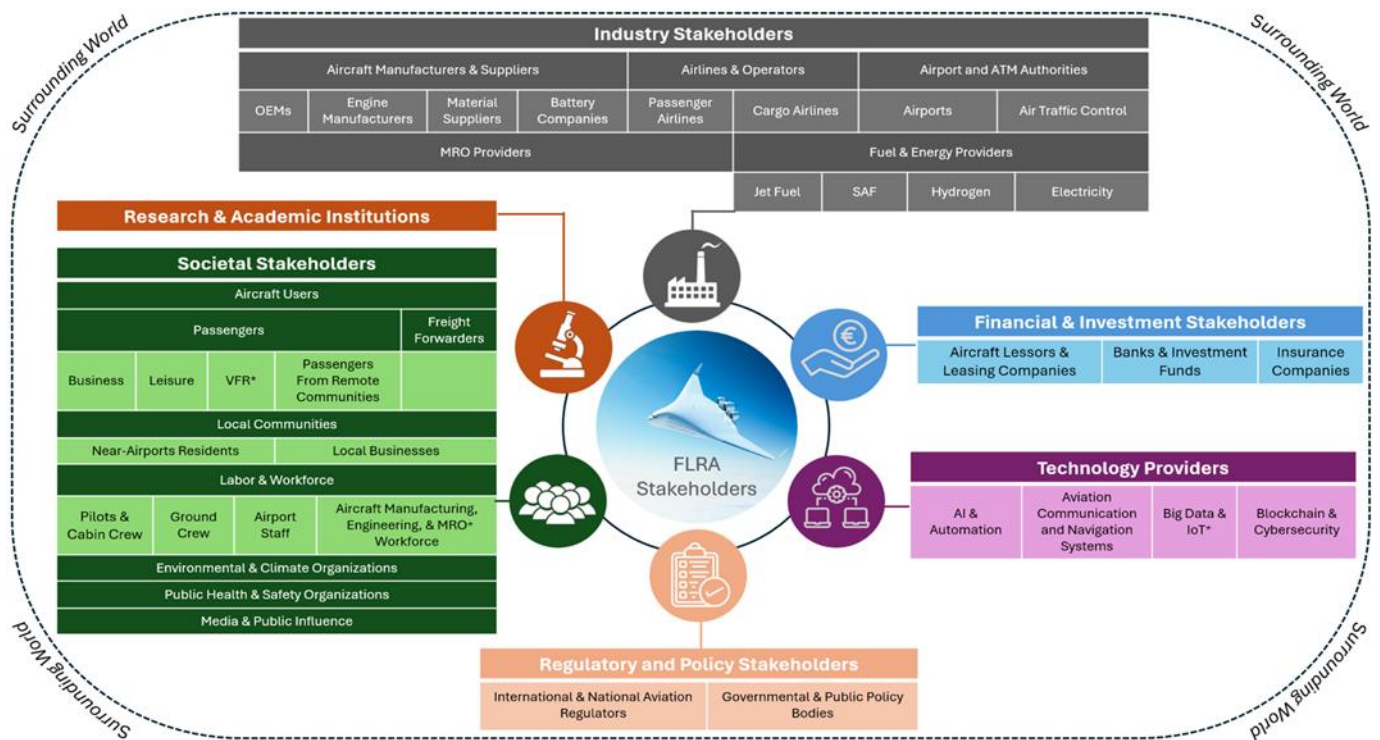


Figure 2. Stakeholder landscape for future long-range aircraft (VFR: Visiting for Friends and Relatives; MRO: Maintenance, Repair and Overhaul, IoT: Internet of Things).

Industrial Stakeholders: This group comprises 13 subgroups, including aircraft manufacturers, OEMs, engine and material suppliers, battery companies, airlines (passenger and cargo), airports, air traffic management authorities, and MRO providers. They are directly involved in the design, production, operation, and maintenance of the aircraft.

Regulatory and Policy Stakeholders: This category comprises 2 subgroups, encompassing aviation regulatory authorities, such as ICAO, EASA, and FAA, as well as broader governmental and public policy bodies, including the European Commission. These stakeholders establish and enforce safety, environmental, and operational regulations, ensuring compliance with evolving legal frameworks and sustainability targets.

Societal Stakeholders: This group comprises 14 subgroups, representing individuals and organizations impacted by or interested in the development and operation of FLRA. It

includes passengers—business, leisure, visiting friends and relatives (VFR), and travelers from remote communities—as well as freight forwarders. Local communities near airports, including residents and businesses, are also represented. The labor and workforce segment includes pilots, cabin crew, ground crew, airport staff, and the manufacturing, engineering, and maintenance workforce. The workforce is included within societal stakeholders rather than industrial stakeholders because the focus is on the human perspective—their well-being, skills, and working conditions—rather than organizational decision-making or operational authority, which is represented by the manufacturing entities themselves. Environmental and climate organizations (e.g., Greenpeace) and public health and safety bodies (e.g., WHO) ensure alignment with broader sustainability and health objectives. Media and public influence entities, including social media platforms, also play a key role in shaping public perception and awareness.

Research and Academic Institutions: This group involves universities, research centers, and academic organizations that contribute by providing scientific knowledge, technological innovation, independent analysis, and education and training for the future aviation workforce.

Financial and Investment Stakeholders: This group comprises three subgroups, including aircraft lessors and leasing companies, banks, investment funds, and insurance companies. They provide the financial resources and risk management mechanisms necessary for development, acquisition, and operation, influencing funding decisions, cost efficiency, and long-term economic viability.

Technology Providers: This group comprises four subgroups and includes companies and organizations specializing in advanced technologies whose expertise is transversal across multiple industries rather than specific to aviation, which justifies their classification as a distinct stakeholder category. It encompasses providers of artificial intelligence (AI) and automation solutions, communication and navigation systems (e.g., Thales), as well as experts in big data, the Internet of Things (IoT), blockchain, and cybersecurity. These stakeholders provide technologies and expertise that are applicable across multiple industries, enabling innovations in aircraft performance, safety, operational efficiency, and resilience, while remaining distinct from traditional aviation-specific industrial roles.

3.2. Stakeholder Needs

Figure 3 presents the distribution of the needs among the main stakeholders' categories (Societal, Industrial, Research and Academic, Financial and Investment, Technology Providers, Regulatory and Policy stakeholders). The distribution shows that the stakeholder needs for the FLRA are predominantly associated with Regulatory and Policy stakeholders, accounting for 83 out of 191 total needs. Societal stakeholders follow with 61 identified needs, reflecting strong emphasis on sustainability, passenger experience, and public expectations. Industrial stakeholders contribute 30 needs, primarily related to the fundamental aspects of aircraft design, while Financial and Investment (11) and Research and Academic Institutions (6) stakeholders had a more focused but essential presence in shaping innovation and funding priorities. No explicit needs were identified for Technology and Innovation Providers because their contributions are generally enabling or cross-cutting in nature, supporting the implementation of other stakeholders' requirements rather than generating unique, independent needs. As a result, the requirements associated with these stakeholders are implicitly captured, mainly within the Industrial stakeholders category. It should be noted that not all identified needs carry an equal level of influence on the aircraft design, so the number of needs per stakeholder category does not necessarily indicate dominance in shaping the design.

