TULIPS

Demonstrating lower polluting solutions for sustainable airports across Europe

GRANT AGREEMENT NO. 101036996

START DATE 01.01.2022 END DATE 31.12.2025

D9.1

Identification of key criteria for future deployment

Public

DUE DATE OF DELIVERABLE: 01/01/2023

SUBMISSION DATE 16/05/2023

Beta-i Collaborative Innovation Lda, Portugal

REVISION	ORGANIZATION & PERSON	DATE
Written by	Beta-i, Ashwin Anandani	22/12/2022
Checked by	Beta-i, Karina Ospina	28/12/2022
Approved by	Beta-i, Ricardo Marvao	28/12/2022

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101036996.

I. DELIVERABLE INFORMATION

Deliverable Number	D9.1
Deliverable Title	Identification of key criteria for future deployment
Work Package	WP 9: Deployability, Upscaling and Exploitation
Date of Issue	16/05/2023
Version Number	V2.1
Nature of Deliverable	Report
Dissemination Level (Public / Confidential)	Public

Author(s)	Karina Ospina
Keywords	Technological readiness criteria for deployment, scalability, and exploitation (commercialization).

Abstract

The purpose of this report is to identify key criteria for data-driven decisions related to validation, prototype metrics, business models, and product market fit for the WP1-7 demos. This report provides the necessary background and references to a workbook that instates the key criteria for deployments/commercialisation as well as mandatory criteria of machine safety to guarantee safe deployment, intended for use as a first step by WP leaders and airports that may consider deploying any of the solutions.

II. DOCUMENT HISTORY

Date	Version	Modified by	Remarks
22/12/2022	V1	Beta-i, Ashwin Anandani	For checks by RM
06/01/2023	V2	Beta-i, Ashwin Anandani	After feedback from expert consult and colleagues
09/01/2023	V2.1	Beta-i, Karina Ospina	Includes final references and Conclusion
08/04/2023	V2.2	Beta-I, Karina Ospina	Included safety guidelines from NLR

III. TABLE OF CONTENTS

IV. LIST OF ACRONYMS

Acronym	Meaning
GA	General Assembly
KOM	Kick Off Meeting
WP	Work Package
SAF	Sustainable Aviation Fuels
CAGR	Compound Annual Growth Rate
KPI	Key Performance Indicator
TAM	Total Available Market
SAM	Serviceable Available Market
SOM	Serviceable Obtainable Market
FTE	Full-Time Employee(s)
PTE	Part-Time Employee(s)

1. Executive Summary

This report provides the necessary background and references to an Excel Sheet that lists the key criteria for deployments/commercialization, intended for use as a first step by WP leaders and airports that may consider deploying any of the solutions. Chapter 3 – Safety Assessment states the safety regulations and risk assessment that must be performed before any demo is deemed as deployable.

The purpose of the deliverable is to create a common set of the most important criteria any partner airport (or external partner) will want to assess to determine if a particular demo/project is deployable through their organization/airport. By identifying and standardizing these criteria, both airports and project leaders may determine what areas are affecting their deployability or scalability positively and negatively.

The criteria itself is split into 6 major areas (Market, Customer, Product, Scalability, Maturity, Investment Risk), with 3-4 sub-criteria within each for grading. Within each sub-criteria, a dropdown is provided with ranges / pre-filled answers to make the Sheet easier to use and fill. Project leads should provide their rating or assessment and the 'strength' (amount of research or confidence in those statements) of that rating accordingly. Afterward, each airport may flag the areas of concern and provide further remarks, as well as an overall assessment of that sub-criteria.

Explained here is the methodology used to determine the criteria, an explanation of the criteria and reasoning, and finally instructions on how best to make use of the Excel Sheet that codifies these. The criteria were determined through extensive online research, meetings with the WP9 RSG Liaison, partner airports, and expert consults within Beta-i.

While not intended as a final document, it should serve as the basis for continued assessment of each demo project's technology to establish a basic picture of a technology's commercial attractiveness, which areas are of most importance to an airport organization when determining deployability, and what nuances need to be further accounted for.

2. Methodology:

The criteria were determined through extensive online research, meetings with the WP9 RSG Liaison, partner airports, NLR, and expert consults within Beta-i.

Primarily, this is developed based on commercialization or scale-up readiness assessments currently in use at various organizations, including an airport commercial department. Some modifications to better fit the TULIPS context were made based on discussions with other leads (WP8, RSG Liaison). These include the addition of a provisional Ongoing Costs sub-criteria, an understanding of dependency on EU Mandates or Policies, and specifically how a project affects an airport's decarbonization goals.

Particular attention was paid to the fact that there are 17 very varied demos. For this reason, the Key Criteria and sub-criteria were kept quite broad, to be applicable (in general terms) to all potential demos. These are intended to be iterated upon as the demos are performed and more data is available.

Also kept in focus here is the large number of stakeholders at play. The Sheet provided as part of this deliverable is the key document that is intended for use by the two key parties -- Airports and Project Leads -- as a common hub or starting point for their discussions around pilot possibilities.

Lastly, it is very likely this methodology overall may be iterated on as project leads and other stakeholders provide more feedback and insight. In that case, the links provided here may be revised and/or broken into varying categories (for example, for Prospective vs Effective demos, or one for each airport).

2.1.1.Outline of Key Criteria (MTRL Assessment, TRL 5+)

1. Project Maturity

1: Project work is beyond basic research and the technology concept has been defined. Principles observed but no experimental proof is available.

2: Applied research has begun, and practical applications have been formulated.

3: Preliminary testing of technology components has begun in a laboratory environment. Proof of concept.

4: Initial testing of the integrated product has been completed in a laboratory environment. Early prototype.

5: Integrated product demonstrates performance in the intended environment. Large scale prototype

2. Product Development

1: Initial product/market fit has been defined.

2: The pilot scale product has been tested in the intended environment close to the expected performance.

3: Demonstration of a full-scale product prototype has been completed in the operational environment

4: The manufacturing issues have been solved and the first commercial product/service exists.

5: Product/service is available for all consumers.

3. Product Definition/Design

1: One or more initial product hypotheses have been defined.

2: Mapping product attributes against customer needs has highlighted a clear value proposition.

3: The product has been scaled from laboratory to pilot scale and issues that may affect achieving full scale have been identified.

4: Comprehensive customer value proposition model has been developed, including a detailed understanding of product design specifications, required certifications, and trade-offs.

5: Product final design optimization has been completed, required certifications have been obtained and the product has incorporated detailed customer and product requirements.

4. Competitive Landscape

1: Market research has been performed and basic knowledge of potential applications and competitive landscape have been identified.

2: Primary market research to prove the product's commercial feasibility has been completed and a basic understanding of competitive products has been demonstrated.

3: Comprehensive market research to prove the product's commercial feasibility has been completed and an intermediate understanding of competitive products has been demonstrated.

4: Competitive analysis to illustrate unique features and advantages of the product compared to competitive products has been completed.

5: Complete understanding of the competitive landscape, target applications, competitive products, and the market has been achieved.

5. Team

1: No team or organization (single individual, no legal entity).

2: Solely technical or non-technical founders running the organization with no outside assistance.

3: Solely technical or non-technical founders running the organization with assistance from outside (advisors, mentors, incubators, accelerators, etc.).

4: Balanced team with technical and business experience running the organization.

