33RD CONGRESS
OF THE INTERNATIONAL COUNCIL
OF THE AERONAUTICAL SCIENCES
STOCKHOLM, SWEDEN, 4-9 SEPTEMBER, 2022

DESIGNING SUSTAINABLE AVIATION SOLUTIONS WITH DIGITAL TWIN APPROACH

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Abstract

The aviation industry outlook has changed dramatically since 2019. The pandemic situation has impacted the airlines and passenger amounts and changed the outlook of the future. Prior to this situation the industry had faced a challenge in confronting the climate change and pursuing the sustainable solutions for the industry. Disruption in these fronts calls for actions to provide solutions and ways forward as part of the future transport solutions. It is proposed that the effort in research should be interlinked with the industry to accelerate and make possible the utilization of research results in future solution in smart mobility and accessibility including the future air transport. One of the key actions is to provide smooth access to and from airfields in which the energy efficiency and sustainability are key design points. In this paper we elaborate the airport operations with infrastructure solutions that provide end-to-end solutions of the operations with zero emissions target. The design is based on digital twin that encompasses the elements crucial in designing such a system on infrastructure and functional viewpoint. Key parameters are based on data and dynamically modelling the operations in an airport and its support processes.

Keywords: Digital twin, infrastructure, logistics, electric flight

1. Introduction

Aviation has faced the disruption that changes the industry landscape dramatically. This calls for novel solutions and practices to addresses the needed changes. Tampere Region has been developed as a modern center of aviation sector for all the disciplines related to aviation. This process is coordinated by the newly established Tampere University, now including all the three previous higher education institutions in Tampere. These partners have joined with the aviation industry under AiRRhow alliance to innovate, promote and implement education and training for all the sectors of aviation including training & simulations, aviation infrastructure development, digitalization of aviation as well as aviation operations – on the ground and in the air (www.airrhow.fi).

The alliance has identified three research directions which are in the focus in creating novel solutions, namely smart mobility, new energy and advanced manufacturing and materials. In this paper we develop the smart mobility solution with the help of digital twin for electrified operation across all functions at airport. We provide concept in which we envision the infrastructure needs for operations in energy, communication (bandwidth, throughput, sensitivity) and economic efficiency of proposed system in pilot training center scenario.

The aim has been set high – renewing the base for smart mobility. The base refers to current operational models used in the transport industry in particular accessing the airports and hubs of transport. Renewing in a current situation where the climate control calls for sustainable

development across all fields and pandemic has changed the outlook how the future travels are envisaged. The tools to create means for renewing are needed and are based on research foundation laid in the areas of smart mobility, energy solutions and advanced materials sciences. Our research basis builds on international research network and co-operation which is connected to industrial developments in Finland with Finnish companies. The aviation related research collaboration has been set-up in numerous research projects over the years and key contributions of these efforts are being brought together.

2. Digital twin

2.1 Definition

This collaborator network is new public private partnership which assumes close collaboration and swift transfer of research findings to the use of industry and service providers of public services alike. This close collaboration is built on continuous integration type of approach, known from software industry which assumes ability and possibility to quickly test and choose proper mechanisms in use for society. As an example, when planning the people flow across the city and transport hubs one can assume simulated tests to be evaluated in real world situation using the digital twin approach. This also allows one to test and experiment several even competing solutions [Fig. 1].

The modeling of a full system is implemented in digital twin which allows modelling of the physical in virtual world and simulating the dynamic operations with several parameters. These parameters are defined in implementation level and they go beyond the traditional Building Information Modeling (BIM) model [1]. This interplay of digital and physical allows one to device suitable solutions in digital domain feeding back the results of design in continuous development cycles. The richer the model becomes the more revealing dependencies become visible [2]. The applications in automation industry in component or process level have emerged [3]. Also, in 5G communications development the approach has been applied [4]. There are also airport operations which take advantage of digital twin approach. In this study the plan is to take the digital twin further with system on system approach and targeting specifically to future electric airport operations in all fronts. We take an infrastructure view and will take into account the requirements identifiable in the roadmap for reference architecture. The reference architecture will encompass different characteristics, namely, technical, economical and societal.