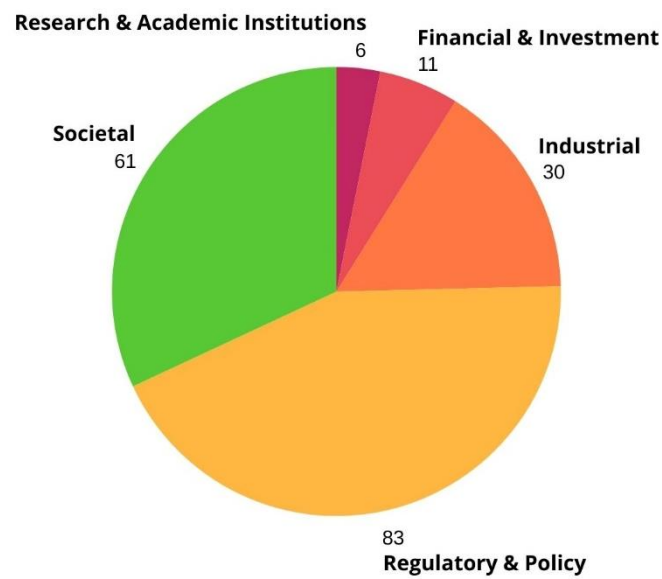


Figure 3. Needs distribution among the different stakeholders.

The following sections present illustrative needs for each stakeholder category and analyze their relevance in the context of holistic sustainability and sustainable aircraft design (Phase 4). The tables presented below (Tables 2–6) serve a dual purpose. First, they provide a structured summary of illustrative needs for each stakeholder category, highlighting recurring themes and cross-cutting concerns such as environmental sustainability, operational efficiency, safety, and social well-being. Second, they function as a bridge between stakeholder input and conceptual aircraft design: by organizing needs by category, sub-category, and theme, the tables enable systematic translation of stakeholder expectations into top-level and system-level aircraft requirements. Approximate counts are provided to illustrate the relative emphasis of each theme, while the narrative highlights overlaps and interconnections across needs. Together, the tables and accompanying analysis clarify the significance of stakeholder requirements and their contribution to a holistic, sustainability-driven aircraft design process. The detailed list of the identified needs, their relationship with stakeholders and the relevant literature source is presented in Appendix A.

Table 2. Illustrative needs of societal stakeholders.

Main Stakeholder Category	Secondary Stakeholder Category	Need ID	Societal Need
Societal Stakeholders	Aircraft users > Passengers	N1	Passengers should have access to affordable and reliable long-haul travel options.
Societal Stakeholders	Aircraft users > Passengers	N3	Passengers need to feel comfortable during the flight.
Societal Stakeholders	Aircraft users > Passengers	N4	Passengers need to feel safe during the flight.
Societal Stakeholders	Local communities > Near-airport residents	N24	Residents living near airports should experience minimal noise emissions.

Table 2. *Cont.*

Main Stakeholder Category	Secondary Stakeholder Category	Need ID	Societal Need
Societal Stakeholders	Labor and Workforce	N38	It is essential to promote fair wages and provide safe working conditions for the aircraft systems workforce.

Table 3. Illustrative needs of industrial stakeholders.

Main Stakeholder Category	Secondary Stakeholder Category	Need ID	Industrial Need
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	N64	The aircraft performance should balance efficiency, passenger comfort, and operational cost-effectiveness.
Industrial Stakeholders	Airlines and Operators	N80	The aircraft fleet should reduce emissions without retarding its economic performance.
Industrial Stakeholders	Maintenance, Repair and Overhaul (MRO) Providers	N85	The MRO industry should reduce environmental impact.
Industrial Stakeholders	Fuel and Energy Providers	N88	The alternative fuels should achieve economic viability and cost competitiveness (SAF Providers, Hydrogen Providers).
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	N91	The manufacturing processes should be automated and streamlined.

Table 4. Illustrative needs of regulatory and policy stakeholders.

Main Stakeholder Category	Secondary Stakeholder Category	Need ID	Regulatory and Policy Need
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	N97	Safety assurance must be provided in aviation operations.
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	N95	Aviation needs to promote environmental protection and the use of sustainable and alternative energy sources.
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	N104	All components of the air transport system—such as air traffic management (ATM), airports, airlines, aircraft, and ground transportation—need to work seamlessly together.

Table 4. Cont.

Main Stakeholder Category	Secondary Stakeholder Category	Need ID	Regulatory and Policy Need
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	N123	Regulators require effective demand management policies to maximize the impact of demand reduction strategies on emissions.
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	N125	EU policymakers require a comprehensive framework to achieve a 90% reduction compared to 1990 levels in transport GHG emissions by 2050 through sustainable mobility solutions.

Table 5. Illustrative needs of research and academic institutions.

Main Stakeholder Category	Secondary Stakeholder Category	Need ID	Research and Academic Institutions Need
Research and Academic Institutions	-	N167	Funding resources should be secured for research in next-generation propulsion research, focusing on hydrogen, hybrid-electric, and SAF engines to drive innovation in sustainable aviation technologies.
Research and Academic Institutions	-	N168	The acceleration of advancements in sustainable aviation technologies should be strengthened through interdisciplinary collaborations between multiple disciplines of aerospace engineering including climate sciences and AI research.
Research and Academic Institutions	-	N169	Collaboration between industry and academia should be promoted to secure funding for the development of disruptive aerospace technologies.
Research and Academic Institutions	-	N181	Research on low-TRL disruptive innovations, emerging underrepresented topics, and lifecycle-based design for sustainability is essential for advancing climate-neutral aviation.
Research and Academic Institutions	-	N182	Research on cost-efficiency, affordability, and scalability of green technologies is needed to ensure the economic viability of sustainable aviation solutions.

3.2.1. Societal Stakeholders Needs

The societal stakeholder needs identified encompass the immediate functional and operational requirements of passengers and local communities, as well as broader considerations related to workforce well-being, environmental impact, and sustainable aviation development. Analysis of societal stakeholder needs highlights several recurring themes that inform future long-range aircraft design. Passenger experience and comfort are the most frequent, including seating, cabin cleanliness, accessibility, in-flight services, and connectivity (~15–17 needs). Operational reliability and accessibility, such as on-time per-

formance, long-distance coverage, and baggage handling, are also prominent (~10 needs). Environmental sustainability and noise reduction appear across passengers, communities, and regulators (~6–7 needs), while community and economic benefits—including local business growth, public transport, and workforce training—are represented in ~8 needs. Labor and workforce concerns, such as job security, safe working conditions, and reskilling for emerging technologies, account for ~10–12 needs. Cross-cutting safety, public health, and regulatory compliance needs are also evident. These themes demonstrate that societal stakeholders prioritize a combination of passenger comfort, operational reliability, environmental responsibility, workforce welfare, and regulatory compliance, providing a structured foundation for integrating social considerations into conceptual aircraft design. The numbers reported for each theme are approximate due to overlapping needs, variations in granularity, and subjective assignment of needs to categories. Some needs may address multiple aspects simultaneously (e.g., passenger comfort and environmental impact), making exact counts dependent on the classification rules applied. Table 2 presents illustrative needs of societal stakeholders.