5: Balanced team with all capabilities onboard (technical, sales, marketing, customer service, operations, etc.) running the organization.

6. Documentation

1: Solely technical descriptions have been elaborated, i.e., software documentation, architecture diagrams, etc.

2: User-oriented documentation has been created, such as user manuals, installation guides, reference manuals, etc.

3: Live demonstration resources have been developed (recorded videos, website with link to demo, etc.).

4: Position papers, press releases, posters, etc. have been elaborated for the dissemination of the project.

5: Marketing documentation has been created, such as a Business Model Canvas, etc

7. Intellectual Property Management

1: No IPR has been defined.

2: Initial means of protection have been considered.

3: A proper and clear definition of shares has been elaborated.

4: An assignation of exploitation rights has been developed.

5: A contractual obligation regarding IPR has been established.

8. Go-to-Market

1: Initial business model and value proposition have been defined.

2: Customers have been interviewed to understand their needs and the business model and value proposition have been redefined based on customer feedback.

3: Market and customer needs and how those translate to product requirements have been defined, and initial relationships have been developed with key stakeholders across the value chain.

4: Partnerships have been formed with key stakeholders across the value chain (suppliers, partners, service providers, customers).

5: Supply agreements with suppliers and partners are in place and initial purchase orders from customers have been received.

9. Manufacturing/Supply Chain

1: Potential suppliers, partners, and customers have been identified and mapped in an initial value chain analysis.

2: Relationships have been established with potential suppliers, partners, service providers, and customers and they have provided input on product and manufacturability requirements.

3: Manufacturing process qualifications have been defined and are in progress.

4: Products have been pilot manufactured and sold to initial customers.

5: Full-scale manufacturing and widespread deployment of products to customers have been achieved.

2.1.2.Outline of Key Criteria (Simplified / TRL 4 or Lower)

1. Market

Defining the market, its size, and growth to assess the desirability of the project from a commercial standpoint

1.1 Market Definition Options

How well-defined is the market for this project?

- Multi, Well-Defined
- Single, Well-defined
- Loosely Defined
- Not Yet Defined

1.2 Market Size (Serviceable Avail. Market)

How large is the Serviceable Available Market (SAM) for this project?

- €3B+
- €1B - 3B
- €500M - €1B
- €100M - €500M
- <€100M

1.3 Market CAGR

At what rate is the market for this project growing so far?

- High (6%+)
- Medium (3 - 6%)
- Low (<3%)

2. Customer

Defining the customer, how large costs are relative to them, and whether there will be an applicable margin for scalability

2.1 Customer Segment

How well-defined is the customer within the market for this project?

- Niche
- Flexible
- Somewhat Clear

- Not Yet Defined

2.2 Time & Cost Requirements for Customer

Are the time and cost requirements for an airport acceptable or in proportion to the project?

- Low or Easily Acceptable
- Proportionate to Impact
- Somewhat Acceptable
- Large Players Only
- Requires Scale or Time to Lower
- Not Yet Determined

2.3 Ability to Charge Premium

Does the project have a clear ability to earn a margin on the provision of the technology?

- Yes/Clear Advantage
- Good Possibility
- Possible, Unclear
- Unlikely

3. Product

Determining how unique or protected the product is against others in the market

3.1 Competitor Landscape

What is the nature of the competitive landscape for this project or technology in terms of the number of competitors?

- Multiple, Established
- Some, Established
- Some, Developing
- Fragmented
- Not Defined

3.2 Competitive Advantage / Differentiation

How clear is the advantage of this project within this competitive landscape?

- Clear Moat/Advantage
- First-Mover
- Some Advantage
- Possible, Unclear
- Not Differentiated Enough

3.3 Technology Type

How would you describe the state of the technology at the current time?

- Very Advanced, Tested
- Advanced, Tested
- Tested / Emerging
- Untested
- Already Proven

4. Scalability

Projecting approximate costs and efforts to understand commitments before deploying a pilot.

4.1 Projected Pilot Initial Cost (approx.)

How much, on average, are you quoting for a pilot project deployment?

- <€500K
- €500K - €1M
- €1M - €2M
- €2M+

4.2 Projected Pilot Ongoing Costs (per year)

How much, on average, are you quoting for a pilot project to be sustained for 1 year?

- <€120K
- €120K - €480K
- €480K - €1M
- €1M+

4.3 Projected Deployment Time

How long does it typically take/is it projected to take for a pilot to begin after the point of initial approval by an airport?

- One month to One year
- One to Two years
- Two to Four years
- Four to Five years

More than 5 years

4.4 Projected Deployment KPIs

What is the nature of the KPI set for pilot projects?

- Already Defined

- Almost Defined
- Loosely Defined
- Defining Now
- Undefined

5. Maturity

Determining a level of maturity that may provide some security to the piloting risks of a large organization.

5.1 Technology Readiness Level

Refers directly to the ESA and EU Commission Deeptech scale referred to in Sheet and References.

- Seven
- Six
- Five
- Four or less

5.2 Years In Operation (of Parent Org if appl.)

How many years has the technology OR its parent organization been in operation so far?

- More than 5 years
- 4 – 5 years
- 2 - 4 years
- 1-2 years
- Early-Stage

5.3 Yearly Turnover (of Parent Org if appl.)

What is the latest fiscal year turnover of the parent organization OR in the case of deployed technologies, the technology's revenues?

- 3M€ +
- 1M€ - 3M€
- <1M€
- 500K - 1M€
- None Yet

6. Investment Risk

Determining what level of investment risk is suitable through various factors that affect the commercialization of a project.

6.1 IP Ownership

Who owns the intellectual property rights behind this technology?

- Owned by Same Org
- Brought In-House
- Owned by Another Org
- Other
- No IP Protection

6.2 Dependent on Mandates/Policies?

Is the technology dependent on a mandate or legal policy to operate/deploy?

- Yes, with certainty
- Yes, high probability
- Likely, unsure of the probability
- Unlikely, unsure of the probability
- No / Unsure

6.3 Level of In-House Support Required

How much support (personnel, liabilities, or organizational support) would be required on the part of the airport to deploy this pilot or technology?

- Low (No FTE)
- Medium (1 FTE, Multi PTE)
- High (2 FTE+)
- Undetermined

6.4 Priority Level of Tech Deployment / Impact on Airport Goals

How impactful is the technology about decarbonization/lower-pollution requirements faced by airports?

- High
- Medium
- Low
- Not Applicable

2.2. Key Criteria Document

Please refer to Annex: Key Criteria MTRL Assessment matrix to perform the market and technological readiness to assess the deployability, scalability, and exploitation potential of a successful TULIPS demo.

2.2.1. Access Notes:

This is stored on the TULIPS Sharepoint within [WP9 > Deliverable T9.1], and should therefore be accessible to all WP leads and other TULIPS stakeholders.

Barring any specific requests or large changes, the file will remain at the above link.

Should you not be able to access it for any reason, contact: karina.ospina@beta-I.com

2.2.2. How to Use This Document:

First, access the document and ensure you are on the sheet that specifies the TRL level of your project. Each sheet contains instructions and calculations that may be used for the assessment by WP Leads and/or airport partners.

