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AIRSHIP TECHNOLOGY FOR AIR CONNECTIVITY AND HUMANITARIAN AID IN THE CARIBBEAN AND THE PACIFIC

Transport and trade connectivity in the age of pandemics

UN solutions for contactless, seamless and collaborative transport and trade

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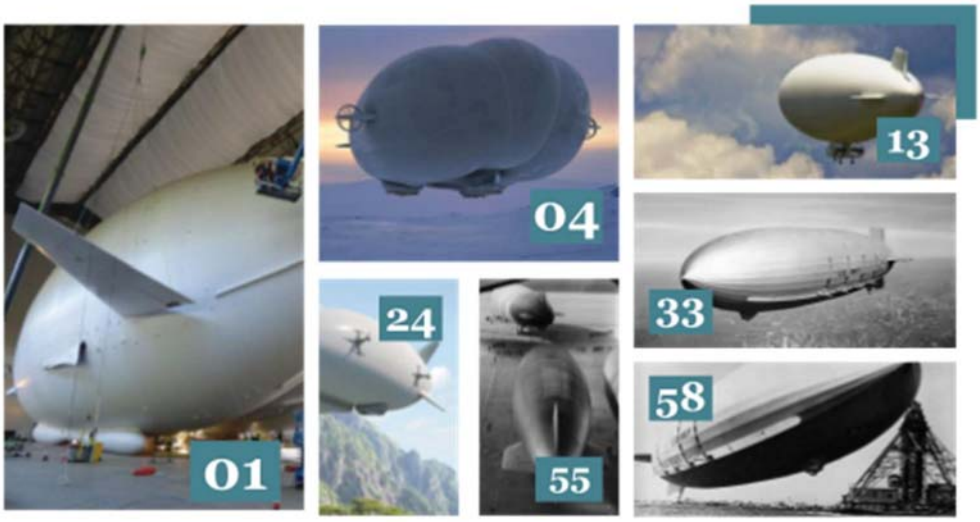

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Credit: Hybrid Air Vehicles;
Source: http://www.ltaflightmagazine.com/return-of-the-airship

EXECUTIVE SUMMARY

The Airship transport alternative, in its diverse engineering variants, has the potential to be a game-changing technology with significant development in recent years. It offers the technical capabilities to make a broad contribution to the optimization of mobility and logistics networks in isolated communities and territories, especially but not only in Small Island Developing States (SIDS). This innovative mode should be incorporated into the transport matrix (both nationally and regionally), for the latter to move towards more efficient, sustainable, and resilient networks. Airships do not necessarily compete with other means of transport, instead, they complement traditional modes which improve co-modality/synchro-modality and perform social functions, achieving a clear improvement in connectivity, interior (hinterland) and external (foreland) accessibility. There is a diversity in Airship technology, operational mode, and in the functions, both in commercial and in non-commercial operations (such as humanitarian aid), as will be showcased in the following sections, along with the logistics and connectivity standards that it has the potential to raise. Besides transporting cargo and passengers for scheduled or rescue flights, Airships can provide communication and monitoring services to remote and vulnerable locations, as well as to provide health care through mobile sanitary units.

This topic is important in the context of the ongoing COVID-19 pandemic. In the event of a disaster, different aid agencies are deployed with support in the distribution and logistics of perishable and essential cargo, equipment, and assistance personnel. The economic capacity and the transport connectivity of the regions directly influence countries' capacity to withstand adversity. Disasters usually have local effects, and the area affected depends on the type of natural hazard. Some of them, such as the COVID-19 pandemic, have a global impact, presenting a significant challenge for the transport and logistics industry.

Remote areas, such as the SIDS in the Pacific and the Caribbean, have certain common features of vulnerability. The distance to demographic centers and markets translates to decreased connectivity. Besides distance, there are implicit transport costs related to logistics services that may be diminished because of a series of developmental, economic, and environmental circumstances. Likewise, small islands are prone to natural disasters, which requires a stable and reliable transport infrastructure. The airship, in a synchro-modal relation with traditional modes and other new technologies, brings to these remote locations an innovative transport solution that promotes a sustainable and resilient approach to logistic services and infrastructure, contributing to the implementation of the United Nations Sustainable Development Goals. The special UNDA (the United Nations Development Account) project on trade and transport connectivity in times of the pandemics launched in May 2020[1] states its priorities in the following three clusters:

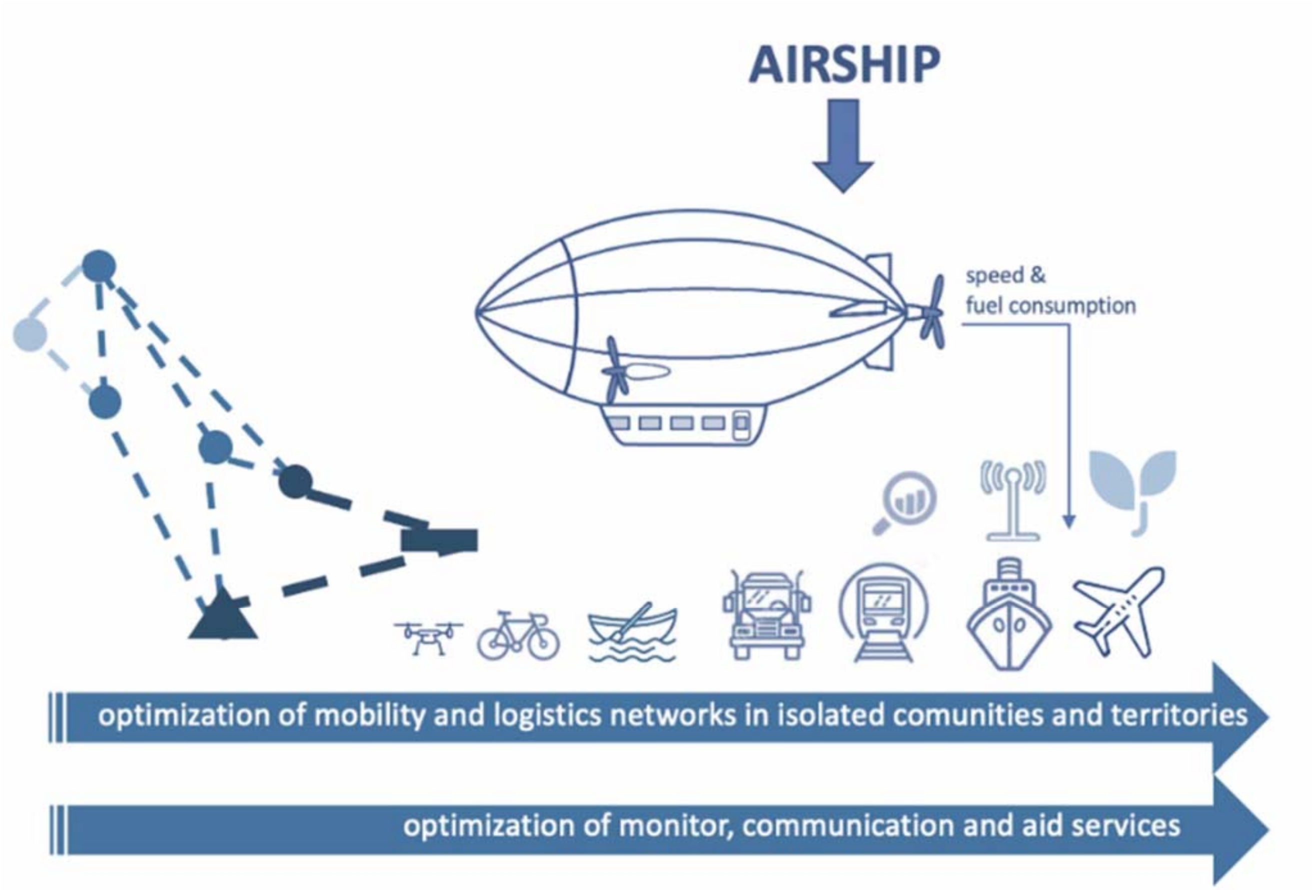
- **Cluster A** – Contactless solutions: It aims at minimizing physical contact among people in cross-border supply chains by facilitating the flow of goods without spreading the virus;
- **Cluster B** – Seamless connectivity: It focuses on eliminating obstacles to cross-border trade and transport operations arising from the COVID-19 crisis;
- **Cluster C** – Collaborative solutions: It seeks to strengthen regional and sectoral cooperation on transport, trade, and logistics operations to facilitate joint actions and solutions in responding to the COVID-19 pandemic.

This document aims to present the state of the airship´s technology, its flexibility, advantages, and study cases. The research highlighted a series of competitive advantages of airships for improving connectivity in SIDS and for addressing humanitarian, sanitary and environmental challenges across the local, regional, and global scales, as a resilient and sustainable logistics solution in synchro-modality with other modes of transport (as illustrated in Figure 1). Airship technology as a mode of air transportation and service provision can help achieve the goals of regional policy programs and agreements, and prospects for its development should be brought up for discussion in these contexts. The United Nations Economic Commission for Latin America and the Caribbean (ECLAC) and the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) are focused on researching the SIDS of the Great Caribbean and Pacific for the improvement of sustainable connectivity and emergency operations using airships. The introductory sections of this document present the state of connectivity in SIDS vulnerable to disasters and associated challenges.

This document, builds on previous research conducted by ECLAC as part of its ongoing initiatives for fostering innovative and resilient solutions, and presented at the 2021 edition of the Transportation Research Forum, is intended to provide evidence upon which public policy recommendations could be developed at the inter-regional level to implement airship solutions in the emergency response logistics network, focusing on SIDS as an example. In achieving that purpose, a set of factors is addressed regarding both the state of the art of airship technology under ongoing development and the state of logistics in regions relevant to the present study. The main technological advances in the airship industry will be assessed, underscoring the set of technical features that would best suit an emergency response, and will present some of the main cases that validated the airships' advantages for emergency operations in isolated regions.

[1] *For more information, please consult:* *https://www.unttc.org/*

Figure 1: The airship and its competitive logistics services



Source: *Authors. A graphical representation of the speed and consumption.*

The findings of this study will be explored in the broader context of the implications of airships use for the logistics networks of the region, as well as challenges to be faced, to advance transport connectivity towards a smooth cross-border trade, seamless logistics operations in the region, and distribution of assets for emergency relief as well as humanitarian and medical services across borders. The methodological guidelines found in the main relevant case studies on the humanitarian application of airships will be presented as a potential precedent for a new economic and logistic assessment of SIDS connectivity and resilience to extreme events. In conclusion, a series of topics and concerns are recommended for further research, mainly related to the main current challenges as identified throughout this research: financing resources, engineering developments, certifications, and regulations.

Credit: Lockheed Martin;
Source: https://www.flightglobal.com/skunk-works-p-791-airship-revived-as-civil-cargo-lifter/99025.article

AIRSHIP: A NEW, COMPLEMENTARY SOLUTION TO ENHANCE CONNECTIVITY, INTEGRATION, AND HUMANITARIAN AIDS

1.1 Airships' main advantages and characteristics

Airship technology refers to resilient, sustainable, and clean air vehicles, the modern stage of vehicles from the first decades of the XX century such as the Zeppelin, for the provision of logistics services for cargo and passenger transport.[2] In their current form, they can also provide humanitarian and health assistance operations, monitoring, and telecommunications service providers, among others. It is characterized by an ascent and propulsion method in which the volume of the vehicle, filled inside its structure with a gas lighter than air, pushes out the surrounding air, thereby achieving buoyancy. In some new hybrid airships, the lift is enhanced by the aerodynamic hull, engines, and other elements of the vehicle, making them heavier than air.

Traditional categorization of airships puts them mainly between 'Rigid', 'Semi-rigid' and 'Non-rigid (blimps)'. Theoretically, all these groups may include Lighter-Than-Air or Heavier-Than-Air vehicles, as will be described further on.[3]

a. ***Rigid airships:*** They employ a rigid framework covered by an envelope, with multiple internal compartments that provide lift when filled with gas. Rigid airships are generally Lighter-Than-Air vehicles and can be built in different sizes due to their being typically unpressurized.

b. ***Semi-rigid airships:*** A simple framework and the pressurization of the envelope by gas hold together the shape of the vehicle, with

[2] *Based on the introduction provided by the Airship Association: http://www.airship-association.org/cms/node/22*
[3] *Typification*

one or more internal compartments. These airships maybe both be Heavier or Lighter-Than-Air.

c. ***Non-rigid airships:*** Also known as "blimps", they rely entirely on internal gas pressure to retain their shape during flight. Promotional blimps such as the 'Goodyear' are typical examples. In the current state of development, many hybrid airships functioning in the cargo and logistics space have no rigid frameworks.

There are many variants to this technology, but as it will be shown, most of the models relevant to this study and most prominent across the case studies reviewed involve a rigid frame of different designs. Technological innovations in contactless operational solutions are among their main advantages, with low environmental impact due to the use of nonflammable gasses such as helium. Below, are some of the main advantages and characteristics of this transport technology:

- Its operation involves *reduced investments* of nodal infrastructure and greater flexibility in comparison to a currently deployed hub and spoke logistics structure.
- It requires *fewer investments* in terrestrial infrastructure since it links nodes by air.
- Its speed is estimated *between 100 and 350 kilometers per hour* and, *not having to follow a path defined by roads or maritime lines*, the transit time is reduced in comparison to currently deployed modes.
- It *improves accessibility*, bringing an efficient alternative for reducing transit time compared to other modes, except for conventional aircraft.
- It *employs static lift*, allowing the energy consumption matrix for transportation to be modified, and offers benefits for reducing Co2 emissions. Its capacity for cargo lifting ranges between 10 and 60 tons, potentially matching or exceeding several truck models and aircraft that serve relatively small communities at present. The engineering is being upgraded for volumetrically higher loads, between 100 and 250 metric tons.[4]
- It is *resilient and adaptable to requirements* of demand; it can carry Unmanned Aircraft Systems (UAS) for last-mile delivery, and certain models can load and unload in stationary flight, among other possibilities of the different technological variants.
- It is *versatile in functionality* and can provide telecommunications, monitoring, healthcare, and other services to remote areas.
- It adds *diversity in distribution and land infrastructure* systems with a wide range of functionalities to achieve cost efficiency in different logistic scenarios and adapt to varying cases of terrain and weather conditions.

The technical features in the engineering of airships that represent both their competitiveness and their proficiency in sustainability skills can be summarized as being *slower but cheaper than an airplane; faster but more expensive than trucks* (Prentice et al., 2021). They have average cruising speeds of 100 km/h or higher, with varying load capacities going from the 10-20 to the 250 tons ranges depending on model and type of operation; this is largely outweighed by its efficiency standards, as will be detailed in the study.

[4] *Varialift is working on an upgraded version of its ARH50 model: https://www.varialift.com/page/specification-arh-50*

1.2 Airship types and technical characteristics

In this section, a brief mention and overview will be made of some of the relevant technology being developed in the present day by the companies of the airship industry. This is by no stretch an exhaustive sample, but a selection following the criteria of discussing models that can be found in the relevant case studies for emergency operations and other recent publications, which will be addressed across the present study. Table 1 shows the main technical features of this mode of transport exemplified on these models. It is important to indicate that these are models still under construction or in planning stages; in some cases, as indicated in the chart, test flight prototypes were completed in recent years.

A brief note on the recent developments of each producer is presented on the bottom row of the table; this is of interest due to the fledgling nature of the airship industry at large at the current point in time, and the prominent role that prototype building and test flights play at this period of financing and business search.

Before moving the table, a short description of different aspects of airships is summarized in the text to follow. The progress of each developer in the sector regarding certification procedures, as well as the situation in the industry at large, were beyond the scope of the present study; however, some general findings regarding the role of inter-regional agencies and institutions that provide technical assistance will be showcased in "Opportunities for integration in inter-regional agreements and investment programs" chapter.

Varialift ARH50: "The first heavy-lift commercial Varialift airship, the ARH 50, is expected to be certified to carry up to 50 metric tons (50,000 kg; 110,200 lbs.) of cargo and will be powered by standard aero gas turbine engines. The rigid aluminum exterior offers the potential for adding thin-film solar panels on the hull and batteries to power a distributed propulsion system on future versions. There is space for almost 10,000 square meters (107,600 square feet) of solar panels on an ARH 50 hull." (Lynceans.org technical profile, 2021)

Flying Whales LCA60T: "The LCA6OT is 200m long by 50m wide with a vast 96m-long cargo bay, making it the first airship in history able to load and offload up to 60 tons of cargo while hovering, effectively transporting heavy loads and opening up hard-to-access areas." (Dubai World Expo, 2021)

HAV Airlander 50: "Airlander 50 is a heavy lifting aircraft offering solutions for industries such as remote mining, oil and gas, and more… Many industries such as remote mining and humanitarian aid rely on substantial, sometimes fragile infrastructure to transport cargo. Airlander 50 will offer a new solution enabling efficient movement of heavy and awkward freight without damaging the environment." (HAV website, 2021)

Lockheed-Martin LMH1**:** "Capable of carrying 47,000 lb. of payload and up to 19 passengers over ranges up to 1,400 nm at a cruise speed of 60 knots, Lockheed Martin's hybrid airship offers lower cargo transport costs to remote areas that road and current air alternatives cannot match. The LMH-1 derives 80% of its lift from the buoyancy of helium gas and 20% from the aerodynamic lift generated by the shape of the tri-lobed vehicle and the thrust of its four propeller engines." (Aviation Week online profile, 2021)

Aeroscraft ML866: "Aeroscraft ML866 is the world's first rigid variable buoyancy air vehicle. It was developed by the Worldwide Aeros Corporation for heavy cargo transportation. The air vehicle is capable of controlling lift in each stage of flight, from take-off to landing. The Aeroscraft ML866 unloads onboard cargo without re-ballasting, unlike airships and hybrid airships. The Aeroscraft ML866 was first unveiled at the National Business Aviation Association (NBAA) show in Atlanta in October 2007. Worldwide Aeros received a design patent for the Aeroscraft from the United States Patent and Trademark Office in July 2012. The company also plans to launch two larger versions of Aeroscraft, designated as ML868 (60t) and ML86X (500t)." (Aerospace Technology online profile, 2021)

BASI MB560: "The BASI airship operates only from fixed bases and lands on a rotating terminal. This allows for some systems to be located on the ground, rather than on the airship. For example, access to ground power reduces the weight and need for onboard electrical power during mooring and transshipping cargo. Ground-handling equipment, e.g., fork-lift trucks, can be staged at the base. Perhaps most importantly, a simpler water-based ballasting system can be used; water ballast can be available at each location to offset weight changes.

A hybrid-electric propulsion system is used to power the airship. Initially, standard turbine generators will be employed, but the plan is to eventually shift to hydrogen fuel to eliminate carbon emissions." (BASI website, 2021)

It should be noted that regardless of the distribution system of each model (characterized by its operational features), the state of the art in the literature shows that operating costs should be lower than those of existing air transportation. As a reference, Tatham et al., 2017, roughly estimates in its methodology to compare the advantages of airships an operating cost for a Hybrid Airship that uses helium - ML 686, with a capacity of 225 tons, 0.3 USD/ton/km, and a cost of investment of the vehicle of 430 million USD, similar to the cost of a Boing 747 F (358 million USD), while other models such as the 21-ton LMH-1 hybrid airship would cost approximately 40 million USD, as validated through sources such as Wells (2016) and Ausick (2014). These figures may be subject to revision and updating, but allow to show that there exists a range in estimative capital costs upon which business case calculations and comparisons may be based. This comparison is shown in detail in chapter 4 of this document.

As regards infrastructure investments, it is generally considered that airships require a hangar for maintenance; in addition, some models require docking and undocking bases and others land facilities for loading and unloading (Prentice et al. 2021). Nonetheless, infrastructure requirements are minimal compared with other air transportation modes; to cover the distances it travels linear courses through the air, and when docking vertically it only requires a free turning radius but does not require a paved runway. The models that are distinguished for humanitarian operations are those that are prepared with greater flexibility and with the ability to respond in the short term. Tatham (2017) distinguishes that the travel from its operational center could take two days to reach the operational zone of the disaster, being able to have autonomy in the site of 4 weeks.

Table 1: Main airship technical features and designs

Vehicle	Varialift ARH50	Flying Whales LCA60T	HAV Airlander 50	Lockheed-Martin LMH1	Aeroscraft ML866	BASI MB560
Loading capacity (in tons)	50	60	50	23.5	20	30
Length (meters)	150	200	119	85	94.5	170.7
Estimated cruise speed (km/h)	350	100	195	111	120	148
Range (nautical miles/kilometers)	6,000/11,112	540/1,000	2,600/4,815	Up to 1,400	1,000	1,200
Crew	2	2	7	2	2	2
Passengers	14	0 (cargo only)	50 (with tourist services)	19	0 (only cargo)	0 (only cargo)
Max. Altitude	30,000 ft.	10,000 ft.	10,000 ft.	10,000 ft.	12,200 ft.	10,000 ft.
Type	Rigid	Rigid	Hybrid/Rigid	Hybrid/Non-Rigid	Hybrid/Rigid	Rigid
Operational features	No infrastructure for landing – autonomous flat surface landing and vertical liftoff	Hovering cargo handling system – 500/1000km range bases for maintenance near warehouses	Autonomous landing	Autonomous landing and docking with grip technology	Air cushion take-off/landing system (ACTLS); autonomous landing w/o extensive ground crew; Internal Ballast Control system to offload cargo w/o employing ballast	Fixed base BART system
Current progress by the developer	The test rig was built in 2011. Prototype ARH-PT under construction (for flight test and training)	Prototype under development, expected for 2023/24 (lift capacity unknown); first flight for LCA60T scheduled for 2024, type certification 2026	Airlander 10 (10-ton lift) completed in March 2016 for test flights (one unit); program completed in 2019 after accidents; production run planned for 2025; Airlander 50 under eng. development	Test flight and technology demonstrator prototype P-791 (21-tons) built in 2006; first 12 LMH-1 units under construction for Straightline Aviation	currently seeking US$3 billion to build 24 vehicles, including larger models 868 (225-ton lift) and 86X (500-ton lift); Dragons Dream test flight prototype built and completed in 2013	Engineering research under development

Source: *Author's, based on the data published by developers. Note: Speed and other figures may be rounded or approximated*

Many industry actors have become involved in research projects to validate their proposals to implement airships in humanitarian operations and performed fieldwork studies in collaboration with specialists in logistics on the locations they posed their hypotheses for service provision. In general terms, they were carried out as a response from the industry to the inquiries and concerns from experts in fields related to distribution logistics in recent years, regarding the viability and feasibility of the airship business case. A set of these will be addressed through their related case studies. One of the major concerns of experts in the fields related to SIDS emergency and disaster relief operations is the ability to deploy airships in a variety of weather conditions, including hurricanes and other extreme events. Amidst the sources consulted, there was a consensus that weather disasters are a problem for airship operation, but not to such an extent as to distinguish it from conventional air vehicles, which implies that this will not be a negative factor in assessing competitiveness and that technological advances in construction materials and shell fabrics make operation easier and avoid damage.

1.3 The trend towards sustainability in logistics

Logistics involve more than the transport function, "logistics integration is a fundamental part of productive integration, to such an extent that without an adequate and efficient interconnection of infrastructure networks and associated services, it is not possible to generate value chains and productive integration in general" (Jaimurzina, Pérez and Sánchez, 2015). Bearing in mind the implementation needs of SDGs, ESCAP points out as a challenge to promote smooth and sustainable freight connectivity through a more efficiently integrated infrastructure for all means of transport and a more balanced modal distribution, with better service to users and considerable energy savings.

The fore-mentioned set of advantages in employing airships would be crucial for advancing the new Blue Economy approach, proposed in recent SDG documents, and particularly relevant for SIDS in the face of climate change, COVID-19 pandemic, and other issues of global impact. An article released by the United Nations Development Programme, reflecting on the impact of the issues of the last year, formulates the following stance:

> *SIDS see themselves as the Large Ocean States, their ocean territories are some 20.7 times greater than their land area. As one of their greatest opportunities, they are pioneering the Blue Economy paradigm that promotes sustainable use of ocean resources while generating economic growth, jobs, and social and financial inclusion and preserving and restoring ocean ecosystems. Seychelles has led by example, launching a first-of-its-kind sovereign blue bond, mobilizing US$15 million for blue economy projects* (UNDP, 2021).