Sustainability targets in the project are set forth considering the logistics, accessibility and efficiency in all operations related to airport. Socio-economic necessity of flying is present in environment with long distances and this fact is factored in the model.

2.2 Characteristics

Characteristics to design sustainable transport system is a complex and multidimensional space. The space has been divided in three domains that are represented by different artefacts. The domains represent from our view the most relevant issues to be discussed. The artefacts represented are a matter of continuous development which exhibit themselves during the design process.

2.3 Software and Platform view

One of the key success factors in using the digital twin is to be able to incorporate needed elements into same digitally representable mode. This has been achieved through different features of system that contribute to the system. In case of electrical networks, the needs on modelling are narrowed down to have control over parameters that are most important from regional development and further will contribute to the decision making. In this case one will for example need to define needed capacity in demand side in kW (MW), which in turn on production side is drawn from storage eg.

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battery 24 MWh and the solar farm of 2 MW or the distribution network. Defining these dependencies will further dictate the need of cabling, control, and other critical factors for final implementation. It is possible to dive deeper in technical parameters describing the electricity network use but that is left out from this study.

Figure 1 – Thematic operational areas of Tampere-Pirkkala airport.

2.4 Reference architecture

The initial task in a process is to define a reference architecture. The reference architecture is a system of systems description which outlines the logical and functional elements in our case of an airport. An airport function maybe ground handling, passenger security services, transport of goods to the airport [4]. These are part of a logical architecture which describes the people flow, parcel flow, and so on which typically could be a service that a user acquires.

Reference architecture is a common point of reference in describing the end state big picture of all elements of the system. It is possible then to define and build suitable solutions to overall system and study their impact on system level. This also allows one to define certain principles that different providers would then follow in respective implementations of the architecture.

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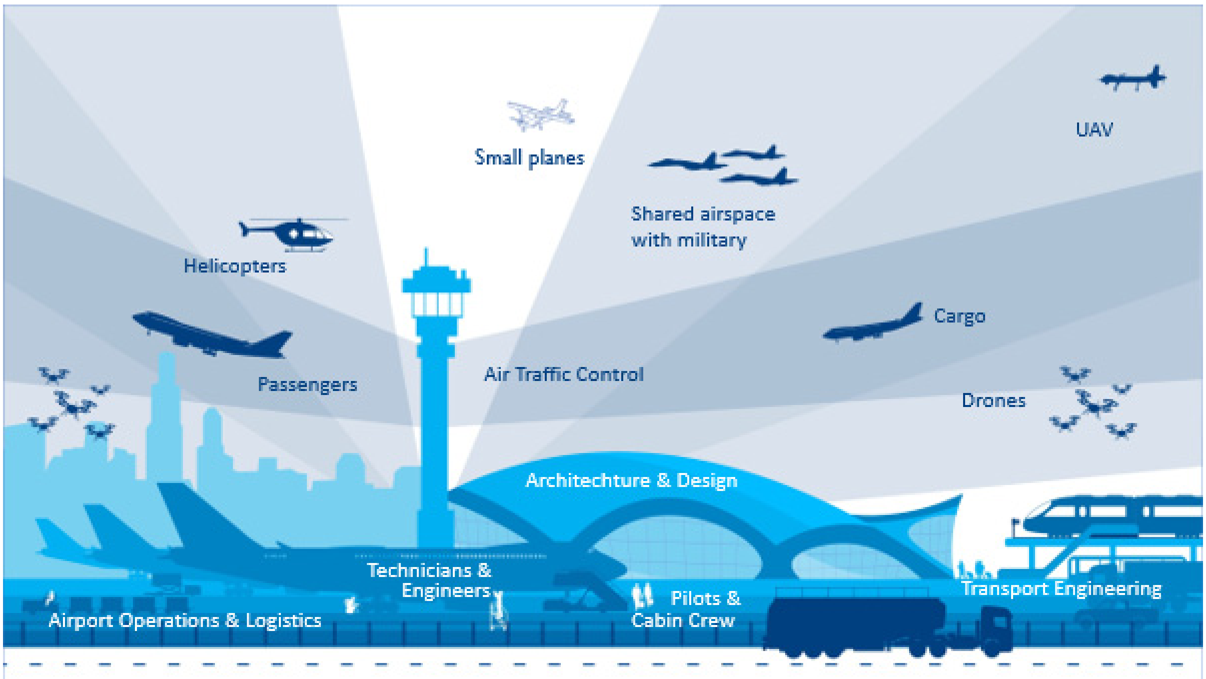