As a WP Lead:

1. Go to File > Make A Copy.
2. Rename the copied file as follows "WPx_Demo y_ MTRL Assessment"
3. Fill in the table "Self Assessment - Deploy". If your score is above 5 proceed to the next step, otherwise, proceed to step 6.
4. Fill in the criteria for MTRL 5+ Assessment.
5. Provide any additional detail, findings, or resources
6. Save your copy and share it via Sharepoint whenever you need to use it.

As an airport

You should receive a copy of this file from the WP/project lead or project demo you are interested in or create your copy for internal assessment of a particular project.

1. Proceed to the first sheet or the second (depending on the TRL level of the project you'd like to assess) and apply a Weight in the designated column.

2. Along with the calculations provided by the WP / Project leads, the sheet's results should indicate market readiness for each project.

All users may disregard other columns than the ones mentioned here.

3. Safety Assessment

Those demos for which deployability readiness is deemed successful need to manage aviation safety and health and safety before entering operations. Failure to adequately manage either may lead to loss of life, injury, ill health, and subsequent business, economic and reputational losses. The precautions which protect aircraft often also protect people. Consequently, the management of health and safety and the management of aviation safety share common themes. The key elements of both are:

- Commitment from work package leaders to follow and report on compliance with the policies, targets, and standards in this document, which define the set of responsibilities and accountabilities;
- A method for identifying hazards, assessing risks, and controlling those risks;
- A method of monitoring and review that includes inspection, and audit, incident investigation, and data trend analysis;
- Documented processes and procedures.

This chapter provides the guidelines that airports should follow to ensure the safety of demos deployed in the real environment. Safety assessment, risk monitoring, risk mitigation as well as machinery safety compliance is to be reported to the NLR partner.

3.1. Airport infrastructure

The availability of standards and regulations to ensure airport safety when using electric, hybrid, and hydrogen aircraft has been checked. Most noteworthy in Europe is EU Directive 2012/18/EU on the control of major-accident hazards involving dangerous substances. Additionally, the United Nations provides Model Regulations that may be used by States to develop their national regulations for the operation, handling, and storage of novel energy sources at airports. ICAO and EC/EASA will likely provide tailored standards and regulations for the use of new energy sources in the coming years.

3.2. Background

Aviation is increasing its efforts toward the electrification of aircraft systems and electric propulsion and investing heavily in electric and hybrid aircraft. This includes the use of liquid hydrogen for civil aviation. Electric, hybrid, and hydrogen aircraft may help to meet environmental goals on noise and local air quality and may help to reduce the impact of aviation on climate change. It is therefore important to ensure that such new and promising technologies may be introduced quickly and safely.

Unfortunately, existing standards and regulations are often not well suited and tailored to the introduction of new and emerging technologies. Therefore, unexpected delays could occur in the approval process by the authorities. Often applicants must develop Alternative Means of Compliance to convince the authority that new technologies will not degrade safety.

To mitigate this issue and accelerate the introduction of new technologies, it is usually recommended to consider safety from early design onwards (through safety-based design). Various safety issues with the introduction of electric, hybrid, and hydrogen aircraft will have to be addressed, resulting in requirements for aircraft certification and airport infrastructures. Examples are given below.

3.3. Intermodal services single source of data

In the area of data integration for green digital solutions, it is essential to ensure compliance with stringent safety guidelines for Intermodal transportation and electric freight. The following key safety measures should be followed to guarantee the smooth implementation and operation of these solutions:

1. Data Security: Implementation of robust data security protocols, including encryption techniques, access controls, and secure data transfer mechanisms, to protect sensitive information related to Intermodal transportation and electric freight. Compliance with standards such as ISO/IEC 27001:2013 is required to establish effective data security practices.
2. Cybersecurity: Mitigation of cybersecurity risks by regularly updating and patching software systems, deploying firewalls, and intrusion detection systems, and conducting thorough vulnerability assessments. It is crucial to have incident response plans in place to promptly address any potential cyber threats and minimize their impact. Compliance with cybersecurity standards such as ISO/IEC 27032 and NIST Cybersecurity Framework is mandatory to ensure robust cybersecurity practices.
3. Interoperability: Standardization of data formats, communication protocols, and interfaces to enable seamless integration of diverse data sources and systems used in Intermodal transportation and electric freight. Compliance with guidelines provided by standards like IEC 62714 and IEEE 1451.1 is necessary to achieve data interoperability.
4. System Reliability: Prioritization of the reliability of data integration systems by implementing redundant systems, backup mechanisms, and failover solutions to minimize disruptions and downtime. Compliance with standards such as IEC 61508 and IEEE 1547 is required to ensure system reliability and resilience.
5. Compliance with Regulations: Adherence to relevant regulations and industry standards governing data privacy, security, and interoperability. It is important to stay updated with evolving legal requirements and incorporate necessary safeguards to protect individuals'

privacy and maintain compliance with data protection regulations. Compliance with standards like ISO/IEC 27701 and IEEE P7000 series is essential for ensuring data privacy and ethical considerations.

6. Data Integrity: Establish mechanisms to ensure the accuracy, consistency, and integrity of data throughout the data integration process. Implement data validation checks, data reconciliation procedures, and error handling mechanisms to minimize the risk of erroneous or corrupted data impacting decision-making processes. Compliance with standards such as IEC 61131 and IEEE 1012 is required for data integrity and software verification and validation.
7. Training and Awareness: Provide comprehensive training to personnel involved in data integration processes to enhance their understanding of safety protocols, data handling best practices, and potential risks associated with Intermodal transportation and electric freight. Foster a culture of awareness and proactive engagement in data security and safety practices. Training programs based on standards like IEC 61511 and IEEE 2600 series should be implemented to educate personnel on safety practices and risk management.

Compliance with these safety guidelines is necessary to ensure the secure and reliable integration of data from green digital solutions in the domains of Intermodal transportation and electric freight. It will enable organizations to maximize the environmental benefits and efficiency gains while minimizing risks and ensuring the overall safety of operations.

3.4. Energy Supply Infrastructure

3.4.1. Unattended charging

Unattended charging must ensure automated hazard monitoring via Supervisory Control and Data Acquisition (SCADA) systems, where airside operation control rooms are aware of any malfunctioning of the unattended charging devices. The following set of criteria must be met during the design and operations of the charger:

- Mechanical stability of all components shall be tested by vibrations test (acc. to IEC 60068-2-6, stringency, see proposed standard) and
- Shock test (acc. to IEC 60068-2-27, stringency, see proposed standard) when specimens are not packaged and not live.
- Temperature and humidity resistance shall be defined and tested following the climatic conditions of the target region (IEC 60068-1).

- For application in warm climates, a “cyclical damp heat test” (acc. to IEC 60068-2-30) will be performed with temperatures up to 55°C (not live) and 40°C (at nominal voltage and maximum input and output current).
- Corrosion resistance and long-term stability will be evaluated after this damp heat test.
- Safety requirements shall be evaluated according to IEC 60335-1.
- Insulation resistance shall be tested according to EN 50178 or IEC 60335-1 (section 13.3) with a test voltage of 500 VDC.
- Heat development under maximum power conditions shall not exceed the limits stated in IEC 60335-1.
- Resistance to heat and fire shall be tested according to IEC 60695-2-1 (glow-wire test) and EN 60742, section 26 (ball-pressure test).
- The mechanical sturdiness of the case shall be tested according to IEC 60068-2-75 (stringency, see proposed standard) with a dead stroke hammer of 250 g from certain directions.
- The protection of the case against access to dangerous parts, penetration of foreign bodies, and the entry of water (IP code) shall be tested according to IEC 60529. The minimum requirements are IP 32 for solid-built indoor applications and IP 54 for outdoor and other applications.
- The robustness of terminations and mounting devices shall be tested according to IEC 61215, test 10.14, for expansion, thrust, bending, pressure, torsion, and twisting.