Since 2014, initiatives for sustainable development for SIDS have been articulated under the scope of UN's inter-regional programmes through the 'Small Islands Developing States Accelerated Modalities of Action (SAMOA) Pathway' with a 10-year plan focused on international assistance, which would be complemented and enhanced by the improvements on connectivity airships can facilitate (UN, 2014).

Research presented by potential operators such as Flying Whales (2021) emphasizes the variable of unlocking the economic potential of isolated regions by increasing accessibility for goods and inputs to offset the initial investment risks. Jeong et al. (2020) places the maximization of last-mile delivery advantages as the explicative variable of airship competitiveness, fostered by its capabilities for combined operations with technologies such as Unmanned Aircraft Systems (as termed by ICAO), colloquially referred to as drones or similar devices. There is progress in research that analyses feasibility and complementarity with other means of transport, highlighting cost savings by using airships in remote areas such as the Northern Canadian steppe, for their geographic and demographic configuration, for the transportation of mineral extraction products, food, and general merchandise and fuel (Prentice, 2013; Prentice and Adaman, 2017; Prentice and Wilms, 2020). The cited studies were prepared by the University of Manitoba, Canada, and are mainly focused on investments and operational cost analyses, based on load distribution by type of consumer's goods and cost savings disaggregated by location.

The feasibility of implementation in distributional circuits and trade routes is developed from the competitive approach with current means of transport (Prentice and Knotts, 2016), and from the standpoint of operational considerations for navigation and ground facilities for mooring, docking, and co-modality (Lynch, 2018; Prentice and Ahmed, 2017). The potential shown by airships for the commercial competition is assessed in the broader historical perspective of air transport technological development (Prentice and Knotts, 2014), which is supplemented at specified levels of market potential assessment in Asia and other regions (Prentice and Lau, 2016), and with case studies for the insertion of these aircraft into other transport systems and operations, such as urban passengers (Romli and Aminian, 2017), the conduct of humanitarian and medical aid (Dorn, Baird and Owen, 2018), assistance in disaster events (Lynch, 2018), the provision of computer and communication services (ADB-BASI, 2019), and military operations (Ghanmi and Sokri, 2010), among others. Public statements from trade agencies and expert associations are shown as evidence of the emergence of a consensus on the feasibility of airships in climate change response as a relevant variable of fuel consumption efficiency in cargo freight operations (Prentice and Knotts, 2016).[5]

Incorporating airships as a new mode of transport capable of improving mobility and logistics in co-modality/synchro-modality terms, is a goal for the transport and logistic industry, focused on integrated logistics services and infrastructures. It is pursuable with new regulations towards a sustainable network with economic and social global integration achievements through improvements in connectivity. ESCAP (2019) conceptualizes the tangible impact of connectivity, sustainability, and resilience categories as follows:

> *Conceptually, connectivity can be perceived as the purpose and the consequence of transport. In this context, connectivity is synonymous with networks.*

[5] *Prentice and Knotts, 2016 (p.4: "The International Association of Air Transport (IATA) has praised the CO_2 efficiency standard that ICAO has adopted for new aircraft built after 2020 (defined as a maximum fuel burn per flight kilometre). From 2023 this standard also applies to existing aircraft designs still in manufacture at that date. Given the long life-cycle of commercial aircraft, this is unlikely to contribute much to the aspirational goal IATA has set for itself to reduce 2050 CO_2 emissions to 2005 levels. Older airplanes will be contributing to CO_2 emissions throughout this period, especially the older passenger jetliners that have been converted to cargo carriage.")*

*Networks, in turn, are a set of interconnected nodes. One of the most succinct descriptions of connectivity among the references for this report refers to connectivity as being an attribute of a network and a measure of how well connected any one node is to all other nodes in the network. It could, therefore, be argued that the value and significance of connectivity is found in the role a node and its hinterland plays, the cost of accessing that node, and the reliability of connecting to the node. Accordingly, connectivity has hard and soft dimensions and, importantly, is associated with concepts of access. This relates to the inherent nature of transport as an engine of economic growth and social development (*ESCAP, 2019).

The main connectivity indicator was developed to measure the quality of maritime services; other advances in the development of indicators have been, for instance, indicators that characterize the infrastructures and services in the hinterland. ESCAP (2019) also proposes to consider indicators related to economic well-being, social inclusion, equity, environmental quality, economic resilience among others.

Logistics advances to co-modality/synchro-modality concepts focus more on sustainability and efficiency of transportation. In 1980, UNCTAD defines multi-modality as cargo transport using two or more means of transport, inter-modality adds that it is in the same transport unit, door-to-door, and with greater integration. Combined transport and co-modality focus mostly on sustainability and efficiency. Synchro-modality (synchronized inter-modality) adds two more attributes, flexibility (adaptive) and transport mode selection based on real-time information. Logistics service providers, in this model, have the flexibility to make real-time decisions based on variations in demand and the availability of resources available in the logistics network; the progress in this theoretical trend is clearly showcased through recent developments in Khakdaman, Rezaei and Tavazzy (2020).

Technology for logistics and mobility progressively incorporated the appropriate equipment for each type of infrastructure and vehicle for the movement of different product classes. For instance: barrel, sack, paddles, and more recently containers, some 60 years ago, express this technological evolution, as did wagons, trains, trucks, boats, and barges, and others before them. Valuable developments exist currently in last-mile logistics, such as cargo bikes, and electric boats, drones to name three examples of potentially disruptive technologies. However, there are needs not yet completely met for territories of special accessibility conditions due to geographical, climatic, orographic, and other difficulties, which complicate their connectivity with other territories that are necessary for them to achieve better living conditions and social development for their inhabitants, following the objectives of sustainable development. In such territories, traditional infrastructure and vehicle combinations are less performant. In the case of SIDS, such as remote islands with a greater vulnerability to natural disasters, the airship represents an opportunity to complete the technological chain for logistics and mobility; this is due to its special operating conditions as an efficient means of transport and with a higher degree of adaptability. Adaptation is characteristic of this mode of transport, mainly due to the flexibility to carry out its loading and unloading cargo operations with fewer requirements of civil infrastructure and logistics services than other modes of transport.

1.4 Extreme events

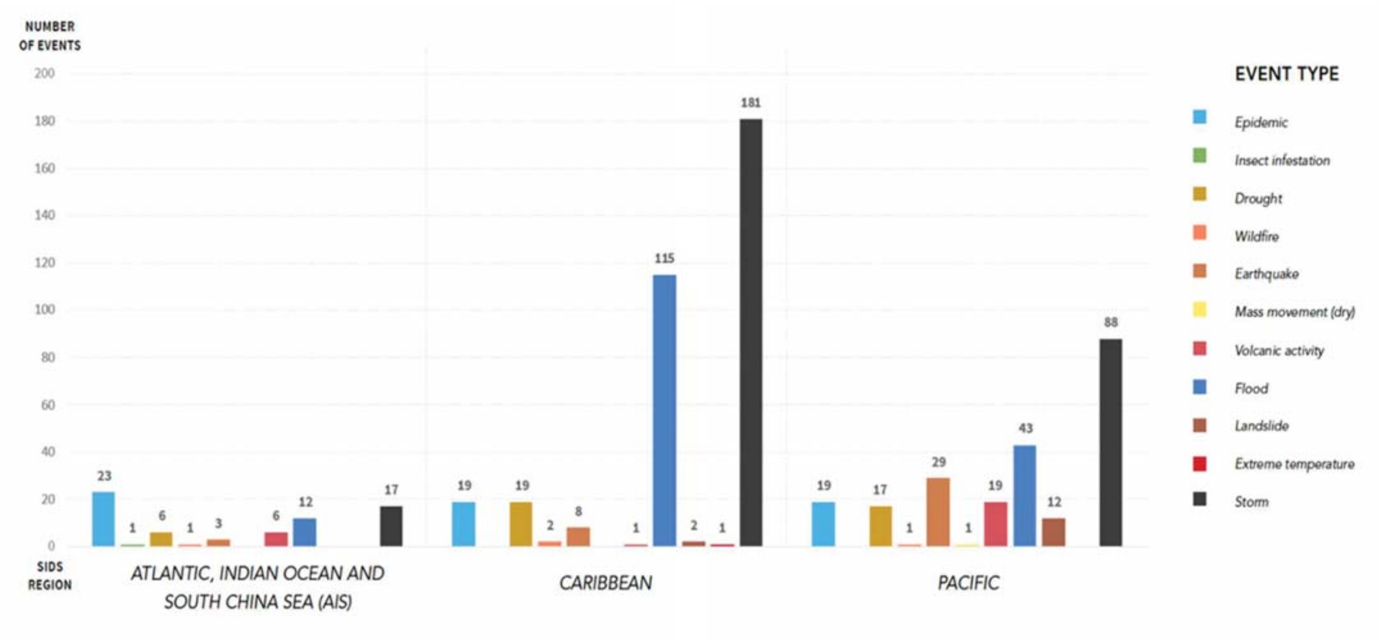
Disasters are the consequence of the combination of two factors: a) the natural phenomena (threats) that trigger processes that affect the assets and flows of an economy, and b) the built vulnerability of human settlements. (ECLAC, 2014)

SIDS countries are amongst the most prone to disasters in the world due to their geographical location, limited physical size, and high population density in low-elevation coastal areas. In relation to their capital stock, investment, and social expenditure, SIDS faces the highest potential losses associated with several hazards. SIDS would be expected to lose 20 times more of their capital stock each year compared to Europe and Central Asia (UNISDR, 2015).

The combined average annual losses (AAL) of SIDS are equivalent to 10 percent of their total annual capital investment, compared to less than 2 percent in East Asia and the Pacific and around 1.2 percent in Europe and Central Asia. The AAL in SIDS is equivalent to almost 20 percent of their total social expenditure, compared to only 1.19 percent in North America and less than 1 percent in Europe and Central Asia. From 1970 till 2020 Caribbean SIDS had more disasters than the Pacific SIDS, has relatively more population affected, and on average, relative to the size of the economy, more damage.

The number of disasters in SIDS referenced by economic population and damage is shown in Figure 2, below.

Figure 2: Catastrophic events associated with different extreme events and hazards (1990-2020) in SIDS macro-regions



Source: *Disaster risk and readiness for insurance solutions in Small Island Developing States. UNU-EHS United Nations University, Institute for Environment and Human Security. Based on the impact data from EM-DAT. Michael Hagenlocher et al. (2020).*

Credit: The Energy Mix;
Source: https://www.theenergymix.com/2021/05/31/hybrid-electric-airships-could-cut-short-haul-flight-emissions-by-90/

AIR AND MARITIME CONNECTIVITY FOR SIDS IN ASIA-PACIFIC AND THE GREATER CARIBBEAN IN THE CONTEXT OF COVID-19

2.1 The COVID-19 Pandemic and transport connectivity of SIDs

Unlike threats like earthquakes, hurricanes, and floods, which last for minutes, days, or weeks, an epidemic can last for years. The COVID-19 pandemic was caused by a natural phenomenon of a biological type and has affected billions of people around the world and all aspects of socio-economic well beings of countries and communities.

__Coronavirus disease (COVID-19)__ is an infectious disease caused by the SARS-CoV-2 virus. Most people infected with the virus will experience mild to moderate respiratory illness and recover without requiring special treatment. However, some will become seriously ill and require medical attention. (...) Anyone can get sick with COVID-19 and become seriously ill or die at any age. (...) The virus can spread from an infected person's mouth or nose in small liquid particles when they cough, sneeze, speak, sing, or breathe (WHO, 2021).

An aggregate statistic of COVID 19 cases and Cases per 100,000 population through July 1, 2021, in selected Caribbean and Pacific countries, is presented in Annex 3 and shows that some 9,222,805 cases or 5.08% of all registered cases happened in the area of interest.

A virus, combined with existing vulnerabilities turned it into a global health disaster: the management and response capacity of the health system, overcrowding, informality, social work practices, and existing public transportation, among others. Particularly air transport services, as a consequence of their having to avoid forms of physical contact that might spread the virus, suffered the loss of regular services, which subsequently affected basic supply aids. Figure 3 shows how lockdown restrictions have affected connectivity between pairs along global routes.

Figure 3: Global route network before (March 2019) and after the pandemic has started (March 2020)

Source: *IATA Economics using data from flight Radar 24, w/c March 25, 2019 – Air Connectivity. Measuring the connections that drive economic growth (IATA, 2020). (Note: recolored in blue)*

The large-scale prolonged effects of the COVID-19 pandemic overlay with the negative impact of natural hazards of different types in recent extreme events around the globe, but certain regions are showing more marked signs of this phenomenon. This generates the double challenge to provide humanitarian aid and simultaneously control the spread of the virus, in the face of disasters such as those caused by Hurricanes Eta and Iota in Guatemala and Honduras in November 2020 in the Great Caribbean, and Cyclone Harold in 2020 affected Vanuatu, Fiji, Salomon Islands, and Tonga nations in April 2020 in the Pacific.

So brought a new paradigm in transport and connectivity, which spotlighted the importance of a series of projects leading to "contactless, seamless and collaborative" solutions. This set of three priorities are stated in the special UNDA project on trade and transport connectivity in times of the pandemics launched in May 2020: **Cluster A** - Contactless solutions: It aims at minimizing physical contact among people in cross-border supply chains by facilitating the flow of goods without spreading the virus; **Cluster B** – Seamless connectivity: It focuses on eliminating obstacles to cross-border trade and transport operations arising from the COVID-19 crisis; **Cluster C** - Collaborative solutions: It seeks to strengthen regional and sectoral cooperation on transport, trade and logistics operations to facilitate joint actions and solutions in responding to the COVID-19 pandemic.

The occurrence of simultaneous disasters mandates new logistics processes to avoid the spread of the virus. Despite restrictions on air transport, based on interviews, no delays were found in the delivery of humanitarian aids, however, it has promoted new challenges.

For countries that are exposed to disasters, the focus is on pre-disaster preparation to face disasters the moment they emerge, the key being connectivity. Regarding how well-connected SIDS are:

Remoteness is one of the main challenges for small island developing States (SIDS). However, this term is commonly used in a *narrow sense, referring only to geographical distance from markets resulting in higher transportation costs (...) remoteness is a broader concept, also involving distance to financing sources and political centers. In addition, it can be aggravated or attenuated by connectivity in transportation networks or through political and cultural linkages. Moreover, with the growing weight of the digital economy, issues of access and performance of information and communication technologies gain higher importance* (Cantu Bazaldua, 2021).

The connectivity, as pair connections, could be improved by employing active policies of different kinds, with improvements on transport infrastructure, trade facilities, and other initiatives; but it is fundamentally characterized by a dependency on the market volume between different countries. The relation between trade development and connectivity presents a similar dynamic to that of the “Chicken and egg” metaphor: the countries with less commerce share the condition of having less connectivity as well, while less connectivity is generally related to a higher vulnerability to fast response.

This makes it crucial to promote the development of sustainable transport networks, which will improve the connectivity of the islands, such as transport systems that integrate airships, together with innovative processes and technologies.

2.2 Connectivity benchmark

Connectivity levels are different for the specific case of each island. The islands that concentrate more on export and import freight cargo generally attract a greater number of services, similar to those with more prominent tourist activity.

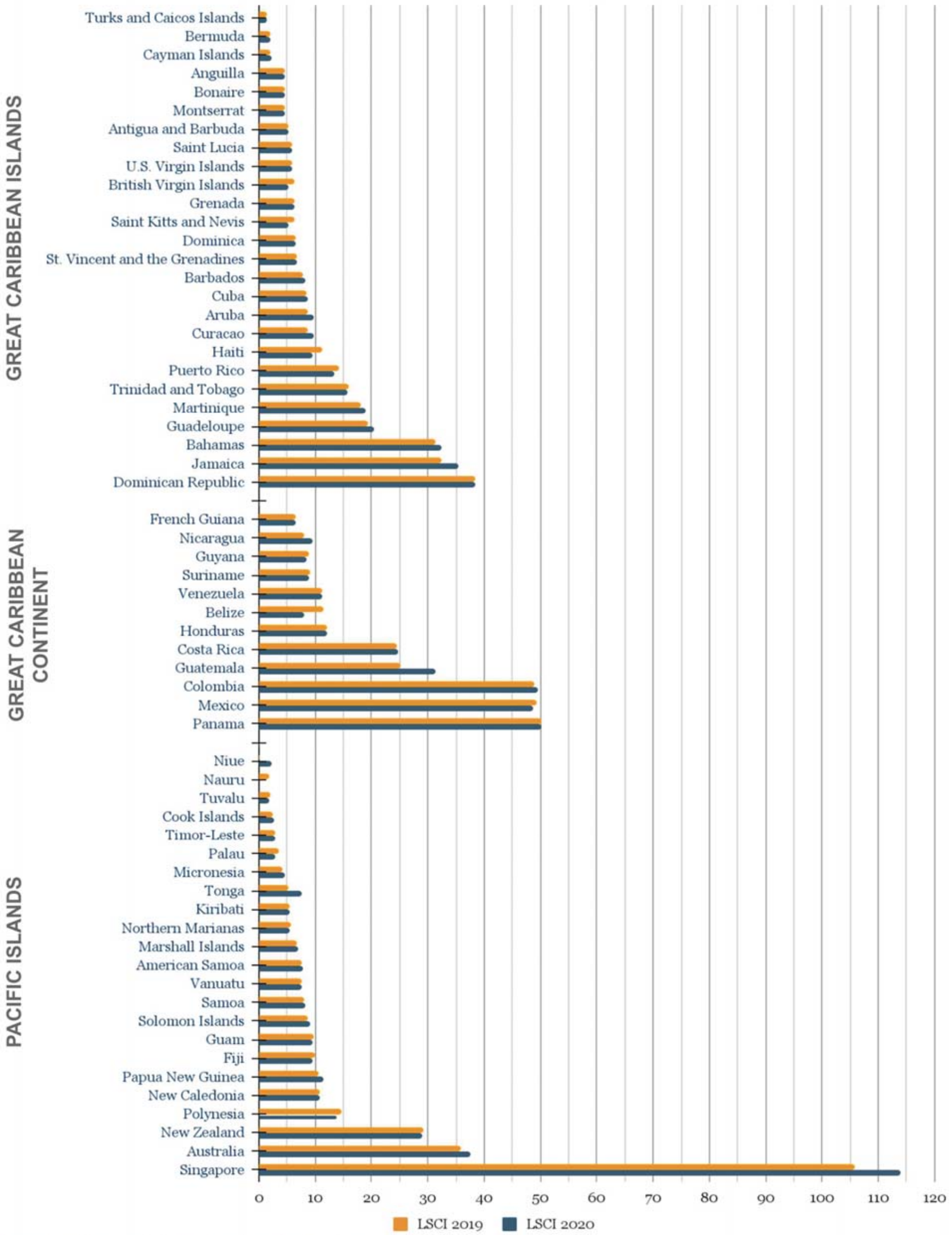
The maritime connectivity of different countries is usually measured by the index “Liner Shipping Connectivity Index” developed by UNCTAD (Figure 4). This index reflects the maritime direct connection of countries with other by service lines, so are characteristics of container cargo. There are different benchmarks of air connectivity: IATA developed an “Air Connectivity Score” (Figure 5) in which air connectivity characterizes the air connection between countries, taking into account the passengers; this is characterized also by the cargo because the cargo is transported on many occasions in the holds of the airplanes. The air and maritime connectivity are not comparable, since they use different methodologies.

The COVID-19 pandemic affected maritime connectivity and mainly air connectivity in the SIDS. Maritime connectivity, at the end of 2020, improved, however, the loss of connectivity is particularly strong in Belize which dropped 16 positions. However, the loss of connectivity due to the interruption of a service has a great impact when the number of available services is low. Statistical data presented in Annex 4 show the maritime connectivity in the fourth quarter of 2019 and 2020.

The global drop in air connectivity 2020 vs 2019 was 57%, according to IATA, in most of the islands it was noted for its close relationship between transport and tourism. The greatest loss, more than 70% of air connectivity as measured by the Air indicator occurred in Cook Islands, Fiji, Vanuatu, Marshall Islands, Nieu, Tuvalu, Micronesia, Kiribati, Tonga, Palau, Cuba, and Trinidad and Tobago. Statistical data presented in Annex 5 show the state of air connectivity in 2019 and 2020.

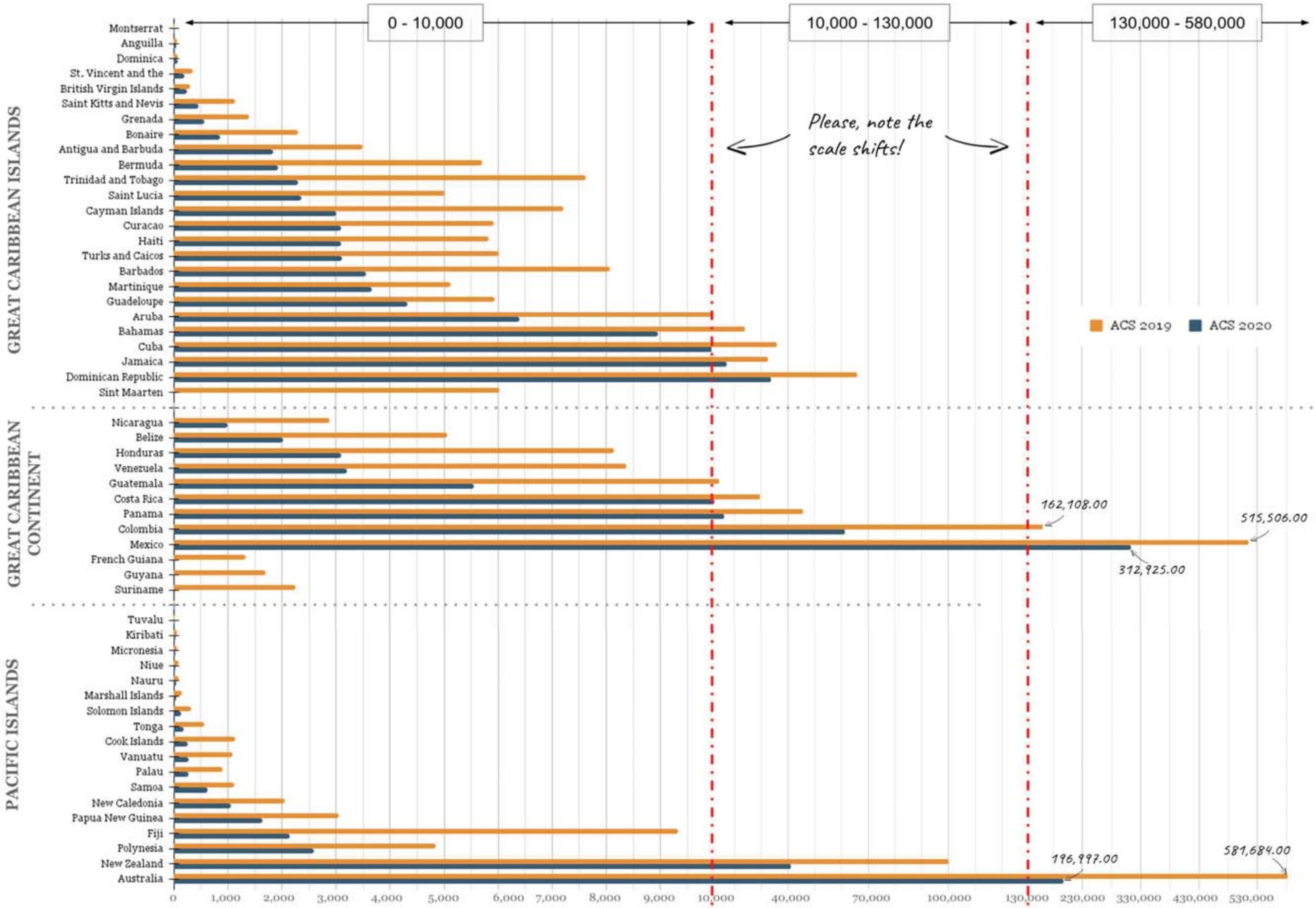
As it can be observed, there are countries that according to the maritime connectivity indicator, have high connectivity. However maritime connectivity is related to specialized container ships that call on the coast and it does not consider the linkage of the nodes on the coast with the nodes in the interior of the territory – Hinterland. For example, the case of French Guiana stands out, where its interior is characterized by a characteristic orography of the Amazon with isolated localities. Likewise, air connectivity considers only the main air infrastructure nodes. The following section, through an example of a disaster, is highlighted the importance of the connectivity of the hinterland, in particular to remote areas, with the commerce gateway to a country can be observed. Progress in benchmarks that measure the connectivity of remote areas based on the transport services available, by country is a pending research task.

