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An integrated research for architecture-based energy management in sustainable airports

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ABSTRACT

Energy Management (EM) has become crucial and much more complicated for airports with the introduction of various energy sources, technologies and different comfort requirements. Regarding the aviation industry as one of the major sources of global warming and air pollution, this situation becomes highly critical. However, the review of literature on Energy Management Information Systems (EMIS) for airports shows that the proposed solutions are usually domain-specific, platform-depended and away from suggesting complete solutions and architectures. Therefore, the main argument of this study is that a holistic and integrated approach should be adopted for EM in airports and we claim the notion of sustainability through the use of Enterprise Architecture (EA)-based EM. In this paper, we present the results of a two-faced research study. Action Research (AR) and Design Science Research (DSR) methods are combined to adopt an integrated approach. At the first phase, an EA is developed and evaluated, and then, this is followed by the second phase with three cases to find the potential energy savings in İstanbul Airport. Along with the findings, the primary and secondary contributions of this research brought to the EM knowledge domain are presented. Consequently, there is an important potential for energy saving in the terminal buildings, which would be approximately 70% of the total airport energy consumption. There is also a nearly 250.000 $/year potential saving, and also 121.397 $/year for the daylight time and period. This research can be seen as an initial attempt to the enhancement of sustainable airports, and therefore, it has showed the potential for using EAs as a means to improve EM in airports. We hope that this study may help researchers to obtain an overview of existing and possible approaches to sustainability through the use of EAs for EM practices.

1. Introduction

In terms of urbanization and construction industry, airports, today, can be regarded as places or small cities that never sleep. Connected by public transportation, aviation has become a dynamic and competitive industry, and airports are the center of domestic and international transportation. The reports on the busiest airports indicate a continuous and considerable increase in the passenger traffic. For example, more than 1.5 billion passengers and nearly 20 million flights with an annual 7% increase trend were recorded for the airports in Europe [1,2].

As being an important part of global and local economies, airports have been comprised of systems and services, many of which support various airside and landside operations. The services are given in different facilities, and they range from retail trade and accommodation to scheduled and charter flights in terminals. Thus, it is possible to maintain this service economy only with a robust, reliable information systems and applications running on top of information technology (IT) infrastructure, which has also to comply with Energy Management (EM) standards.

The recent developments have brought another challenge, establishing a “sustainable aviation” industry, while trying to assure energy efficiency as well as to meet the business, commercial, technical and domain specific requirements. Kyoto Protocol, signed in 1997, requires significant restrictions for the reduction of greenhouse gas emissions. Therefore, airports and aviation industry are regarded as one of the major sources of environmental problems and also a prominent cause of sustainability. Moreover, trends and foresights in future aviation indicate a major impediment to

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sustainable development in terms of social, environmental and economic perspectives. That is to say, sustainable aviation needs long term strategies, on the other hand, today, innovative and urgent solutions are needed for the challenges facing aviation industry. To that aim, there have been attempts like Pietzcker's et al. study, by which the long-term transportation in China, energy demand and emission projections are explored [3]. Turan proposed a new methodology about exergetic metrics for mapping the exergy flows in sustainable turboprop engine [4]. Kılkış developed a composite index defined as SDEWES (Sustainable Development of Energy, Water, and Environment Systems), which includes various dimensions and main indicators for port cities [5]. Qiang et al. presented a study on the indicators effecting energy efficiency in airports and included related analysis. A measurement method was also proposed using the data from 21 airways between 2008 and 2012. With this measurement, new parameters affecting EM efficiency were defined [6] Ye et al. focused on the effects and airline efficiency considering European Union Emission Trading Scheme. They designed and used two methods, and thus, the main result was found as the efficiency increased in most of European Airlines [7].

With the introduction of various energy sources, such as renewable and new transport technologies, EM in airports has become crucial and much more complicated for these safety-critical and mission-critical facilities [8]. On the other hand, airports have been comprised of systems, technologies and services, which may belong to various disciplines, such as mechanical, electronics, IT. To this end, different type of Energy Management Information Systems (EMIS) have been designed and utilized. Ranging from embedded control systems to third party applications, they usually manage complex, hybrid technologies and components running on different platforms.