3.5. Smart Energy Hub

3.5.1. Photovoltaic (PV) direct charging

The charge controllers of stand-alone photovoltaic (PV) systems, regulate the current from the PV array to protect the battery from being overcharged. Most controllers regulate the current to the load, ensuring battery health and therefore the safety of humans and other components in the surrounding area. The charge controller is therefore the energy manager in a stand-alone PV system, ensuring that the battery is cycled under conditions that do not represent any health and safety harm to the airport infrastructure and human lives.

For controller performance concerning overvoltage protection and electromagnetic radiation, existing standards for other electrical devices are applicable. For EMI, the European standards IEC61000, IEC 801-2, IEC 801-3, and IEC 801- 4 are also applicable. For electrostatic discharge, IEC 61000-4-2 is applicable.

3.6. Airside operations

3.6.1. Hydrogen fuelled aircrafts

Hydrogen is very flammable and can cause fires and explosions if it is not handled properly. This is also why hydrogen is classified as a dangerous good by ICAO and the safe storage, transport, and handling of gaseous and liquid hydrogen in aviation is controlled by standards and regulations.

The following main challenges for hydrogen at airports have been raised at the 41st ICAO Assembly:

- Deployment of refueling infrastructure: either a light one, by trucks, or significant changes with on-site storage and dedicated H2 facilities. Need to manage the coexistence of liquid hydrocarbon fuels and H2 infrastructures;
- Infrastructure update (e.g. at gate) to accommodate new aircraft concepts (longer fuselage);
- Safety framework to be developed (leakage, firefighting, safe handling of cryogenic H2…); and
- Adaptation of regulations in the airport management system (safety, operations…).

The following main challenges for hydrogen aircraft have been raised at the 41st ICAO Assembly:

- Aircraft design storing important H2 volumes while minimizing performance penalty;
- Master liquid H2 tanks technology with a high enough ratio of H2 mass over system mass;
- H2 high-pressure tanks with increased ratio could allow earlier deployment of smaller aircraft;
- Optimized propulsion: high efficiency, low weight fuel cells, efficient and safe H2 turbines;
- Safe and reliable fuel distribution and components, including sanitizing the system; and - Economics of the aircraft, including potential H2 impact on turnaround time.

The associated ICAO Working Paper [5] motivates that "in all cases, it is necessary to develop suitable regulatory frameworks, and to manage hydrogen losses over the whole supply chain, for safety and economic reasons, and because such losses might induce a climate forcing."

3.7. Electric aircraft

EASA has received several applications for type certification of small non-traditional aircraft with electrical and hybrid propulsion systems. The traditional continuing airworthiness framework is not adequate for these applications, since these aircraft were not considered under traditional current rules at the time EU 1321/2014 with continuing airworthiness requirements was developed.

EASA considers the following gaps in EU Regulation 1321/2014 in Rulemaking Task (RMT) 0731, to create a regulatory framework that would cover also electrical propulsion [8]:

- “With regard to the possible scope of approval for maintenance organizations (all approvals), for the class ‘Engine’, there is no adequate rating for electrical engines, since the only possible ratings are: turbine, piston, and Auxiliary Power Unit (APU). The same applies to the choices regarding the scope of approval of training organizations that are subject to Part-147.
- “When it comes to the full aircraft, considering the title of the Part-66 licenses on categories A, B1, and B3, these are not suitable for electrical airplanes or helicopters. Electrical propulsion is not considered in the Part-66 Basic Knowledge syllabus.”
- “Electrical engine aircraft are not considered when establishing the training levels for each aircraft type in Appendix III of Part-66, except for some ‘L’ subcategories. Also, the existing rules do not take into consideration non-traditional aircraft. This is apparent for Part66 licenses, but also other Parts of Regulation (EU) No 1321/2014 need to be adapted. […]”

Existing (aviation) standards and regulations from ICAO and EC/EASA relevant to the use of electric, hybrid, and hydrogen aircraft in civil aviation are presented and summarized in the following.

3.8. SAF logistics and operations

3.8.1. Hydrogen on airside

Regarding the storage of hydrogen at an establishment, not per se at an airport, a relevant EU directive is already applicable. The Directive is EU 2012/18/EU (Ref. 26) and is meant for the control of major-accident hazards involving dangerous substances. An EU Directive is a legislative act that sets out a goal that all EU countries must achieve; individual countries are however allowed to set up their laws to achieve the goal. The EU Directive aims to prevent and mitigate the effects of major accidents with dangerous substances for storage of hazardous substances including hydrogen. There is a difference made between the lower-tier and upper-tier requirements. The lower tier applies for a quantity of up to 5 tons, it then requires a Major Accident Prevention Policy

(MAPP). The upper tier applies for 50 tons or above, it additionally requires a safety report, emergency response plan, and information to be supplied to local authorities and the public.

Annex III of EU Directive 2012/18/EU presents the elements for implementing a Safety Management System by the operator. In the case of storing or processing hydrogen at an airport, the airport operator is responsible for this. The following elements shall be considered:

“ (a) the safety management system shall be proportionate to the hazards, industrial activities and complexity of the organization in the establishment and be based on the assessment of the risks; it should include the part of the general management system which includes the organizational structure, responsibilities, practices, procedures, processes, and resources for determining and implementing the major-accident prevention policy (MAPP);

(b) the following issues shall be addressed by the safety management system:

(i) organization and personnel — the roles and responsibilities of personnel involved in the management of major hazards at all levels in the organization, together with the measures taken to raise awareness of the need for continuous improvement. The identification of training needs of such personnel and the provision of the training so identified. The involvement of employees and the subcontracted personnel working in the establishment is important from the point of view of safety;

(ii) identification and evaluation of major hazards — adoption and implementation of procedures for systematically identifying major hazards arising from normal and abnormal operation including subcontracted activities where applicable and the assessment of their likelihood and severity;

(iii) operational control — adoption and implementation of procedures and instructions for safe operation, including maintenance, of plant, processes, and equipment, and for alarm management and temporary stoppages; taking into account available information on best practices for monitoring and control, to reduce the risk of system failure; management and control of the risks associated with aging equipment installed in the establishment and corrosion; inventory of the establishment’s equipment, strategy and methodology for monitoring and control of the condition of the equipment; appropriate follow-up actions and any necessary countermeasures;

(iv) management of change — adoption and implementation of procedures for planning modifications to or the design of new installations, processes, or storage facilities;

(v) planning for emergencies — adoption and implementation of procedures to identify foreseeable emergencies by systematic analysis, to prepare, test and review emergency plans to respond to such emergencies, and to provide specific training for the staff concerned. Such training shall be given to all personnel working in the establishment, including relevant subcontracted personnel;

(vi) monitoring performance — adoption and implementation of procedures for the ongoing assessment of compliance with the objectives set by the operator's MAPP and safety management system, and the mechanisms for investigation and taking corrective action in case of non-compliance. The procedures shall cover the operator's system for reporting major accidents or 'near misses', particularly those involving failure of protective measures, and their investigation and follow-up based on the lessons learned. The procedures could also include performance indicators such as safety performance indicators (SPIs) and/or other relevant indicators;

(vii) audit and review — adoption and implementation of procedures for periodic systematic assessment of the MAPP and the effectiveness and suitability of the safety management system; the documented review of the performance of the policy and safety management system and its updating by senior management, including consideration and incorporation of necessary changes indicated by the audit and review."