Figure 4: Liner Shipping Connectivity Index by the country for Q 4 of 2019 and 2020



Source: *Author´s calculation, based on the data from UNCTADstat.*

Figure 5: IATA Air Connectivity Score by the country for 2019 and 2020



Source: *Author´s calculation, based on the data from IATA – Air Connectivity.*

2.3 The role of logistics, mobility, and connectivity in the assessment of humanitarian aid

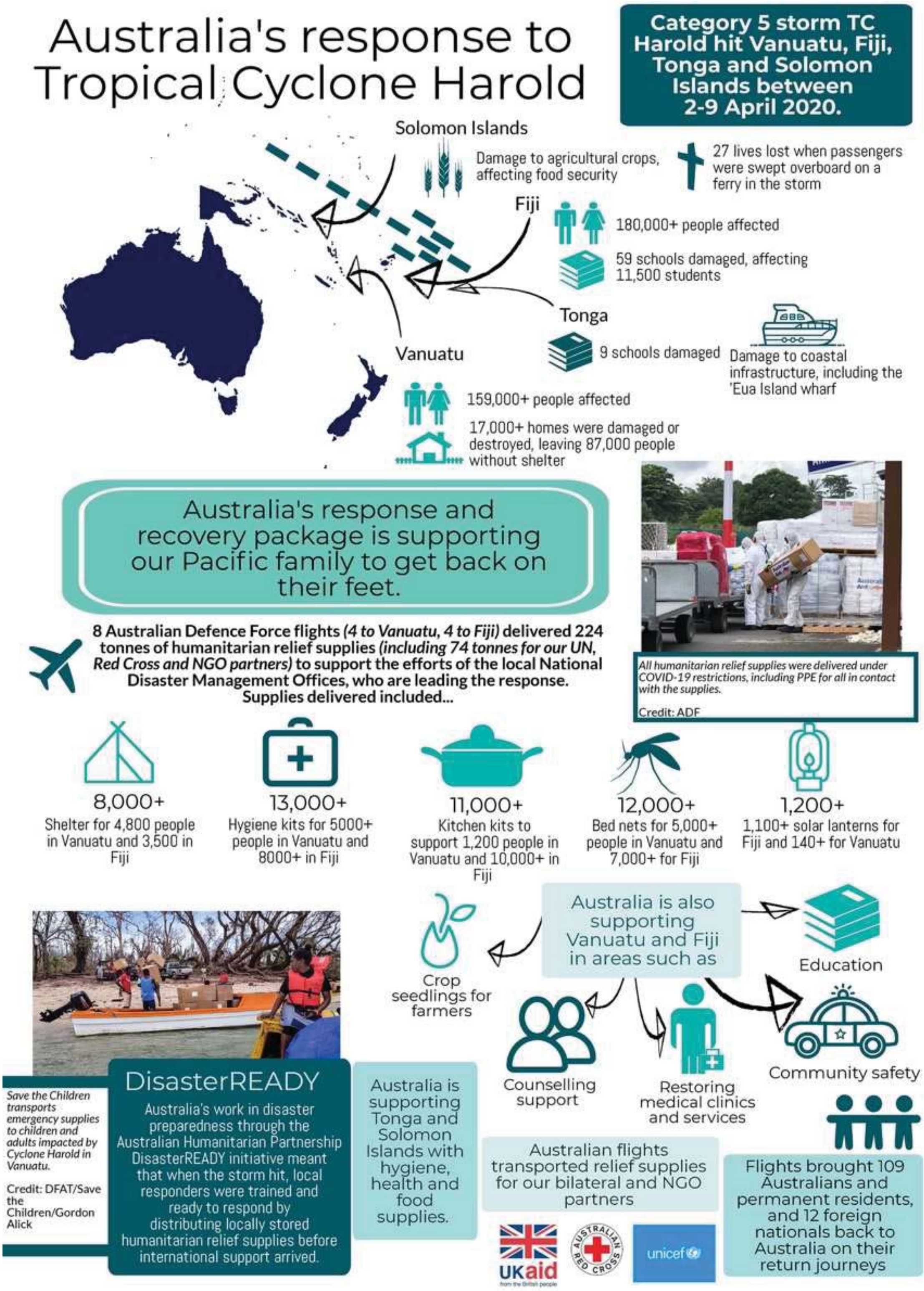
As regards the role of logistics, integration of the auxiliary and transport services is a key factor for humanitarian aid operations. Being prepared and knowing the characteristics of the affected area, the availability of resources in services and infrastructure, and the origin of the aid is crucial because each disaster has its particular set of features, and there are cases in which they impact simultaneously. Anticipation reduces time when disasters came.

Traditional time is the main factor, despite this, the availability of services with flexibility is the main paradigm for new technological solutions, as will be seen in the chapters dedicated to technical development. Likewise, the sustainability factor of the humanitarian aid service is pursued by the SDGs.

The aid response arrives at the site of the disaster from a different warehouse of the organizations that provide resources for relief, and afterward, it is distributed regionally. The following image shows a clear example of the aid provided by Australian Aid in cyclone Harold.

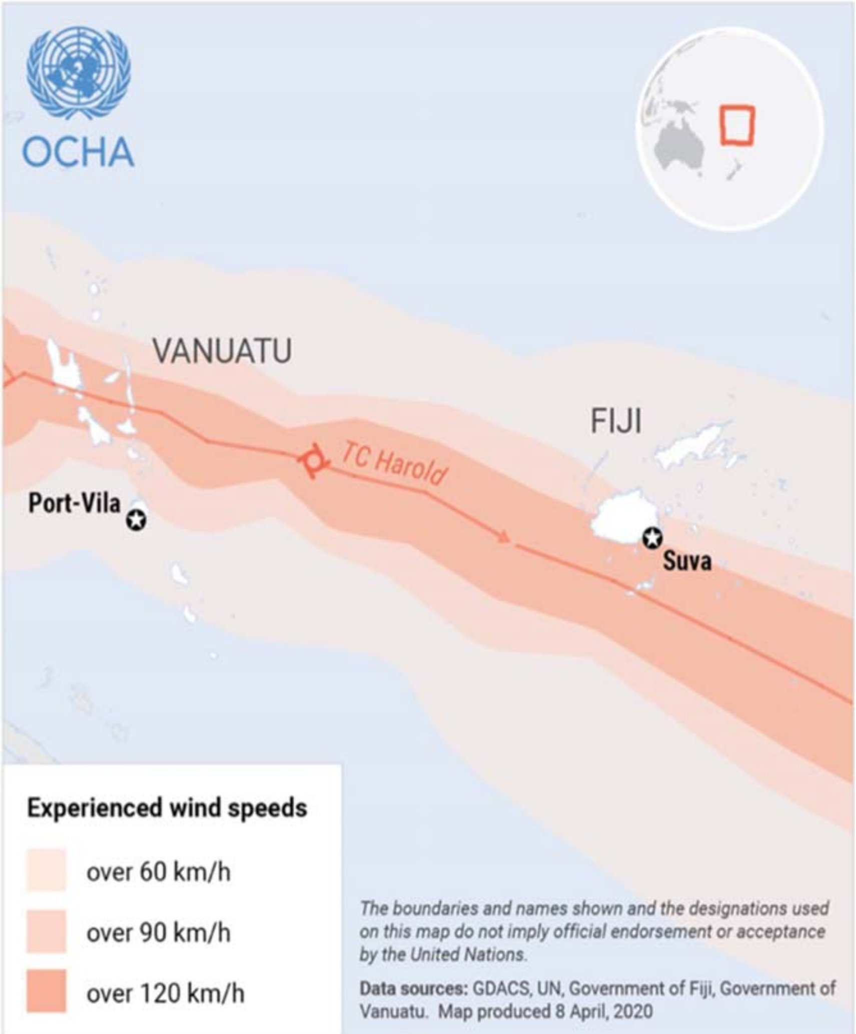
The Tropical Cyclone first hit the Solomon Islands with a Category 1 rating on 2-3 April 2020, before progressing to Vanuatu on 5 April, where it escalated to a Category 5. The cyclone went on to impact the south of Fiji as a Category 4 on 8 April, before reaching Tonga early on 9 April, having re-intensified to Category 5" "On request of the Government of Vanuatu, four flights delivered humanitarian relief supplies to Vanuatu on 13, 21, 26 April and 16 May. Supplies included shelter (tents and tarpaulins) for 4,800 people, hygiene kits for more than 5,000 people, kitchen kits for more than 1,200 people, bed nets for more than 5,000 people, and solar lanterns for more than 140 people. Supplies were provided by the Australian Government, the UK, UN, Australian NGOs, and the Red Cross. Australia also provided essential medical supplies to support Vanuatu's response to COVID-19, including GeneXpert COVID-19 cartridges, enabling Vanuatu to test for COVID-19 in-country. Strict protocols were implemented when delivering supplies to minimize any chance of transmission of the COVID-19 virus to Vanuatu. (Australian Government, 2020)

Figure 6: Australia´s response to Tropical Cyclone Harrold



Source: *https://www.dfat.gov.au/crisis-hub/Pages/tropical-cyclone-harold.*

Figure 7: Cyclone Harold Vanuatu – Area affected

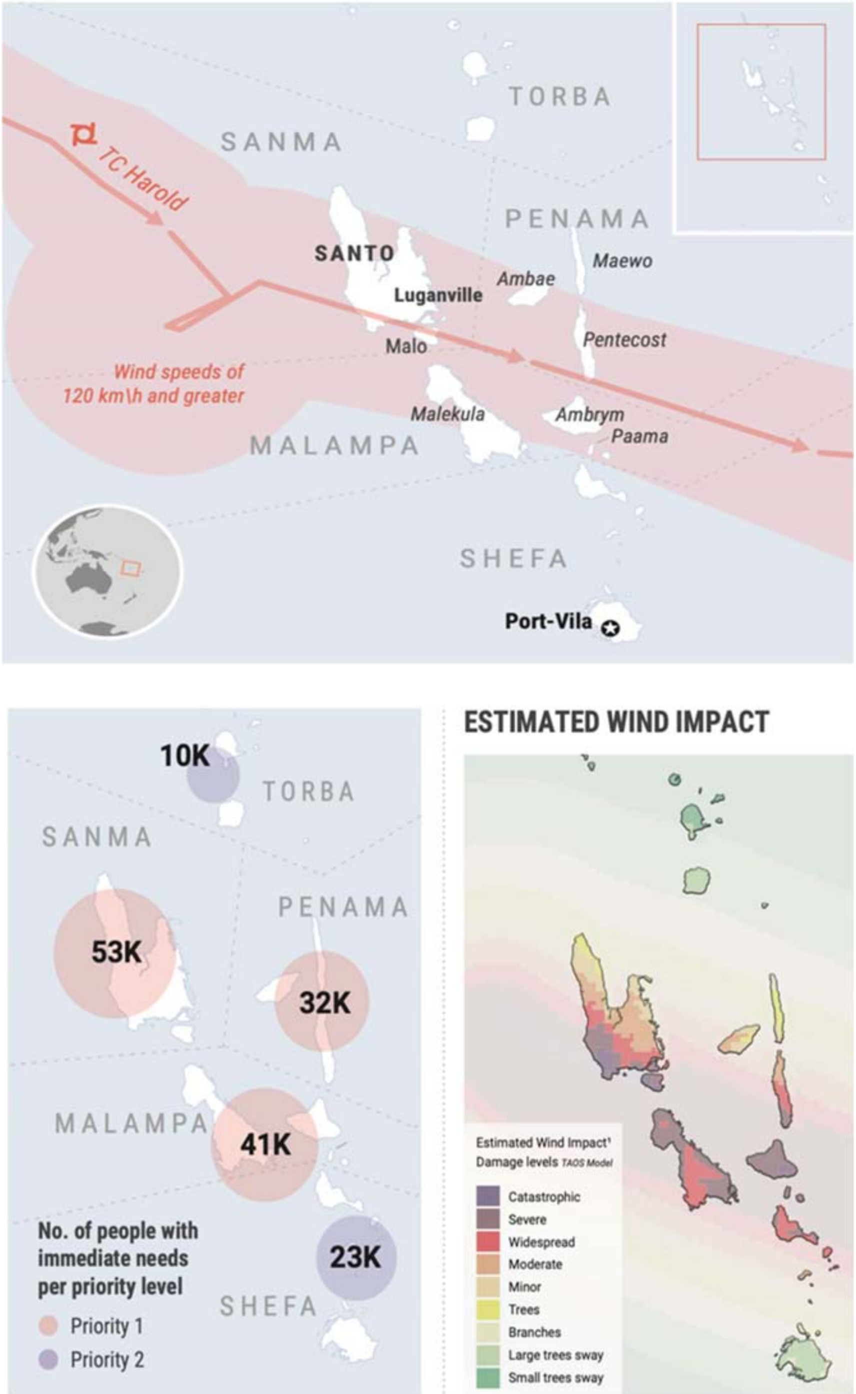


Source : *OCHA*
https://reliefweb.int/sites/reliefweb.int/files/resources/OCHA%20Flash%20Update%20no.1%20on%20TC%20Harold%20-%208%20April%202020.pdf

"The Pacific Islands are a group of 20 small island developing nations scattered across the Pacific Ocean that are especially vulnerable to large-scale disasters, such as cyclones. Climate change is making these disasters more frequent and intense. Over the last five years, the region has dealt with some of the most destructive cyclones on record, including Tropical Cyclone (TC) Pam in 2015, TC Winston in 2016, and TC Gita in 2018. In 2020, the Pacific Islands had to face a new challenge: weathering a Category 5 cyclone, the highest measurement on the cyclone intensity scale, while facing the paralyzing conditions and economic uncertainty brought on by the COVID-19 pandemic" as reflected on the brief report "A new vulnerability: COVID-19 and tropical cyclone Harold create the perfect storm in the Pacific" (OCHA, 2020). This highlighted the delays in aid distribution to local communities.

"Tropical Cyclone Harold made landfall in Vanuatu as a category 5 cyclone on 6 April with sustained winds of more than 200 km/h. The northern provinces of Sanma, Malampa, and Panama are most affected. Due to its path across the centre of Vanuatu, TC Harold has directly impacted on a large number of populated islands and the large island of Santo with the country's second-largest city Luganville" (OCHA, 2020). In the Figures 7 and 8, the different affected areas can be appraised; it is noteworthy that different last-mile modes of transport were used to reach these.

Figure 8: Cyclone Harold Vanuatu – Areas most affected and impacts estimations



Source: *OCHA https://reliefweb.int/sites/reliefweb.int/files/resources/OCHA-VUT-TCHarold-Snapshot-200408-2.pdf*

On the report "Tropical Cyclone Harold Lessons Learned Workshop Report" prepared by the National Disaster Management Office, the Government of the Republic of Vanuatu can notice the first response, and followings from the declaration of emergency per COVID-19 (26 March), TC Harold impacts (6 April) to 1st of September (National Disaster Management Office, Government of the Republic of Vanuatu, 2020).

In the following chapter, the advantages of the airships are highlighted as a possible 'game changer' on humanitarian logistic organization, validated through a set of sources developing theoretical operative scenarios. It is noteworthy for developing this topic that the consulted literature proposes a framework for operational and business modeling in emergency response based on a definition of the concept of Humanitarian Logistics informed by different academic and industrial sources reflecting the sensitivities of the matter in question: *"The process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials as well as related information, from* *the point of origin to the point of consumption to meet the end beneficiary's requirements*" (Tatham et al., 2017). Furthermore, the framework poses the meeting of requirements of *end beneficiaries* rather than *clients* as an indication of a difference between commercial and humanitarian logistics in nature: "In the former, an individual or organization creates a demand that the supply chain (and its logistic components) satisfies appropriately. In the case of the humanitarian context, however, it is often the case that those affected by the disaster are not in a position to place a 'demand' on the system as they are simply engaged in the process of staying alive and recovering from the disaster's impact." The defining characteristic of this framework is that it poses a set of logistic requirements where failure is not conceived as causative of *reduced profits* but of "*lives unnecessarily lost and/or prolonged hardship for those who have survived*" (Tatham et al., 2017).

Source: https://www.eleconomista.es/empresas-finanzas/noticias/7453852/03/16/Lockheed-Martin-presenta-comienza-a-vender-su-aeronave-con-forma-de-botillo.html

STATE OF THE ART IN AIRSHIPS TECHNOLOGY AND HUMANITARIAN AID OPERATIONS

In the following sections, the state of the art in airships technology and operational parameters are described with a focus on a series of current issues identified across the industry, relating to the engineering, operational, economic, and regulatory parameters in which it thrives to advance to introduce the airship solution in logistic services at a competitive scale.

3.1 Main challenges and operational parameters

The description of the diverse distribution systems (related to the operational parameters of cargo handling and delivery, take-off, landing, and docking procedures, among others) applied in the relevant case studies literature for humanitarian response operations via airship must be placed into the perspective of the economic challenges they are posed to tackle. The studies by Tatham et al. (2017) on humanitarian applications for airships and by Prentice et al. (2021) on a specific emergency aid case for the Arctic take into account the variables of cost information insufficiency and regulatory barriers (for flight authorization and licensing, as well as for the employment of hydrogen fuel cells as a structural power supply) as main challenges for the airship business case shortly; while the engineering capabilities for flight safety and logistic competitiveness against existing systems are posed as sufficiently advanced, the theoretical basis of which will be assessed in the following paragraphs.

The current services in place for emergency and humanitarian aid experience an array of operational and economic obstacles in climate-sensitive regions such as SIDS or the Arctic due to infrastructural deficiencies in transportation and assistance. Many proposed airship designs present a useful load capacity of over 30 tons and cover distances at more than approximately 100-200 km/h in most cases. Cargo airships of different sizes and engineering approaches facilitate delivery at the last mile and the reaching of isolated locations. Jeong et al. (2020) illustrate the potential of last-mile delivery optimization using drones and other technologies in combination with the storage capabilities of airships as the "*multi-objective of maximizing supply coverage while minimizing operational cost and risk*".

There is an important economic debate around the issue of an airship remaining on standby for delivery; waiting for an emergency call while various operational and capital costs are still running. A proposed answer found across the reviewed literature is to develop a combined service model that will attend a regular schedule for economic and trade activities, according to the necessities and characteristics of each serviced population, while keeping a window for auxiliary operations. According to Prentice et al. (2021), national policy decision-makers could employ contingency contracts for civilian operations, to apply more flexible budgetary allocations and gain access to 'the latest airship models and trained crews at locations'. Different approaches to this issue will be observed throughout the section dedicated to specific case studies, each applying a different technological and logistic solution.

From the studies mentioned in the previous paragraphs, it is possible to draw that the cost efficiency that stems from a fuel consumption decrease is correlative with a positive environmental impact that is characteristic of airships as it will be shown in this document and that its auxiliary functions such as surveillance and emergency response assistance are factors of enhancement for the correlation between logistics optimization and sustainable reduction of environmental pollution as well. A set of these case studies will be revised more thoroughly further on to develop on the previous point.

Lockheed Martin's LMH-1 and Aeroscraft's ML866/868 models operate in vertical take-off and landing (VTOL) mode, a circular area with a diameter of some 360 m (1,200 ft.) is required for both take-off and landing. This type of maneuver is enabled by the capacity of the airship's motors to redirect airflow and, according to Jeong et al. (2020), "eliminates the need for a wide range of ground handling equipment on the ground." Aeros, the producer of the ML Series, describes its VTOL method of variable buoyancy as follows:

> *One obstacle that conventional and hybrid airships face is their inability to control buoyancy without venting helium. Another operational challenge faced by airships and hybrid airships is the inability to control or adjust static lift during operations. Traditional airships' requirement for external ballast exchange and existing ground infrastructure has significantly limited their cargo utility. Once the cargo is off-loaded, traditional helium-dependent airships become extremely light, and this static lift causes them to float away. To combat these forces, they require external ballast exchange, using rocks, ice, water, or lead bags, to keep the airship anchored to the ground. Because the Aeroscraft is equipped with VTOL capability, it can deliver cargo directly from point-of-origin to point-of-need.*[6]

For the present study, the term 'airship' is taken in general for all variants of the technology, with the 'hybrid' category fitting within it.

Tatham et al. (2017) mention the employment of 'underslung loads' being considered by Lockheed Martin engineers as an alternative

[6] *Aeroscraft website (Capabilities):* *http://aeroscraft.com/capabilities-copy/4580476906*

method to circumvent the need for a landing area, which would, however, reduce the useful lift capacity of the vehicle to approximately 6 tons, added to the fact that it would need to avoid strong wind conditions to operate. This is illustrative of how the useful lift capacity is in different forms conditioned by lift-off maneuver methods, making it a particularly sensitive aspect of the engineering of airships. According to a source from the hybrid airship procurement industry by direct consultation: "Take-off distances vary greatly depending on a heaviness which is, in turn, a dependent on load and buoyancy (which in turn varies with helium fill/purity, temperature, and altitude). It also depends on the type of takeoff - whether using the aerodynamic lift and/or vectored thrust. At around 75% load vertical takeoff is possible using vectored thrust from the engines. Alternatively, assuming a takeoff/landing weight of 13,000 lbs the ship can safely depart over a 50' obstacle at a takeoff distance of 2,400'." The technical provisions apply to the features of the LMH-1 model. Tatham et al. (2017) mention as self-evident in this regard that the wind strength and direction will affect the operation of the airship and especially the cruising speed estimation figures. According to Prentice et al. (2004) with good information and experienced pilots, the wind could be managed to advantage due to cargo airships operating with a suite of electronics including weather radar and other surveillance and communications devices that will facilitate a most efficient flight plan. Weather prediction advice transmitted in real-time from a logistics center would work in tandem with this technology to optimize flight conditions even with low visibility which in this scenario would only demand a temporary speed reduction to ensure safety. This set of advantages is explored and validated in Tatham et al. (2017).

Costs must be taken as two separate issues between operational and capital costs in the different methodological approaches found in the available literature of airship cost-efficiency propositions. For both factors, the information available is sufficient for estimating orders of magnitude in investment requirements and efficiency assessments, but comparable costs between model designs give room for a further advance in financial assessment given that there are numerous ways in which the costs per flight hour can be calculated and that the standardized accepted protocols are currently under public debate. The same is true in the relevant literature for comparisons with traditional modes. Experts from inter-regional and logistics agencies in the humanitarian sector agree that public and inter-regional institutions must become involved in the debate to agree upon a cost-efficiency standard for the cargo airship business case. Placing the operational properties in perspective with different transport modes not only highlights the competitive advantages of the Airship, but it also raises the need to think of logistics in innovative ways. As stated by the Institute for Infrastructure, Environment, and Innovation of the European Union (IMIEU),

A very particular aspect of Lighter-Than-Air vehicles (LTA) is that the way LTA crafts operate is entirely different than conventional aviation. The way an LTA platform operates is very specific and conventional aviation engineering insights are not very useful. This makes the development of new approaches involving LTA carriers not easy. In the 1920s and 1930s, there was more know-how and expertise/equipment and infrastructure than in the current times. However, meanwhile, great advances in materials have been made, as well as in remote functioning and sensors, so much more is possible now and probably with new and larger-scale investments this backlog can be overhauled. The difference with conventional aviation is large, however. This is an essential aspect of upscaling, both perhaps challenging as well as providing opportunities. For *example, LTA –platform landing and take-off areas are broader (e.g., Zeppelin NT needs about 400M diameter) and square-shaped, or round, instead of rectangular, long (up to 1-3 km) and narrower, as airports are for conventional aviation.* (IMIEU, 2021

3.2 Cost efficiency and engineering parameters

Recent progress in airship engineering, which conforms to a state of the art characterized by shared efforts among industry developers and researchers to enhance operative advantages but with an ongoing debate about standardization, is closely related to a series of economic variables which it attempts to tackle to develop a business case that will foster investments, manufacturing, and service provision. Some of these variables are approached in the inter-modal cost efficiency perspective by logistics experts involved in an array of currently active projects for the development of airships construction and research, incorporating technical advances focused on optimizing the relation between payload lift capacity, speed, and dimensions of the vehicle with the distances and characteristics of the markets and territories it would serve to improve the connectivity conditions of existing transportation modes.

Neal and Koo (2020) adopt the variable of market share potential as explicative of its feasibility, applied to an analysis of a 'Potential Airship Fleet Demand' starting in 2012 and projected to 2030. The calculation consists of the multiplication of the FTK in non-bulk shipments by the result of market share simulations, over the annual FTK of each airship model. In that assessment, the airship's FTK is based on "an individual airship operating 300 days per year, 12 hours a day" (Neal and Koo, 2020).

