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A Multi-Disciplinary Approach for the Design and Management of Airport Terminals

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Abstract:- Multi-disciplinary approaches to complex problems are becoming more common – they enable criteria manifested in distinct (and potentially conflicting) domains to be jointly balanced and satisfied. In this paper we present airport terminals as a case study which requires multi-disciplinary knowledge in order to balance conflicting security, economic and passenger-driven needs and correspondingly enhance the design, management and operation of airport terminals. The need for a truly multi-disciplinary scientific approach which integrates information, process, people, technology and space domains is highlighted through a brief discussion of two challenges currently faced by airport operators. The paper outlines the approach taken by this project, detailing the aims and objectives of each of seven diverse research programs.

Keywords: Multi-disciplinary engineering, complex systems, airport terminals.

1. INTRODUCTION

The term “multi-disciplinary” is becoming a catchphrase in the research community. Working in multi-disciplinary teams is part and parcel of being an engineer, and is becoming more prevalent as time goes by. The nature of multi-disciplinary teams is however evolving to encompass more diverse knowledge, perspectives and problem solving approaches.

Multi-disciplinary teams are particularly common in medical and engineering applications. In the field of medicine, multi-disciplinary teams are often formed to investigate rehabilitation treatments, or prevention programs for particular medical conditions [1-2]. Systems engineering often requires the collaboration of multi-disciplinary teams of engineers to develop robust and optimised designs for a particular problem such as the development of land-based vehicles [3] or aircraft [4]. This has led to diverse frameworks to support multi-disciplinary understanding and problem solving [3, 5]. Multi-disciplinary engineering principles have also permeated into engineering education in order to better prepare graduates for real-world problem solving [6].

Despite this attention to multi-disciplinary teams, the commonality between these examples is the nature of the team which consists of members of the same general discipline, e.g. engineering or medicine. In this paper, we describe a diverse multi-disciplinary approach that involves engineers, mathematicians, management professionals, architects, product designers, and IT specialists forming a collaborative team to work with airport operators to meet the many challenges they currently face. The project described in this paper is truly unique in the aviation industry, and we believe it has the potential to not only generate collective understanding about airport systems, but has application to a myriad of engineering-type problems.

The rest of this paper is organised as follows. Section 2 briefly describes two current challenges faced by airport operators and highlights the need for a multi-disciplinary approach. In Section 3 we detail the objectives of this project, briefly describing each of the seven research programs which comprise this diverse and multi-disciplinary study.

2. CHALLENGES FACING AIRPORTS

Airports are a perfect example of a complex system where a multitude of factors are in play, many of them undergoing continual change such as technological innovations and the need to provide a secure and safe travel experience in the face of malicious threats. Coupled with this continual change is the large number of independent stakeholders (including government, border protection agencies, airport staff and passengers) who have the ability to exert significant influence on the operation of airport systems.

Each stakeholder has a different perspective on airport operations, and places different criteria on which successful airport operation is measured. For example, passengers want an efficient and pleasant travel experience, policing agencies want to ensure the building and aircraft are at low risk of malicious attacks, whilst the airport and retail firms want to maximise their profits. Often these criteria are in conflict, and so in order to resolve challenges and to derive solutions benefiting all stakeholders, a truly multi-disciplinary approach is required.

To highlight this need, let us briefly consider two challenges currently facing airport operators: (1) the introduction of the Airbus A380; and (2) full-body security scanning. Particular reference is made to five domains which are the focus of our multi-disciplinary approach outlined in Section 3 (people, process, information, technology and space).

2.1 The Introduction of the A380

The Airbus A380 is the largest aircraft flying our skies, and its deployment is slowly gaining momentum worldwide. The specifications of the airliner sum up its feat as an engineering masterpiece: a double-deck passenger cabin providing almost 50% more floor space than the next largest airliner (the Boeing 747-400); seating for up to 850 people (depending on class configurations); and a maximum flight range of 15,000 km. Whilst impressive, these characteristics pose many challenges for existing airports aspiring to accommodate this state-of-the-art aircraft. In this section we consider one of these challenges – adapting to greater passenger capacity – however there are a multitude of other challenges including (but not limited to) [7]:

- Ensuring runways and taxiways meet safety standards
- Accommodating increased wingspan in gate utilisation
- Accommodating multi-deck aircraft in boarding gate design
- Ensuring emergency response procedures can evacuate the aircraft in the required time.