Table 6. Illustrative needs of financial and investment stakeholders.

Main Stakeholder Category	Secondary Stakeholder Category	Need ID	Financial and Investment Need
Financial and Investment Stakeholders	Aircraft lessors and Leasing Companies	N170	Investors desire a high return on investment and long-term profitability.
Financial and Investment Stakeholders	Aircraft lessors and Leasing Companies	N172	Leasing companies seek fuel-efficient and low-maintenance aircraft to attract airline customers.
Financial and Investment Stakeholders	Aircraft lessors and Leasing Companies	N175	Lessors desire regulatory compliance and sustainability features to align with future market trends.
Financial and Investment Stakeholders	Banks and Investment Funds	N176	Banks need a reliable, fuel-efficient, and sustainable aircraft to justify long-term financing.
Financial and Investment Stakeholders	Insurance companies	N179	Insurance companies need aircraft with advanced safety features to minimize accident risk and liability.

3.2.2. Industrial Stakeholders Needs

Industrial stakeholder needs encompass the operational, technological, and economic requirements of aircraft manufacturers, suppliers, airlines, MRO providers, and fuel and energy companies. Analysis of industrial stakeholder needs reveals several dominant themes that guide the design, operation, and sustainability of future long-range aircraft. Aircraft performance and safety emerge as the most frequent category, covering range, speed, take-off and landing performance, payload, weight distribution, and structural integrity (~12–14 needs). Economic competitiveness and operational efficiency, including minimizing operational and production costs, fleet efficiency, and manufacturer competitiveness, are also highly represented (~8–10 needs). Environmental sustainability is another recurring theme, with needs related to emissions reduction, waste minimization, compliance with global regulations, and net-zero operations for airports and MRO providers (~8 needs). Adaptation to new technologies—such as alternative propulsion systems, hydrogen, SAF, and automated manufacturing—appears in ~5–6 needs, reflecting the industrial sector’s focus on innovation and future readiness. Finally, passenger comfort and connectivity (~3–4 needs) also appear, highlighting the interplay between operational performance

and societal expectations. Overall, these themes show that industrial stakeholders prioritize aircraft performance, safety, economic and operational efficiency, environmental responsibility, and technological innovation, forming a structured basis for translating stakeholder expectations into top-level and system-level aircraft requirements. The counts of industrial stakeholder needs by theme are approximate, as some needs span multiple operational, technical, or economic aspects, and the granularity of need statements varies. Consequently, exact numbers depend on how needs are assigned to categories, and some needs may contribute to more than one theme simultaneously. Table 3 presents illustrative needs of Industrial stakeholders.

3.2.3. Regulatory and Policy Stakeholders Needs

Regulatory and policy stakeholder needs capture the requirements and expectations of authorities, regulators, and policy bodies responsible for aviation safety, environmental compliance, and strategic planning. These needs capture the broader societal goals of sustainable, safe, and resilient aviation systems, ensuring that technological innovations align with regulatory frameworks and public interests. Analysis of regulatory and policy stakeholder needs highlights several key priorities shaping the future aviation ecosystem. Safety, security, and compliance are dominant themes, encompassing requirements for robust certification, risk mitigation, continuous descent operations, cybersecurity, and operational safety (~15–20 needs). Environmental and sustainability objectives are strongly represented, including emissions reduction, energy efficiency, noise mitigation, circular economy and ecodesign principles (~15–18 needs). Operational efficiency and connectivity are also central, covering air traffic management, multimodal integration, punctuality, infrastructure compatibility, and seamless mobility (~10–12 needs). Innovation, research, and workforce development appear frequently, reflecting the importance of supporting technological advancement, education, and high-skilled job creation (~6–8 needs). Finally, public engagement, transparency, and societal acceptance emerge as recurring concerns (~5–6 needs), emphasizing the need for communication, information sharing, and trust-building with affected communities. Overall, regulatory and policy stakeholders prioritize safe, sustainable, and efficient aviation operations, while enabling technological innovation, workforce development, and societal engagement, forming a structured basis for translating these expectations into high-level requirements and governance frameworks. Once again, the counts of regulatory and policy stakeholder needs by theme are approximate, as many needs address multiple domains—such as safety, environmental impact, innovation, and social objectives—and some needs overlap across categories. Exact numbers depend on how needs are assigned and grouped, and certain needs contribute to more than one thematic area simultaneously. Table 4 presents illustrative needs of Regulatory and Policy stakeholders.

3.2.4. Research and Academic Institutions Needs

Research and academic institutions play a key role in advancing sustainable aviation by driving innovation, generating knowledge, and fostering collaboration. Their needs include securing funding for next-generation propulsion and low-TRL disruptive technologies, promoting interdisciplinary and industry–academia partnerships, and conducting research on lifecycle-based and circular economy design approaches. They also focus on ensuring the economic viability of green technologies through cost-efficiency and scalability studies, as well as supporting social inclusivity, workforce upskilling, and enhanced passenger experience. Collectively, these needs highlight the central role of research and academia in enabling a sustainable, innovative, and socially responsible future aviation system. Table 5 presents illustrative needs of this stakeholder group.

3.2.5. Financial and Investment Stakeholders

Financial and investment stakeholders, including aircraft lessors, leasing companies, banks, investment funds, and insurers, focus on the economic and financial performance of future aircraft. Their needs emphasize high return on investment, long-term profitability, and strong residual value, alongside regulatory compliance and sustainability features that align with evolving market trends. They also require aircraft to be fuel-efficient, low-maintenance, and operationally flexible to support leasing and financing strategies, while insurers prioritize advanced safety features and reliable maintenance records to minimize liability and financial risk. Collectively, these needs highlight the importance of financial viability, risk management, and market adaptability in guiding sustainable and commercially competitive aircraft development. Table 6 presents illustrative needs of Financial and Investment stakeholders.

4. Discussion

The present study systematically identifies stakeholder needs across social, environmental, industrial, regulatory, financial, and technological domains. While previous research has examined future aircraft concepts, fuel efficiency, and environmental performance, these studies often did not capture the full range of stakeholder needs across social, economic, and technological dimensions. By addressing this gap, the current research incorporates the perspectives of a broad spectrum of stakeholders—including passengers, local communities, labor and workforce, regulatory bodies, financial investors, research institutions, and technology providers—emphasizing holistic sustainability considerations that integrate economic, social, operational, and environmental factors. An initial comparison with classical Top-Level Aircraft Requirements (TLARs) highlights a key contrast: traditional TLARs focus primarily on technical and operational performance—range, speed, payload, take-off and landing capabilities, fuel efficiency, and regulatory compliance—while largely omitting broader social, environmental, and human-centered considerations. Passenger comfort, accessibility, noise reduction, workforce well-being and reskilling, circular economy practices, and community benefits are underrepresented in classical TLARs, underscoring the added value of a stakeholder-driven approach in shaping more comprehensive and sustainability-oriented aircraft design requirements.