Figure 2 – Reference architecture with key operations at site

In this description of reference architecture main focus in the first phase is the Airport operations and logistics, Small planes (training operations) and the Transport engineering [Fig. 2].

3. System view

3.1 Technical

The start of analysis in this study is divided in technical, economical and societal aspects. To start with the technical aspects of interest are considered first. it should be noted that these areas are not by any means isolated from each other.

Technical considerations and research in sustainable airport operations includes:

- safe and efficient solutions, passenger safety including health, air quality inside and outside [5]
- smart logistics, accessibility of transport operations
- digital solutions for traffic optimization (passenger and parcel movement) both in and out of hubs
- connectivity to and from the cities and other locations
- connectivity between the devices (planes, tower, passenger, maintenance)
- alternative solutions for medium and small airports and hubs, concepting the mesh connectivity paradigm
- on-demand solutions for mobility needs

In particular the energy and infrastructure thereof is of interest. The topics depicted are

- electric aviation, hydrogen address the fuel and fuel logistics
- electric aviation with solutions for ground operations (recharge, maintain, logistics and safety)
- capacity of ground operations to support electric aviation/hydrogen operated aircraft

and vessels

The model is designed and presented in functional model. Interlinked developments will be carried out and hosted in shared facilities within the university and local airfield which currently hosts a center for aviation operations. This center is an educational hub for creating professionals for the field and is planned to be used as a living lab for this joint effort.

3.2 Economical

The economical view on the system is crucially important in trying to understand the impacts of developed solutions in large scale. At times this can be difficult task to model into a Digital twin implementation especially trying to model more abstract phenomena such as usability or consumer acceptance. Physical and more tangible parts of the system can be modelled and with good certainty they also predict the total cost of ownership, investment size and typical maintenance need of operation.

3.3 Societal

The people flow and related services and solutions are important in bringing the research results into use and to understand the impacts of the solution. This area covers the wide variety of operations found in transport hub and therefore assumes complex systems of systems approach. Inherently, there will be an impact on society how the practices for example for patient care helicopter emergency service or passenger's security systems are carried out [6].