According to Prentice et al. (2021), although there are major discrepancies in the available information fuel costs may be estimated at 35% to 50% of current cargo aircraft costs with airship models currently employing helium due to regulations that restrict hydrogen cell use, and which according to the same set of sources would increase efficiency as well as safety.

The facts of airship engineering development providing with static airlift and improving on building and fabric materials for a simplified structure blueprint lowers the expectations of capital costs per ton of lift. In terms of the ongoing development of vehicles designs in maximizing the payload capacity in balance with other technical features, it is agreed upon that 'doubling cargo capacity less than doubles cost. In the same sense, airships are agreed to be prone to achieving significant economies of a size similar to oceanic ships. There is a significant factor of restriction in investment requirements information as illustrated by Tatham et al. (2017) in the case of the capital cost of the ML866/868 series of hybrid airships not being ascertained, leading in its methodology to the adoption of a simplistic multiplication of the cost for a given payload of the LMH-1 for a comparison of orders of magnitude. In applying the aforementioned methodology, it is fully accepted that the resultant calculation represents a general "order of magnitude" estimation. The capital cost of the hybrid LMH-1 is estimated at lower levels than those of the Aeroscraft models employing a more complex and expensive rigid frame design together with an internal buoyancy control system that allows for a more versatile and secure VTOL operation, as referred to above.

As it was mentioned before, economies of scale are a probability assuming the capital cost/MT of cargo capacity is lower for the larger aircraft (Tatham et al., 2017). This leads to the capital cost order of magnitude for hybrid cargo airships (taking the technical and economic features of the LMH-1 model as a basis) approximating

US$2M/MT of lift, which is comparable with the equivalent for a fixed-wing freighter in the order of US$2.5M/MT. The Aeroscraft and Lockheed Martin hybrid airships operate with systems of autonomous landing and docking mechanisms for flat surfaces, while the BASI case studies are proposed for the use of airships with a fixed base distribution model (the BART system). A similar approach, more focused on the operational costs of the airship, was applied on a case study carried out jointly by the prospective airship operator Straightline Aviation and developer Lockheed-Martin for an airfield in Komo, Papua New Guinea completed in 2013 for LNG transportation mainly, comparing infrastructure costs to an airship project ($924,5M vs $23,6) among a set of other advantages utilizing the LMH-1, with an autonomous landing system and no ground infrastructure requirements for cargo handling similarly as the Aeroscraft ML866/868.

The capability airships provide for achieving last-mile delivery is one of its major assets for overcoming limitations in humanitarian aid coverage for isolated communities. Their extended navigational range and flexibility facilitate accessibility more extensively than with the traditional aircraft and land vehicles currently employed in small islands. Their air surveillance functionality of the airship brings a decisive advantage in preventing and containing disasters such as widespread fires, earthquakes, hurricanes, and floods that might affect those same communities frequently. Its operating simultaneously with other vehicles that mitigate disasters can guarantee a significant improvement in the chances of the response to be delivered in a timely fashion. The integration of the airship solutions with other modes and with new technological devices such as UAS (in general, drones and similar devices) has the potential to enhance its mobility features and overcome certain challenges related to its dimensions and the characteristics of the territories it would navigate, with different technologies adapting to a set of functions and types of operations, as it will be explored in following sections.

3.3 Ground infrastructure and sustainability parameters

A set of sources found in the relevant literature point to the state of the art in Hybrid Airship technological development as providing a game-changer feature with the recent development of the capability to reduce traditional ground infrastructure for air transportation, which will be continued to be developed on is approached by different developers with different engineering design schemes.

In that sense, the current developments in airship technology may allow for a more sustainable infrastructural development in sensitive ecosystems such as rainforests, and major studies across the board maintain both its cost-effectiveness in comparison with the total cost of traditional road and airfield infrastructure and its advantages for environmental care.

Akin to the concept of resilience elaborated on in the present study following the guidelines of sustainable development, the point is stressed on logistical flexibility by Tatham et al. (2017), reviewing the evidence found on the relevant literature for supply chain modeling as to the suitability of certain key elements for the preparedness in the face of unforeseen circumstances that are a key factor of relevance in an extreme event in isolated locations scenarios. The factor of unpredictability is key for the demand aspect of the business case modeling for involving new stakeholders and Tatham et al. (2017) places the feature of flexibility as paramount in airships, validated by sources such as Gattorna (2015), Beamon and Balcik (2008) and Tatham and Hughes (2011) for a humanitarian relief supply chain model to be able to tackle unexpected situations that might arise after an extreme event.

Tatham et al. (2017) highlight the role played by the regional warehouses coupled with official international assistance from neighboring areas outside the affected centers in providing stock for the emergency response to the disaster events it takes as an example for its case study. It nonetheless stresses the point that accessibility provided by infrastructure is as key a factor as vehicle availability, with an important point being the compatibility in sizes and operability between the aircraft and the airport infrastructure. Logistic efficiency must be ensured taking into consideration that break-bulk operations might require additional storage space and as it will be seen in the designs of the distribution systems models, the placement of infrastructure is adjusted to the variables of the vehicle lift capacity and speed against the distances to cover.

As it stems from the precedents found in the studied literature, the business case for hybrid airships in overcoming the aforementioned limitations in logistical flexibility might be achieved with an innovative and resilient solution with the capacity to perform direct deliveries from a regional warehouse to the location of the affected population which would greatly facilitate a swifter response.

Tatham et al. mention some of the instances in which this feature in its different forms would be applicable for emergency response in a way that contributes to logistical flexibility, presenting the capacity to perform landing/take-off maneuvers from locations such as *'fields, swamps or even from coastal waters adjacent to a beach'*. This would enhance the flexibility parameter as previously mentioned and allow for cargo delivery adjustments during flight and in real-time with the course of the disaster event. Expanding the focus of hybrid airships as cargo-carriers for relief operations which is applied to the main structural aspects of its case modeling, the authors point to other functionalities for the airship, such as mobile sanitary and healthcare units carrying medical equipment, inputs, and crew to different affected locations with quick response flexibility; water and other essential services facilities and their engineering and operating personnel, among many others (Tatham et al., 2017).

There is progress in research that analyses feasibility and complementarity with other means of transport, highlighting cost savings by using airships in remote areas such as the Northern Canadian steppe, for their geographic and demographic configuration, for the transportation of mineral extractive products (Prentice, 2013), food and general merchandise (Prentice and Adaman, 2017) and fuel (Prentice and Wilms, 2020). The cited studies were prepared by the University of Manitoba, Canada, and are mainly based on investments and operational cost analyses, based on load distribution by type of consumer's goods and cost savings disaggregated by location. The most recent development in this line of study is found in the research paper 'Transport Airships for Scheduled Supply and Emergency Response in the Arctic' by Prentice et al. (2021) which proposes a case study of an existing rare earth mine for modeling a contingency service scenario by cargo airships, based on a cost-efficiency comparison against the road modality and infrastructure economic approach, and taking the evolution of climate change as an emergency logistics case: "*Climate change has moved from theory to fact, and we are in the early stages of experiencing the effects of that change. In the past few decades, we have experienced changing climate change patterns* *and tremendous weather incidents such as droughts, sea-level rise, heat waves, landslides, flooding, and storms, to name but a few. According to research, almost 70% of carbon dioxide released since the 1750s can be traced to the 90 largest cement and fossil fuel producers.*"

Researchers consulted on this survey[7] agree the airship would be able to perform operations with approximately minimal contact, due to its low need of crew members on board. As expressed by Dr. Barry Prentice from the University of Manitoba in an interview carried out by the authors, "no more than just one (crew member) that would require any physical contact" would be needed on a regular schedule. This offers game-changing benefits for sanitary and epidemiologic response measures.

There is still debate as to whether a fixed landing base system will ultimately be possible to be avoided in favor of autonomous systems. For some developers, this question boils down to operational specificity, a stance that might be summarized as:

Eventually all airships will have to transship cargoes this way if it is a scheduled transportation service. The ability to just land anywhere is only for emergency use.

Significant advances have been reported for using airships in combination with other recent technological solutions such as UAS, mainly for the completion of goods delivery at difficult-to-access terrains. Developers consulted in this study attest that this combination is compatible as well with other features of sustainability in lighter-than-air technology such as the development of hydrogen fuel cells, and with the operational characteristics of the airship. Dr. Barry Prentice describes these operations as follows:

The airship would come in loaded with drones and supplies. Once the drones are released, the airship would become lighter and start to rise. The H2 would be released, and the propellers would keep the airship down until the empty drones returned. Then the H2 would be released to obtain the right buoyancy. After the airship returns to its base, more hydrogen would need to be added for a lift to equal the new loads going out.

Furthermore, a recent research paper from Purdue University proposes a humanitarian flying warehouse (HFW), "... an airship that stays at high altitudes and uses unmanned aerial vehicles (UAVs) to deliver supplies" (Jeong et al., 2020).

Hybrid airships are also low emission vehicles that supply heavy cargo delivery at an unparalleled differential of environmental footprint. Most case studies for transport by airships take heavy-lift helicopters as the main comparison object in operations to small islands due to it being the prevalent mode in use. The most methodically sound results have been shown through the fuel consumption/speed ratio approach by a significant range of researchers, and the findings across the board allow to place the airship at the point of equilibrium among all significant logistic services modes in existence.

Varied sources estimate the fuel consumption and carbon emissions of a Hybrid airship at nearly one-tenth of those of a Heavy-lift helicopter by the measure of each nautical ton-

[7] A consensus represented by the set of experts mentioned in the first paragraph of the References section in this study, and extrapolated by the authors.

mile. According to a technical assistance document on the LMH-1 model provided by members of Straightline Aviation: "With one-third the fuel burn and carbon emissions of a similar payload fixed-wing aircraft, Hybrids will reduce the environmental impact of roads, airports and other infrastructure traditionally needed that permanently scars the landscape, particularly in wilderness areas. Hybrids will also make previously inaccessible areas now available thus reducing the burden on many existing sites and the need for road or rail connections. Studies from the Social Stock Exchange Report show a 66.7 percent reduction in carbon emissions compared to fixed-wing, and 92.5 percent compared to a typical heavy-lift helicopter. Through the reduction of carbon emissions, greenhouse gases, damaging environmental infrastructure, transport congestion, etc. Hybrids will be less harmful to the environment whilst improving global communication links, which in turn, support fair trade and bring opportunities to communities previously out of reach of global markets." Consultations on this matter to industry actors working with different technological variants suggest that there is a case for translating these estimations to other airship models in varying degrees. Cost-effectiveness by reduction of infrastructure needs has been demonstrated by case studies of different approaches, and the airship's suitability for emergency aid and disaster mitigation makes its environmental friendliness a factor of exponential growth inefficiency.

Within the airship industry in the present day, there is a variety of prospective operators and producers developing models that have certain engineering aspects in common as well as fundamental and decisive discrepancies. The degree of the advanced in-vehicle building is heterogeneous as well among producers, but in the wider view, the airship technology requires the participation and funding of both public organisms and private parties to reach a desirable and productive stage. Guaranteeing the operational features of a specific model are feasible for the landscape and distances of which an operative schedule is to be set is paramount for developing policies involving airships that will be carried out successfully.

There is an assortment of functionalities that are relevant for humanitarian aid missions in SIDS by airship, many of which may be considered for being performed in tandem with one another. Lighter-than-air vehicles and airships in a broader sense can carry a range of payloads according to model, with variations in the 10/20-ton range in some Hybrid Airships with built-in landing cushion mechanisms are researching the possibility to reduce the need for airports or similar land facilities for docking, cargo handling or maintenance stops during missions, which gives them a greater resilience for servicing locations and population centers that are normally difficult to access due to terrain characteristics (among which the distance between small islands in a particular area should be counted) or deficiencies in infrastructure. Other airships of the lighter-than-air type can load and unload cargo in stationary flights.

These Hybrid airships are flexible for a variety of scheduled or emergency flights. Hybrid airships with a broad reduction in infrastructure needs during missions are rapidly advancing in the increase of their payload capacities. There exist smaller blimp/non-rigid type vehicles near the same cargo capacity range that are remotely operated for regular delivery operations, and Lighter-Than-Air airships around the 60-ton load capacity range with hovering capabilities for load and unload maneuvers which also decreases ground infrastructure needs.

3.4 Emergency aid and inter-modality parameters

Emergency aid operations respond to delicate and distinctive parameters that should be attended to under the light of inter-modal logistics coordination, and of the specifics of the necessities it aims to serve. A study by the University of Manitoba explains:

Like any supply chain, climate disaster relief logistics involves delivering the right supplies to the right people, at the right place, at the right time, and in the right quantities. Unlike commercial logistics, however, none of the coordination has been established between transport and storage services providers. Response delays can be ameliorated by maintaining full logistics readiness during non-disaster periods. Although readiness is an essential requirement of relief activities, no two events are ever likely to be the same, while the costs of standby preparedness further limit response capabilities. Disaster relief supply chains operate within perhaps the most challenging logistics environment. They must be able to respond rapidly, serve multiple destinations simultaneously, coordinate global and local supplies, and more often than not, deal with inefficient means of communication and transportation, or in the worst case, an almost total lack of civil means of communication and transportation (Prentice et al, 2021).

The proficiency of the airship for last-mile service is certainly one of the cornerstones of the airship advantages in connectivity, and particularly so for difficult-to-reach areas in small islands. Moreover, small islands with a greater propensity for extreme natural or climate events have an even higher differential of efficiency to obtain from the use of this technology:

In cases of natural disasters, the most challenging logistics is the final leg of the delivery in which surface transport infrastructure is disrupted. An airship would be able to fill this role better than any other known device. An airship's ability to vertically take off and land would allow it to reach remote areas not accessible by conventional aircraft. An airship, far cheaper to operate than a conventional aircraft, can transport aid directly from the point of supply to the point of need, with minimal support infrastructure. The strength of cargo airships is to provide sustained logistics response to aid survival and reconstruction (Prentice et al, 2021).

The provision of telecommunication and network connection services is possible by many Airship models and a key asset for isolated communities and the mitigation of disaster events, along with air surveillance capabilities.

Advances have been attested by prospective airship operators such as Flying Whales and Straightline Aviation in different models of mobile healthcare service units for being deployed by airship to remote locations in varying and flexible ranges of frequency according to the specific needs of each demographic group. Dr. Barry Prentice of the University of Manitoba, interviewed for this survey, states: "*The airships would be ideal to move mobile clinics into difficult areas or to the islands. Of course, nothing can be done during the current pandemic, but as we now know, we must be prepared for the next one*". Together with contactless solutions among others, these advantages make the airship technology not only competitive but also a relevant response to present and future sanitary challenges at a global scale.

Credit: LTA Research and Exploration
Source: https://www.linkedin.com/company/lta-research/

OPERATIONAL PARAMETERS FOR AIRSHIPS

The main relevant case studies for emergency aid response via airships will be briefly reviewed to assess the state of progress in the relevant literature in terms of operational modeling, these cases include the magnitude of the vehicles and infrastructure investments, costs, and other operational parameters. This reflects the advantage of this new mode of transport as a complement mode of transport, response to connectivity issues in remote locations such as SIDS. The main operational features of each proposed system will be showcased with the reference engineering model and the distribution modality each one implements, and the problems presented by the scenario that would be tackled by the airship solution.

The limitations found in how the existing logistics means responded to the emergencies addressed in the case studies were found to compromise the fulfillment of the Sustainable Development Goals set by the UN; the prospects of applying the airship solution is addressed according to the distribution system proposed by each piece of relevant literature to mitigate the negative impacts of extreme events, thus supporting the SIDS and countries with isolated populations in reaching their SDGs. Some of its main assets in meeting this purpose are its proficiency in contactless, more secure solutions from a sanitary standpoint; its advances in the development of clean energy sources and reduction of conventional fuel consumption for travel; its adequacy for unlocking the development potential of more vulnerable or isolated populations, and for providing medical and humanitarian aid services to accessibility challenged communities, among other key functionality features.

The following table 2 and table 3 summarize the different cases taken into account and their main features:

Table 2: Summarized commercial case studies

Author	Prentice 2013	Prentice & Adaman 2017	Prentice & Wilms 2020	Neal & Koo 2020
Zone	**Northern Canadian communities**	**Northern Canadian communities**	**Northern Canadian communities**	**Australian desert**
Use	**Commercial freight**	**Commercial freight**	**Commercial freight**	**Commercial freight**
Cargo	Mineral extraction products	Food and general merchandise	Fuel	Perishables, non perishables, oversize overmass, and high value time sensitive
Dependent variable	Transportation costs	Transportation costs	Transportation costs	Market share potential
Explicative variables	• Ton/ km • Duration of the operation	• Demand levels • Freight costs • Airship investment and operation costs	• Demand levels • Freight costs • Airship investment and operation costs • Inventory cost	• Price (FTK) • Frequency (daily service) • Reliability (%) • Time (d-t-d delivery hrs)
Main conclusion	Airships are an alternative when cargo volumes are relatively low and the duration of operation is of a few years	Estimate of transportation costs reduction for two regions and two cases, with or without continuity of truck roads	Estimate of transportation costs reduction	Estimate of demand and expectations from transport logistics professionals

Source: *The author's based on referenced literature.*

Table 3: Summarized emergency response case studies

Author	Tatham et al. (2021)	Jeong et al. (2020)	Prentice et al. (2021)	FLYING WHALES (2021)
Zone	**Lau group of islands in Fiji**	**Northern Syria**	**Arctic/Northern Quebec**	**French Guiana**
Use	**Disaster emergency aid (Cyclone Winston)**	**Disaster emergency aid (Armed conflict)**	**Commercial freight/ oil spillage and shipwreck aid**	**Commercial freight**
Cargo	Relief assets; food, medicine, general merchandise	Relief assets; food, medicine, general merchandise	Mineral resources/ sanitation procedures	Perishables, non perishables, oversize overmass, and high value time sensitive
Model/ System	**Aeroscraft ML868/hybrid; autonomous landing**	**Aeroscraft ML868/hybrid; autonomous landing**	**BASI MB560/LTA rigid fixed base and hangar**	**FW LC60T/LTA rigid hovering cargo maneuver**
Variables	• Freight Ton/ km • Comparative timing between modes	• Demand levels • Freight costs • Airship investment and operation costs	• Demand levels • Freight costs • Inventory cost	• Intermodal cost efficiency comparison • Intermodal frequency comparison (daily service)
Main challenge and solution	Logistic disruption and late relief response; flexibility of airships for last-mile delivery optimization	Damage risk to cargo, equipment and personnel; flexibility and mobility of Humanitarian Flying Warehouse combined with UAVs (drones)	Lack of connectivity and lack of response; intermodal efficiency for combination between auxiliary and commercial operations.	Lack of connectivity for construction materials to reach site; logistics solution for unlocking development potential

Source: *The author's based on referenced literature.*

Case study 1: Relief operations after the Cyclone Winston in Fiji

The study by Tatham et al. (2017) presents three cases of extreme events in which the humanitarian response would have been enhanced by the implementation of airships, developing a series of alternatives for the distribution and economic operational modeling of each case. The analyzed events are Typhoon Haiyan which took place in the Philippines in 2013, the Nepal earthquake of 2015, and Cyclone Winston which took place in Fiji in the year 2016, with similar problem scenarios where "*not only was the international airport a significant distance from the disaster's main impact area, it was actually on a different island leading to the requirement for the on-move of the cargo by sea, helicopter or small aircraft, (...) in the case of Nepal, the poor state of the road network also resulted in considerable use of helicopters to enable the more remote locations to be reached.*" The reference model is the hybrid cargo airship (aerostatic + aerodynamic lift) Aeroscraft ML868 with 225 MT lift capacity and 185 kilometers per hour speed. As mentioned before, this model presents an autonomous landing mechanism that avoids the need for additional infrastructure.

Of the three cases presented by Tatham et al. (2017), one of them, the ***Cyclone Winston 2016 event in Fiji*** will be taken as an example for the present study, as it most closely relates to disasters reports previously considered in this study (the Cyclone Winston originated close to Vanuatu), and it shares the operational and economic parameters of the other studies. It is of particular relevance due to its theoretical depiction of operations in a group of small islands, which involves the planning for infrastructural solutions in movements of cargo through reduced spaces, and the operational maneuvers of hybrid airships between small islands inside the cluster.

Description of the proposed system: Tatham et al. (2017) estimate loading and unloading times for this system at three hours, compared to the approximate 90-minutes turnaround time for a 140 MT Boeing 747-800 airplane. While the compared airplane requires special handling equipment and procedures for cargo operations, the ML868 airship would sit on the ground using its autonomous landing system, and its cargo deck is accessed by a ramp and forklift truck. The system proposed places the airship relocating for maintenance to installation on an airship hub, the positions and distances of which are estimative in the study, providing a one-to-two-day window in each mission[8]. The appropriate hangar for the airship in these hubs would be the only infrastructure additional to that which appears on the different empiric scenarios. The initial scenario is a lack of timely response of the available systems to perform timely relief operations due to them being overpowered by the disasters, which would have been mitigated by the airship solution; the empirical information upon which the scenarios are described have variables such as a total of relief goods delivered in tons and the time in which that was accomplished, which are estimated roughly from reports of the incidents that reflect disruptions in the monitoring of the events.

The system is modeled upon the consideration of two alternative scenarios within the range of

[8] *"First, it would be reasonable to expect hubs to be formed in areas near remote mining operations as these are already perceived to be key users of HCAs (...). Therefore, one could anticipate HCA hubs being located in Africa, Australia, North America, and Eastern Europe/Asia (e.g. Russia and Mongolia). From these hubs an HCA could relocate within one to two days to provide the movement requirements for Options A and B discussed above." (Tatham et al., 2017)*

expected possibilities: in 'Option A' the cargo airship replaces the existing modes of land or sea vehicles from a nearby international airport to the emergency location, while in 'Option B' the cargo airship operates directly from a logistics hub such as the United Nations Humanitarian Response Depots previously presented in this study to the emergency location. For both options the economic variable implemented is the US$/MT-KM comparison with the Road (0.06) and Air (1.12) modes, estimating 0.30/MT-KM for the cargo Airship, increased from a similar calculation by Prentice et al. (2004) to establish a conservative margin for its approach. The economic approach for Option A acknowledges an insufficiency of costs information and estimates an order of magnitude of 5 times higher costs in comparison with the road infrastructure mode but between 2.9 and 9.8 times faster total delivery; Option B takes as a principal variable the inter-modal cost comparison with the airplane mode estimating it 3.75 times lower than conventional air transport, and obviating transshipment operations at the origin hub which for instance in the Fiji case is an already existing United Nations Humanitarian Response Depots in Kuala Lumpur.