The analysis of stakeholder needs for future long-range aircraft demonstrates the value of a holistic, multi-dimensional approach. Societal stakeholders emphasize passenger experience, community well-being, workforce welfare, and environmental responsibility, highlighting the human-centered and social dimensions of sustainable aviation. Industrial stakeholders focus on aircraft performance, safety, operational efficiency, economic competitiveness, environmental compliance, and adaptation to new technologies, underscoring the technical and operational priorities. Regulatory and policy stakeholders drive safety, security, environmental sustainability, operational efficiency, innovation, and public engagement, reflecting the governance and societal oversight requirements. Research and academic institutions contribute needs that enable innovation, interdisciplinary collaboration, and sustainable technology development, while financial and investment stakeholders prioritize economic viability, market adaptability, and risk management. Technology providers, although not associated with explicit needs, play a cross-cutting enabling role in implementing innovations across industrial and societal expectations. Collectively, these results illustrate that integrating diverse stakeholder perspectives provides a robust foundation for translating social, environmental, economic, and technological considerations into comprehensive aircraft requirements, enabling the development of future aircraft that

are not only technically feasible but also socially acceptable, environmentally responsible, and economically sustainable.

The analysis identifies significant patterns, distributions, and cross-cutting themes across multiple stakeholder groups. Environmental sustainability emerges as a dominant concern, reflecting regulatory pressures and societal expectations to reduce greenhouse gas emissions, noise, and local environmental impacts. Economic and operational priorities remain critical for industry and financial stakeholders, emphasizing the need to balance sustainability objectives with cost-effectiveness, market competitiveness, and operational feasibility.

Several needs consistently appear across different stakeholder groups, revealing shared priorities such as regulatory compliance, operational efficiency, safety, and human-centered considerations, including passenger comfort, accessibility, workforce well-being, and skills development. Identifying these convergences enables a more nuanced understanding of where stakeholder interests align and where trade-offs or prioritization decisions may be required. Conversely, areas of divergence—such as differing emphases between industrial efficiency and social/environmental considerations—highlight potential conflicts that aircraft designers and policymakers must address.

Direct comparisons with similar studies are limited, as, to the authors' knowledge, FUTPRINT50 project is currently the only initiative that has addressed future aircraft sustainability from a system-level perspective, while a fully holistic, multi-stakeholder approach covering social, economic, operational, and environmental dimensions has not been extensively explored. Most existing research focuses primarily on technological solutions aimed at reducing environmental impacts, such as advanced propulsion concepts, alternative fuels, or aerodynamic improvements. While FUTPRINT50 project [11] provides valuable insights into future aviation technologies and environmental performance, the present study complements this by systematically identifying and structuring stakeholder needs across the aviation ecosystem. This highlights the novelty of the current work, which emphasizes a stakeholder-driven approach that captures a broad range of sustainability considerations in early aircraft design phases.

Despite its comprehensive approach, the study has several limitations. Stakeholder coverage, while broad, may underrepresent certain groups such as emerging technology startups, small regional operators, and niche passenger segments. The data sources used, primarily literature, reports, and prior studies, may have introduced regional or sectoral biases, and the importance of some stakeholder needs may evolve rapidly due to technological advances or regulatory changes. A further limitation of the study is that the identified stakeholder needs are presented as a comprehensive baseline without assigning quantitative importance or prioritization. Due to the qualitative nature of many stakeholder expectations and the diversity of stakeholder groups, assessing relative importance at this early stage is challenging. In practical aircraft development processes, prioritization is typically performed in later stages using techniques such as stakeholder weighting, multi-criteria decision analysis, or requirement prioritization frameworks. Future research could apply these methods to determine the most critical stakeholder needs and support more targeted design decisions. Finally, classifying needs by stakeholder type, secondary sub-categories, and relevance to aircraft systems involves interpretive judgments, introducing potential subjectivity that could influence prioritization.

5. Conclusions and Future Work

This study provides a systematic and comprehensive analysis of stakeholder needs for future sustainable aircraft, covering a broad spectrum of participants including passengers, local communities, workforce and labor organizations, regulatory authorities, financial and

investment stakeholders, research institutions, and technology providers. These needs reflect both primary and secondary stakeholder perspectives, highlighting interdependencies, potential trade-offs, and opportunities for innovation in aircraft design.

The main contribution of this work lies in the development of a structured approach that systematically translates stakeholder expectations into key insights for sustainable aircraft development. Unlike previous studies, which often focused on isolated dimensions such as fuel efficiency, emissions, or economic performance, this approach considers environmental, social, and economic factors while also accounting for operational and technological feasibility. By linking stakeholder needs to key insights, the approach supports a needs-driven, sustainability-oriented process [3,4] that can inform innovation, regulatory compliance, and societal acceptance.

The analysis highlights clear patterns and cross-cutting priorities among the identified stakeholder needs, most notably the consistent emphasis on environmental sustainability, operational efficiency, and economic viability across multiple stakeholder groups. Environmental considerations—such as emissions reduction, noise mitigation, and improved resource efficiency—emerge as key expectations particularly from regulatory bodies, societal stakeholders, and policy-related actors, reflecting the growing importance of sustainability in aviation development. At the same time, operational stakeholders, including airlines and manufacturers, place strong emphasis on operational efficiency, reliability, and lifecycle cost performance, indicating the need for design solutions that balance environmental objectives with practical and economic constraints. The findings demonstrate that integrating stakeholder perspectives during the early design stages is essential for developing aircraft concepts that are not only technically feasible but also aligned with societal expectations, regulatory trends, and market demands. Furthermore, the structured identification and synthesis of stakeholder needs provide a transparent baseline that can support requirement definition and prioritization during conceptual aircraft design. In particular, the results can inform the formulation of top-level aircraft requirements and guide trade-off analyses between sustainability, performance, and cost objectives. The study therefore contributes a methodological approach that facilitates the systematic incorporation of stakeholder perspectives into early design processes. At the same time, it acknowledges that quantitative prioritization or weighting of individual needs—using approaches such as multi-criteria decision-making methods or expert-based evaluation—may be applied in subsequent design phases. This ensures that the conclusions are actionable and directly linked both to the analytical process presented in this study and to future design and decision-support activities.

Looking forward, the results of this study offer a basis for the EXAELIA project to explore how stakeholder needs may inform the development of formal design requirements and conceptual aircraft solutions. Future steps include prioritizing the identified needs, developing measurable and verifiable aircraft design requirements using systematic approaches, and integrating these into model-based systems engineering processes.

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Appendix A

The detailed list of the identified needs, their relationship with stakeholders and the relevant literature sources are presented in Appendix A (Table A1). Each need is assigned a unique ID to facilitate identification, traceability, and link with the derived requirements. Additionally, each need is evaluated to determine whether it is directly related to the aircraft system, rather than to airport infrastructure, airline operations, or air traffic services (ATS). This screening helps identify those needs that can be translated into requirements with the potential to drive the aircraft design during the conceptual and subsequent design phases. The stakeholder identification in the study follows a structured, two-layered approach to ensure comprehensive coverage of all relevant groups. The first layer identifies the main stakeholder category to which each need is associated. The subsequent layer (sub-categories) progressively narrows down the stakeholder group within the main category, providing a more specific classification.

