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ANALYSIS OF APPLICATION OF ENTERPRISE ARCHITECTURE FOR MODERNISATION OF AIR TRAFFIC MANAGEMENT SYSTEMS

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Abstract

Purpose: *Due to growing demand for air transportation and a shortage of current capacities of air traffic management systems to accommodate future air traffic, there is a need to transform current air traffic management systems. Any change in a complex system like an air traffic management system might have an impact on various stakeholders, the performance of the system and its safety. Thus, there is a need for means to assess and predict the impact of a change as well as plan its introduction in the most efficient way.* ***Methods****: An enterprise architecture provides means to have a holistic view on complex systems like air traffic management system allowing to assess the impact of the changes and help to deploy them.* ***Results****: It can be seen that the enterprise architecture is used by various agencies, organizations and enterprises across the world to better manage and plan their activities. The same methodology could be applied to air traffic management systems to enable their transformation to accommodate the increasing demand for air transportation. From the performed research, it can be seen that the enterprise architecture has been used by major research programs in the United States and Europe to plan the transformation of their air traffic management systems and ensure smooth and timely deployment of the results of the research programs.* ***Discussion:*** *While allowing to get a holistic overview of the state of the enterprise, it might be a challenge to introduce an enterprise architecture at the enterprise. A wide set of experts is required to describe the enterprise from different perspectives (business, operational, technological, etc.) which makes the process quite time-consuming. However, there are a number of enterprise architecture frameworks and architecture development methods to facilitate more smooth and fast deployment of the enterprise architecture.*

Keywords: air traffic management; enterprise architecture; enterprise architecture framework; European Air Traffic Management Architecture; Next Generation Air Transport System; Single European Sky ATM Research

1. Introduction

The aviation industry plays one of the main roles in a global economy providing the only rapid transportation network making it vital for the global business. The total economic impact of the global aviation industry is estimated to be around 3.5% of the global gross domestic product (GDP). With economic globalization and growing demand for the air transportation, it is forecasted that the volume of the air traffic will at least double in the next 15 years, with the annual growth of around 4.4 – 4.6% per year [1]. However, the capacities of the current air traffic management (ATM) systems are limited and reached or approaching the limit of the ability to handle more traffic. Thus, in order to accommodate and support the growth of the traffic in a safe and sustainable way, there is a need to transform and change the current ATM systems.

That's why a number of initiatives were launched worldwide to support transformations of the air traffic management systems, e.g. Single European Sky and its technological pillar Single European Sky ATM Research (SESAR) in Europe, Next Generation Air Transportation System (NextGen) in U.S., Collaborative Actions for Renovation of Air Traffic Systems (CARATS) in Japan and a number of other regional initiatives. These initiatives, in general, are not just single projects but rather an integration of many projects that contribute to the evolution of the ATM systems.

To ensure that the research and development activities are performed in a harmonised and consistent way it is necessary to have a common

reference and language that can be provided through the enterprise architecture.

2. Analysis of the latest research and publication

There is a number of researches available that are focused on the role of the enterprise architecture in the transformation of the complex systems or enterprises. *William M. Donalsdon, Timothy D. Blackburn, Paul Blessner and Bill A. Olson* in their work "An examination of the role of enterprise architecture frameworks in enterprise transformation" describe enterprise architecture and enterprise architecture frameworks as powerful tools to transform an enterprise. However, they outline the certain limitations of the enterprise architecture frameworks and stress on the importance of the proper use and application of them [2]. *Harry H. M. Hendrickx* from Enterprise Services, Hewlett Packard, outlines that controlled language especially while describing a holistic view of the enterprise is an important asset to facilitate transformation of the enterprise [3]. This controlled language can be provided by an enterprise architecture framework.

A number of organisations have deployed enterprise architecture to enable better management of resources and assets. Architects from Lufthansa and Capgemini have collaborated on developing an Aviation Reference Architecture to improve business efficiency and effectiveness in the aviation domain through use of standardised reference architecture [4]. *Ulrik Franke* and *Pontus Johnson* in their paper "An Enterprise Architecture Framework for Application Consolidation in the Swedish Armed Forces" describe how the enterprise architecture helps to transform Swedish Armed Forces through application consolidation. They outline one of the greatest advantages of the enterprise architecture – support to decision making. While running experiments to support a decision is costly and time consuming, the enterprise architecture allows to see consequences of the decision before it's actually made [5].