The greater seating capacity aboard the A380 means airport operators are faced with new challenges relating to processing larger numbers of passengers in both inward and outward movements. There are a number of potential changes to the passenger facilitation process to counteract this influx. For instance, more personnel could be tasked to occupy service desks (e.g. check-in, security etc) in periods of A380 arrivals and departures, or new technology could be introduced to make security screening more efficient. In making whatever changes are necessary however it is very important to consider how people (both passengers and personnel) and processes within the facilitation chain will be affected as the airport must remain secure, efficient, and provide a passenger experience of a high standard. The only way to ensure this is to consider such changes from the perspective of multiple disciplines, and have a thorough understanding of the current state of airport operations.

2.2 Full-Body Scanners

Airports and aircraft are often primary targets for malicious activities; a look at the last ten years demonstrates the threats posed. Protection of aircraft and passengers is therefore of utmost importance, and we are seeing rapid developments of technology in order to improve safety. Full-body scanners are the latest of these technologies currently being installed and trialled at airports across the world.

Recent commentary on this new technology has accentuated some interesting peripheral effects. Firstly, the scanners typically require more physical space than existing scanning equipment, forcing airports to redesign screening areas to accommodate them.

Some concern has also been raised by industry that full-body scanners slow down the flow of passengers, increasing processing times, and potentially reducing the quality of the passenger experience. A more controversial aspect of the scanners with respect to passenger experience is the nature of the information which is produced by the scanners as well as how this information is utilised; this has caused considerable uproar in the worldwide media.

This example demonstrates that the introduction of new technology can cause widespread controversy and significant challenges for airport operators. Taking a multi-disciplinary approach to consider the effects on passengers, on the security process, on information security and physical requirements as well as the technological development has the potential to make the transition smoother.

3. MULTI-DISCIPLINARY APPROACH

The two examples in the previous section highlight a strong need for multi-disciplinary

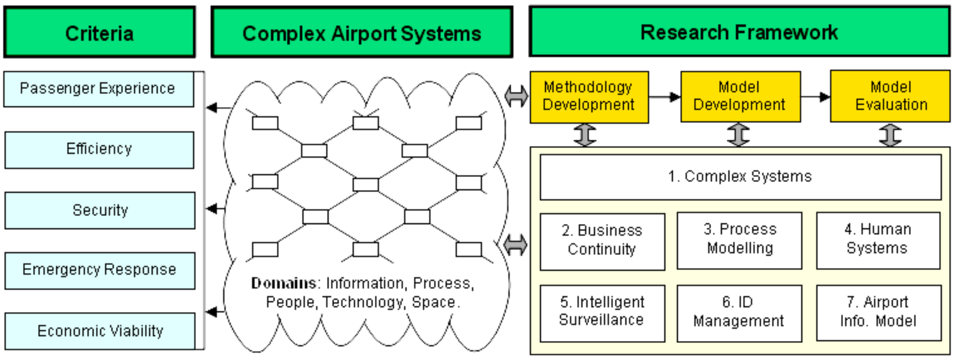

Fig.1. Research framework adopted by the Airports of the Future project.

approach to airport operations, in order to create innovations and generate new knowledge. Current research in the airport system typically addresses individual components in isolation, including: advanced passenger processing systems and registered traveller programs [8], security equipment, techniques for improving security checks, IT security, logistics, emerging technologies such as radio frequency identification, biometrics, surveillance, expert systems for x-ray screening, and economic research [9]. However, no existing work synoptically synthesises these disparate components to form an integrated, adaptive and multi-disciplinary understanding of airport operations.

With this in mind, the Airports of the Future project aims to improve the security, efficiency and passenger experience within airports by simultaneously considering all five domains (people, process, information, technology and space). This approach will lead to the development of holistic, integrated knowledge and corresponding solutions which will better equip airports to respond to current and future challenges.

This pioneering multi-disciplinary study is supported by over 30 industry and research partners including domestic and international airports, airlines, government border protection agencies, service providers and industry representative bodies including the International Air Transport Association (IATA) and Airports Council International (ACI).

The research framework adopted by the Airports of the Future project is shown in Fig.1. This framework demonstrates the consideration of the five domains in order to jointly satisfy a range of criteria including passenger experience, efficiency, security and emergency response. The project integrates knowledge from seven different research programs encompassing the five domains; these programs are summarised in the following sections.