Table A1. Detailed list of FLRA stakeholder needs.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Societal Stakeholders	Aircraft users > Passengers	Passengers should have access to affordable and reliable long-haul travel options.	N1	[16–23]
Societal Stakeholders	Aircraft users > Passengers > Business travelers and Leisure travelers	Flights should arrive and depart on schedule.	N2	[16–25]
Societal Stakeholders	Aircraft users > Passengers	Passengers need to feel comfortable during the flight.	N3	[16–25]
Societal Stakeholders	Aircraft users > Passengers	Passengers need to feel safe during the flight.	N4	[16–25]
Societal Stakeholders	Aircraft users > Passengers > Business travelers and Leisure travelers and VFR	Airlines should provide flexible and customer-friendly policies for cancellations, rebooking, and modifications.	N5	[16–23]
Societal Stakeholders	Aircraft users > Passengers > Passengers from Remote Communities	Flights should be capable of covering long distances in a short time.	N6	[16–23]
Societal Stakeholders	Aircraft users > Passengers	Passengers should receive courteous and polite service throughout their flight.	N7	[16–25]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Societal Stakeholders	Aircraft users > Passengers	Passenger seats must be spacious enough to comfortably accommodate larger individuals.	N8	[16–23]
Societal Stakeholders	Aircraft users > Passengers > Business travelers and Leisure travelers and VFR	Airlines shall offer decent food and drinks on board service.	N9	[16–23]
Societal Stakeholders	Aircraft users > Passengers	Cabin and passenger seats should be thoroughly cleaned and sanitized.	N10	[16,17]
Societal Stakeholders	Aircraft users > Passengers	The cabin shall be aesthetically designed to provide a comfortable feeling for the passengers.	N11	[16–25]
Societal Stakeholders	Aircraft users > Passengers	Passengers should experience minimal noise levels during the flight.	N12	[16,17,26]
Societal Stakeholders	Aircraft users > Passengers	Aircraft should have adequate number of lavatories.	N13	[16,17,26,27]
Societal Stakeholders	Aircraft users > Passengers	Aircraft system design should facilitate accessibility, enabling passengers with reduced mobility and disabilities to board, navigate, and travel seamlessly.	N14	[23–25]
Societal Stakeholders	Aircraft users > Passengers > Leisure travelers	Passenger entertainment options should be made available during the flight.	N15	[16–20]
Societal Stakeholders	Aircraft users > Passengers > Leisure travelers and VFR	Ticket prices should be kept as affordable as possible.	N16	[16–23]
Societal Stakeholders	Aircraft users > Passengers > Leisure travelers	Passengers should be allowed to bring larger baggage on board.	N17	[16–23]
Societal Stakeholders	Aircraft users > Passengers > Business travelers and Leisure travelers	Passenger baggage and luggage should be delivered reliably.	N18	[16–23]
Societal Stakeholders	Aircraft users > Passengers > Business travelers and Leisure travelers and VFR	Passengers should be allowed to use mobile phones and the internet during flights.	N19	[16–23]
Societal Stakeholders	Aircraft users > Passengers > Business travelers and Leisure travelers	Passengers would prefer to travel in aircraft that have a lower environmental impact (reduced carbon footprint).	N20	[16,21,25]
Societal Stakeholders	Aircraft users > Passengers > Business travelers and Leisure travelers and VFR	Passengers should have immediate and seamless connections to other modes of transportation.	N21	[16–25]
Societal Stakeholders	Aircraft users > Passengers > Business travelers and Leisure travelers	Airlines should provide diverse choice of destinations.	N22	[16,17,25]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Societal Stakeholders	Aircraft users > Passengers > Passengers from Remote Communities	Airlines should provide regular flights to distant destinations.	N23	[16,17,25]
Societal Stakeholders	Local communities > Near-airport residents	Residents living near airports should experience minimal noise emissions.	N24	[26–31]
Societal Stakeholders	Local communities > Near-airport residents	Residents living near airports should be exposed to minimal air pollution and emissions that affect their physical and mental health.	N25	[31–34]
Societal Stakeholders	Local communities > Near-airport residents	Airports should provide economic benefits from expansions while minimizing disruptions.	N26	[35]
Societal Stakeholders	Local communities + Passengers	Public transportation to airports should be efficient and accessible for both passengers and local residents.	N27	[36]
Societal Stakeholders	Local communities + Passengers	Public education and awareness initiatives should address hydrogen safety concerns in hydrogen-powered aircraft.	N28	[37,38]
Societal Stakeholders	Local communities > Near-airport residents	Airports should incorporate smart designs, utilizing AI-optimized traffic flow, noise mitigation, and sustainable ground transportation to minimize impacts on nearby residents.	N29	[39]
Societal Stakeholders	Local communities > Local businesses	Local businesses need a well-connected airport that has the potential to bring more customers, tourism, and business opportunities, boosting local commerce.	N30	[35,40]
Societal Stakeholders	Local communities > Local businesses	Local businesses need reliable and affordable air freight services to ensure efficient logistics, timely delivery of goods, and support for supply chains and export-driven growth.	N31	[41]
Societal Stakeholders	Local communities > Local businesses	Airports should offer retail, office, and service spaces that enhance local businesses and stimulate economic activity.	N32	[42]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Societal Stakeholders	Local communities > Local businesses	Local businesses need aviation growth to create jobs and provide workforce training opportunities, supporting economic stability and community development.	N33	[41]
Societal Stakeholders	Local communities > Local businesses	To ensure efficient public transport and road networks connect airports, seamless multimodal transportation should be developed, making it easier for employees and customers to access their services.	N34	[35,42]
Societal Stakeholders	Local communities > Local businesses	Aviation policies should promote partnerships with local businesses, ensuring they benefit from contracts and service agreements.	N35	[35,42]
Societal Stakeholders	Labor and Workforce > Aircraft Manufacturing, Engineering workforce, and MRO workforce	Job security should be ensured as the integration of automation and new technologies become more prominent.	N36	[43,44]
Societal Stakeholders	Labor and Workforce > Pilots and Cabin Crew	Training programs for next-generation aircraft systems should be offered to ensure familiarity with new technologies in aircraft.	N37	[43]
Societal Stakeholders	Labor and Workforce	It is essential to promote fair wages and provide safe working conditions for those in the aircraft systems workforce (pilots, cabin crew, ground crew, manufacturing employees, etc.), ensuring a supportive and productive environment for all.	N38	[45,46]
Societal Stakeholders	Labor and Workforce > Pilots and Cabin Crew and Ground Crew and Aircraft Manufacturing, Engineering workforce, and MRO workforce	Clear and effective transition plans need to be developed to empower the workforce to successfully adapt to new fuel systems (e.g., hydrogen-powered systems).	N39	[45]
Societal Stakeholders	Labor and Workforce > Aircraft Manufacturing, Engineering workforce, and MRO workforce	Training Programs for Reskilling in Hydrogen and Sustainable Aviation Fuel (SAF) Systems for Engineers and Technicians should be developed.	N40	[45]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Societal Stakeholders	Labor and Workforce > Pilots and Cabin Crew and Airport Staff Ground Crew	Aircraft system workforce should be working in safe and clean environment.	N41	[43–45]
Societal Stakeholders	Labor and Workforce > Pilots and Cabin Crew and Airport Staff Ground Crew	The aircraft systems workforce should work in a safe, clean environment with low noise levels.	N42	[43–46]
Societal Stakeholders	Labor and Workforce > Aircraft Manufacturing, Engineering workforce, and MRO workforce	The assembly and disassembly processes should be simplified to facilitate manufacturers and technicians.	N43	[47]
Societal Stakeholders	Labor and Workforce > Ground Crew	The fueling and re-fueling systems, particularly those involving new fuel technologies, should be operated in full compliance with all relevant safety regulations and standards, or new standards should be developed as needed.	N44	[35]
Societal Stakeholders	Labor and Workforce > Aircraft Manufacturing, Engineering workforce, and MRO workforce	Materials processing techniques should minimize hazardous exposures, including toxic substances, excessive temperatures, and harmful radiation, to protect technician health.	N45	[48]
Societal Stakeholders	Labor and Workforce > Pilots and Ground Crew and Airport Staff and Aircraft Manufacturing, Engineering workforce, and MRO workforce	Ergonomic and user-friendly equipment shall be provided to aircraft and manufacturers technicians to reduce physical strain and enhance comfort, ensuring safe and efficient task execution over long periods.	N46	[47]