During this research, a number of enterprise architecture frameworks were reviewed and are described in the next chapters [8, 9, 11, 14].

3. Enterprise architecture and enterprise architecture frameworks

Enterprise architecture is a relatively new discipline that has appeared recently, at the end of the last century, and a major event for it was publication of the John Zachman's early framework that has been used later on as basis for many other enterprise architecture frameworks, e.g. Department of Defense Architecture Framework (DoDAF), The Open Group Architecture Framework (TOGAF), etc. [2].

According to Federation of Enterprise Architecture Professional Organisations, enterprise architecture can be defined as a well-defined practice for conducting enterprise analysis, design, planning, and implementation, using a holistic approach at all times, for the successful development and execution of strategy. Enterprise architecture applies architecture principles and practices to guide organizations through the business, information, process, and technology changes necessary to execute their strategies [6]. Thus, enterprise architecture can be considered as a great means to support execution of change and decision making in the enterprise since it allows to capture complex dependencies that exist in large-scale organizations and enterprises.

In order to develop and implement enterprise architecture, the enterprise architecture framework is used. It can be defined as a set of models, methods and principles that are used to implement enterprise architecture. It also provides a means to communicate information about architectural elements and their relationships using a common vocabulary.

Since enterprise architecture has emerged, a number of enterprise architecture frameworks were developed and were adopted by a wide range of agencies and organizations.

3.1 Zachman framework

Zachman Framework has been developed back in 1987 and became one of the most widely used frameworks. Zachman Framework is a logical structure for classifying and organizing the descriptive representations of the enterprise that are important for the management of the enterprise as well as for the development of the enterprise's systems. The framework utilizes a number of cells to describe the business, information and technical layers and these cells are organized by data, function, network, people, time and motivation that are driven by business requirements of the enterprise. The framework combines people, data and technology and provides a comprehensive overview of their inter-relationships within the enterprise. It worth mentioning that Zachman Framework is an ontology for describing the

enterprise and it cannot be considered as a methodology or a modelling language [7].

Zachman Framework has been employed in many large organizations (e.g. Health Canada, United States Department of Veteran Affairs, Bank of America, etc.) and a number of other frameworks have been derived from the Zachman Framework, like TOGAF, DoDAF, MoDAF which will be considered below.

3.2 Department of Defence Architecture Framework

The Department of Defence Architecture Framework has been developed for United States Department of Defence in an effort to provide a common denominator for understanding, comparing and integration of architectures across various organizations and enterprises. The framework consists of four views that define a common approach for architecture description, development and presentation as well as the integration of military and business operations. Those views are:

- All view (AV) – provides an overarching description of the architecture and defines it scope and context
- Operational View (OV) – provides a description of tasks, activities, operational elements, information exchanges that are necessary to fulfil enterprise needs (in case of DoD, its missions)
- Systems View (SV) – describes systems, services and their interconnections that support enterprise functions
- Technical Standards View (TV) – describes policies, standards and constraints of the enterprise.

Initially developed for military use, it is widely used for private and public organization and become a basis for a number of enterprise architecture frameworks. One of them is British Ministry of Defence Architecture Framework (MODAF), a framework developed by United Kingdom Ministry of Defence (MoD) to capture and present information about defence enterprise in a rigorous and coherent way to support solving complex issues and decision making. Except for Ministry of Defence, the framework is used by other governmental organizations and agency, by a number of industry partners of MoD, e.g. BAE Systems, Thales, Lockheed Martin and by Swedish Armed Forces [5].

Based on the developments of DoDAF and MODAF, North Atlantic Treaty Organization (NATO) has developed its own architecture framework called NATO Architecture Framework (NAF). The framework helps to fulfil the need for a more structured approach to manage the complexity of such a large enterprise as NATO whilst balancing all appropriate user perspectives. Since enterprise architecture touches every part of the organization, it can be used as an analytical tool to develop new capabilities, structure organization and to facilitate the optimization of processes and hence spending in the organization. Also, due to an increasing need for international coalition operations (NATO Response Force) and growing need to deliver end-to-end capability, it is necessary to ensure interoperability within the organization which can be achieved through the use of NAF [8].

3.3 The Open Group Architecture Framework

The Open Group Architecture Framework (TOGAF) has originated from Technical Architecture for Information Management developed by the US Department of Defence. At first, it was considered as a framework and methodology for the development of the technical architecture of the enterprise but starting from version 8 of the framework TOGAF has been expanded to cover all the aspects of the enterprise architecture [9]. According to The Open Group, TOGAF is used by 80% of companies from Global 50 list and 60% of companies from the Fortune 500 list [10].