Further, Annex IV of the Directive addresses the data and information that must be included in the Emergency Plans.

" 1. Internal emergency plans:

(a) Names or positions of persons authorized to set emergency procedures in motion and the person in charge of and coordinating the on-site mitigatory action;

(b) Name or position of the person with responsibility for liaising with the authority responsible for the external emergency plan;

(c) For foreseeable conditions or events which could be significant in bringing about a major accident, a description of the action which should be taken to control the conditions or events and to limit their consequences, including a description of the safety equipment and the resources available;

(d) Arrangements for limiting the risks to persons on site including how warnings are to be given and the actions persons are expected to take on receipt of a warning;

(e) Arrangements for providing early warning of the incident to the authority responsible for setting the external emergency plan in motion, the type of information which should be contained in an initial warning, and the arrangements for the provision of more detailed information as it becomes available;

(f) where necessary, arrangements for training staff in the duties they will be expected to perform and, as appropriate, coordinating this with off-site emergency services;

(g) Arrangements for assisting with off-site mitigatory action.

2. External emergency plans:

(a) Names or positions of persons authorized to set emergency procedures in motion and of persons authorized to take charge of and coordinate off-site action;

(b) Arrangements for receiving early warning of incidents, and alert and call-out procedures;

(c) Arrangements for coordinating resources necessary to implement the external emergency plan;

(d) Arrangements for assisting with on-site mitigatory action;

(e) Arrangements for off-site mitigatory action, including responses to major-accident scenarios as set out in the safety report and considering possible domino effects, including those having an impact on the environment;

(f) Arrangements for providing the public and any neighboring establishments or sites that fall outside the scope of this Directive following Article 9 with specific information relating to the accident and the behavior which should be adopted;

(g) Arrangements for the provision of information to the emergency services of other Member States in the event of a major accident with possible transboundary consequences."

Both internal and external emergency plans are useful for an airport operator to set up its own first responders' firefighting plans.

3.8.2. Transport of hydrogen

Hydrogen can be transported to an airport via pipeline, via rail, and road. For these different modes of transportation, some current regulations regarding safety are applicable. EU has Directive 2008/68/EC on the inland transport of dangerous goods (Ref. 27).

For rail transport of hydrogen stored in Fibre Reinforced Plastics tanks (see Figure below), the UN-Model regulations Rev. 22 (2021) (Ref. 28) is applicable. This includes a set of amendments to the Model Regulations on the Transport of Dangerous Goods (see ST/SG/AC.10/48/Add.1), concerning, inter alia:

- Electric storage systems (including modification of the lithium battery mark and provisions for the transport of assembled batteries not equipped with overcharge protection);
- Requirements for the design, construction, inspection, and testing of portable tanks with shells made of fiber-reinforced plastics (FRP) materials;
- Listing of dangerous goods; and
- Harmonization with the IAEA Regulations for the Safe Transport of Radioactive Material.

For road transport of hydrogen stored either in horizontal tubes or in vertical Multiple Element Gas Containers (MEGCs) existing national regulations are applicable. For transport in cryogenic or refrigerated or liquid form, the hydrogen is classified as dangerous goods by road according to UN 1966 (Ref. 29).

For pipeline transport of hydrogen, only pressurized in gas form is considered. This is no different than the existing pipeline transport of natural gas. However, technical and safety concerns related to pipeline transmission of gaseous hydrogen are still needed to be addressed and research for these are needed. These concerns (reference 30) include:

- the potential for hydrogen to embrittle the steel and welds used to fabricate the pipelines and the existing pipeline structure;
- the need to control hydrogen permeation and leaks; and
- the need for lower cost, more reliable, and durable compression technology.

The technical and safety standards are not in place. As referred to in [30], converting existing natural gas pipelines to deliver pure hydrogen may require substantial modifications. A possibility for rapidly expanding the hydrogen delivery infrastructure is to adapt part of the natural gas delivery infrastructure. Another possibility is to convert natural gas pipelines to carry a blend of natural gas and hydrogen (up to about 15% hydrogen); this may require only modest modifications to the existing pipeline.

It is unlikely to transport cryogenic hydrogen using a pipeline due to physical characteristics (-253 degree Celsius) (reference 31)

3.8.3. Airside Electrification

To enable electrification at the airside, different options can be considered for electric charging of high-capacity batteries (reference 32):

- recharge by fixed ground chargers, also known as charging stations;
- recharge by the mobile supercharger on batteries (truck or trailer); and
- battery swap at the gate (batteries are recharged separately).

Some (limited) references and standards on aircraft charging are available at SAE AE7-D Aircraft Energy Storage and Charging Committee. Specific procedures, standards, and guidance for airport / airside operations are still to be developed.

3.9. Green air and land

It has been observed that there is currently a lack of specific standards in place for addressing the potential risks posed by outdoor ultrafine particles (UFP) to airside workers in the context of technical demonstrations for Green Air initiatives. However, the World Health Organization (WHO) has published the Global Air Quality Guidelines, which encompass various parameters such as PM2.5, PM10, ozone, nitrogen dioxide, and others. While these guidelines do not specifically cater to airside occupational health and safety, they can serve as a valuable point of reference to ensure the well-being of workers involved in such activities.

Furthermore, a study conducted by the Defra/Air Quality Expert Group in the United Kingdom has made references to two standards: ISO 7708:1983 and EN 12341:2014. It is important to note that the latter standard is anticipated to be replaced by a revised version in 2022, which is currently under development. However, it should be emphasized that both references or standards were not explicitly designed to address the specific challenges faced in airside operations. ISO 7708:1983 provides guidelines for health-related sampling, while EN 12341:2014 presents sampling curves primarily for regulatory purposes.

3.10. Existing regulations and standards

International Civil Aviation Organization (ICAO)

Relevant ICAO standards and guidance material for the transport of dangerous goods by air include:

- ICAO Annex 18 The Safe Transport of Dangerous Goods by Air
- ICAO Doc 9284 Technical Instructions for the Safe Transport of Dangerous Goods By Air
- ICAO Doc 9284SU; Supplement to the Technical Instructions for the Safe Transport of Dangerous Goods by Air,
- ICAO Advisory Circular (AC) 102-37 - UAS Carrying Dangerous Goods

Dangerous goods are any articles or substances which are capable of posing a hazard to health, safety, or property of the environment, and which are listed as dangerous goods in the ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air (ICAO Doc 9284), known as the 'Technical Instructions', or which are classified as such according to the Technical Instructions.

Hydrogen and certain types of batteries for electric aircraft are therefore categorized as dangerous goods and the ICAO standards and guidelines apply to their transport by air and the transport to/from airport infrastructure(s). However, dangerous goods required to be on board the aircraft for propulsion or which are required by the pertinent operating requirements are generally not considered as transported dangerous goods. Nevertheless, Annex 8 Airworthiness of Aircraft and

Annex 16 Environmental Protection does not provide standards covering such aircraft types. ICAO is monitoring the developments for these new entrants and the need for new standards.