Societal Stakeholders	Environmental and Climate Organizations (e.g., Greenpeace)	The aircraft design should comply with the growing environmental regulations and sustainability guidelines.	N47	[32,49]
Societal Stakeholders	Environmental and Climate Organizations (e.g., Greenpeace)	Aircraft designers and manufacturers should provide clear and accessible information on how to integrate sustainability and environmental considerations into aircraft design.	N48	[32,49]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Societal Stakeholders	Public Health and Safety Organizations (e.g., WHO)	Preventive measures should be in place to reduce the transmission of infectious diseases during air travel, ensuring cleaner air and safer travel environments.	N49	[50,51]
Societal Stakeholders	Public Health and Safety Organizations (e.g., WHO)	Occupational health and safety protocols should be strengthened for aircrew members, addressing issues such as radiation exposure, irregular working hours, and long-term health effects from frequent flying.	N50	[50–53]
Societal Stakeholders	Public Health and Safety Organizations (e.g., WHO)	Aircraft noise levels should be reduced to minimize the impact on public health, especially for communities living near airports.	N51	[30,31,34]
Societal Stakeholders	Public Health and Safety Organizations (e.g., WHO)	Aircraft design and operations should minimize harmful emissions both inside the cabin and externally, to protect passenger health and reduce environmental impact.	N52	[32,33]
Societal Stakeholders	Media and Public Influence (e.g., social media)	The aviation industry should provide transparent and timely communication regarding aircraft safety, performance, and environmental impacts to keep the public informed.	N53	[54–57]
Societal Stakeholders	Media and Public Influence (e.g., social media)	The media should foster inclusivity and improve public understanding of modern aircraft technologies, ensuring that advancements in aviation are accessible and comprehensible to a wide segment of society.	N54	[54–57]
Societal Stakeholders	International and National Aviation Regulators	Aircraft design, manufacturing and operation should fully comply with safety, operational, and airworthiness certification standards to ensure reliability and regulatory approval.	N55	[58–60]
Societal Stakeholders	International and National Aviation Regulators	The certification process for emerging aircraft technologies should be streamlined to accelerate innovation while ensuring safety and regulatory compliance.	N56	[58–60]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Societal Stakeholders	International and National Aviation Regulators	Aviation systems should be equipped with robust cybersecurity measures and advanced data protection protocols to ensure safety, reliability, and resilience against cyber threats.	N57	[58–60]
Societal Stakeholders	Governmental and Public Policy Bodies (e.g., EU Commission, Green Deal, National Ministries)	Environmental regulators should implement and enforce stricter carbon-neutrality mandates to drive sustainable aviation and reduce the industry's environmental impact.	N58	[14,61]
Societal Stakeholders	Governmental and Public Policy Bodies (e.g., EU Commission, Green Deal, National Ministries)	Environmental regulators should promote and accelerate the adoption of 100% SAF, hydrogen, and other alternative propulsion systems to advance sustainable aviation.	N59	[14,61]
Societal Stakeholders	Governmental and Public Policy Bodies (e.g., EU Commission, Green Deal, National Ministries)	Environmental regulators should promote and implement next-generation noise reduction policies to enable ultra-quiet aircraft operations and minimize noise pollution.	N60	[14,61]
Societal Stakeholders	Governmental and Public Policy Bodies (e.g., EU Commission, Green Deal, National Ministries)	Environmental regulators should promote and enforce full lifecycle sustainability standards, from eco-friendly manufacturing to end-of-life recycling, to minimize aviation's environmental impact.	N61	[14,61]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should cover a distance under nominal operating conditions without refueling.	N62	[62–69]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should maintain an optimal speed during cruise.	N63	[62–68]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft performance should balance efficiency, passenger comfort, and operational cost-effectiveness.	N64	[62–68]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should accommodate several passengers while ensuring their comfort and safety.	N65	[62–68]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should be capable of carrying a range of payloads suitable for long-range missions, including passengers, baggage, and cargo.	N66	[62–68]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should be able to achieve a safe take-off.	N67	[62–69]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should land safely without losing stability.	N68	[62–69]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should be able to decelerate to a standstill after landing within a given distance.	N69	[62–69]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should be able to operate safely within airport infrastructure constraints, particularly during taxiing, parking, and ground handling.	N70	[70]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft needs to perform safe, efficient, and structurally sound flight operations while maintaining compliance with aerodynamic and regulatory limits.	N71	[62–65]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should be able to provide adequate cargo and baggage storage capacity and to maintain proper weight distribution for safe and balanced flight performance.	N72	[62–68]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should present competitive economic performance.	N73	[62–68]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should minimize operational costs.	N74	[62–68]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft should support the competitiveness of manufacturers by reducing production costs while maintaining high performance.	N75	[62–68]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft design should comply with evolving global emissions and safety regulations.	N76	[70–75]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The manufacturing processes related to the aircraft systems should be efficiently streamlined for improved productivity and quality.	N77	[48]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The aircraft lifecycle should be extended.	N78	[70–75]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Industrial Stakeholders	Aircraft Manufacturers and Suppliers > OEMs	The waste related to the aircraft system should be reduced.	N79	[70–75]
Industrial Stakeholders	Airlines and Operators	The aircraft fleet should reduce emissions without retarding its economic performance.	N80	[76]
Industrial Stakeholders	Airlines and Operators	The airport should integrate better waste management and energy use practices.	N81	[77–81]
Industrial Stakeholders	Airlines and Operators > Passenger Airlines	The air traffic management system should optimize routing and reduce delays.	N82	[82]
Industrial Stakeholders	Airlines and Operators > Passenger Airlines	Passenger comfort and connectivity should be improved.	N83	[82]
Industrial Stakeholders	Airport and ATM Authorities > Airport	The airport should operate with net-zero emissions.	N84	[78,80,81]
Industrial Stakeholders	Maintenance, Repair and Overhaul (MRO) Providers	The MRO industry should reduce environmental impact.	N85	[83,84]
Industrial Stakeholders	Maintenance, Repair and Overhaul (MRO) Providers	The MRO industry should adapt to new propulsion systems (hydrogen-electric, hybrid, SAF-based engines) by training technicians and upgrading infrastructure	N86	[83,85]
Industrial Stakeholders	Maintenance, Repair and Overhaul (MRO) Providers	The MRO providers should maintain competitiveness	N87	[86]
Industrial Stakeholders	Fuel and Energy Providers	The alternative fuels should achieve economic viability and cost competitiveness (SAF Providers, Hydrogen Providers).	N88	[87–91]
Industrial Stakeholders	Fuel and Energy Providers	The fuel providers should invest in research and innovation to reduce the cost of alternative fuels (SAF Providers, Hydrogen Providers, Battery and Electric Companies).	N89	[87–91]
Industrial Stakeholders	Fuel and Energy Providers	The fuel systems should comply with aviation safety and emissions regulations.	N90	[87–91]