TOGAF supports four interconnected areas called architecture domains that are commonly accepted as the overall subset of the whole enterprise architecture. They namely are:

- Business Architecture – defines the business strategy, governance, organization, and key business processes
- Data Architecture – describes the structure of an organization's logical and physical data assets and data management resources
- Application Architecture – provides a blueprint for the individual applications to be deployed, their interactions, and their relationships to the core business processes of the organization
- Technology Architecture – describes the logical software and hardware capabilities that are required to support the deployment of business, data, and application services; this includes IT infrastructure, middleware, networks, communications, processing, standards, etc.

Also, TOGAF consists of the following main components:

- Architecture Development Method which defines an approach for the development of the enterprise architecture by architects. It is considered to be a core of TOGAF and consists of a stepwise cyclic approach for the development of the enterprise architecture.
- Enterprise Continuum consists of various reference models (Technical Reference Model, Standards Information Base, etc.) that illustrate how the architecture evolves from foundational-based architecture to an enterprise's own architecture
- Architecture Content Framework that provides a structural model for architectural content that allows major work products to be consistently defined, structured, and presented.
- Architecture Capability Framework addresses the organization structures, roles, responsibilities, skills, and processes that are necessary to put in place an appropriate business capability [9, 11].

As can be seen from the covered architecture domains, TOGAF aims to support all the layers of the enterprise, starting from the business and up to the technological and data layers.

4. Use of enterprise architecture to manage changes in air traffic management

Any air traffic management system can be considered as a rather complex enterprise that involves multiple stakeholders and interactions among them which might make the introduction of a change in ATM quite challenging since it might affect multiple stakeholders. And due to the growing demand for air transportation and the shortage of capacity to accommodate the future air traffic, it is necessary to implement a number of changes to transform ATM systems to facilitate the growing air traffic and to implement these changes in a synchronized and timely manner to maximize the benefits from them.

Another challenge is to identify areas of ATM to improve and to focus the research and development activities on those areas avoiding any duplication or overlapping of R&D. That's why the ATM research programs initiated by US and European Commission included enterprise architecture activities to harmonize and integrate the research and development activities within the programs and to develop roadmaps for implementation that can be used by stakeholders.

4.1 Next Generation Air Transportation System

In 2003 the US Congress has established Joint Planning and Development Office (that has been replaced by Interagency Planning Office in 2014) to plan and manage the collaborative work on the Next Generation Air Transportation System. The Joint Planning and Development Office (JPDO) has been tasked to coordinate efforts of various agencies in US such as Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), Departments of Transportation (DOT), Defense (DOD), Commerce (DOC) and Homeland Security (DHS) and White House Office of Science and Technology Policy (OSTP).

The Concept of Operations (ConOps) developed by JPDO defined the following key areas of planning activities to support NextGen Integrated Plan:

- Concept of Operations
- Enterprise Architecture
- Integrated Work Plan (IWP)

ConOps describes the vision and the transformed state of NextGen while Enterprise Architecture provides the next level of technical details about the transformed NextGen system and is developed in parallel with ConOps. Finally, the Integrated Work Plan specifies the timing and interdependencies of the multi-agency research, developments, validations and demonstrations required to achieve vision described in ConOps [12].

The Enterprise Architecture for NextGen utilizes National Airspace System (NAS) Enterprise Architecture Model – a modified version of DoDAF 1.5 that allows to the model to be examined and tested using different views and provides a means for coordinating among partner agencies like FAA, NASA, DOT, etc. and private sector manufactures, aligning relevant R&D activities and integrating equipment ensuring better interoperability in the air transportation system. Also, the architecture defines the key capabilities of NextGen, how they fit together and how they affect the aviation community. It can be considered as a structured, disciplined approach to the ConOps where each segment of the Enterprise Architecture contains specific details describing the activities, alignments, mappings, requirements and connections to the ConOps. The architecture is used as a tool for planning, negotiating and understanding the dynamic, interrelated business processes and technical solutions that impact the air traffic management system [13].

As it can be seen, the Enterprise Architecture is an integer and important part of the Next Generation Air Transportation System that facilitates the coordination and planning of development and deployment activities and provides a better understanding of the transformation of US National Airspace System aiding the decision-making.