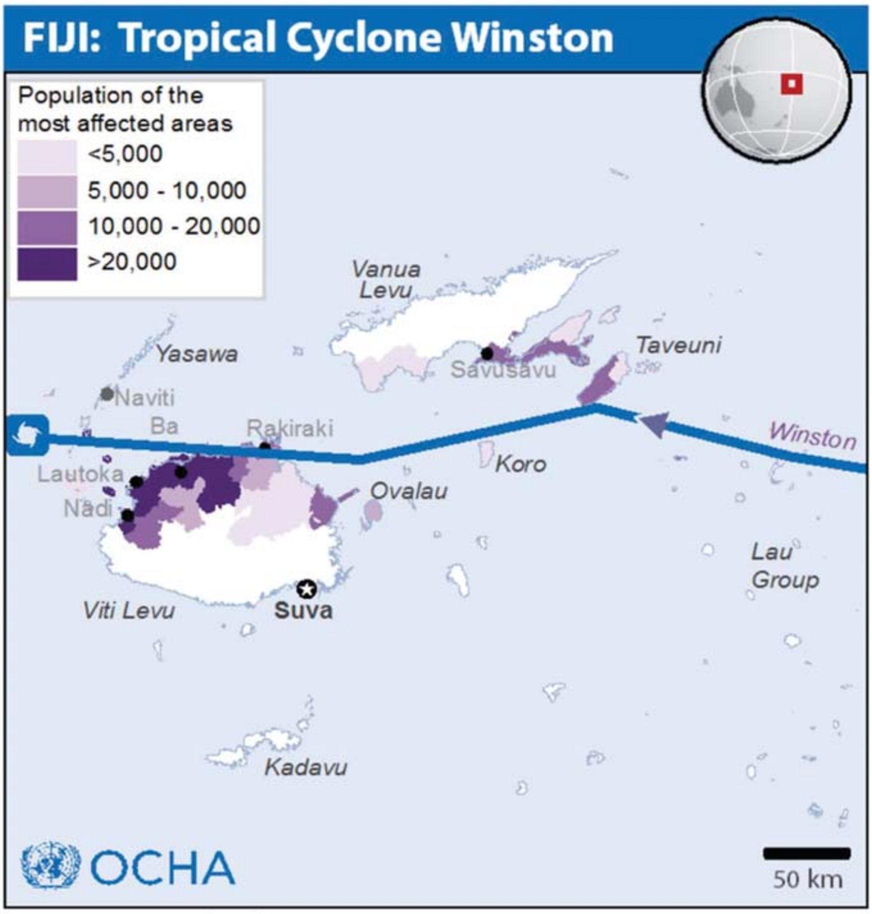
Location and characteristics of the emergency: Fiji is a nation of two major and over 110 smaller inhabited islands covering a total land area of 18,300 sq. km (7,100 sq. mi) impacted in this event by winds at 260-270 kilometers per hour, the most powerful in recorded history (Tatham et al., 2017). This resulted in a death toll of 42, and over 55,000 people (15% of the population) "taking shelter in 800 evacuation centers and schools, with the damage to properties and infrastructure estimated to cost more than US$1Bn" (Tatham et al., 2017). The majority of communications systems that served the affected territories were destroyed, which made the situation more difficult to monitor and evaluate, a solution that can also be achieved with the use of airships. The unpredictability and aggressiveness of the event prevented the only available mode, sea transport to evacuate the affected islands. Approximately 350,000 people (40% of the population) could have been affected, with the damage to crops (including the destruction in the worst affected areas) being estimated at US$61 M.

The map of the Fiji Islands shown in Figure 9, reproduced from OCHA reports, allows making a visual appraisal of the affected territory and population centers illustrated about its distribution, as well as the trajectory of the event in the case. As it can be observed, the worse affected areas according to the OCHA report are Northern Lau Group, the south and east coast of Taveuni, the south coast of Vanua Levu (Savusavu, Nasonisoni, and Nabouwalu), Koro Island, Ovalau, Naigani, and northeast Viti Levu.

Emergency response deployed: From data published by the Logistics Cluster Database the study shows that by Day 49 since the start of the response operation by sea transport 1,068 MT had been transferred via Suva to the affected areas. It is important to note that this estimation by Tatham is preliminary due to insufficiencies of access to information acknowledged in its paper due to circumstances related to the disaster itself, and are taken only as the basis for a hypothetical case to simulate an analogous response by the airship solution. The total amount of cargo and the time it took for it to be delivered to the different affected locations are estimated roughly to propose a theoretical case and might be subject to further evaluation of the variables in use. The system by Tatham et al. (2017) takes the previous figures as a reference to estimate the same movement requirement of 1,070 MT implementing the airship solution, with all cargo originating from Suva in Option A to the Lau Islands with a distance of 300 km, and from the hub at Kuala Lumpur at 9,000 km in Option B:

In the case of Option A, the trip from Suva to the Lau Group could be flown by an ML868 in two hours each way (four hours return). Thus, using conservative estimates to take into account three hours loading and three hours unloading times, it is reasonable to assume that two round trips/24 hours could be undertaken, each carrying 225 MT, i.e., a total daily lift of 450 MT. Therefore, including a two-day HCA relocation time, the total lift would have been achieved by Day 5, rather than Day 49 as was the reality. In the case of Option B, the flight time from Kuala Lumpur to the Lau Group is some 49 hours, therefore, in theory, and including three hours loading and three hours unloading, the round trip would take 104 hours. Thus, including the two-day HCA relocation time, the movement of the total lift of 1,070 MT carried in five round trips would be achieved on Day 24 rather than Day 49 as was the reality.

Figure 9: Winston Cyclone in Fiji[9]



Map Sources: Fiji Dep of Lands, SPC, Fiji Met Service
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Map created on 25 February, 2016

How the airship solution could optimize the response: Tatham et al. (2017) state that a mixed-response approach can be recommended as a result of its case study, to overcome the limitations of relying on a single transport mode, and to combine their advantages for delivery from a business case perspective, applying the US$/MT-KM variable in both cases: *"In the case of* ***Option A****, the HCA produces a swifter response, but is also significantly more expensive – albeit this reflects the relative*

[9] Source: from produced by the OCHA Regional Office for the Pacific (ROP) in collaboration with humanitarian partners. It covers the period from 24 to 25 February 2016. The next report will be issued on or around 26 February 2016. OCHA https://reliefweb.int/sites/reliefweb.int/files/resources/OCHA%20TC%20Winston%20Situation%20Report%20%235.pdf

cheapness of road transport and is this at a much smaller scale. In the case of ***Option B****, the use of cargo planes leads to a speedy response, but the cost is extremely high at some US$400,000 per flight and there is no guarantee that a suitable airport will be accessible in the vicinity of the disaster's epicenter. On the other hand, the use of HCAs, although cheaper at some US$175,000 per flight and with greater inherent flexibility, would result in most cases, in a longer timeframe to move the relief goods than that of the cargo aircraft option. These results unsurprisingly exemplify the classic supply chain efficiency vs effectiveness vs flexibility conundrum which has challenged multiple organizations over the years."* The study estimates that *"any necessary unscheduled maintenance could be completed during the combined six-hour load/unload windows, scheduled maintenance could be delayed until the initial disaster response phase of some 4 weeks has been completed,"* which coincides with the normal flexible time window practices for fixed-wing aircraft.

Tatham et al. (2017) recommend that to offset the current limitations of the airship industry in terms of vehicle availability conventional airplanes are employed in the initial stages of response and cargo airships provide the longer-term heavy lift, which would also assist in the process of them being re-located to the emergency area.

Case study 2: North-West Syria rescue operations with the Humanitarian Flying Warehouse system

Description of the proposed system: Jeong et al. (2020) assesses the vulnerability of cargo and transportation means in the contexts of social and political turmoil that call for aid missions in the first place, and coincides with Tatham et al. (2017) in pointing out the advantages of some hybrid airship variants for avoiding the disruptions that cause losses in human lives of aid workers and aid subject civilians as well as the material loss of cargo and equipment. As a further development on the technical application of airships, Jeong et al. (2020) propose the combination with new airborne delivery technology in the form of the aforementioned Humanitarian Flying Warehouse model incorporating Unmanned Aerial Vehicles (UAVs, or 'drones' a component of the ICAO denominated UAS), and researching the more suitable technological variants for operating in combination with hybrid airships. The case study proposed for this system utilizes the hybrid (aerostatic + aerodynamic buoyancy) Aeroscraft 868 model under development, with a 225-ton payload as a reference design, assuming a lift capacity of approximately 200 MT for carrying UAVs and emergency relief cargo on its model. This system, as was previously seen, has reduced ground infrastructure needs due to its autonomous landing. The modeling variables for the estimation of economic efficiency in this system are *(i) maximization of total covered demand, (ii) minimization of the operation cost including HFW's and UAVs' travel cost, and irretrievable UAV's costs, and (iii) minimization of total risk* with operational costs derived from the relevant literature, assuming limitations.

Location and characteristics of the emergency: The conflict area covered by the case study is northwest Syria recreating one of the worst humanitarian scenarios of the last century with over 2.1 million estimated inhabitants in need of assistance, as reported by the World Health Organization (WHO). The model distributes 10 candidate locations and 60 demand locations at random locations on a map of Syria. The risk assessment for this scenario is based on data of reported conflicting events in Syria provided by the Armed Conflict Location and Events Dataset (ACLED, 2019). The HFW operation cost is set to US$ 40/km taken from Prentice et al. (2004) assuming the Humanitarian Flying Warehouse will have a 200 MT capacity. The operation cost of UAVs was set to US$ 0.03/km based on the cost estimation of Deutsche Bank (Kim, 2016). The Phantom 3 Standard model of DJI is taken as a reference for the technical specification of UAVs (DJI, 2015).

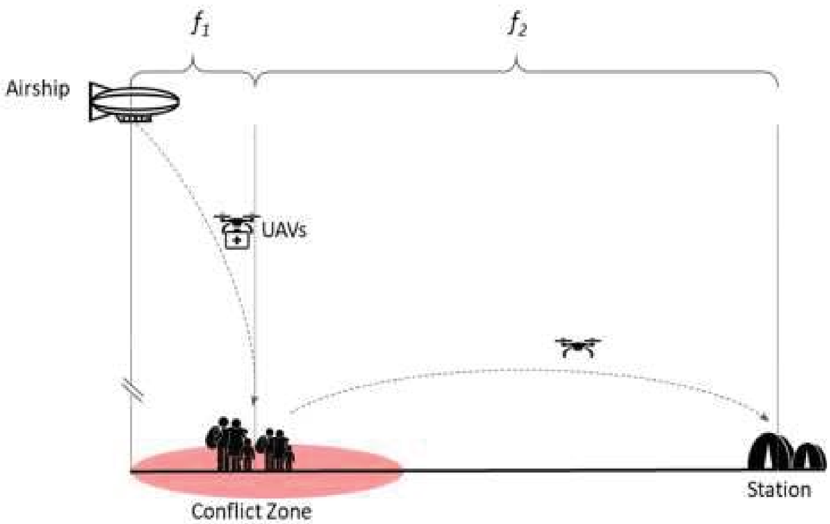
How the airship solution could optimize the response: The model for the operations incorporating the Aeroscraft vehicle assumes a buoyancy altitude of 45,000 ft. for the HFW with the UAVs moving at sea level after descending to the ground. The number of UAVs in each system is set equal to the number of demand locations to have enough capacity to satisfy all supplies. As Jeong et al. (2020) describe:

> *In these systems, a gas-filled aerial transport remains at a high altitude and moves horizontally while carrying an inventory of goods and UAVs. The UAVs are deployed from the airship and sent to specified end recipients with the delivery items. Since the flying warehouse carries the UAVs near the delivery point, it partly solves the problem of limited battery, which is a key shortcoming of the UAVs. Further, the mobility and dynamic operation of the UAVs mitigate the drawbacks of the long take-off and landing time of the gigantic airship. These benefits become especially apparent in conflict zones because the*

deliveries do not require direct involvement of human workers (...) The HFW is an airship that stays at high altitudes and uses UAVs to deliver critical supplies such as food and health supplies to end-users. It works by moving an HFW to a location near recipients and then launching a swarm of UAVs to specific delivery locations.

The safety issues for cargo and equipment in conflict zones affecting conventional air transport modes and also putting to test the engineering innovations of hybrid airships are addressed by the additional resilience provided by the element of combination with other new technologies on an emergency aid distribution model. Jeong et al. (2020) validate the mobility and flexibility prospects of the drone technology models implemented in its study for the operational parameters, from both humanitarian and military perspectives, of the system it proposes through mathematical modeling of statistics and operative physics and engineering data. Furthermore, the study quotes Huang et al. (2017) and Giordan et al. (2017) among others to support the features of the versatility of the UAVs in the performance of surveillance and monitoring for a variety of functions such as *spotting people, delivering supply and monitoring affected areas* as well as *observations, surveys, and mapping* in both post-disaster and real-time emergency scenarios due to their technical resilience and agility (Tatham et al., 2017). The study applies *a mathematical model with multi-objective functions corresponding to the humanitarian logistics* for the quantitative demonstration of the advantages it proposes for preventing *safety incidences of aid workers while providing persistent and timely aid supply*. This mathematical modeling verifies the operational parameters of the system with data from *realistic case studies and operational issues* together with a comparative analysis of the Ground-based UAV System (GUS), which will be presented in the following paragraphs (Jeong et al., 2020).

Figure 10: Operation model of the HFW system



***Source:** Jeong et al. 2020.*

Jeong et al. (2020) describe the operation mechanism, as shown in Figure 10, designed to deliver goods to workers and civilians safely, and safeguarding the vehicles and equipment to relay stations during emergency operations with hybrid airships and drones, as shown in the diagram reproduced from the same study. The system carries out large deliveries with stealth mode capabilities in conflict zones, preventing losses in both cargo and human lives. Airships loaded with relief cargo and drones fly over conflict areas at high altitudes, preventing encounters with enemy fire on the ground and with weather inclemency. It moves to a surface location for cargo delivery and launches a swarm of unmanned aircraft, previously loaded with the required supplies which they will drop after descending and navigating to the designated spot using gravity and technical devices. Because the cargo airship remains at a high altitude, the drones must reach a station outside the danger area from which they will be picked up and recharged. The operational scenario must consider the proximity of a relay station to the drop zone to avoid any power insufficiency by the drones in their attempt to complete the mission. While the drones are completing the delivery of supplies, the cargo airship goes on to assist population centers that lack medical services or connectivity (Jeong et al., 2020).

Case study 3: Emergency response in the Arctic and mining activities in Northern Quebec

Description of the proposed system: The airship model used in this case study is the BASI MB560 of 30 tons of lift capacity and 148 kilometers per hour of cruise speed, with a fixed based distribution modality implementing the BART ground infrastructure system plus a hangar for regular inspections, different from the autonomous landing hybrid models of Aeroscraft and other developers. The distribution model has different alternatives for the placing of the infrastructure according to variables of the operation which will be illustrated in the following paragraphs with the information of the available cost. The explicative variable for the business case proposed is the unlocking of economic activity potential together with sustainable services provision for environmental and humanitarian aid missions on a territory deemed unfeasible for ground logistics is that of the Strange Lake rare earth mining site in Northern Quebec. The distribution modality is applied from a business case perspective accounting for the characteristics of the territory by using a fixed base system of distribution by airship. The research by Prentice et al (2021) is set on the perspective of a business case for an emergency response operational scenario that prioritizes the economic competitiveness of airships relative to other modes rather than emphasizing its technological advantages, an approach that matches other findings on the present study as regards recommendations from experts and actors on the logistics and humanitarian aid sectors. In the same sense, the operational parameters prioritized for the economic efficiency case of the airship solution in the study for operations in the Arctic point to a swift deployment of crew members and cargo required in each location before the possibility of unforeseen events.

Location and characteristics of the emergency: The paper presents the evidence of a need for logistics improvements on the navigational conditions of the Northwest Passage (NWP) on the seas of the Northern Hemisphere in the context of the notorious retreat in ice masses caused by the acceleration of global warming, propitiating the development of natural resources activities while the creation of new logistic routes increases inter-ocean touristic and commercial traffic towards the upcoming decades, validating its assessment of the risk scenario in oil extractive activities with the support of sources such as Van and Richard (2009) with its main parameters being 'unconventional locations, climatic conditions, lack of infrastructure, and the unique features of the Arctic ecosystems' assessing the emergency response required by marine accidents and oil spill events. The transportation conditions that may warrant the implementation of the airship solution in the Arctic area as posed by BASI are the limitations of the existing model and its infrastructure at handling disasters promptly:

> *Moving large amounts of personnel and materiel to remote areas with virtually no existing infrastructure would be difficult under any conditions in the Arctic, but speed is important. Once the oil spill becomes too large, booms are impractical. Furthermore, high winds, rough seas, and large tides can limit the use of booms. The time required for the Coast Guard to reach an oil spill could easily take a week or longer.*

Bringing airships into this auxiliary service would demand for a business case of a main economic activity carried out by the fleet that would make them available from a nearby location and with compatible time windows, which implies the airship solution must prove its competency at both regular and emergency services in comparison with the existing modes. The economic proposition devised for the BASI humanitarian aid solution takes into account the sensitive matter of vehicle availability against the variable timings of the different functionalities it is designed to perform, taking into consideration that the initial investment required for the building of a new type of vehicle must be rendered efficient against the risks it supposes, meaning the airship must perform its main activity and unlock the economic potential of its locations of service instead of being on standby waiting for a disaster to bring a response. As a legal framework to achieve this combination dynamics, Prentice et al. (2021) propose the implementation of contingency contracts, to make the auxiliary and commercial functions of the airship complementary efficiently in a coordinated operative effort*:*

> *The use of airships on scheduled services to mines and remote villages could be interrupted briefly to carry emergence supplies from prepositioned locations to the site of a shipwreck or oil spill. In such arrangements, governments normally pay an annual stand-by to the aircraft operators that are much less than the cost of owning and operating equipment. At the same time, financial support for stand-by operations could reduce the costs of commercial operations of airships in the North.*

As mentioned before, the case taken for the theoretical devising of unlocking of economic activity potential together with sustainable services provision for environmental and humanitarian aid missions on a territory deemed unfeasible for ground logistics is that of the Strange Lake rare earth mining site in Northern Quebec. The distribution modality is applied from a business case perspective accounting for the characteristics of the territory it is focused on. The location is placed at a distance of 240 km north of the closest railway line across '*rough terrain, river crossings, muskeg and permafrost soils'*. The initial problem scenario places the Schefferville rail station as a key node in an intermodal supply chain to which a gravel road costing *$720 million ($3 million/km)* must be built for the delivery of 200,000 tons of concentrate each year for the business case to become active, and the site developer Torngat Metals is unable to raise the funds. Prentice et al. (2021) pose that airship would bring a solution to unlock this business case. Besides indicating it as a plausible example among a generality of similar sites possible to receive advantages through the airship solution, the BASI model finds an empirical precedent for its modeling: *"The mine announced plans to use the 20-ton lift, Lockheed-Martin airship to fly the rare earth concentrate from Strange Lake to Schefferville. This plan was side-lined when a major investor withdrew, but the project is still active and open to any airship that can offer an economic service."*

The following Figure 11 reproduces the model presented by BASI for performing distribution and transshipment operations as proposed by BASI. This system of infrastructure incorporates the BART (Buoyant Aircraft Rotating Terminal) station relay system to achieve the requirement of an annual 200 thousand tons concentrate cargo proposed in the study by Prentice et al. (2021) for the Strange Lake mining deposit case, involving a fleet of seven vehicles of an airship model with a 30-ton payload capacity operating on 325 days with three daily flights basis, in economic competition with gravel roads infrastructure cost requirements. BART stations are described as "large turntable structures that allow the airship to 'weathervane' with changes in the wind, but provide a safe surface where the cargo can be handled" with an estimated installation cost of $2 million each.

Figure 11: Conceptual model of the transshipment operation implementing the BART infrastructure system by BASI

Source: *Prentice et al. 2021.*

How the airship solution could optimize the response: The operational perspective of the distribution and infrastructure model for the Strange Lake mining deposit case proposal assumes each airship would make three daily round trips with a hangar located at the transshipment site (Schefferville) or closer to Becancour (Montreal) where the vehicles would be originally assembled, for undertaking major repairs and inspections, with the distribution system developed upon as follows: "*The 480 km round-trip from the transshipment points to the mine would take approximately 3.5 h allowing for some headwinds, and 1.5 h at each end for loading/unloading. This is a conservative estimate that allows a 4.5 h margin for unexpected delays. Assuming only inbound freight, and empty returns, seven airships could deliver 200,000 tons per year allowing 40 days for each airship to receive maintenance, inspections or be grounded by in inclement weather.*" The business case is proposed through an estimation of the profit margins required to tackle the investment risks on a competitive cost-efficiency basis, with 50 million dollars to build the hangar and an investment amortization of 20 years for the vehicles and 25 years for the fixed facilities.

The study estimates a yearly total of $53,180,000 for the complete cargo movement operation adding $12.7 million of variable costs to almost $40.5 million of fixed costs with a revenue of $66,475,000 and a profit margin of $13,295,00 that achieves the 0.8 operating ratios estimated to be required to offset investments (from typical aviation mode practices).

The operating cost assumptions are based on crew costs for 20 h per day (two flight crew and one ground-handler). This is $9.1 million ($200/h @20 h/day, seven airships, 325 days) and $2.6 million for fuel ($500/flying hour for seven airships), plus $1 million for maintenance and contingencies. This amounts to variable costs of $12.7 million per year for the fleet based on 325-day operations. This is calculated by dividing the operating expense (minus depreciation) by its gross operating income. The cost comparison of using airships versus building a $720 million road and trucks requires some estimate of trucking costs and road maintenance. Current trucking rates are approximately $3 per kilometer or about $1500 for a round-trip. On an annual basis, this is $15 million to move 200,000 tons. In addition, road maintenance and snow-clearing average about $16,000 per kilometer for an annual cost of $0.5 million. (...) To make the comparison fair, the three-year time frame to build the road is also used to provide the airship hangar, BARTs, and the airships that would be delivered in the third year. The cost of the road is spread out over the three years. The base case of moving 200,000 tons of concentrate per year, over 20 years favors the airship method by approximately $200 million (Prentice et al., 2021).

Operational parameters for the business case: As was the case in the proposal by Tatham et al. (2017) that was previously referred to in the present work, the model developed by Prentice et al. (2021) presents two alternative operational scenarios for the Net Present Value comparison between the cargo airship and the gravel road truck systems, in which the first scenario considers a duplication of operative costs explained by either a lesser than expected amount of yearly completed trips or the unexpected increase in certain cost variables resulting in a $70 million advantage from airships over trucks*;* in the second scenario the mining output increases by half and the Net Present Value results approximately the same for both systems. The author reflects on the probable durability of this economic comparison over time taking into account the evolution of airship engineering and manufacturing that will produce vehicles with an ever-growing tonnage lift capacity:

> *Generally speaking, the economics of an investment in road infrastructure should improve the longer the lifetime of the mining operation. The analysis could be extended, but it is not clear that the results would be much different. After 20 years of operations, roads and bridges need substantial re-investment.*

To overcome the limitations on the business case proposal stemming from insufficiency of information, a set of guidelines for an emergency response simulation are outlined, based on a series of logistical questions that would determine the size of the airship fleet and response times required for a determined incident. Some of the guidelines are *'For various sizes of oil spills, how much equipment and accommodations for the crews would have to be moved? Where would the caches of critical components be located?'* and so on. *Finally, governments should bring together the stakeholders and vested interests to obtain the collective views on the development of new airship transportation to benefit and protect the North.*" In the attempt to carry out a new case study for operations in SIDS on a business case perspective for the present study, those policy and research recommendations are taken into account.

Key aspects of operational safety and the prospect of contactless solutions are made feasible through the ongoing development of integrated IT devices for navigation and vectoring on the design of a rigid airship to reduce its labor intensity, requiring for example *only two pilots onboard GPS and engine thrust to land and take off unassisted. The lift of an airship equals the weight of the air they displace* as in the case of models such as the Zeppelin NT (Prentice et al., 2021). The engineering advancements procure the possibility to turn weather conditions that are challenging for navigation into actual advantages for the airship. Because there are no thermal updrafts, the airship can have a smoother flight which enables it to increase its payload lift during the seasonal temperature decrease and air density increase.

The following table summarizes the key variables pointed out by the above cases to explain the advantages brought by the airship solution for the emergency aid scenarios proposed, that would warrant an efficient and sustainable contribution to the connectivity of locations impacted by extreme events. For the case of Prentice et al. (2021) both the auxiliary sanitation and aid operations at the Arctic in the context of ice, masses retreat due to climate change and the commercial implementation of airships for unlocking mining activities potential for development were incorporated, due to the complementary characteristics of the approach established by the authors.

Table 4: Main logistic variables and advantages in humanitarian case studies

Source	Location studied	Event	Challenge	System (airship)	Main variable (airship)	Advantage
Tatham et al. (2021)	Lau group of islands in Fiji	Cyclone Winston	Logistic disruption and late relief response	Hybrid cargo airship with autonomous landing system	Flexibility	Last-mile delivery optimization
Jeong et al. (2020)	Northern Syria	Armed conflict	Damage risk to cargo, equipment, and personnel	Humanitarian Flying Warehouse combined with UAVs (drones)	Flexibility and mobility	Last-mile delivery optimization
Prentice et al. (2021)	Arctic/Northern Quebec	Oil spillage and maritime accidents/lack of connectivity for mining deposit	Connectivity and infrastructure insufficiency, late response/unfeasible road infrastructure costs	LTA cargo airship with a fixed base distribution system	Inter-modal cost-efficiency	Efficiency for a combination between auxiliary and commercial operations, unlocking of development potential

Source: *Author's own elaboration.*

The feature of 'flexibility', although not academically defined as a term in the quoted sources, refers in the context of the above reference studies, to the capacity of new air transportation technology to adjust its navigational and cargo discharge maneuvers to the characteristic of the scenario and the unfolding of the events in which it operates, and to adapt to changing or unpredictable conditions ensuring a safe and quick response, ultimately ensuring a delivery solution that contributes to connectivity and emergency response in a sustainable manner. Similarly, the mobility variable relates to the technical ability to 'mitigate the drawbacks of the long take-off and landing time of the gigantic airship' (Jeong et al., 2020) in combination with other technologies and with the integration of ongoing engineering advancements. Inter-modal cost efficiency is estimated in orders of magnitude that incorporate operational cost variables subject to ongoing research.