The Technical Instructions Manual (Doc 9284) and its supplement contain the source of regulations for the safe transport of dangerous goods. Shippers, operators, State authorities, and anyone else involved in the air transport chain will find in this manual all of the detailed regulations necessary for the safe transport of dangerous goods in aviation, including to and from airport infrastructure(s).

ICAO follows the industry developments in electric and hybrid aircraft designs using the Electric and Hybrid Aircraft Platform for Innovation (E-HAPI) [4]. This website contains a list of relevant projects, ranging from general aviation or recreational aircraft; business and regional aircraft; large commercial aircraft; and vertical take-off and landing (VTOL) aircraft. Most target an entry-in-service date between 2020 and 2030, and some are already commercially available.

European Aviation Safety Agency

Relevant EASA documentation includes the following:

- EASA; Final Special Condition Electric / Hybrid Propulsion System (EHPS) [10];
- EASA; Special Condition Electric Propulsion Powerplant for CS LSA airplanes, SC-LSA-15-01 [11];
- EASA; Special Condition Light Sports Aircraft Propulsion Lithium Batteries, SC-LSA-F2480-01 [12]
- EASA; General AMC for Airworthiness of Products, Parts, and Appliances (AMC-20), Amendment 23 on Certification of Aircraft Propulsion Systems Equipped with Electronic Control Systems [14].

The EHPS special conditions provide the certification requirements for an Electric and/or Hybrid Propulsion System when the intended aircraft application has already been identified. The EHPS SC applies to any EHPS used to provide or produce lift/thrust/power for flight in a manned and unmanned aircraft, during both normal and emergency operations, except for CS-22, CS-LSA, CS-23 Level 1 Day VFR, and Light UAS. It should be noted that for CS-25 aircraft, this Special Condition shall be complemented with appropriate emissions requirements that are yet to be defined for EHPS.

Designs that include the use of hydrogen, whether used to feed fuel cells or combustion engines are currently considered outside the scope of the EHPS Special Condition. EASA stated [10] that these designs require further work and research before defining the associated certification requirements.

CS-LSA Amendment 1 [11] provides a full set of requirements for the certification of an LSA Electric Propulsion Unit (EPU) powerplant, starting from the ASTM standards F2245-12d (Standard Specification for Design and Performance of a Light Sport Airplane) and ASTM F2840-11 (Standard Practice for Design and Manufacture of Electric Propulsion Units for Light Sport Aircraft).

The LSA Propulsion Lithium Batteries Special Condition [12] establishes airworthiness standards for lithium batteries used for electric propulsion for Light Sport Aircraft (LSA). It states requirements that the LSA Propulsion batteries design and installation must comply with to address their specific failure and operational characteristics and introduces maintenance requirements for safety.

EASA AMC 20-136A Aircraft Electrical and Electronic System Lightning Protection provides an AMC for demonstrating compliance with the certification specifications (CSS) related to system lightning protection (CS 23.1306/2515, CS 25.1316, CS 27.1316, CS 29.1316). It addresses effects on electrical and electronic systems due to lightning transients induced or conducted onto equipment and wiring.

EASA AMC 20-158A Aircraft electrical and electronic system high-intensity radiated fields (HIRF) protection provides an AMC for demonstrating compliance with the CSs related to high-intensity radiated fields (HIRF) protection (CS 23.1308, 25.1317, 27.1317, and 29.1317).

3.11. Deployability based on Machinery Safety

The legal basis of the Machinery Directive is provided by Article 95 of the EC Treaty (now replaced by Article 114 of the Treaty on the Functioning of the European Union - TFEU) which enables the EU to adopt measures to harmonize the legislation of the Member States to ensure the establishment and functioning of the internal market. Such measures must take as a base a high level of protection of the health and safety of people and the environment. The Machinery Directive thus has a dual objective: to permit the free movement of machinery within the internal market whilst ensuring a high level of protection of health and safety.

The protection of health and safety is both a fundamental duty and a prerogative of the TULIPS work package leaders. Since the Machinery Directive harmonizes the health and safety requirements for the design and construction of any machinery at EU level. Every successful demo should present a risk assessment matrix according to EC Machinery Directive before is cleared for deployment in the real environment.

The risk assessment should be conducted according to EN ISO 14121. Fulfillment of this requirement is mandatory for a demo to be eligible to be deployed or scaled into different airports.

ISO 14121-1:2007 establishes general principles intended to be used to meet the risk reduction objectives established in ISO 12100-1:2003, Clause 5. These principles of risk assessment bring together knowledge and experience of the design, use, incidents, accidents, and harm related to machinery to assess the risks posed during the relevant phases of the life cycle of a machine.

ISO 14121-1:2007 provides guidance on the information that will be required to enable risk assessment to be carried out. Procedures are described for identifying hazards and estimating and evaluating risk. It also gives guidance on the making of decisions relating to the safety of machinery and on the type of documentation required to verify the risk assessment carried out.

Refer to Annex: Risk Assessment matrix to identify hazards and required risk mitigations to deploy demos in their final environment.

4. Conclusion

This document provides the necessary background and references to an Excel Sheet that lists the key criteria for deployments/commercialization, intended for use as a first step by WP leaders and airports that may consider deploying any of the solutions.

Every Work Package responsible partner should fulfill a safety risk assessment of the component or subsystem under test, the safety assessment matrix is going to be analyzed by NLR safety experts, and only after this clearance the demo shall be deployed on its final operational environment.

Primarily, this is achieved through a common set of the most important criteria any partner airport (or external partner) will want to assess to determine if a particular demo/project is deployable through their organization/airport. By identifying and standardizing these criteria, both airports and project leaders may determine what areas are affecting their deployability or scalability positively and negatively.

The criteria itself is split into common major areas that help to determine product-market fit, as well as achieve an estimation of the general risk of a project. The methodology used to determine the criteria was determined through extensive online research, meetings with the WP9 RSG Liaison, partner airports, and expert consults within Beta-i.

While not intended as a final document, this now serves as the basis for continued assessment of each demo project's technology to establish a basic picture of a technology's commercial attractiveness, which areas are of most importance to an airport organization when determining deployability, and what nuances need to be further accounted for.

Particular attention was paid to the fact that there are 17 very varied demos. For this reason, the Key Criteria and sub-criteria were kept quite broad; to apply (in general terms) to all potential demos. These are intended to be iterated upon as the demos are performed and more data is available.

Finally, it is very likely this methodology overall may be iterated on as project leads and other stakeholders provide more feedback and insight. In that case, the links provided here may be revised and/or broken into varying categories (for example, for Prospective vs Effective demos, or one for each airport).