3.1 Complex Systems

The need for a complex systems approach arises from recognising that airport systems are comprised of a number of strongly interacting components, and the behaviour of any one component depends on (and affects) the behaviour of other components in a nonlinear manner. For example, consider significant delays at the outwards border control point which cause large queues to form – this queue may eventually grow to the point where it will impact on the security screening point, and this in turn could impact the check-in area. For successful airport operation, it is therefore vital to understand how an aggregation of otherwise independent systems leads to emergent behaviour which cannot be inferred by examining the components separately [10].

The characteristics of airports often violate key assumptions required by traditional systems engineering [11] and are therefore no longer suitable for these applications. New approaches and models are therefore required to allow flexible identification and description of complex patterns, multi-scale processes, and to balance the multi-faceted demands of emergency response, security, efficiency and economic viability. The Complex Systems approach draws together all five domains to provide tools in order for airports to better prepare for future changes to the already complex airport system.

3.2 Business Continuity & Incident Response Management

Airports play a significant role in supporting their surrounding regions economically through stimulating business, promoting tourism and trade, as well as creating employment. They also form part of a much wider aviation network, ensuring each airport contributes to and influences network effectiveness at a national and/or international level. The continuity of an individual airport's operations is therefore paramount to not only sustaining the local economy, but to also avoid crippling the entire network.

Business Continuity Management (BCM) is a process of ensuring the uninterrupted availability of essential services, programs and operations in the event of unexpected interruptions [12], in order to sustain critical business activities. Such approaches are not only about initially limiting the effect of disturbances and containing them, but also ensuring return to a state of normal operations within an acceptable timeframe.

The BCM component of this research explores the current risk, contingency and recovery planning practices at airports. This approach will enable improvements in current plans at specific airports, and inform the development of a 'best practice' guide to assist continuity planning of both national and international airports. Detailed understanding of the 'business as usual' passenger facilitation process is crucial to assessing the effectiveness of a continuity plan.

Since it is impossible to plan for and avoid all possible undesirable scenarios, airports will still be confronted with many incidents, ranging from minor incidents (e.g. localised water spills) through to malicious attacks such as that at Glasgow Airport in 2007. Effective response to incidents within the terminal is further complicated by the large number of stakeholders present, making it difficult to coordinate effective response, evacuation (if necessary) and recovery protocols.

This research assesses current Incident Response Management (IRM) plans at airports and enhances existing practices by clearly defining the scale of the response and the responsibility of each party in the response based on a wide range of technological and informational intelligence as well as spatial characteristics. In this way, response teams will be able to act quickly and effectively in order to limit the impact on passengers, personnel, and the physical infrastructure.

3.3 Business Process Management

Understanding how a particular business operates is vital to optimising business processes in order to maximise organisational efficiency and profit. In the airport context, a thorough analysis of the passenger facilitation process is vital to make it more efficient. Such an understanding can guide changes to the facilitation process from a range of perspectives including improved efficiency (operational and resource), security and/or passenger experience.

The approach to create process models (high and low-level representations of the facilitation chain) involves a range of techniques including surveys, interviews, explorative case studies and conceptual modelling using a standard representation. The standard process modelling tools will also be extended to incorporate knowledge from the other domains, in particular spatial characteristics.

This case study methodology helps to not only map the facilitation process, but also to identify current weaknesses in airport operations, allowing airports to make improvements to their business. This project extends the case study approach by analysing facilitation processes at multiple airports in order to generate a passenger facilitation reference model. This reference model will be made configurable to different contexts (e.g. international versus domestic, full-cost versus low-cost etc.) in order define "best practice" facilitation at any airport.

3.4 Human Systems

Passengers are the primary customers for airports, and consequently airports adopt new technologies and processes to improve the passenger experience such as IATA's Simplifying Passenger Travel initiative [8]. To determine the appropriateness and effectiveness of technology and other services within airports, it is vital to investigate and fully understand what airport users currently do at the airport, what decisions they make, how they allocate their discretionary time, and with whom/what they interact with whilst at an airport.

Passenger activities are typically divided into two categories: processing activities and discretionary activities. Processing activities are those related to the regulatory processes involved with boarding a plane including check-in, security checks and immigration. Any activity outside of these processing activities (e.g. duty-free shopping or using an airline lounge) is identified as a discretionary activity. Typically only a small proportion of the total time spent at an airport is spent in processing activities [13] although this has attracted the bulk of the research focus to date [14].