Industrial Stakeholders	Aircraft Manufacturers and Suppliers	The manufacturing processes should be automated and streamlined.	N91	[92,93]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Future aviation needs to provide affordable, sustainable, and reliable connectivity for passengers and freight with sufficient capacity.	N92	[40,94,95]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aviation needs to promote integration and cohesion within the EU, its neighbors, and partners.	N93	[40,94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Non-transport aerial applications (Infrastructure and Airspace Integration, Safety and Security Systems, Sustainability and Energy Systems) leveraging new flight control technologies.	N94	[40,94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aviation needs to promote environmental protection and the use of sustainable and alternative energy sources.	N95	[40,94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Complete and non-intrusive security measures.	N96	[40,94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Safety assurance must be provided in aviation operations.	N97	[40,94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aerospace industry and the future aviation related industries should provide opportunities for highly skilled jobs in Europe.	N98	[40,94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Information on mobility choices and affordable access should be provided to the passengers.	N99	[40,94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	The majority of European travelers need to completing door-to-door journeys within 4 h.	N100	[14]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Accurate flight arrival times are needed as well as a resilient system for managing disruptions.	N101	[94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	ATM system needs to handle diverse vehicles (manned/unmanned, autonomous, rotorcraft, fixed-wing, etc.)	N102	[94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	A well-organized, interconnected, and efficiently designed network of facilities that support air transportation is needed.	N103	[94,95]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	All components of the air transport system -such as air traffic management (ATM), airports, airlines, aircraft (manned and unmanned), and ground transportation-need work seamlessly together.	N104	[94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Joint definition and coordination between public and private stakeholders are needed across the entire innovation chain.	N105	[94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Creation of multi-disciplinary clusters should be made based on collaboration between industry, universities, and research institutes.	N106	[94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Development, maintenance, and continuous improvement of strategic test, simulation, and development facilities, with integrated validation and certification processes are needed.	N107	[94,95]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Attraction of students to aviation careers and providing education that aligns with industry needs, along with continuous lifelong learning.	N108	[14,40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Simple and effective mechanisms need to be established for coordinating shared and common objectives at private, European, national, and regional levels.	N109	[14,40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Innovative funding and financing instruments need to be established that provide excellent governance, well-defined roadmaps, long-term goals, and improved administration.	N110	[14,40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Shorter time to market from research to commercialization needs to be enabled for aircraft technology, supported by an integrated, research-innovation-friendly environment.	N111	[14,40]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Fair competition conditions should be developed that enable European industry to compete fairly in the global market.	N112	[14,40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	A coordinated management of a comprehensive research program should be established, including aeronautics, traffic management, and alternative fuels research.	N113	[14,40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	New aviation research should be conducted with a plan for the development and innovation roadmap that accounts for technological evolution and disruptive advancements.	N114	[14]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	The participation of women should be promoted in all professional and leadership positions in the global aviation sector.	N115	[14,40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Women's rights should be advanced and promoted in the aerospace industry and gender equality measures should be implemented.	N116	[14]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aerospace industry needs to provide career development opportunities for women through professional assignments, mentorship, and industry collaborations.	N117	[14]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Policymakers require a clear and unified vision for aviation decarbonization to align different roadmaps towards net-zero emissions by 2050.	N118	[14]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aviation stakeholders seek a reliable and scalable SAF supply chain to ensure its availability, affordability, and sustainability.	N119	[14]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Technology developers need continuous advancements in aircraft efficiency and operational improvements to contribute consistently to emissions reduction.	N120	[14]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Governments require strong pro-hydrogen policies and investment in renewable energy to enable the adoption of hydrogen and battery-powered aircraft.	N121	[14,40,96]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aviation planners seek a well-defined baseline emissions model that accounts for realistic efficiency improvements and demand growth.	N122	[14,40,96]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Regulators require effective demand management policies to maximize the impact of demand reduction strategies on emissions.	N123	[14,40,96]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	The aviation industry needs robust market-based measures and carbon removal technologies to close the gap between residual emissions and net zero targets.	N124	[14,40,96]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	EU Policymakers require a comprehensive framework to achieve a 90% reduction in transport GHG emissions by 2050 through sustainable mobility solutions.	N125	[14,94]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aircraft manufacturers need to develop aircraft that emit zero net CO ₂ emissions by 2050.	N126	[14,94]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Engine designers require aircraft to emit 10% of NO _x emissions compared to the 2000 baseline by 2050.	N127	[14]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aerospace engineers need aircraft to emit 10% of non-volatile particulate matter (nvPM) emissions compared to the 2000 baseline by 2050.	N128	[14]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Operators require aircraft operations to cause only 10% of contrails compared to the 2000 baseline by 2050.	N129	[14]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	The aviation industry needs aircraft to achieve a 90% reduction in climate impact from CO ₂ and non-CO ₂ effects compared to 2000.	N130	[14]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aircraft has to comply with Noise Abatement Departure procedures.	N131	[14,40,96]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aviation authorities need aircraft to record and provide operational data for impact measurement.	N132	[14,40,96]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aircraft needs to be ready on time before departure.	N133	[14,40,96]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Operators need aircraft to avoid delays due to system failures.	N134	[14,40,96]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Airlines need aircraft to allow quick and organized boarding, deboarding, and cargo handling.	N135	[14,40,96]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Fuel providers and ground handlers require aircraft to support refueling/recharging within a specified time.	N136	[14,40,96]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Airports need aircraft to support faster and/or longer pushback and assisted taxiing operations.	N137	[9,97,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Navigation authorities require aircraft to have equipment for following the fastest route to the destination.	N138	[9,97,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Transport planners need aircraft to coordinate schedules with other transportation modes.	N139	[9,97,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Traffic management systems require aircraft to use a common communication system with other modes of transport.	N140	[9,97,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Communities need aircraft to reduce perceived noise emissions by 65% per operation relative to 2000.	N141	[9,97,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Air traffic controllers require aircraft to sustain continuous descent operations.	