LIST OF REFERENCES

1. Isaac Animah, M. Shafiee, "A framework for assessment of Technological Readiness Level (TRL) and Commercial Readiness Index (CRI) of asset end-of-life strategies" [Online]. Available: https://www.researchgate.net/publication/329695459_A_framework_for_assessment_of_Technological_Readiness_Level_TRL_and_Commercial_Readiness_Index_CRI_of_asset_end-of-life_strategies. [Accessed 10 Dec 2022].
2. FormLabs, "Validation Testing in Product Development" [Online]. Available: https://formlabs.com/eu/blog/validation-testing-product-development-poc-evt-dvt-pvt-mp/. [Accessed Dec 10, 2022].
3. NASA, "Procedures & Guidelines - Chapter 3. Formulating a Technology Commercialization Strategy and Plan" NPR 7500.1. Available: https://nodis3.gsfc.nasa.gov/displayCA.cfm?Internal_ID=N_PR_7500_0001_&page_name=Chp3. [Accessed Dec 10, 2022].
4. ARENA (Australian Renewable Energy Agency), "Commercial Readiness Index for Renewable Energy Sectors". Available: https://arena.gov.au/assets/2014/02/Commercial-Readiness-Index.pdf. February 2014. [Accessed Dec 10 2022].
5. Nathasit Gerdsri and Nisit Manotungvorapun. "Readiness Assessment for IDE Startups: A Pathway toward Sustainable Growth". 11 Dec 2021. [Accessed Dec 10 2022].
6. Prof David Wallom, "Market and Technology Readiness Level (MTRL) methodology and assessments (Draft/V1)" [Online]. Available: https://swforum.eu/sites/default/files/2022-05/D4.4%20-%20MTRL%20Methodology%20and%20Assessments%20V1.0%20DRAFT.pdf. [Accessed Jan 2, 2023].
7. NASA, “Technology Readiness Level,” NASA, 28 October 2012. [Online]. Available: https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level. [Accessed Nov 28 2022].
8. ICAO Annex 18; Annex 18 - The Safe Transport of Dangerous Goods by Air, 4th Edition, July 2011
9. ICAO; Technical Instructions for the Safe Transport of Dangerous Goods By Air, Doc 9284;
10. ICAO; Supplement to the Technical Instructions for the Safe Transport of Dangerous Goods by Air, Doc 9284SU

11. ICAO; Electric and Hybrid Aircraft Platform for Innovation (E-HAPI), available at: https://www.icao.int/environmental-protection/Pages/electric-aircraft.aspx
12. ICAO Assembly 41; Hydrogen, a key solution to decarbonize aviation, presented by Netherlands and France for Item 17: Environmental Protection - International Aviation and Climate Change
13. EU Regulation 1321/2014 of 26 November 2014 on the continuing airworthiness of aircraft and aeronautical products, parts and appliances, and on the approval of organizations and personnel involved in these tasks (OJ L 362, 17.12.2014, p. 1)
14. EU Regulation 748/2012 of 3 August 2012 laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts, and appliances, as well as for the certification of design and production organizations (OJ L 224, 21.8.2012, p. 1
15. EASA; Terms of Reference for rulemaking task RMT.0731, New air mobility, 2020
16. EASA's type certification of a fully electric aircraft, available at https://www.easa.europa.eu/light/topics/easas-type-certification-fully-electric-aircraft
17. EASA; Final Special Condition Electric / Hybrid Propulsion System, SC E-19, Issue 1, 07/04/2021.
18. EASA; Special Condition Electric Propulsion Powerplant for CS LSA airplanes, SC-LSA-15-01, Issue 1, 13/02/2019
19. EASA; Special Condition Light Sports Aircraft (LSA) Propulsion Lithium Batteries, SC-LSA-F2480-01
20. EASA; General Acceptable Means of Compliance for Airworthiness of Products, Parts, and Appliances (AMC-20), Amendment 23 on Certification of Aircraft Propulsion Systems Equipped with Electronic Control Systems, 21 January 2022
21. EASA; Presentations Electric & Hybrid Aviation Project Workshop, 2019
22. K. Sarsfield; Pipistrel Velis Electro earns first all-electric aircraft type certification," FlightGlobal, available at https://www.flightglobal.com/news/pipistrel-velis-electro-earns-first-all-electric-aircraft-type-certification/138779.article
23. A.K. Karwal, M.K.H. Giesberts; Safety aspects of electric flight operations, Royal Netherlands Aerospace Centre, NLR-CR-2020-286, May 2021
24. R.C. van Benthem(1), A.I. de Boer(2), J. van der Vorst(3), W.B. van Doorn(4); Hydrogen drone research aircraft, Royal Netherlands Aerospace Centre, Aerospace Europe Conference 2020, Bordeaux, France, 25 – 28 February 2020
25. W.F. Lammen, B. Peerlings, E.S. van der Sman, J. Kos; Hydrogen-powered propulsion aircraft: conceptual sizing and fleet-level impact analysis, NLR-TP-2022-233, September 2022

26. W.F. Lammen, W.J. Vankan; Electrification studies of single-aisle aircraft - A 'retrofit' investigation including parallel hybrid electric propulsion, NLR-TP-2019-312, July 2019.
27. Dutch Safety Board, Fatal loss of control accident with a Pipistrel Alpha Electro near Stadskanaal airfield, (2020).
28. AIAA, Guidelines for Analysis of Hybrid Electric Aircraft System Studies, (2019).
29. NASA, A NASA Approach to Safety Considerations for Electric Propulsion Aircraft Testbeds, Papathakis, K., Sessiosn, A., Burkhardt, P. and Ehmann, W., AIAA, (2017).
30. Visvikis, Costandinos, Safety considerations for electric vehicles and regulatory activities, 26th Electric Vehicle Symposium (EVS), (2012).
31. CITELEC, Bossche, P. van der, Safety Considerations for Electric Vehicles, EVS, (2017).
32. MIT International Center for Air Transportation, Courtin, C. and Hansman, J., Safety Considerations in Emerging Electric Aircraft Architectures, 18th AIAA Aviation Technology, Integration and Operations Conference, Atlanta, (2018).
33. Directive 2012/18/EU of the European Parliament and the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC.
34. Directive 2008/68/EC of the European Parliament and the Council of 24 September 2008 on the inland transport of dangerous goods.
35. UN Model Regulations Rev. 22 (UN Model Regulations Rev. 22 (2021) | UNECE)
36. UN 1966
37. https://www.energy.gov/eere/fuelcells/hydrogen-pipelines
38. Omgevingsveiligheid van toekomstige stromen waterstofrijke energiedragers, TNO, Arcadis and Berenschot, Report no. 68008, 26 January 2023.
39. ACRP, Preparing your airport for electric aircraft and hydrogen technologies (2022), Report 26512.

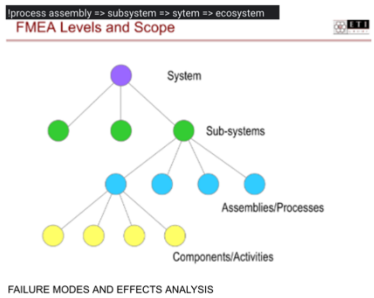
KEY CRITERIA MTRL ASSESSMENT MATRIX

The key selection criteria matrix is to be used for assessing deployability after risk assessments and safety compliance with machinery directives are verified by Airport operations authorities. The matrix incorporates a first sheet with instructions:

Instructions

1. Name your Excel File as follows "WPx_Demo y_ MTRL Assessment"
2. Fill in the tab "Self Assessment - MTRL 4 or low"
2.1 IF the score is above 5 proceed to next step (step 3), otherwise proceed to step 4
3. Fill in the tab "MTRL Assessment 5+"
4. Notify via email WP9 that you have finished your technological readiness assessment

FMEA Level of assessed demonstrator	Select
System	
Sub system	
Assembly	
Component	



A second sheet with a self-assessment to be performed by WP leaders and assessed by Airport operations to determine whether the demo is eligible to be deployed in its relevant environment under controlled conditions for test purposes.