4.2 Single European Sky ATM Research

The Single European Sky ATM Research program has been established back in 2004 as a technological pillar of the Single European Sky initiative to support the high-level goals set by European Commission such as reduction of cost of air navigation service by half, three-fold increase in capacity to decrease delays both in the air and on the ground, improve safety by factor of 10, etc.

Since the task of transformation of European ATM is too large for one organization to handle, SESAR Joint Undertaking (the body that is responsible for the modernisation of European ATM system) has been established as a public-private partnership that unites the European aviation community through its 19 members. And together with all the affiliates and sub-contractors around 100 organizations actively participate in the R&D activities under SESAR.

Having 100 organizations contributing to the research program makes it necessary to have a common context and reference for the SESAR research and development activities and deliverables. This is provided by European ATM Architecture (EATMA) – an essential tool to ensure consistency and alignment of the research within the program. European ATM Architecture utilizes European ATM Architecture framework that is mainly based on the NATO Architecture Framework, however, the architecting process is inspired by TOGAF (Fig. 1). The framework is tailored specifically to reflect ATM needs and suit SESAR program.

EATMA contains six layers (Programme, Capability, Operational, Service, System and Standards) that allow describing and viewing the European ATM system from different angles and perspectives taking into account all the aspects of business, operational and technical sides. Each layer contains a set of elements that can be used to describe the view of the enterprise. The EATMA framework also defines how the elements relate to each other. Through these relationships between elements, it is possible to create architecture that provides traceability from performance or business needs down to the technological solutions that can satisfy these needs.

Similarly to the Integrated Work Plan in NextGen, European ATM Master Plan is an integer part of European ATM Architecture and is presented by Programme layer in the EATMA framework. The layer contains Operational Improvement Steps and Enablers elements that are used to describe the European ATM implementation schedule providing a project management view on the architecture. The Operational Improvement Steps are the means to describe changes in the ATM Operational Environment and are linked to the Operational layer of EATMA describing how the operational concept has to change to introduce the necessary changes. Based on the changes in the operational concept various technological solutions can be developed to support the Operational Improvement Steps. New or modified technical systems, procedures, standards, etc. are linked to Enablers – means to implement changes in the ATM Operational Environment. Enablers are linked to Operational Improvement Steps that allows a stakeholder to get a view on what and how has to be implemented to achieve business benefits described by Operational Improvement Steps.

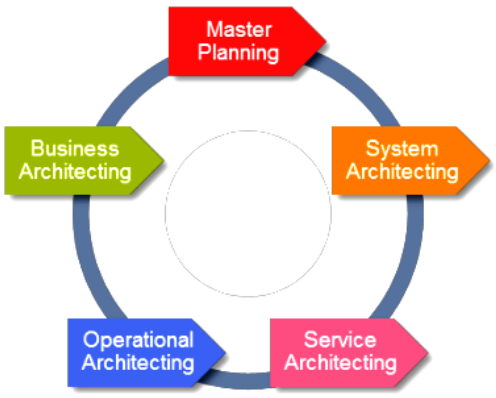

Fig. 1. EATMA Architecting process overview [14]

This architecting process established by EATMA allows to identify gaps and inconsistency during the evolution of the concept along with its lifecycle, to optimize the research activities through reuse of the existing elements and avoidance of duplication.

The outcome of the architecture work is later on integrated into the European ATM Master Plan and provides a global view on how the European ATM system will evolve in the nearest future to meet the high-level goals set by Single European Sky.

5. Conclusion

The enterprise architecture is a powerful tool that has been used by various organizations to support these organizations in the planning and implementation of business, process and technological changes to execute their strategies in an efficient manner. Enterprise Architecture can help to define the future state of the enterprise as well as to analyse the gaps and inconsistency between the current and future state of the organisation and provides roadmaps on how to transform the enterprise to achieve the future state.

Any air traffic management system can be considered as a very complex enterprise which makes the introduction of any change quite challenging. However, growing demand for air transportation makes it necessary to transform the current ATM systems to accommodate the increasing air traffic that grows every year without compromising the level of safety and security. Since ATM involves multiple stakeholders with different business needs, this type of transformation requires coordinated and collaborative research and development activities and later on the implementation of the outcomes of the R&D in the synchronized and timely manner by various stakeholders to maximize the benefits.

That's why the ATM research programs like NextGen and SESAR has employed enterprise architecture as an important means for:

- Optimisation of the R&D activities to avoid any duplications and overlapping and to identify gaps and inconsistency within the programs,
- Provision of various views on the overall architecture of the ATM systems from different perspectives and
- Provision of the integrated roadmaps on how and when the outcomes of R&D can be deployed by stakeholders to achieve the necessary business improvements.