Researchers emphasize as well that by calculating investments in road infrastructure of special characteristics, which are commonly used to connect remote areas that are difficult to access, every year and taking traditional infrastructure costs as a whole, airships are proved to be cost-effective, based on the ton/km and distances to be covered and the associated costs.

A survey focused on the Australian desert expanse, is to be noted for its different focus on cost theory and approach to potential market analysis, applied to an estimate of a 'Potential Airship Fleet Demand' over 2012 and a projection of it by 2030. The calculation consists of the multiplication of the FTK in non-bulk shipments by the result of market share simulations, over the annual FTK of each airship model. The airship's FTK is based on "an individual airship operating 300 days per year, 12 hours a day" (Neal and Koo, 2020)

Climate change is an ongoing global concern and the change the Airship solution can bring is arguably unparalleled in the context of synchro-modality and transport competitiveness. A recent study by the University of Manitoba states:

> *It is possible to estimate the total carbon emissions from transporting fresh produce by truck to Canada. The average travel distance from the various North American production zones to Canadian cities is about 3,000 kilometers. Diesel fuel consumption for a refrigerated tractor-trailer is about 39.5L/100km, thereby consuming about 1,185L of fuel to drive a 3,000 km distance. The refrigeration system of the trailer (reefer unit) is estimated to consume 250L of diesel fuel for the journey; increasing total consumption to about 1,435L. The carbon emissions from each liter of diesel fuel are 2.64 kg of CO_2. Therefore the 160,000 reefer trucks bringing fresh produce to Canada from the US and Mexico in 2019 released 3.8 MT of CO_2 per truck, for a total of approximately 606,000 MT of CO_2. The current truck transport of fresh produce from Mexico and the USA along selected transportation corridors to Canada could be replaced by zero-carbon emission, electrically powered, cargo airships. The technology is available, and the market appears to be ready.*

Case study 4: Komo Airfield case by Straightline Aviation

The principle of sustainability and environmental care of airships is rooted to a large extent in the consensus around its proficiency for reducing the need for new infrastructure. Although there is debate around many of its engineering aspects from the wide array of technical proposals, that principle is consensual. According to IMIEU:

> *In conventional current airports therefore, there may be not much space for LTA platforms, however, in large ports, or on old industrial terrains there is sometimes the vast amount of surfaces and land empty and available, unused. These kinds of sites (a lot of times available against relatively low costs) could also provide opportunities for LTA ground operations. Furthermore, LTA ground operations do not need a very large or heavy infrastructure (as the crafts are not very heavy), so that also could provide an asset for the business-case for LTA technologies.*

An analogous approach, more focused on the operational costs of the airship, was applied on a case study carried out jointly by operator Straightline Aviation and developer Lockheed-Martin for an airfield in Komo, Papua New Guinea completed in 2013 for LNG transportation mainly, comparing infrastructure costs to an airship project ($924,5M vs $23,6) among a set of other advantages. Assuming this system would implement the LMH-1 hybrid airship model by developer Lockheed Martin, it is important to point out that it incorporates an autonomous *grip technology* landing system on its structure, as shown in previous cases. Also as shown before, Tatham estimates the cost of this vehicle at approximately 40 million USD validated in Wells (2016), although the capital cost estimation may be subject to revision and update. As previously stated, the features of the flexibility of the hybrid airship allow to prevent further damage to sensitive natural landscapes that may be caused by the construction and renewal processes of conventional systems, as well as providing other green sustainable advantages and contributing to its economic efficiency case. Additional road infrastructure needs would be avoided by the system proposed in this case, its main facts are observed on Figure 12.

The role of the critical mass in consolidating scientific advances and general agreements is evident in the conclusion of collaboration agreements between industry actors, from which innovative initiatives and proposals arise to provide logistics systems with a legal and regulatory framework conducive to the insertion of airship (ADB-BASI[10], 2019; Aertec Solutions, 2020; Sträter, 2020); the debate is also brought forward to introduce LTA vehicles to the framework of regional and community programmes such as the European Union's Green Deal and the pursuit of the SDGs (Aerodays Forum, 2020; ONU, 2020; UNCTAD, 2020).

[10] *ADB - Airship do Brazil Indústria e Serviços Aéreos Especializados is a Brazilian company focused on airships development (http://www.adb.ind.br/index.jsp). BASI - Buoyant Airships Systems International is a Canadian company (https://www.buoyantaircraft.ca/). Aertec Solutions is a Spanish company (https://www.aertecsolutions.com)*

Figure 12: Hybrid Airship case study in Komo

Source: *Straightline Aviation.*

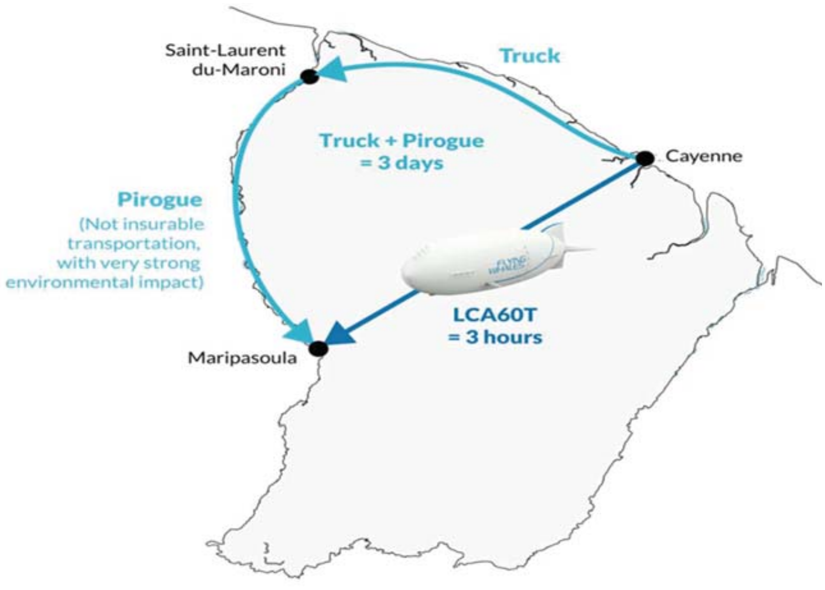
Case study 5: FLYING WHALES construction material delivery for French Guiana

Placing the focus on carbon footprint, landscape care, and the cost of different means of transport for construction materials reaching isolated locations, prospective French operator FLYING WHALES developed a case study for the use of Airship in service provision for the population centers of the French Guiana territory, covered in 96% by a tropical forest and with *strong discrepancies between the areas of the littoral and the interior*. The presented model proposes the provision of hundreds of tons of construction resources (among them raw materials, equipment, and machinery) to a worksite in Maripasoula, the most important population center of French Guiana with no connections to road infrastructure and a less than competitive fluvial access.

Current situation and proposed system: The initial scenario to resolve is that of a lack of connectivity and restricted development potential. The airship model design used for the case of the logistic is FLYING WHALES own LCA60T lighter-than-air airship, currently in plans for building stage with up to 60 Tons of lift with a cargo lifting device integrated into the vehicle for hovering cargo handling and the capacity to load and unload the cargo in stationary flight with greater independence from ground infrastructure which would eliminate the need for the road, port, airport, rail during these operations. The main variables of the economic case, according to the planning by FLYING WHALES, are the orders of magnitude of time efficiency by delivery in comparison with current systems, with operational costs remaining confidential.

According to estimations presented by Flying Whales, the time of transport per trip to provide to the aforementioned construction site in French Guiana would be 2 to 3 hours, compared to the 2 days and a half that it currently takes by the intermodal combination of pirogue and truck, which induces delays that may be avoided by the fast operations facilitated by the airship mode. Likewise, the more resilient seasonal window of the airship is favored in comparison with the paralysis of transports of heavy loads by the other mode, for which in the 7 months summed up by the dry seasons between February to March and July to November, transporting payloads greater than 4 tons becomes problematic. On the other hand, airships would be able to operate during those periods and match the timing of the industry it would service.

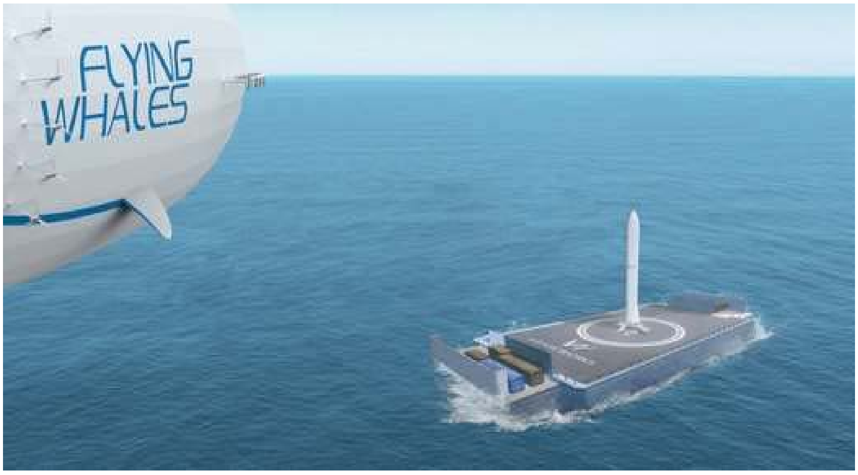
Figure 13: FLYING WHALES French Guiana distribution model



Source: *Flying Whales*

In addition, the airship brings a lot of advantages in terms of safety, security, flexibility, worksite design savings. The possibility to overcome the limitations of existing means of transportation such as trucks and pirogues would bring significant support to the construction worksite with an air transport service. FLYING WHALES presents their target estimations for this project *with savings of 38% in the cost of transport*[11] *for the shipper and reduction by circa 63% the CO_2 produced, according to FLYING WHALES* (the figure varies depending on the weather). It would also offer more optimal parameters of adaptability to the specific features of the industries it would service, boosting the development of infrastructure that is less damaging by bringing construction materials and equipment to the site in a more efficient manner. The development of the proposed project would bring basic services to the surrounding population centers. A case study of an existing rare earth mine proposal by Prentice et al. (2021) is used to illustrate the cost comparison of roads versus airships that could provide contingency services with limitations in connectivity by traditional modes as in the case by FLYING WHALES.

Figure 14: FLYING WHALES Spacecraft Launcher



Source: *Flying Whales (direct interview and consultation)*

Impact on economic and connectivity indicators: FLYING WHALES considers a major asset brought by the airship technology to territories of this character to be the unlocking of their industrial, productive, and socio-economic potentials. FLYING WHALES includes within these possibilities the development of forestry activities in the interior of French Guiana without the need to build additional road infrastructure trails and the creation of an aerial link for other industries following the same principle. Likewise, FLYING WHALES envisions the LCA60T operating as an aerial connection with a spacecraft launcher at sea for recovery operations, facilitating the movement of aerospace cargo of greater magnitude and weight. The following picture illustrates the project.

As it will be seen regarding other distribution models based on different technology models of airships, other services are expected to be provided simultaneously to those that attain the main target of the case study. Moreover, FLYING WHALES appraises the improvement of connectivity to the French Guiana territory for its strategic prospects in both regional trade and market development, considering its potential as a "first base in South America" for the commercial expansion of the Guiana shield using its more optimal insertion in inter-regional trade and the environmental and socioeconomic advancement of the Amazonian basin.

[11] *FLYING WHALES estimated the cost of transport taking into account variable and fixed –base infrastructure and vehicle amortization- costs*

There is greater robustness in the safety and security aspects of cargo freight via airship according to the study by FLYING WHALES, mainly through the storage features of its 96-meter-long cargo hold which would avoid damage to the goods during flight, and offer a protection that is superior to that of ground and fluvial freight which induce delays and additional associated costs, as well as the possible theft of goods such as fuel or metals associated with the presence of piracy activities on the Maroni River in French Guiana, for which one shipment is estimated to be lost per week. The safe delivery of fuel to the construction site in Maripasoula would prevent the necessity to build further facilities for the same purpose.

The LCA60T airship by FLYING WHALES has an integrated lifting tool that provides for a significantly improved flexibility in comparison with the constant dismantling and reassembly maneuvers required by the cargo tools of the road and fluvial modes, which is proposed to assess the challenge of equipment recertification (cranes as an example) at their previous level of performance after dismantling and reassembly induced by road and fluvial modes of transportation. This is also often the case for equipment carried by helicopter. Moreover, there is a considerably higher payload capacity offered by the airship (60 tons in the case of this model compared with the 10-ton pirogues used in the Maroni River).

It is important to note that the technology proposed for the case studies of the French Guiana territory is currently under development, and the logistic field studies equipment for testing its distribution and feasibility approach might be limited at the time of conducting the present research. Nonetheless, the assessment of the logistics for the provision of services and inputs to isolated areas is of relevance for the cross-referencing of the case studies carried out at varying stages of progress for different geographical locations and logistics networks that constitute the standing literature of reference for promoting innovative and resilient solutions in transport.

Case study 6: FLYING WHALES emergency aid response for Indonesia

Another set of case studies by FLYING WHALES as both an operator and a manufacturer is situated in the Indonesian archipelago and serves as an illustrative example of the companies' implementation of a system comprised of a series of ground bases for its LCA60T model, covering the entirety of a territory paired with intermediate bases strategically placed to confirm interconnecting areas, and each close to warehouse deposits for emergency relief goods. Once the bases system is established on the islands, the airship can provide significant advantages for emergency relief operations. Cost variables follow the principle of the above-mentioned case by the same company. The following map, extracted from a FLYING WHALES official presentation, depicts the layout of this system.

The design of this system is of relevance for the modeling of operations in SIDS due to the similarities between the territories in the study, and taking into account that the testing for the engineering feasibility of the aforementioned system is still under development, it presents a sufficiently rich scheme for cross-referencing with the literature of compatible case studies to establish a set of working principles for advancing in the proposition of the airship transportation technology.

Current situation and proposed system: FLYING WHALES applied this system to the study of two potential services to Indonesia, in the region of Krayan in North Kalimantan Province and several provinces of the Papua region, both for the delivery of fuel. Both regions are currently serviced by Air Tractor-802s of 3.2 tons' load capacity, costing[12] approximately 72% more and requiring roughly 94% more shipments per month than the proposed airship according to calculations by FLYING WHALES. The total monthly delivery of fuel to the Kalimantan region would be 200 kilolitres, done in 2 days of the month with the airship covering ground of 218 km, while it takes 2 shipments per day with the current model. Meanwhile, the five drop-off points of the Papua Region would amount to a yearly payload of 20,430 kilolitres, covering from 140 to 300 km in eleven days per month by airship. One of the aspects that are of interest for cross-referencing with analogous case studies is that of the storage capabilities at the designated spots with the increase of payload delivery by each flight when applying airship.

Location and characteristics of the emergency: The same principles of logistics optimization are applied to disaster response, based on two examples of response logistics organizations for two previous events in the Indonesian archipelago: the 7.2 Richter Scale earthquake of 2019 in South Halmahera, which produced 14 reported fatalities and 129 injured, with over 50,000 inhabitants being displaced to more than 14 locations; and the 7.5 earthquakes and tsunami simultaneous event of 2018 in Central Sulawesi. The assessments performed by FLYING WHALES for both cases account for the limitations presented by the conventional available means of transport, based on their practical performance in those occasions. Specific territorial challenges are approached in the light of the airship presenting the technical potential to overcome the limitations of current modes, as in the previously mentioned case of the air tractor AT-802.

[12] *FLYING WHALES estimated the cost of transport taking into account variable and fixed –base infrastructure and vehicle amortization- costs*

Figure 15: FLYING WHALES LCA60T bases system

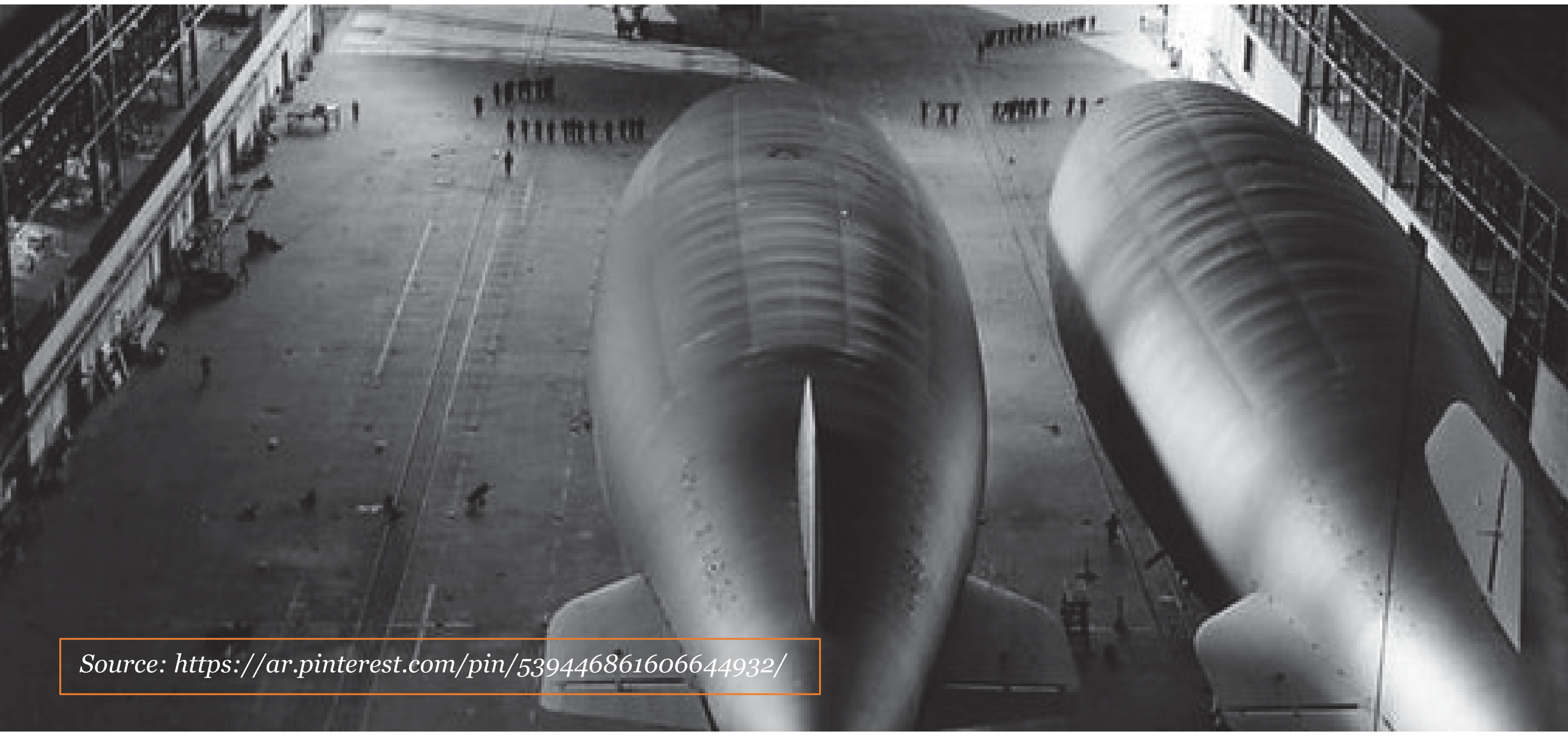
Source: *Flying Whales*

How the airship solution could optimize the response: Some of these challenges specific to the Indonesian area and in many aspects translatable to the modelling of operations in SIDS under study, are mentioned in a presentation by FLYING WHALES as follows:

To reach the southern part of the island, 30 hours are necessary (250km); To reach Palu from Kalimantan's closest port, 20 hours are necessary (200km by sea); Several roads having a high risk of landslides, only 3-tonne or 5-tonne trucks were not allowed to pass; Ports and airports were damaged in the disaster-hit area, supply could not be done by air and boat.

The proposition to overcome these challenges through the implementation of the airship is under a scrutiny that involves which type of technology design would be more suitable in each case for the functionalities involved, and for which the availability of material conditions for testing is ultimately paramount.

As a closing statement for this section, it is important to note that the case study literature applied to emergency, humanitarian and auxiliary type operations by airship is significantly wider than the sample presented in this document, and the selected cases were included following the criteria of the possibility for drawing connections with the engineering and operational parameters that were made possible to outline under this research project in accordance to the logistics and emergency response challenges for the territories under survey in the face of a variety of extreme events and humanitarian emergencies. This would bring forward a new set of resources for the nations with isolated locations to reach their Sustainable Development Goals.



Source: https://ar.pinterest.com/pin/539446861606644932/

OPPORTUNITIES FOR INTEGRATION IN INTER-REGIONAL AGREEMENTS AND INVESTMENT PROGRAMS

As was stated before, the airship technology offers a number of logistic solutions and optimizations that significantly coincide with the objectives of regional agreements and programs in social and environmental sustainability and resilience, such as those outlined by the United Nation's Sustainable Development Goals, the EU's Green Deal communitarian initiatives and many others in the same vein.

Policy decision makers at all levels, from local to inter-regional, would be required to participate in the evaluation of the feasibility of airship technology and its diverse variants in development together with private actors from all transportation modes industries, encompassing from the practical expertise of traditional aeronautics to maritime transport and others in pursuit of and optimal synchro-modality. If this is observed, the contribution of advantages between the technical capabilities of the airship and the communitarian policy programs it can benefit would be reciprocate. Moreover, raising public awareness of the potential of airship technology is necessary to bring it into the context of regional policy, which will allow obtaining the funding needed for its development.

Many airship developers have engaged in development and cooperation agreements with international institutions such as the World Food Program and the World Health Organization for achieving a more thorough integration of the technical features of the airship in its response to challenges in issues of global reach. Institutions such as IMIEU in the European community have incorporated airships into their development programs and are actively promoting their suitability in the funding initiatives that are coordinated between their stakeholders, regional policy forums and institutional agencies of the European Union. There are advances in studying the positive impact in employment that would result from the development of airship manufacturing at an industrial scale, as well as its long-reaching effects in trade reactivation for developing communities.

Licensing and regulatory issues are sensitive as well and should be addressed at inter-regional forums to reach agreements that will be capitalized by logistics networks as a whole. A recent Stakeholder Investment Program bulletin by IMIEU explains it as follows:

> *Currently, only a handful of LTA-carriers that have passenger or publicity functions worldwide are certified. The current basis for certification of e.g., semi-rigid or rigid airships are based upon the certification of the Zeppelin NT (LZ NO7-100 and 102), certification basis (CS) 30 N and CS 31 (Hot Air Balloons). New types of transport platforms as e.g., Flying Whales or Flywin, are based upon this basis but also (for a to be defined part on CS 30H and T. The basis for these specifications came from the earlier stopped development project 'Cargo Lifter', where there was at the end of the project a small demonstrator. As the basis for certification is narrow and many aspects need to be further clarified, information exchange on the aspects to be clarified and safety seems nearly a necessity, also to reduce certification costs* (IMIEU, 2021).