A	B	C	D	E
HOW TO USE:		Select from dropdown 👇	Provide further detail	How confident are you in this area?
Area	Criteria	Rating (1:loosely defined, 3:very well defined)	Detail / Findings	Fact Strength (1 = Low to 3 = High)
	Market Definition	1		3
MARKET	Market Size (Serviceable Avail. Market)	2		3
	Market CAGR	1		3
	Customer Segment			
CUSTOMER	Time & Cost Requirements for Customer			
	Ability to Charge Premium?			
	Competitor Landscape			
PRODUCT	Competitive Advantage / Differentiation			
	Technology Type			
	Projected Pilot Initial Cost (approx.)			
SCALABILITY	Projected Pilot Ongoing Costs (per year)			
	Projected Deployment Time			
	Projected Deployment KPIs			
	Technology Readiness Level			
MATURITY	Years In Operation (of Parent Org if appl.)			
	Yearly Turnover (of Parent Org if appl.)			
	IP Ownership			
INVESTMENT RISK	Dependent on Mandates/Policies?			
	Level of In-House Support Required			
	Priority Level of Tech Deployment / Impact to Airport Goals			

Instructions | Self Assessment - MTRL 4 or low | MRTL Assessment 5+

A third sheet with scored criteria to determine the market and technology readiness of the demo to be eligible to deploy at its final operational environment. The criteria assess the potential to be scaled to other airports.

		Score here from 1 to 5 each criteria	[DO NOT CHANGE]	$TRLscore = \begin{cases} q_2 + 4, & (q_2 \ge 2) \\ q_1, & otherwise \end{cases}$			$MRLscore = \frac{9 \times \Sigma(q_i \times w_i)}{5 \times \Sigma w_i}$		
DIMENSION	**CRITERIA**	**SCORE**	**WEIGHT**	**Q1**	**Q2**	**TRL**	**Qi**	**MRL**	**MTRL**
(A) Product Maturity	1. Project work is beyond basic research and technology concept has been defined. Principles observed but no experimental proof available.	1	N/A	2	N/A	#DIV/0!	N/A	N/A	
	2. Applied research has begun and practical applications have been formulated.	2							
	3. Preliminary testing of technology components has begun in a laboratory environment. Proof of concept.	4							
	4. Initial testing of integrated product has been completed in a laboratory environment. Early prototype.	5							
	5. Integrated product demonstrates performance in the intended environment. Large scale prototype	1							
(B) Product Development	1. Initial product/market fit has been defined.			N/A	#DIV/0!				
	2. Pilot scale product has been tested in the intended environment close to the expected performance.								
	3. Demonstration of a full scale product prototype has been completed in operational environment								
	4. The manufacturing issues has been solved and a first commercial product/service exists.								
	5. Product/service is available for all consumers.								
(C) Product Definition/Design	1. One or more initial product hypotheses have been defined.		3	N/A			#DIV/0!		
	2. Mapping product attributes against customer needs has highlighted a clear value proposition.								
	3. The product has been scaled from laboratory to pilot scale and issues that may affect achieving full scale have been identified.								
	4. Comprehensive customer value proposition model has been developed, including a detailed understanding of product design specifications, required certifications, and trade-offs.								
	5. Product final design optimization has been completed, required certifications have been obtained and product has incorporated detailed customer and product requirements.								
(D) Competitive Landscape	1. Market research has been performed and basic knowledge of potential applications and competitive landscape have been identified.		5	N/A			#DIV/0!		
	2. Primary market research to prove the product commercial feasibility has been completed and basic understanding of competitive products has been demonstrated.								
	3. Comprehensive market research to prove the product commercial feasibility has been completed and intermediate understanding of competitive products has been demonstrated.								
	4. Competitive analysis to illustrate unique features and advantages of the product compared to competitive products has been completed.								
	5. Full and complete understanding of the competitive landscape, target applications, competitive products and market has been achieved.								
	1. No team or organization (single individual, no legal entity).								

Instructions | Self Assessment - MTRL 4 or low | MRTL Assessment 5+

Deployability assessment plays a vital role in determining the feasibility and effectiveness of introducing new technologies in aviation systems. The matrix assists in evaluating the deployability of TULIPS technologies, considering critical factors such as safety, market, and technological readiness as well as a holistic scalability assessment performed by Airports depending on its operational models to determine whether a successful demo in one airport might be deployed in another one. This approach considers multiple key criteria that impact the successful integration and operation of new systems within an airport environment.

RISK ASSESSMENT MATRIX

The ISO 12100 risk assessment matrix is a tool for conducting a comprehensive risk assessment by Machinery Directive safety requirements. In the context of ensuring a safe deployment of the TULIPS demos in its final environment, adhering to this standard becomes crucial.

Table B.2 — Risk assessment (risk estimation and risk evaluation) and risk reduction

Risk assessment (risk estimation and risk evaluation) and risk reduction

Machine | Analyst
Sources | Version
Extent | Date
Method | Page

Abbreviations:
S — S severity S1 slight S2 serious
F — F exposure F1 seldom F2 frequent
O — O probability of occurrence of the hazardous event O1 very low O2 feasit
A — A possibility of avoidance A1 possible A2 impossible
RI — Risk index: from 1 (min.) to 6 (max)

Ref. no.	Risk estimation (initial risk)					Risk reduction Protective measures	Risk estimation (after risk reduction)					Further risk reduction required	Ref .no.
	S	F	O	A	RI		S	F	O	A	RI	Y / N	
1													1
2													2
3													3
4													4
5													5
6													6
7													7
8													8
9													9

The risk assessment process involves the following steps:

Step 1: Identify Hazards - Thoroughly identify and list all potential hazards associated with the TULIPS demo. Hazards may include mechanical, electrical, or operational risks that could pose harm to personnel, equipment, or the environment.

Step 2: Evaluate Hazards - Assess the severity of each identified hazard. Consider the potential consequences in terms of injury, damage, or negative impacts on the TULIPS demo and its surroundings.

Step 3: Determine Risk - Evaluate the probability of each hazard occurring and the level of exposure to it. This step helps determine the overall risk associated with each hazard.

Step 4: Establish Risk Reduction Measures - Identify and implement appropriate risk reduction measures. These may include engineering controls, safety devices, warning labels, training procedures, or administrative controls to mitigate or eliminate the identified risks.

Step 5: Residual Risk Assessment - Reassess the residual risks remaining after implementing the risk reduction measures. Determine if the remaining risks are acceptable and within the predefined safety limits.

Step 6: Documentation - Maintain comprehensive documentation of the risk assessment process, including hazard identification, risk evaluation, risk reduction measures, and residual risk assessment. This documentation serves as evidence of due diligence and helps ensure compliance with safety regulations.

Step 7: Review and Update - Periodically review and update the risk assessment as necessary. This ensures that the assessment remains relevant and up-to-date with any changes in the TULIPS demo or its operating environment.

By following the ISO 12100 risk assessment matrix and performing a thorough risk assessment according to the Safety Machinery Directive, the TULIPS demo can be ensured to meet the required safety standards. This systematic approach helps identify and address potential hazards, mitigate risks, and create a safe environment for the successful deployment of the TULIPS demo in its final operating environment.