This holistic and integrated approach provided by enterprise architecture to the development and deployment of changes delivered by the research programs can be vital for the successful transformation of ATM systems to address future needs and challenges in air traffic management.

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Аналіз використання архітектури підприємства для модернізації систем організації повітряного руху

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Мета: у зв'язку зі зростаючою потребою в повітряному транспорті та браком поточної пропускної здатності систем організації повітряного руху (ОрПР) для майбутніх потреб авіатранспорту, є потреба у трансформації поточних систем ОрПР. Будь-яка зміна у складній систем такій як система організації повітряного руху може мати вплив на різних учасників організації повітряного руху, продуктивність системи та її безпеку. Саме тому, є необхідність в засобі для оцінки та передбачення впливу зміни та планування її впровадження в найбільш ефективний спосіб. **Методи:** архітектура підприємства надає засоби для формування цілісного уявлення про складну систему таку як система організації повітряного руху дозволяючи оцінити вплив змін так допомогти їх впровадити. Результати: можна побачити що архітектура підприємства використовується різними агенціями, організаціями та підприємствами по всьому світі для кращого управління та планування їх діяльності. Така ж методологія може бути застосована в системі організації повітряного руху для її трансформації, щоб задовільнити зростаючу потребу в повітряному транспорті. З виконаного дослідження, можна побачити, що архітектура підприємства використовується в дослідницьких програмах Сполучених Штатів Америки та Європи задля планування трансформації їх систем організації повітряного руху та забезпечення плавного та швидкого впровадження результатів дослідницьких програм. **Обговорення:** в той час як архітектура підприємства дозволяє отримати цілісне уявлення про стан підприємства, впровадження її може бути викликом. Широке коло експертів є необхідним для опису підприємства з різних перспектив (бізнес-перспективи, операційної та технологічної перспектив, тощо), що робить процес доволі трудомістким. Але існує велика кількість структур для архітектури підприємства та методів розробки архітектури, що сприяють більш плавному та швидкому впровадженню архітектури підприємства.

Ключові слова: архітектура підприємства; архітектура європейської системи організації повітряного руху; Дослідження ОрПР «Єдине небо Європи»; організація повітряного руху; Система повітряного транспорту наступного покоління; структура архітектури підприємства

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Анализ применения архитектуры предприятия для модернизации систем организации воздушного движения

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Цель: в связи с растущей потребностью в воздушном транспорте и недостатком текущей пропускной способности систем организации воздушного движения для будущих потребностей авиатранспорта, есть потребность в трансформации текущих систем организации воздушного движения. Любое изменение в сложной систем такой как система организации воздушного движения может иметь влияние на различных участников организации воздушного движения, производительность системы и ее безопасность. Именно поэтому, имеется необходимость в средстве для оценки и предсказания влияния изменения и планирования его внедрения наиболее эффективным способом. **Методы:** архитектура предприятия предоставляет средства для формирования целостного представления о сложной системе такой как система организации воздушного движения позволяя оценить влияние изменений и способствовать их внедрению. **Результаты:** можно увидеть, что архитектура предприятия используется различными агентствами, организациями и предприятиями по всему миру для лучшего управления и планирования их деятельности. Такая же методология может быть применена в системе организации воздушного движения для ее трансформации, чтобы удовлетворить растущую потребность в воздушном транспорте. С выполненного исследования, можно увидеть, что архитектура предприятия используется в исследовательских программах Соединенных Штатов Америки и Европы для планирования трансформации их систем организации воздушного движения и

обеспечения плавного и быстрого внедрения результатов исследовательских программ. **Обсуждение:** в то время как архитектура предприятия позволяет получить целостное представление о состоянии предприятия, внедрение ее может быть вызовом. Необходим широкий круг экспертов для описания предприятия с различных перспектив (бизнес-перспективы, операционной и технологической перспектив и т.д.), что делает процесс довольно трудоемким. Но существует большое количество структур для архитектуры предприятия и методов разработки архитектуры, которые способствуют более плавному и быстрому внедрению архитектуры предприятия.

Ключевые слова: архитектура предприятия; архитектура европейской системы организации воздушного движения; Исследование ОрВД «Единое небо Европы»; организация воздушного движения; Система воздушного транспорта следующего поколения; структура архитектуры предприятия

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