Since 2019 FLYING WHALES, Hybrid Air Vehicles, Zeppelin, WDL and EASA are working on the harmonization of the regulations. As regards the required adjustment to Airworthiness Directives, a new regulation SC-GAS (Special Condition for Gas Airships) has been proposed and will be published by EASA (European Union Aviation Safety Agency) by end of 2021. This SC-GAS has been defined to accommodate various types of airships and innovative technologies with a safety approach.[13]

It is important to highlight some of the initiatives carried out by IMIEU in its U-LTA (Upscaling Lighter Than Air)[14] Platform and other sustainable transport schedules and forums, so as to raise awareness of a possible path for the funding and development of airship technology:

> *At this moment there are not many fully developed projects using Lighter-Than-Air technology, and the ones already in existence are not yet large scale. Due to this, LTA technological applications are not well known at the European level, other than a few unsuccessful projects at the beginning of the millennium. Because of those past issues, and several recent incidents with larger initiatives and demonstrators (Airships do Brazil, and Airlander), the technology does not seem to deliver an impression that it is close to commercialization, with the exception of the initiatives involving communication and observation (e.g., Sceye and Altran, Cloudline).*
>
> *To counter this, in the first year of the project two meetings are planned at European Level. First, a small-scale meeting was prepared with the most relevant departments within the European Commission on 24 September 2018. Then in November 2019, a meeting was planned in co-operation with the relevant intergroups in the European Commission. In addition, an active input in the information channels of the European information channels is foreseen by a publication in the key information channels, used by cabinets and EC Staff. An informal deliberation group with the European Commission relevant departments is also formed, in order to discuss key document output*

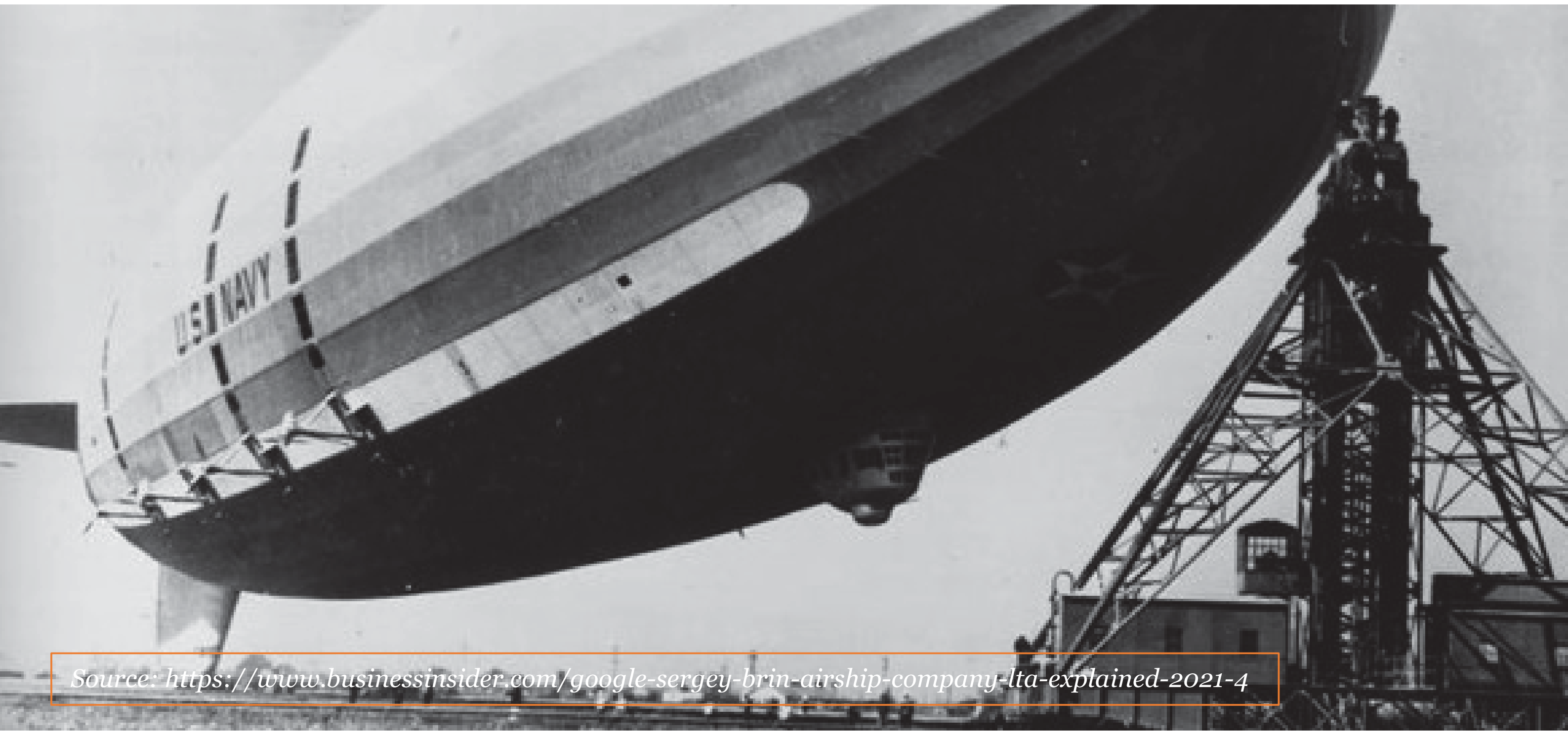
[13] *Reported by FLYING WHALES (2021)*

[14] http://imieu.eu/

of the strategic co-operation and take care that the outcomes of the studies land in the relevant DGs and Cabinets (DG Move, DG RTD, DG Grow).[15]

With the purpose of fostering inter-regional debate on the incorporation of new transport technologies, the UN regional Commissions for Asia-Pacific (ESCAP) and Latin America and the Caribbean (ECLAC) are jointly analyzing the technical prospects of carrying humanitarian aid operations via Airship in Small Islands as well as the economic variables that would foster its business case and access to investment. The game-changing competitive advantages and the multiplicity of applications (from cargo freight to communication and monitoring services) of this new resilient and sustainable logistics mode are weighted under the lens of air connectivity in the face of the challenges posed by the COVID-19 pandemic. The working hypotheses, tested and expanded with the help and collaboration of industry researchers and developers, is that Airship technology can bring long-lasting benefits in connectivity, accessibility, and development to isolated locations such as Small Islands beyond the scope of emergency aid operations. Its set of advantages would be crucial for advancing in Sustainability and Blue Economy goals, particularly relevant for Small Islands Developing States in the face of climate change, the COVID-19 pandemic, and other issues of global impact, as the progress in the current survey indicates. The global initiatives to coordinate actions for new resilient solutions contribute significantly to that ongoing work, and an invitation to bring the potential of these innovative solutions to an open debate of inter-regional public transport and development policies.

[15] http://imieu.eu/



Source: https://www.businessinsider.com/google-sergey-brin-airship-company-lta-explained-2021-4

CONCLUDING REMARKS AND FURTHER RESEARCH TOPICS

The trend towards sustainable logistics networks, which incorporate new technologies solutions that allow improving connectivity in conjunction with current logistic services and infrastructures, generating greater integration of the regions and economic and social growth, today has a great role at the global level and it is a concern of public and private actors. The connectivity is a concept linked to accessibility and this is measured based on the quality of the services and logistics infrastructures available to access a territory, region.

The connectivity component becomes a priority; after the COVID-19 shock, the air transport connectivity post pandemic dropped 57%, 2020 vs 2019 according to IATA, and the maritime freight increases to 10 times. This shock, along with natural disasters, accelerated new challenges in the most vulnerable regions. During 2020, the Great Caribbean and the Pacific were affected by extreme events such as Hurricanes Eta and Lota in Guatemala and Honduras, and the Pacific by Cyclone Harold in Vanuatu, Fiji, Salomon Islands and Tonga. In these cases, the humanitarian response carried out through the conventional, existing means showed a series of limitations; overcoming those by means of an innovative logistics solution in the near future must take into account the pertinent sanitary protocols to tackle the ensuing pandemic and post-pandemic scenarios.

The new airship technology presents itself as a game changing solution, with a diversity in distribution systems and ground operational modes; these diverse systems adapt to different geographies with a wide range of functionalities to achieve flexibility and cost savings with damage prevention for the cargo and crew. It shows unparalleled resilience in various terrain and weather conditions to access remote areas while mitigating the environmental footprint. Incorporating airships as a new mode of transport in new or existing routes and logistics networks is pursuable with the overcoming of regulatory barriers, moving towards a more sustainable logistics that will provide economic and social integration through the enhancement of connectivity.

As showcased through the assessment of the economic competitiveness of airships and their proficiency in sustainability aims are complex in nature and scope, but for speed of delivery can be summarized as it being *slower but cheaper than an airplane; faster but more expensive than trucks* (Prentice et al., 2021), with an average cruising speeds of 100 km/h or higher, and varying load capacities going from the 10-20 to the 250 tons ranges depending on model and type of operation. Most case studies for transport by airship take heavy lift helicopters as a main comparison object in operations to small islands due to it being the prevalent mode in use. The most methodically sound results have been shown through the fuel consumption / speed ratio approach by a significant range of researchers, and the findings across the board allow to place the airship at the point of equilibrium among all significant logistic services modes in existence.

The present document exhibited and assessed the current global trends with a focus on Small Islands in the Great Caribbean and The Pacific. In accounting for the airship as a solution to the challenges of the islands, the state of the art of the main technological advances was presented, thus validating the alternative of incorporating airship as a solution in a synchro-modality logistics system, where modes of transport and related infrastructures interact in a flexible and sustainable way. The study cases found on the available literature for operative functionalities allow to identify a series of challenges. These findings are relevant on the wider context of the implications of the use of airships for the logistics networks of the region as well as its challenges to face, in order to advance towards a smooth cross-border trade, seamless logistics operations in the region, and distribution of emergency assets and provision of humanitarian and healthcare services across borders.

The present research document showcased a variety of airship development proposals, both from the industry and from the theoretical engineering perspective, to apply the cargo airship technological solution to a set of relevant functions in the humanitarian and sanitary aid logistics system. The information assessed on the conditions of logistics connectivity found at the studied SIDS and the impact they received from extreme natural and sanitary events allow to pose a necessity for improvement on transportation systems. Information disruptions related in many cases with the same extreme events the response was surveyed for were faced in both the connectivity and disaster reports and the business case models for the airship solution, which demands further research. The findings are relevant on the wider context of the implications of the use of airships for the logistics networks of the region as well as its challenges to face, in order to advance towards a smooth cross-border trade, seamless logistics operations in the region, and distribution of emergency assets and provision of humanitarian and healthcare services across borders.

A series of topics and concerns are recommended in the following paragraphs for further research, in an ongoing investigation and consultation effort with different stakeholders. Many of these topics, as it stems from the present study, may be explicative of the possibilities for the effective availability of operative airships performing flights and services both commercial and auxiliary in the near future, and are advised to be subject to further research.

Engineering and Operative methods: An evolved development is observed with different technological advances by different manufacturers. However, it has not been possible to validate the viability of these advances. One of the reasons is the airship industry is at present time a developing and competing sector that maintains the confidentiality of the progress in the manufacturing and testing of its vehicles. We expect in the short time advances in this subject. A main recommendation is to stablish a reciprocal consultation basis with the certificate organizations. The operational expertise, suitability and demonstrable capability of the different proposed service providers in the current stage of the industry must be thoroughly surveyed together with logistics and aeronautics experts and service procurement actors and authorities to assess the degree in which the proposed technological models and service operations are feasible to be carried out in a safe and efficient manner.

Business and Financing cases: A set of case studies have been developed in academic literature, with similar assumptions regarding demand, and cost or fee estimations in comparison with competitive traditional vehicles. However, the relevant literature highlights the weaknesses and insufficiency in the data due to there still not being sufficient airships built and in operation. Even though the relevance of the existing case studies can be appraised in a variety of factors as a reflection of the state of the industry, its public development, targets, intentions and capabilities, progress could be made in a joint effort with the industry in the development of business case studies with more precise information. The state of the industry must be surveyed to understand the available financial capacity for project funding in airship solutions.

Certification: There is a consensus in the industry that the integral certification process for a new vehicle such as the airship in its diverse variants can be a complex and protracted one due to a variety of factors, among them the fact that each piece involved in the manufacturing of the vehicle must be separately certified and authorized before the developer can proceed to assemblage, among other circumstances that should be studied further in consultation with certificate experts and authorities.

Regulation: Flights and air space management and regulations should be investigated in the same manner to elucidate the prospects of airships to perform the commercial, emergency and auxiliary operations proposed in the reviewed literature with the proper legal authorizations in the near future.

Additional research: Particularly in the study of humanitarian response, it has been observed that most of the publicly available information focuses on disasters and logistics distribution, however there is a lack of a deeper focus on longer term infrastructure and vehicles requirements for connecting remote areas susceptible to disasters. A game changing opportunity is available for regions with remote and accessibility challenged locations, incorporating airships as a flexible mode of transport, avoiding the construction of fixed ground infrastructure that may be prone to damage by a disaster or be affected by the hazards of climate change.

Likewise, it is necessary to advance in questions regarding the complete distribution and logistics system of the different types of airship technology, considering, in addition to the vehicles, their associated infrastructures for operation and maintenance. The importance of understanding the LTA gas requirements (Helium or Hydrogen) and its upkeep/recharge schedules, is also a topic to advance in further research. Innovative means of transports have emerged in the recent years, as well as different forms of combination and integration among them, as in the case of airships with drones, which calls for advancing the intermodal complementary features of airships and its operational methods.

Moreover, it is crucial to develop in inland connectivity indicators, which measure the trade and accessibility levels of remote areas; traditional connectivity indicators measure the main gates of a country by plane or deep sea ships. Likewise, it is important to build indicators that contain variables that measure, in addition to the quantity and frequency of services available for inland connection, the costs and characteristics of logistics services and infrastructures, as well as the economic and social impact in the inland areas.

Government policies and humanitarian response: Some government agencies as well as different organizations are seeking a solution for financing airship solutions projects focusing on the stage of implementation and operation. The financing for the development of the airships, research, prototype construction, tests, certification, is one of the challenges for the successful development of this game changing transport mode.

The topics above reflect some of the main concerns and challenge assessments that arise both from the testimony of experts, industry leaders and institutional authorities and from the own criteria of the authors of this research document in evaluating the current state of the art and industry of the airship solution, and its prospects for upscaling in the near future. The opportunities represented by this innovative mode of transportation for the optimization of connectivity and the enhancement of air transport service provision on a synchro-modal and resilient perspective are ground-breaking and present the potential of a disruptive technological leap. For reaching an assessment of its organic finding of a course of action that involves all relevant industry actors and logistics stakeholders, a joint effort of ongoing research must be carried out, taking as a reference the above-mentioned recommendations, and possibly many others that may emerge from investigative work.

Airship technology can bring long-lasting benefits in connectivity, accessibility and development to isolated locations such as Small Islands beyond the scope of emergency aid operations. Its set of advantages would be crucial for advancing in Sustainability and Blue Economy goals, particularly relevant for Small Islands Developing States in the face of climate change, the COVID-19 pandemic and other issues of global impact, as the progress in the current survey indicates. The present document was intended as an introduction to that ongoing work, and an invitation to bring the potential of these innovative solutions to an open debate of inter-regional public transport and development policies.

There is an opportunity for further research to evaluate the economic and logistical variables used in the case studies for operational scenarios of humanitarian assistance using airships, as shown in this paper, in order to develop a working model for distribution taking into account the unpredictability of extreme events with efficient and sustainable use of infrastructure, avoiding further environmental damage and preventing material and human losses. The technical and economic advantages demonstrated in the relevant literature on airships allow some of their theoretical recommendations to be used as a starting point for future research.

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ANNEXES

Annex 1: Interviewees and discussions

1 - BASI (Buoyant Aircraft Systems International)

Main topics discussed: The state of the art in engineering development for innovative energy systems for flight with environmental protection within the airship industry; operational parameters for emergency aid and long-distance transportation of goods, the prospects for unlocking economic and development potential of affected populations through the airship solution.

- **Dr. Barry Prentice: Co-founder and president of BASI.** Dr. Prentice is a Professor at the University of Manitoba and the former Director (1996-2005) of the Transport Institute. His major research and teaching interests include logistics, transportation economics, northern transport, and trade policy. Dr. Prentice holds a degree in economics from University of Western Ontario (1973) and graduate degrees from University of Guelph (MSc, 1979) and University of Manitoba (PhD, 1986).
- **Ross Prentice: CEO of BASI.** Ross has a strong background in transportation and is truly passionate about understanding how it shapes our world. In addition to a professional designation in logistics, he has worked for nearly 20 years in the intermodal transportation industry.

2 - Aerovehicles

Main topics discussed: The state of development of the airship industry in the LATAM and Caribbean regions; service deployment and certification procedures.

- **Bob Fowler: CEO at Aerovehicles.** US Air Force Command Academy organizational leadership honor grad.

3 - Flying Whales

Main topics discussed: The state of the art in airship applicability in SIDS and other isolated locations; distribution systems on different terrains with the airship solution and infrastructure requirements; the prospects for unlocking economic and development potential of affected populations through the airship solution.

- **Octave Jolimoy: Market Manager for China and South-East Asia in Flying Whales.** Master's degree, Automotive Engineering at Tongji University.
- **Armelle Tarrieu: Sales Manager in Flying Whales.** Postgraduate Master in Economics, Université Paris 1 Panthéon-Sorbonne.
- **Michele Renaud: Market, Sales and Communication Director in Flying Whales.** Diplôme d'ingénieur, DEA Génie des Procédés, Ecole Nationale Supérieure des Industries Chimiques de Nancy.
- **Argann Simonin: Market Manager in Flying Whales.** Mastère Spécialisé, Management de l'Innovation Technologique, Toulouse Business School (TBS). Diplôme d'ingénieur,Ingénierie aérospatiale, aéronautique et astronautique, ENAC - Ecole Nationale de l'Aviation Civile.

4 - Straightline Aviation

Main topics discussed: The prospects for the airship industry economic feasibility and economic competitiveness; operational suitability in diverse logistics systems and service providers in SIDS and other isolated locations; regulatory frameworks and flight certification procedures; the prospects for unlocking economic and development potential of affected populations through the airship solution.

- **Frederic Goig: Investor and Senior Advisor – Strategy and Growth in Straightline Aviation.** IAE FRANCE - Ecoles Universitaires de Management graduate.
- **Laurence Kalinsky: VP Corporate Development and Business Planning in Straightline Aviation.** MBA Cum Laude from The University of Southern California Marshall School of Business.
- **Dr. Mike Kendrick: Co-Founder and Chief Executive Officer of Straightline Aviation.** Honorary Degree of Doctor of Technology from the University of Wolverhampton.
- **Mark Dorey: Co-Founder and Chief Executive Officer of Straightline Aviation.** London School of Economics and Political Science graduate.

5 - LTA Research and Exploration

Main topics discussed: The state of the art in engineering; prospects for growth in the airship industry.

- **Alan Weston: CEO of LTA Research.** NASA Aerospace Engineer.

6 - Institute for Infrastructure, Environment, and Innovation of the European Union

Main topics discussed: Inter-regional agreements for connectivity and environmental protection; financing programs for stakeholders in the airship business; the prospects for unlocking economic and development potential of affected populations through the airship solution.

- **Frank Neumann: Director of the Institute for Infrastructure, Environment, and Innovation (IMEU)** based in Brussels and in Amsterdam, works on innovative clean energy projects and energy transition in the EU and Asia, in addition to maritime innovations and sustainable aviation. Masters in Public Administration from Leiden University; Doctorate in Environmental Management of Erasmus University.
- **Kunal Chowdhury: Junior Technical Advisor in IMIEU.** Sustainable Energy Technology Master at Delft University of Technology.

7 - United Nations Organization

Main topics discussed: Disaster risk assessment and mitigation, empirical data on the impact of extreme events on SIDS and other isolated locations in the context of the pandemic era; the prospects for unlocking the development potential of affected populations through the airship solution.

- **Omar Bello: Economic Affairs Officer at ECLAC.** UCLA economics graduate.

8 - IATA (International Civil Aviation Organization)

Main topics discussed: The IATA connectivity score values and their methodology.

9 - ICAO (International Civil Aviation Organization)

Main topics discussed: The state of regional air connectivity in isolated and endangered areas, the propensity of natural and humanitarian disasters on the studied SIDS and other locations; the challenges and prospects for logistics optimization through synchro-modality; the feasibility of the airship solution for overcoming the limitations of the existing networks and regulatory barriers.

- **José Odini: Expert - Senior Aviation Officer at The International Civil Aviation Organization.** Air Command and Staff College, Military Strategic Studies, Air Command and Staff College at Air University, Air Command and Staff College, Montgomery, Alabama.
- **Cortney Robinson: Air Transport Officer, Air Cargo at The International Civil Aviation Organization.** Master of Public Policy, University of Michigan.

10 - World Food Programme

Main topics discussed: Current state of aviation services procurement for emergency aid and humanitarian services logistics; the role of the airship solution in future connectivity and its economic feasibility.

- **Oleg Aleksandrov: Aviation Officer, RPAS-UAS Cargo Projects at World Food Programme.** University of Buckingham Master of Business Administration – MBA, International Marketing with Distinction.

Annex 2: Recurrent Acronyms

These are some of the most frequent acronyms found across the chapters of the present research document, and a brief explanation of each from public sources published online by the United Nations and pieces of relevant literature quoted in the present study.

ECLAC: The United Nations Economic Commission for Latin America and the Caribbean*, known as ECLAC, UNECLAC or in Spanish and Portuguese CEPAL, is a United Nations regional commission to encourage economic cooperation. ECLAC includes 46 member States (20 in Latin America, 13 in the Caribbean and 13 from outside the region), and 13 associate members which are various non-independent territories, associated island countries and a commonwealth in the Caribbean. ECLAC publishes statistics covering the countries of the region and makes cooperative agreements with nonprofit institutions. The headquarters of ECLAC is in Santiago, Chile.* (UN, 2020)

ESCAP: The United Nations Economic and Social Commission for Asia and the Pacific *is the Secretariat of the United Nations for the Asian and Pacific region. One of the main functions of UNESCAP is to promote economic and social development through regional and subregional cooperation and integration. UNESCAP has 53 member states and 9 associate members. Priority areas of UNESCAP include, among others: social issues; environment and sustainable development; information, communication and space technology; poverty reduction and development; statistics; trade and investment; and transport and tourism.* (UN, 2020)

HFW: Humanitarian Flying Warehouse *is an airship that stays at high altitudes and uses unmanned aerial vehicles (UAVs) to deliver supplies. This innovation will enable safe and timely delivery to hard-to-reach populations in a manner that significantly exceeds the capacity of current practices. Crucially, the HFW eliminates the motivations behind many delivery disruptions. These disruptions are caused by asymmetric commons dilemmas: entities with different accessibility and power race to grab shared relief goods before others* (Jeong et al., 2020)

ICAO: International Civil Aviation Organization of the United Nations *is funded and directed by 193 national governments to support their diplomacy and cooperation in air transport as signatory states to the Chicago Convention (1944). Its core function is to maintain an administrative and expert bureaucracy (the ICAO Secretariat) supporting these diplomatic interactions, and to research new air transport policy and standardization innovations as directed and endorsed by governments through the ICAO Assembly, or by the El Consejo de la OACI which the assembly elects.* (UN, 2020)

OEM: Original Equipment Manufacturer *is an original equipment manufacturer (OEM) traditionally is defined as a company whose goods are used as components in the products of another company, which then sells the finished item to users. The second firm is referred to as a value-added reseller (VAR) because by augmenting or incorporating features or services, it adds value to the original item. The VAR works closely with the OEM, which often customizes designs based on the VAR company's needs and specifications.* (Kagan, 2021)

SIDS: Small Islands Developing States *are a distinct group of 38 UN Member States and 20 Non-UN Members/Associate Members of*

United Nations regional commissions that face unique social, economic, and environmental vulnerabilities. The three geographical regions in which SIDS are located are: the Caribbean, the Pacific, and the Atlantic, Indian Ocean and South China Sea (AIS). SIDS were recognized as a special case both for their environment and development at the 1992 United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil. The aggregate population of all the SIDS is 65 million, slightly less than 1% of the world's population, yet this group faces unique social, economic, and environmental challenges. (UN, 2020)

SDGs: United Nations Sustainable Development Goals*, also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. The 17 SDGs are integrated—they recognize that action in one area will affect outcomes in others, and that development must balance social, economic, and environmental sustainability. Countries have committed to prioritize progress for those who're furthest behind. The SDGs are designed to end poverty, hunger, AIDS, and discrimination against women and girls. The creativity, knowhow, technology and financial resources from all of society is necessary to achieve the SDGs in every context.* (UN, 2020)

UAS: Unmanned Aircraft Systems *are a new component of the aviation system, one which ICAO, States and the aerospace industry are working to understand, define and ultimately integrate. These systems are based on cutting edge developments in aerospace technologies, offering advancements which may open new and improved civil/ commercial applications as well as improvements to the safety and efficiency of all civil aviation. The safe integration of UAS into non-segregated airspace will be a long-term activity with many stakeholders adding their expertise on such diverse topics as licensing and medical qualification of UAS crew, technologies for detect and avoid systems, frequency spectrum (including its protection from unintentional or unlawful interference), separation standards from other aircraft, and development of a robust regulatory framework.* (ICAO, 2011)

UAV: Unmanned Aerial Vehicle *are a class of aircrafts that can fly without the onboard presence of pilots. Unmanned aircraft systems consist of the aircraft component, sensor payloads and a ground control station. They can be controlled by onboard electronic equipment or via control equipment from the ground.* (Wireless Public Safety Networks 1, 2015)

