Architecture Approach in System Development

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Abstract: *The purpose of this paper is to describe a practical solution of architecture approach in system development. The software application is the system which optimizes the transport service. The first part of the paper defines the enterprise architecture, its parts and frameworks. Next is explained the NATO Architecture Framework (NAF), a tool for command and control systems development in military environment. The NAF is used for architecture design of the system for optimization of the transport service.*

Key words: Enterprise architecture, NATO Architecture Framework, information system, system of transport services.

1. Introduction

The system architecture is a basic representation of the system concept. It defines the basic system configuration (elements, functions, associations between elements and their interfaces) in relation to the management system, organizational structure and forms the starting point for composition / decomposition of the system (Methodology, 2010).

The goal of architecture is to unify the description and interpretation of the system in project planning, implementation (development), and purchase with respect to:

- The life cycle of the system.
- Clearly defined purpose.
- Description, and easy-to-understanding language and format.
- Applying a set of standard templates.
- Modularity and repeatability of using.

In the article is the first characterized the system (enterprise) architecture, its standards and frameworks. The second part describes the NATO Architecture Framework (NAF), a tool for the development of C3 (Command, Control and Consultation) systems. They are given the NAF architecture views and templates and the relationships between them, the suggested rules and procedures. NAF is applied to the optimization transport services, listed by dissertation (Zeman, 2016).

2. Enterprise architecture

The Enterprise Architecture (EA) deals with processes modeling and planning in organizations and companies. EA is often compared to the plan of the city, when the architect proposes the concept of neighborhoods, streets and houses to meet their purpose as a unit and also operate throughout the city as a whole. The essence of architecture is its multidimensionality, a chance to look at the problem from different angles (Novotný, 2006).

In the town plan, this means creating a zoning plan, technological infrastructure (water, sewage and electricity network) management of public transport or distribution of public services (police, hospital, school). All these views relate to the same city, interact with each other and are very closely related (Nosková, 2012).

EA is according to MIT Center for Information Systems Research (Weill, 2007) „Enterprise architecture is the organizing logic for business processes and IT infrastructure reflecting the integration and standardization requirements of the company's operating model. The operating model is the desired state of business process integration and business process standardization for delivering goods and services to customers “.

2.1 Problems of EA

Academics and practitioners have made various claims regarding the benefits that EA delivers for both individual projects and the organization as a whole. At the same time, there is a lack of explanatory theory regarding how EA delivers these benefits. Moreover, EA practices and benefits have not been extensively investigated by empirical research, with especially quantitative studies on the topic being few and far between. Paper (Foorthuis & van Steenbergen & Brinkkemper, 2016) presents the statistical findings of a theory-building survey study. The resulting PLS model is a synthesis of current implicit and fragmented theory, and shows how EA practices and intermediate benefits jointly work to help the organization reap benefits for both the organization and its projects. The model shows that EA and EA practices do not deliver benefits directly, but operate through intermediate results, most notably compliance with EA and architectural insight. Furthermore, the research identifies the EA practices that have a major impact on these results, the most important being compliance assessments, management propagation of EA, and different types of knowledge exchange. The results also demonstrate that projects play an important role in obtaining benefits from EA, but that they generally benefit less than the organization as a whole.

In recent years, EA has been of interest to both researchers and practitioners. However, EA benefit realization has not been focused on much. Even though a few studies have addressed the subject, the results are somewhat fragmented and are subjected to limited empirical validation, particularly from the viewpoint of different theoretical constructs and their interrelations in the benefit realization process. To understand how the EA benefits accumulate and how related constructs influence each other, we propose a model and criteria for analyzing the explanatory power of the existing EA benefit realization models. Our model emerged from the data of a qualitative case study with 14 semi structured EA stakeholder interviews. The results support earlier findings, thereby contributing to the enhancement of the relevance and generalizability of the constructs present in previous studies. However, the results also indicate that no existing EA benefit realization model fully captures the complex process of EA benefit realization. Our findings highlight the following: the importance of EA process quality; EA service quality and supportive social environment; constructs that have received less attention in previous studies (Niemi & Pekkola, 2016).

Errors in business processes result in poor data accuracy. Article method (Narman & Holm & Johnson, 2011) proposes an architecture analysis method which utilizes ArchiMate and the Probabilistic Relational Model formalism to model and analyze data accuracy. Since the resources available for architecture analysis are usually quite scarce, the method advocates interviews as the primary data collection technique. A case study demonstrates that the method yields correct data accuracy estimates and is more resource-efficient than competing sampling-based data accuracy estimation.

Stakeholders in business and information technology (IT) enterprises are faced with challenges that result from technological changes occurring at accelerated paces, economic and environmental issues demanding immediate actions, and a need for more precise collaborative decision making. Consequently, chief executive officers are required to respond with solutions that can only be sustained if built upon solid foundations. Paper (Isom & Miller-Sylvia & Vaidya, 2010) introduces Intelligent Enterprise Architecture (IEA) as an architectural style and technique that addresses current and future business and IT trends, along with the technological impacts of a Smarter Planet on EA. The building of a Smarter Planet involves thinking and acting in new ways to make systems more efficient and productive. Thus, we describe an IEA and ways in which foundations can be laid for enterprises to address business complexities that demonstrate Smarter Planet characteristics, including instrumented, interconnected, and intelligent characteristics. IEA is composed of four entry points, referred to as IEA for Cloud, IEA for Social Computing, IEA for Green & Beyond, and IEA for Information Intelligence.