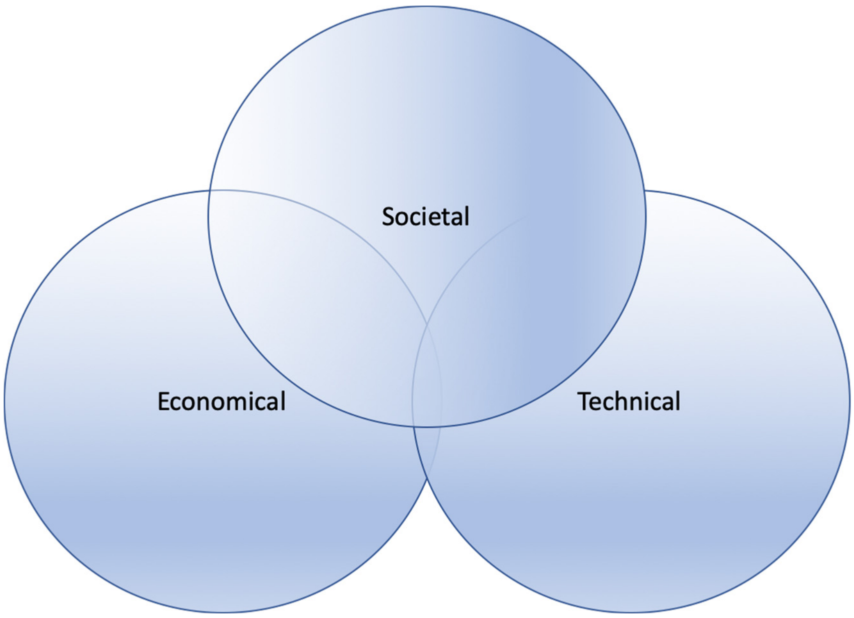

Figure 3: Impact domains of system

As with any new service one needs to gain the acceptance of users at large. This implies acceptance in several different levels including the environmental concerns, feeling secure and accessible to all. An example of a new service currently seeking general acceptance is drone based services that create a disruption in technical economical and societal levels at the same time tangled into dependencies that currently are being explored.

4. Infrastructure

4.1 Description of site and considerations

For building the digital twin model there are several approaches in use depending on the system at hand. In this case the data driven modeling approach has been advocated. In the data driven approach the collected data is the representation of physical world including the known and unknown phenomenon. The data sources are multiple and amounts of data are vast [7]. To control the environment, one needs to use efficient computing platforms, Machine Learning (ML), real time data collection, sensor fusion, and real-time communications 5G.

Actions:

1. Crete digital twin for planning and operational use
2. Air navigation services in shared space
3. Education and training of air traffic controllers, pilot, ground staff using virtual environments
4. Integration of existing virtual environments to one single use space

In our Digital twin we have created a model which represents the subsystems view of the most crucial parts of the complete system. This view is composed of energy perspective of the airport operations envisaged. The system has been divided into subsystems namely, Building energy, Transport, Flight operations, and Energy supply subsystem. The system view assumes a control that maybe distributed or centralized in nature. In both cases the communications part is a crucial element in full scale Digital twin implementation.