UN: United Nations *is an intergovernmental organization aiming to maintain international peace and security, develop friendly relations among nations, achieve international cooperation, and be a centre for harmonizing the actions of nations. It is the world's largest and most familiar international organization. The UN is headquartered on international territory in New York City, and has other main offices in Geneva, Nairobi, Vienna, and The Hague.* (UN, 2020)

UNDA: United Nations Development Account *was established in 1997 by virtue of General Assembly resolution 52/12 B, as a mechanism to channel regular budget resources to funding capacity-building projects implemented by 10 entities working on the United Nations Secretariat development pillar. These are the Department of Economic and Social Affairs (DESA), the five regional commissions (including ECLAC), the United Nations Conference on Trade and Development (UCTAD), the United Nations Environment Programme (UNEP), the United Nations Human Settlement programme (UN-Habitat)* *and the United Nations Office on Drugs and Crime (UNODC).* (UN, 2020)

VTOL: Vertical Takeoff and Landing, *a vertical take-off and landing (VTOL) aircraft is one that can hover, take off, and land vertically. This classification can include a variety of types of aircraft including fixed-wing aircraft as well as helicopters and other aircraft with powered rotors, such as cyclogyros/cyclocopters and tiltrotors.* (Laskowitz, 1961)

WHO: World Health Organization *is a specialized agency of the United Nations responsible for international public health. The WHO Constitution states its main objective as "the attainment by all peoples of the highest possible level of health". Headquartered in Geneva, Switzerland, it has six regional offices and 150 field offices worldwide.* (UN, 2020)

Annex 3: The Great Caribbean and the Pacific COVID-19 aggregate cases until 1st July 2021 and cases per 100.000 population

GREAT CARIBBEAN ISLANDS		
	COVID CASES	COVID CASES per 100.000 population
Dominican Republic	324.364	2.990
Cuba	188.023	1.660
Puerto Rico	140.021	4.894
Jamaica	50.080	1.691
Trinidad and Tobago	32.343	2.311
Haiti	18.562	163
Guadeloupe	17.539	4.383
Bahamas	12.586	3.201
Curaçao	12.332	7.515
Martinique	12.286	3.274
Aruba	11.132	10.427
Saint Lucia	5.284	2.878
Barbados	4.079	1.419
United States Virgin Islands	3.850	3.687
Sint Maarten	2.613	6.093
Bermuda	2.514	4.037
Turks and Caicos Islands	2.424	6.261
Saint Martin	2.367	6.123
Saint Vincent and the Grenadines	2.219	2.000
Bonaire	1.618	7.736
Antigua and Barbuda	1.263	1.290
Saint Barthélemy	1.043	10.551
Cayman Islands	614	934
Saint Kitts and Nevis	439	825
British Virgin Islands	298	986
Dominica	193	268
Grenada	162	144
Anguilla	109	727
Montserrat	20	400
Sint Eustatius	20	637
Saba	7	362

GREAT CARIBBEAN CONTINENT		
	COVID CASES	COVID CASES per 100.000 population
Colombia	4.187.194	8.229
Mexico	2.507.453	1.945
Panama	401.332	9.301
Costa Rica	364.304	7.151
Guatemala	292.674	1.634
Venezuela	270.654	952
Honduras	260.331	2.628
French Guiana	27.415	9.179
Suriname	21.360	3.641
Guiana	19.891	2.529
Belize	13.189	3.317
Nicaragua	6.604	100

PACIFIC ISLANDS		
	COVID CASES	COVID CASES per 100.000 population
Australia	30.562	120
French Polynesia	19.003	6.765
Papua New Guinea	17.190	192
Guam	8.092	4.795
Fiji	4.144	462
New Zealand	2.386	49
Northern Mariana Islands	183	318
New Caledonia	129	45
Solomon Islands	20	3
Marshall Islands	4	7
Vanuatu	3	1
Samoa	1	1
Nauru	0	0
Kiribati	0	0
Tonga	0	0
Tuvalu	0	0
Micronesia	0	0
Palau	0	0
American Samoa	0	0
Cook Islands	0	0
Niue	0	0

Source: Author´s calculation, based on data from WHO.

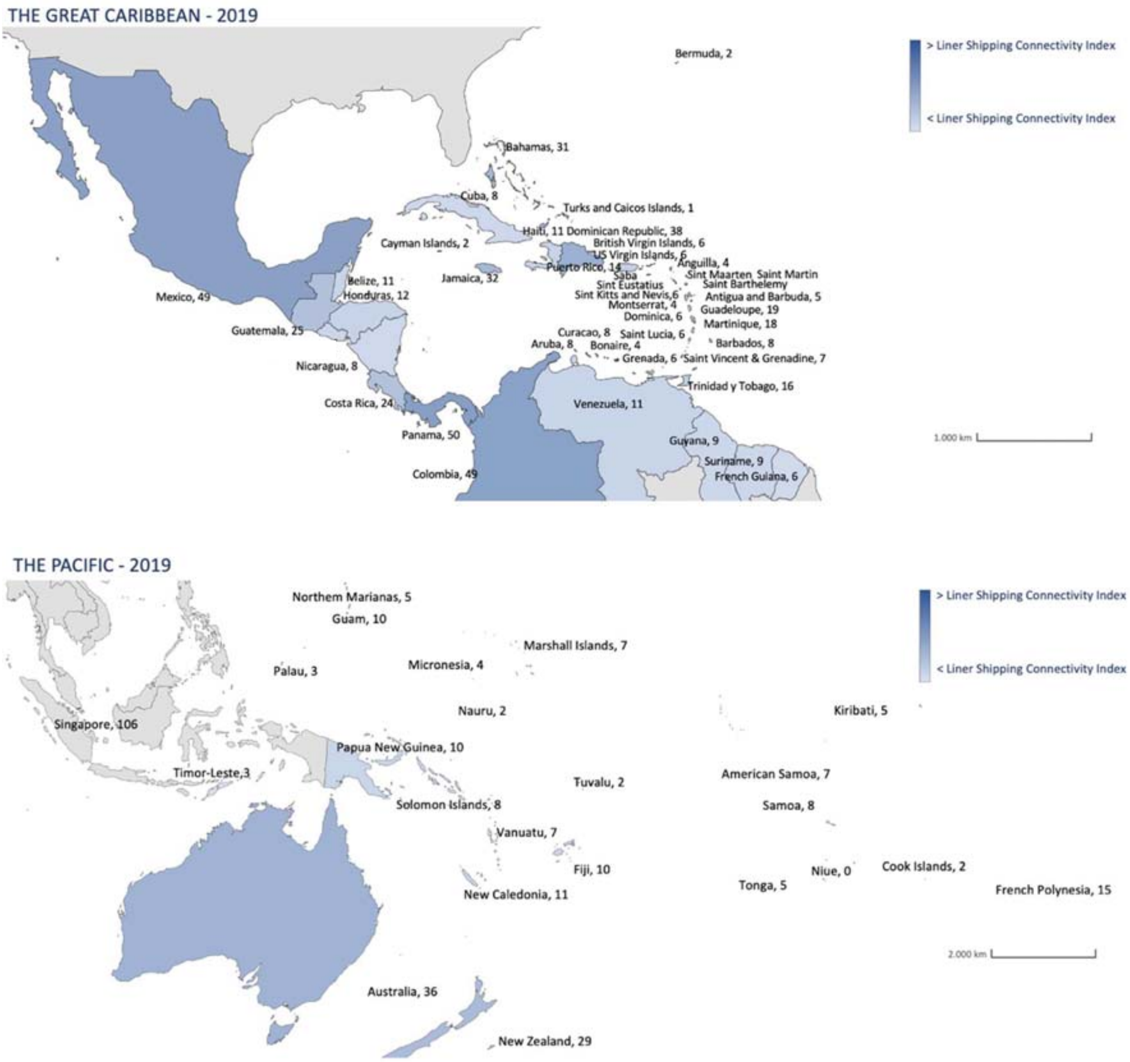
Annex 4: Liner Shipping Connectivity Index by country

Table 5: Maritime connectivity by country at the Great Caribbean and the Pacific - LSCI Fourth Quarter 2019 UNCTAD

GREAT CARIBBEAN ISLANDS		GREAT CARIBBEANT CONTINENT		PACIFIC ISLANDS	
Country	LSCI 2019	Country	LSCI 2019	Country	LSCI 2019
Dominican Republic	38,13	Panama	49,98	Singapore	105,63
Jamaica	32,26	Mexico	49,07	Australia	35,66
Bahamas	31,17	Colombia	48,57	New Zealand	29,05
Guadeloupe	19,08	Guatemala	24,98	Polynesia	14,53
Martinique	17,89	Costa Rica	24,28	New Caledonia	10,68
Trinidad and Tobago	15,83	Honduras	11,81	Papua New Guinea	10,48
Puerto Rico	13,92	Belize	11,16	Fiji	9,63
Haiti	10,96	Venezuela	11,09	Guam	9,52
Aruba	8,37	Suriname	8,89	Solomon Islands	8,50
Curacao	8,37	Guyana	8,76	Samoa	7,76
Cuba	8,25	Nicaragua	7,90	Vanuatu	7,36
Barbados	7,51	French Guiana	6,40	American Samoa	7,31
Saint Vincent and the Grenadines	6,51			Marshall Islands	6,57
Dominica	6,33			Northern Marianas	5,36
Grenada	6,19			Kiribati	5,32
British Virgin Islands	6,19			Tonga	5,06
Saint Kitts and Nevis	6,19			Micronesia	4,03
U.S. Virgin Islands	5,72			Palau	3,23
Saint Lucia	5,61			Timor-Leste	2,63
Antigua and Barbuda	5,01			Cook Islands	2,28
Anguilla	4,47			Tuvalu	1,81
Montserrat	4,47			Nauru	1,70
Bonaire	4,47			Niue	0,00
Cayman Islands	1,88				
Bermuda	1,79				
Turks and Caicos Islands	1,13				

Source: Author´s calculation, based on the data from UNCTADstat

Figure 16: Maritime connectivity by country at the Great Caribbean and the Pacific - LSCI Fourth Quarter 2019 UNCTAD



Source: Author´s calculation, based on the data from UNCTADstat.

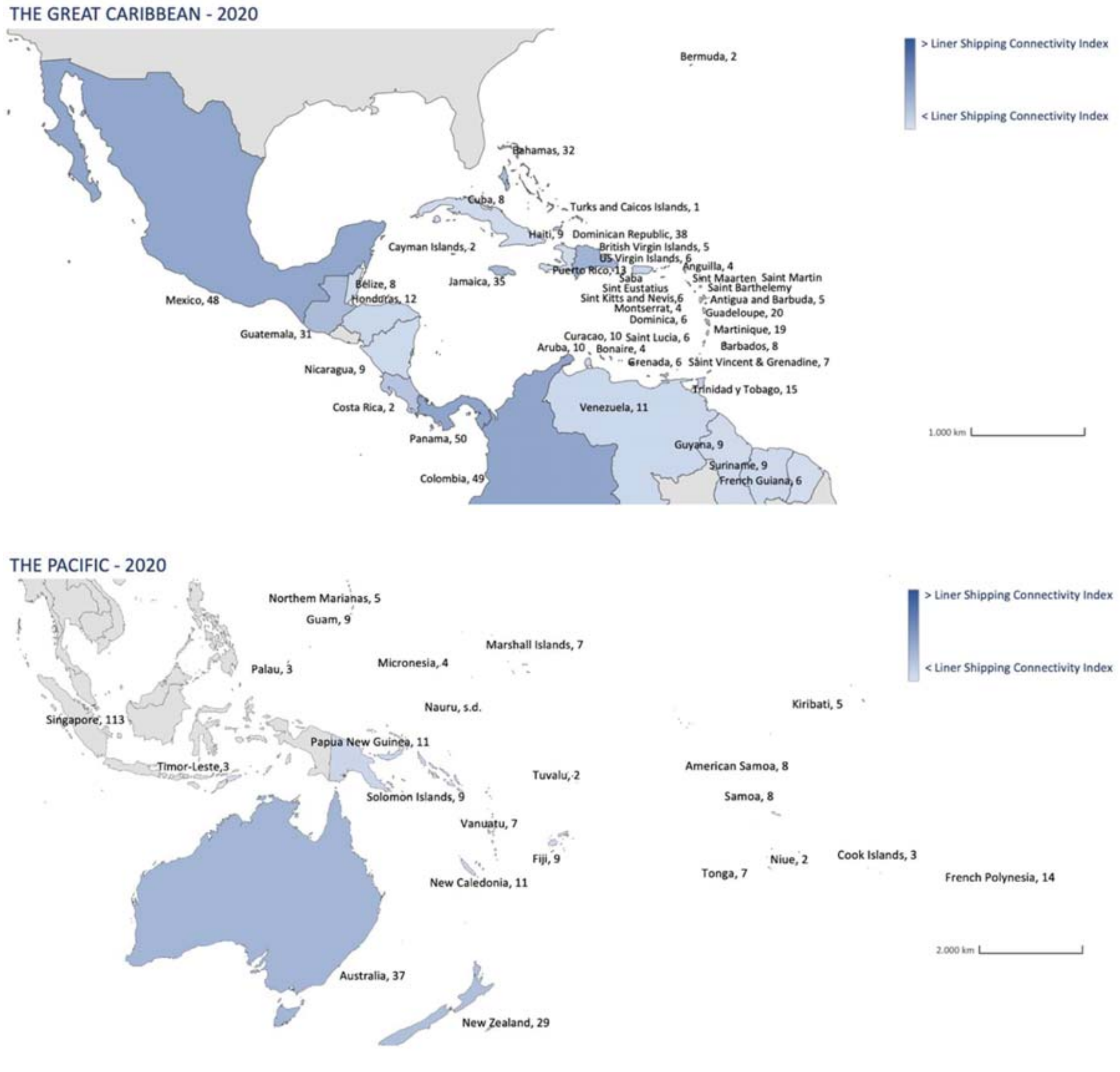
Note: the highest intensity corresponds to countries with greater maritime connectivity measure by LSCI and km scale is a reference to notice the distances between islands

Table 6: Maritime connectivity by country at the Great Caribbean and the Pacific - LSCI Fourth Quarter 2020 UNCTAD

GREAT CARIBBEAN ISLANDS		GREAT CARIBBEANT CONTINENT		PACIFIC ISLANDS	
Country	LSCI 2020	Country	LSCI 2020	Country	LSCI 2020
Dominican Republic	38,23	Panama	50,02	Singapore	113,78
Jamaica	35,18	Colombia	49,34	Australia	37,23
Bahamas	32,23	Mexico	48,38	New Zealand	28,86
Guadeloupe	20,26	Guatemala	31,23	Polynesia	13,86
Martinique	18,80	Costa Rica	24,54	Papua New Guinea	11,16
Trinidad and Tobago	15,49	Honduras	11,98	New Caledonia	10,51
Puerto Rico	13,06	Venezuela	10,99	Guam	9,36
Aruba	9,53	Nicaragua	9,40	Fiji	9,24
Curacao	9,53	Suriname	8,76	Solomon Islands	8,95
Haiti	9,26	Guyana	8,20	Samoa	8,05
Cuba	8,50	Belize	7,73	American Samoa	7,51
Barbados	7,98	French Guiana	6,36	Tonga	7,40
Saint Vincent and the Grenadines	6,51			Vanuatu	7,36
Dominica	6,33			Marshall Islands	6,72
Grenada	6,19			Kiribati	5,32
U.S. Virgin Islands	5,72			Northern Marianas	5,19
Saint Lucia	5,61			Micronesia	4,40
British Virgin Islands	5,05			Timor-Leste	2,63
Saint Kitts and Nevis	5,05			Palau	2,61
Antigua and Barbuda	5,01			Cook Islands	2,52
Anguilla	4,47			Niue	2,04
Montserrat	4,47			Tuvalu	1,70
Bonaire	4,44			Nauru	
Cayman Islands	2,04				
Bermuda	1,79				
Turks and Caicos Islands	1,13				

Source: Author´s calculation, based on the data from UNCTADstat

Figure 17: Maritime connectivity by country at the Great Caribbean and the Pacific - LSCI Fourth Quarter 2020 UNCTAD



Source: Author´s calculation, based on the data from UNCTADstat

Annex 5: Air connectivity score by country

Table 7: Air connectivity by country at the Great Caribbean and the Pacific - Air connectivity score 2019 IATA

GREAT CARIBBEAN ISLANDS		GREAT CARIBBEANT CONTINENT		PACIFIC ISLANDS	
Country	ACS 2019	Country	ACS 2019	Country	ACS 2019
Dominican Republic	65.668	Mexico	515.506	Australia	581.684
Cuba	35.810	Colombia	162.108	New Zealand	99.825
Jamaica	32.489	Panama	45.492	Fiji	9.313
Bahamas	23.749	Costa Rica	29.543	Polynesia	4.826
Aruba	11.983	Guatemala	14.263	Papua New Guinea	3.035
Barbados	8.047	Venezuela	8.354	New Caledonia	2.040
Trinidad and Tobago	7.608	Honduras	8.126	Cook Islands	1.121
Cayman Islands	7.192	Belize	5.048	Samoa	1.102
Sint Maarten	6.010	Nicaragua	2.861	Vanuatu	1.069
Turks and Caicos Islands	5.993	Suriname	2.244	Palau	889
Guadeloupe	5.927	Guyana	1.691	Tonga	542
Curacao	5.907	French Guiana	1.323	Solomon Islands	309
Haiti	5.819			Marshall Islands	135
Bermuda	5.692			Nauru	75
Martinique	5.105			Niue	67
Saint Lucia	5.001			Micronesia	44
Antigua and Barbuda	3.487			Kiribati	38
Bonaire	2.285			Tuvalu	1
Grenada	1.375				
Saint Kitts and Nevis	1.120				
Saint Vincent and the Grenadines	333				
British Virgin Islands	280				
Dominica	57				
Anguilla	36				
Montserrat	2				

Source: Author´s calculation, based on the data from IATA – Air Connectivity.

Figure18: Air connectivity by country at the Great Caribbean and the Pacific - Air connectivity score 2019 IATA

Source: Author´s calculation, based on the data from IATA – Air Connectivity. IATA collaboration (updated from previous figures)

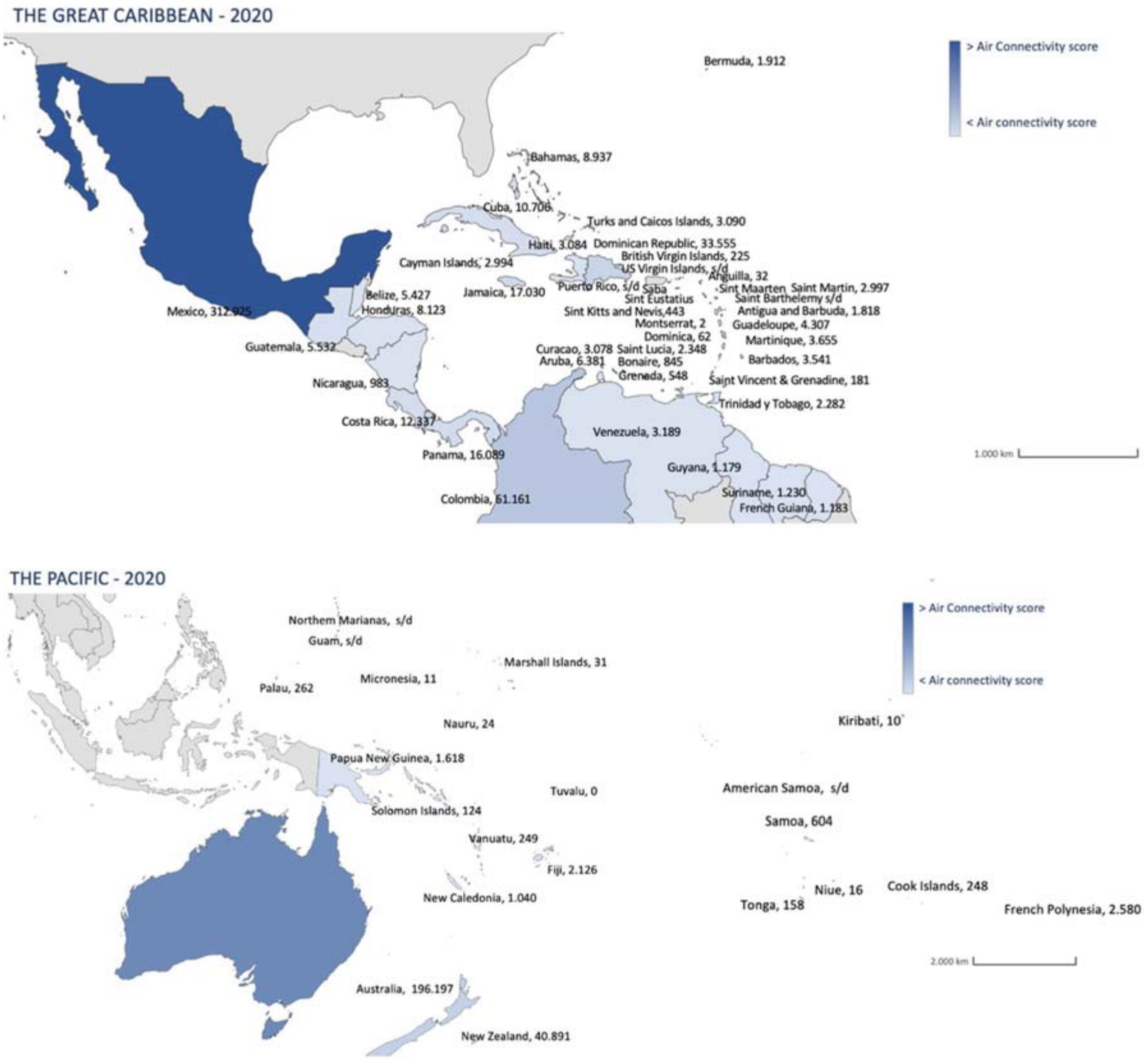
Note: the highest intensity corresponds to countries with greater air connectivity measure by IATA Air Connectivity score and km scale is a reference to notice the distances between islands.

Table 8: Air connectivity by country at the Great Caribbean and the Pacific - Air connectivity score 2020 IATA

GREAT CARIBBEAN ISLANDS		GREAT CARIBBEANT CONTINENT		PACIFIC ISLANDS	
Country	ACS 2020	Country	ACS 2020	Country	ACS 2020
Dominican Republic	33.555	Mexico	312.925	Australia	196.997
Jamaica	17.030	Colombia	61.161	New Zealand	40.891
Cuba	10.706	Panama	16.089	Polynesia	2.580
Bahamas	8.937	Costa Rica	12.337	Fiji	2.126
Aruba	6.381	Guatemala	5.532	Papua New Guinea	1.618
Guadeloupe	4.307	Venezuela	3.189	New Caledonia	1.040
Martinique	3.655	Honduras	3.073	Samoa	604
Barbados	3.541	Belize	2.000	Palau	262
Turks and Caicos Islands	3.090	Nicaragua	983	Vanuatu	249
Haiti	3.084			Cook Islands	248
Curacao	3.078			Tonga	158
Sint Maarten	2.997			Solomon Islands	124
Cayman Islands	2.994			Marshall Islands	31
Saint Lucia	2.348			Nauru	24
Trinidad and Tobago	2.282			Niue	16
Bermuda	1.912			Micronesia	11
Antigua and Barbuda	1.818			Kiribati	10
Bonaire	845			Tuvalu	0
Grenada	548				
Saint Kitts and Nevis	443				
British Virgin Islands	225				
Saint Vincent and the Grenadines	181				
Dominica	62				
Anguilla	32				
Montserrat	2				

Source: Author´s calculation, based on the data from IATA – Air Connectivity.

Figure 19: Air connectivity by country at the Great Caribbean and the Pacific – Air connectivity score 2020 IATA



Source: Author´s calculation, based on the data from IATA – Air Connectivity. IATA collaboration (updated from previous figures)

Note: Figures 16 to 19: The graphics are schematic and not to scale (Different scales to represent The Greater Caribbean and The Pacific). Some countries on the maps are not colored due to small image size; grey-painted countries indicate a lack of data or outside the area covered in the study. The color scale corresponds to the color intensity increasing relative to the value of the indicator. The range of color degradation is not accurate to the ratio of variation of the indicator.