N142	[9,97,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Airlines need aircraft to be 30% more cost-competitive compared to 2022 true cost.	N143	[14,40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Regulatory agencies require aircraft certification costs to be reduced by 50%.	N144	[14,40]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Energy sector stakeholders need aircraft to operate with any available sustainable energy source.	N145	[14,40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Manufacturers require aircraft to achieve at least 30% energy efficiency compared to 2018 levels.	N146	[14,40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Sustainability experts need aircraft to be designed using circular economy principles.	N147	[9,14]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Environmental policymakers require aircraft to be designed according to ecodesign principles.	N148	[9,14]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Operators need aircraft to perform energy-efficient operations in-flight.	N149	[9,97,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Airports require aircraft to operate on the ground with limited to no noise.	N150	[9,97,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Pilots and traffic controllers need aircraft to change routes in real time.	N151	[9,97,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Airport planners require aircraft to fit existing airport infrastructure.	N152	[9,97,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Sustainability regulators need aircraft to fit zero-emission aviation infrastructure.	N153	[9,97,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Digital transformation experts require aircraft to have a digital twin, thread, or product passport.	N154	[99]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Cybersecurity experts need aircraft to resist cyber-attacks.	N155	[99]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Passenger experience designers require aircraft to allow easy movement and accessibility for all passengers.	N156	[40,96]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Airlines need aircraft to have sufficient in-cabin baggage storage for all passengers.	N157	[40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Safety regulators require aircraft to be five times safer than in 2020.	N158	[96]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Regulatory bodies need aircraft to comply with ICAO's noise certification limits to ensure only increasingly quieter aircraft are certified and allowed to operate.	N159	[9,97,98,100]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Environmental authorities require aircraft noise to be monitored and assessed using strategic noise mappings, dose-response curves, and indicators as mandated by the EU Environmental Noise Directive (2002/49).	N160	[9,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aviation policymakers need aircraft operations to adhere to noise-related restrictions as reinforced by EU Regulation 598/2014, which emphasizes operational limitations at Union airports.	N161	[9,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Airport authorities and policymakers need to mitigate the impact of aviation emissions on air quality in airport regions to address public health concerns.	N162	[9,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Health and environmental agencies need to reduce aviation noise and emissions of toxic pollutants to minimize cardiovascular disease risks.	N163	[9,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Employers and economic stakeholders need to address the negative effects of noise-induced fatigue to prevent productivity loss and reduce risks of work-related injuries and redundancies.	N164	[9,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Airport operators, airlines, and governments need to provide transparent information to communities affected by low-altitude flights to build public trust and acceptance.	N165	[9,98]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aviation stakeholders need to clearly communicate the advantages and disadvantages of airport expansions and new aircraft developments to improve public engagement.	N166	[9,98]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Research and Academic Institutions	-	Funding resources should be secured for research in next-generation propulsion research, focusing on hydrogen, hybrid-electric, and SAF engines to drive innovation in sustainable aviation technologies.	N167	[40,100,101]
Research and Academic Institutions	-	The acceleration of advancements in sustainable aviation technologies should be strengthened through interdisciplinary collaborations between multiple disciplines of aerospace engineering including climate sciences and AI research.	N168	[40,100,101]
Research and Academic Institutions	-	Collaboration between industry and academia should be promoted to secure funding for the development of disruptive aerospace technologies.	N169	[40,100,101]
Financial and Investment Stakeholders	Aircraft lessors and Leasing Companies	Investors desire a high return on investment and long-term profitability.	N170	[102–104]
Financial and Investment Stakeholders	Aircraft lessors and Leasing Companies	Lessors need an aircraft with high residual value to maximize long-term profitability.	N171	[102–104]
Financial and Investment Stakeholders	Aircraft lessors and Leasing Companies	Leasing companies seek fuel-efficient and low-maintenance aircraft to attract airline customers.	N172	[102–105]
Financial and Investment Stakeholders	Aircraft lessors and Leasing Companies	Lessors need fleet flexibility to accommodate various airline operational needs.	N173	[102,103,105]
Financial and Investment Stakeholders	Aircraft lessors and Leasing Companies	Leasing firms desire aircraft with strong secondary market demand for resale or re-leasing.	N174	[106,107]
Financial and Investment Stakeholders	Aircraft lessors and Leasing Companies	Lessors desire regulatory compliance and sustainability features to align with future market trends.	N175	[104,107,108]
Financial and Investment Stakeholders	Banks and Investment Funds	Banks need a reliable, fuel-efficient and sustainable aircraft to justify long-term financing.	N176	[102,109–111]
Financial and Investment Stakeholders	Banks and Investment Funds	Financial institutions seek low-risk investments in aircraft with strong residual value and market demand.	N177	[102,109–111]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Financial and Investment Stakeholders	Insurance companies	Lenders need predictable airline revenue streams to ensure loan repayment stability.	N178	[112,113]
Financial and Investment Stakeholders	Insurance companies	Insurance companies need aircraft with advanced safety features to minimize accident risk and liability.	N179	[112,113]
Financial and Investment Stakeholders	Insurance companies	Insurance companies seek reliable maintenance and operational records to assess and manage financial risk.	N180	[112,113]
Research and Academic Institutions	-	Research on low-TRL disruptive innovations, emerging underrepresented topics, and lifecycle-based design for sustainability is essential for advancing climate-neutral aviation.	N181	[100,101]
Research and Academic Institutions	-	Research on cost-efficiency, affordability, and scalability of green technologies is needed to ensure the economic viability of sustainable aviation solutions.	N182	[100,101]
Research and Academic Institutions	-	Research on social inclusivity, workforce upskilling, and passenger experience enhancement is needed to support a just transition toward sustainable aviation systems.	N183	[100,101]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	LRA introduced from 2040 onwards need to be at least 30% more energy-efficient (per flight) compared to recent and imminent aircraft (e.g., B777X).	N184	[65]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	The aircraft needs to be able to participate in 'wake energy retrieval' flights (e.g., extended formation flight).	N185	[65]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	Aviation needs to deliver against agreed environmental goals.	N186	[40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	The aviation sector needs to show "intensified action" [and results] on its negative impacts (noise, air quality and climate change) on the health and quality of life of European citizens.	N187	[40]

Table A1. Cont.

Stakeholder (Main Category)	Stakeholder Sub-Categories	Need	Need ID	References
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	The aircraft needs to comply with the ICAO CO ₂ standard.	N188	[40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	The aircraft engines need to comply with the CAEP/8 NOX standard.	N189	[40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	The aircraft needs to be able to use 100% drop-in SAF.	N190	[40]
Regulatory and Policy Stakeholders	International and National Regulatory and Policy Stakeholders	The aircraft needs to be able to use 100% non-drop-in SAF.	N191	[40]

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