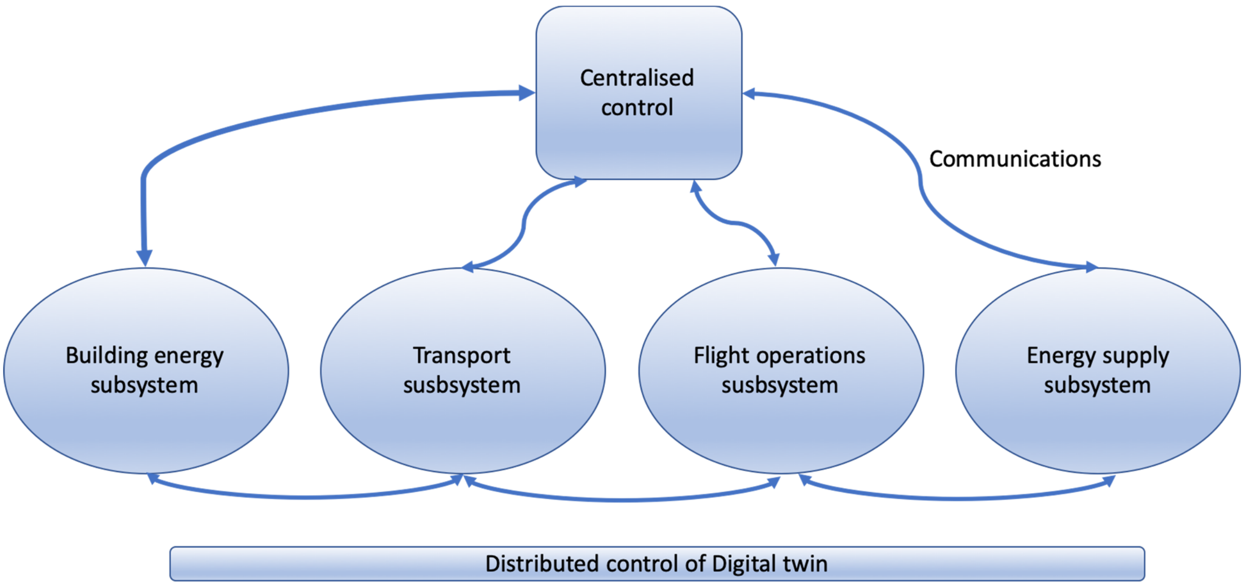

Figure 4: Logical view on the system

4.2 Energy subsystem

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The building energy subsystem consists of different building operations at site. There are different types of building for various operations at the airport. At this point of time the airport terminal operations are in focus. Much of energy use in this facility is heating and power used in different operations varying from restaurant, baggage handling, conveyor systems and so forth. The representation of subsystem is of interest also for the capacity to provide sensor information about operations and surroundings including for example weather. This information along with energy use is of interest to Digital twin implementation. Furthermore, it can be that the information flow is third party provided in which case the subsystem acts as an aggregator.

One source for this data in this case is a local meteorological center which can provide multitude of data points.

There are continuously made observations that are used for monitoring the atmosphere and environment. Measurements are made at observation stations and sensory system as close to real-time as possible. This information is also quite useful to energy subsystem allowing predictions and reactive adjustments to the system level parameters. Apart from weather observations there are sun radiation observations, air quality observations and so forth which are of interest in system level.

4.3 Transport subsystem

With Transport subsystem the focus is on logistics chain operations for accessing the airport by different means of transport, including road and rail electrified traffic. The consideration is for both passenger as well as transport of goods.

The first part of implementation concentrates in transport of goods and passenger traffic that typically are performed with vehicles. We assume the use of electric vehicles and consider their contribution to the overall system. The assumption of all electrified traffic is the basis on system design, however, the Digital twin implementation is started with initial assumption of current state what comes to energy supply infrastructure capability.

4.4 Flight operations

Finally, the Flight operations represent those actions related to getting the device airborne and arriving to destination. In this study we concentrate on a use case which involves pilot training at flight school. This example provides a multifaceted use case for planning and dimensioning the energy system appropriately.

In the flight school the equipment is all electric plane with two seats. The training cycles are such that the plane can be charged in between the training sessions. Furthermore, the capacity of electric plane is used for charging the battery in optimal time be that during night or day depending on tariff slots.

4.5 Energy supply

The energy supply subsystem consists of the production or storage capable energy sources which can be on different type. Naturally the electricity network and nationwide capacity is one source of electricity. On top of that the local solutions feasible are considered, namely, the solar energy, hydrogen and other PtoX solutions available. In addition, in this study the battery capacity and different types of battery solutions are considered.

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Furthermore, the parallel existence of AC and DC distribution networks is under research. There are several system level open issues that have impact on system level.

4.6 Communications

One of the key elements in smart Digital twin solution is the communications between the logical elements of the system. The existence of several communications channels and use of different protocols in functions of the system is reality. In many cases there are clear choices to be used. There exists a space for new improved solutions that improve the safety and the user experience. Emerging 5G technology is one such candidate that evolves quickly becoming ubiquitous networking standard. The regulatory domain is still something that needs attention, for example, the use of 5G or any cellular technology from aerial vehicle is in current legal framework forbidden. The impact of this is present in many levels and increases the cost if a dedicates solution is needed. This is in drone operations for example one clear hindrance on some use cases.

5. Conclusions

This study and previous efforts demonstrate the important role that system design architecture plays in the technical context. Furthermore, architecture documentation serves as an elementary tool in communicating with vendors, decision-makers, users and the rest of the community including municipalities and cities operating the mobility infrastructure.

This paper has described critical success factors and findings. Difficulties associated with integrating these systems have limited the pace and extent of the reform.

Future research could explore a scenario in which this legacy constraint is lifted when the system can be built from scratch. An interesting case study could developing markets, for example in Africa, where the opportunity space in this respect allows more flexibility and grounds for innovation. The frugal innovation opportunity is another trend that could be examined in future work. First steps in this direction have been taken by the AiRRhow alliance, which explores opportunities in Namibia together with local authorities and actors.

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7. Copyright Statement

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