This aspect of the research is therefore primarily concerned with people, although it will investigate how passengers interact with technology, processes, information and the terminal space. Early research in this area has revealed some important outcomes including baggage ownership and sharing of activities, amongst others [14].

A study from both passenger and personnel perspectives is very important in creating an effective model of the people aspect of an airport. In time, this research will also extend to observing how airport personnel experience the airport and how the interaction with passengers is perceived from their perspective.

3.5 Intelligent Surveillance

Modern-day airports are already well equipped with closed-circuit television (CCTV) networks. For purposes of maintaining airport security, surveillance in these environments has traditionally been carried out manually by human operators. Intelligent Surveillance research aims to enhance the human component of visual surveillance through the automatic merging of intelligence acquired from large-scale networks of CCTV technology. In particular, the research focuses on object tracking algorithms [15] (for following or retracing the movements of specified passengers or baggage through the terminal in real-time or post-event), as well as on human activity recognition to enable automatic detection of pre-determined suspicious behaviour.

A less traditional use of surveillance camera networks investigated by this project is in estimating airport performance, and identifying patterns of interest directly related to enterprise function (e.g. time-based efficiencies of check-in service counters). For example, this type of information can be used to better prepare passengers for timely arrival at airside by alerting them to expected delays in passing security and border controls. Crowd counting [16] and queue length estimation algorithms are being developed for these applications.

In order to implement these algorithmic developments in real airport environments, the aforementioned applications are supported by research into automatic camera calibration and management techniques. Such capabilities will enable airport operators to dynamically deploy cameras throughout the entire airport, ensure information is quickly and effectively synchronised across the CCTV network, and accordingly improve security outcomes.

3.6 Identity Management

Airport facilities and information systems are typically operated and administered by different organisational entities. A great deal of coordination and cooperation is required to ensure airport personnel have the required access (but not all inclusive access) to sensitive systems including flight information displays, travel information management and baggage handling to name a few. Keeping access rights up-to-date as personnel are hired, cease employment, or as they change roles and task assignments is a major challenge.

Consequently, there is a need for a federated airport identity management system that maintains the administrative autonomy of individual sub-system operators (e.g. the airline or border control agency) but allows greater real time cross-recognition of user identities and their associated attributes and capabilities.

Identity Management research is investigating mechanisms by which airport-wide (and to an extent industry-wide) identity management systems could operate. This involves analysing the nature of physical access and information systems within the airport, and developing a suitable architecture to support this. This framework will be extended to be supported by technology solutions derived from Intelligent Surveillance, as well as being tightly coupled with a 3D spatial model (from the Airport Information Model) which can assist in airport-wide identity management.

3.7 Airport Information Model

Having a detailed understanding of the physical structure of a building plays a fundamental role in initial building design and subsequent re-design, as well as managing the building throughout its life cycle. This information extends beyond a 3-dimensional representation of the building, supporting information related to light and energy analysis, and properties of building materials. This type of system is referred to as a Building Information Model (BIM).

This project looks at extending the BIM framework by specialising it to an airport context, thereby creating an Airport Information Model (AIM). On top of traditional BIM components, the envisaged AIM will support storage, manipulation and visualisation of information related to all aspects of airport operations, likening it to a database in a 3D spatial environment. As an example, real-time information about queue lengths or densities of people in the departure lounge would be stored in the centralised model in order to assist in monitoring airport efficiency, to detect undesirable crowd-based events, or to aid in emergency response procedures.

Another important element of this research is the development tools to assist security planners to determine the likely effects of an explosion within the airport terminal. The state-of-the-art tool will provide rapid visualisation of the blast effects by considering the type of explosive device, its associated fragmentation effects, and the impact on the airport terminal environment in order to assist airport design and inform incident response strategies.

4. CONCLUSION

Multi-disciplinary approaches to generate new scientific knowledge and to solve modern-day problems are becoming more and more common. Engineers – whose primary role is to solve problems – will experience diverse multi-disciplinary teams more and more as society becomes more complex, and it is important to embrace it as a way of solving new challenges.

In this paper we have chosen airports as a case study for demonstrating a diverse multi-disciplinary approach in order to meet a number of challenges and to jointly satisfy performance criteria arising from diverse domains. By considering and integrating aspects of people, process, information, technology and space domains, the approach taken by the Airports of the Future project is truly unique in the domain of airports. This project should inspire a new way of approaching complex problems not just in airports, but also in the wider scientific and industrial communities.

5. ACKNOWLEDGEMENT

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