The review of literature on IT and EMISs for airports shows that the proposed solutions are usually domain-specific and platform-depended [9,46]. Moreover, they are away from suggesting complete architectures allowing the integrated management of energy systems required for airside and landside operations, especially when considering different type of energy sources i.e. fossil fuel and renewable [10]. Therefore, our main argument is such that EM in airports should be achieved and addressed by holistic and integrated methods as well as it should have extensible, architectural and computational foundations.

Depending on various energy sources and requirements, on the other hand, “one EM architectural model fits all” approach may not address the organization-specific energy needs of airports and this may not manage dependencies between components. However, an Enterprise Architecture (EA) can address this issue. An EA is defined as “a coherent whole of principles, methods, and models that are used in the design and realization of an enterprise's organizational structure, business processes, information systems, and infrastructure” [11]. Thus, EAs enable the alignment through the use of models that describe various aspects of organizations and they represent the views of different stakeholders. Moreover, the other challenges are considered as the integration, extension and interoperability of different EM systems in airports while trying to ensure consistency, dependency and coherence to EM standards and specifications. In this context, ontologies and their associated techniques can resolve the conceptual and structural evaluation issues in EAs [11].

In this paper, therefore, we present the results of a two-faced integrated research study for the architecture-based EM in sustainable airports. Action Research (AR) and Design Science Research (DSR) methods are combined to adopt this integrated approach. At the first phase, an EA is developed for sustainable airports, and then, this is followed by the second phase to implement and to find the potential energy saving of İstanbul Airport. The primary and secondary contributions brought by this research can be described as follows:

Primary contributions (To the EM Knowledge Domain):

- Finding the potential energy savings for İstanbul Airport,
- To the best of our knowledge, it is the first EA proposed for EM systems at the time of writing this report,
- The introduction of AR and DSR methods as the candidate methods for the research area of EM systems.

Secondary contributions (To the EM Systems Knowledge Domain):

- Establishment of the consistency, dependency and coherence to specifications of EAs for EM in airports through the use of ontological methods,
- Improved evaluation, expressiveness and extensibility of EAs for EM Systems.

2. Energy management and airports

There have been various attempts to reduce the effects of energy costs. Along with the developments in construction and building technologies, sustainability and fossil fuels together have become critical factor in terms of EM. However, realization of sustainable development and providing the efficient use of energy resources in airports are affected by complex, inter-related and socio-economic issues. Facilities using renewable energy sources, development of business and control mechanisms, and the creation of EM models for the dissemination of low carbon technology are the popular topics explored by various studies. It is also observed that the research studies on sustainable EM in airports addressing related issues are in an increasing fashion. However, it is still difficult to put the strategies on sustainable EM into practices for the industry and society, let alone for sustainable airports.

Today, there is still a significant potential for improving the energy efficiency in airports, which can be provided by holistic approaches that have an important potential for the reduction of energy consumption on a scale between 20% and 50%. For example, Balares et al. [9] identified a 35% energy potential in Greek airports in terms of thermal loads. Sun et al.'s study showed a 5, 93% improvement in Hong Kong airport [10], while Huang et al. [11] reported an 18% save in energy consumptions in Adelaide airport. Although energy efficiency measures can provide advantages for aviation industry and airports, they are usually difficult to implement. Assuring the system security and stability in transition processes, funding and/or providing resources, management of landside operations and services are amongst the other major obstacles. Moreover, the energy efficiency in airports is influenced by the factors, such as, CO_2 emission and irreversibility [12–14]. Therefore, reducing the CO_2 emissions in aviation industry is the primary goal for sustainable airports [15,16] as presented by Fig. 1.

It is possible to suggest different types of airport EM systems

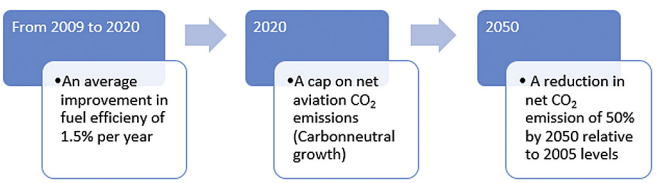

Fig. 1. Specific climate change targets of aviation industry.

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