2.2 Levels of EA

The structure of EA involves the relationships between the business logic (business processes and activities), management system (organizational rules and structure), and information system (users, applications, data, and information and communication technology), and includes 4 levels (EA Approaches, 2016):

1. Business architecture - modeling business activities that include the functionality of business processes at all levels; customer approach, product portfolio (product or service).

2. Information architecture - it specifies the information requirements under which create an information model, including data models and data flows.
3. Application architecture - describes the functionality of the applications, their maintenance and documentation; defines the interface between applications of different suppliers and their functional units.
4. Technical Architecture - covers the technological aspects of information and communication technology (computer networks, hardware and software).

2.3 Frameworks of EA

Framework is understood as a set of models, principles, services, approaches, standards, formulas, components, visualizations, and configurations which are created using specific aspects of architecture (Nosková, 2012). Frameworks introduce standards used in each area. Defined standards are designed to provide a clear definition of each business process for simplification of communication within the company and enterprise communication with its surroundings.

Standards may define requirements for the formats used documents and their processing procedures, data structures and data exchange; requirements for the specification of uniform technology and so on. Defined standards not only enable efficient management of the entire company as well as planning its future activities (Novotný, 2006).

2.3.1 TOGAF

The TOGAF (The Open Group Architecture Framework) is a comprehensive approach to planning, design, implementation and maintenance of the system. It defines an enterprise as a group of elements that have a common goal. The Architecture Development Method (ADM) is an iterative process model which provides guidance for creating enterprise architecture. ADM offers proven and repeatable processes, supported by best practices and repeatable used architectural components that lead to successful implementation of EA (TOGAF, 2011), see Fig. 1.

The whole process of development the EA is, by Ross and Weill and Robertson (2016), divided into nine phases: Initial phase, (A) Vision of architecture, (B) Business architecture, (C) IS architecture, (D) Technology architecture, (E) Finding opportunities and solutions, (F) Planning migration, (G) Implementation, and (H) Change management.

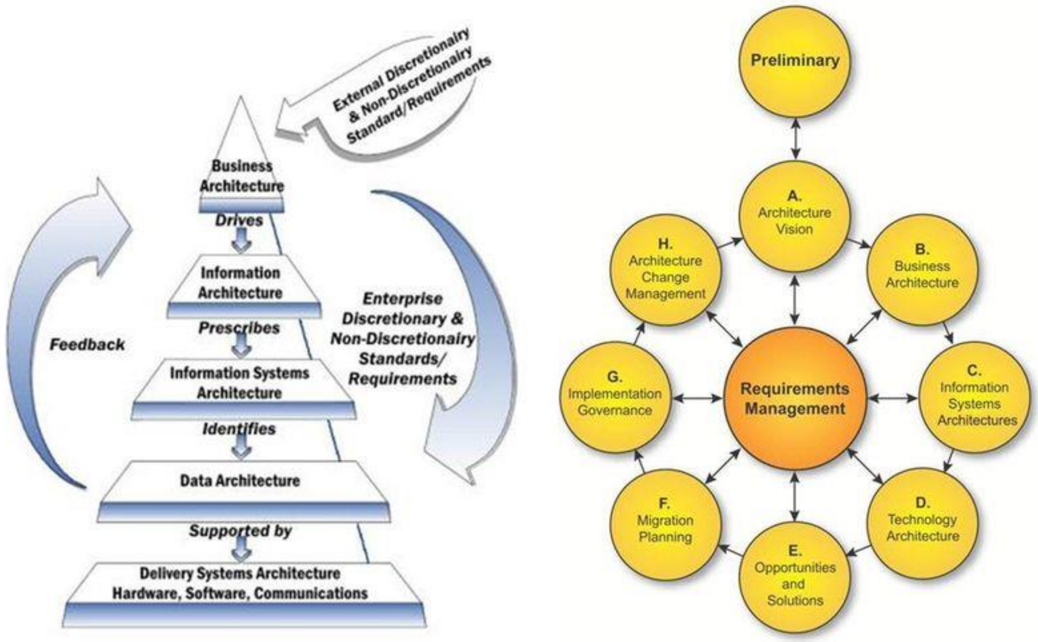

Fig. 1: TOGAF (Ross & Weill & Robertson, 2006)

2.3.2 Initial phase

At this stage is performed the preparatory work for the creation of EA, defining its principles, impact on the organization, composition of working teams and implementation of support tools. The outcome is an organizational model, method of development, and specification the content of EA.

2.3.3 Phase A – Vision of architecture

The aim of this phase is to define the scope of the EA, identification of participants, process management with management of enterprise; leading to the approval of the EA goals. The output is an approved methodical plan along with customized procedures and methodologies of EA, and communications plan.

2.3.4 Phase B to D – Business, IS, and Technology architecture

Phases are oriented to the description of the current and target architectures with analysis of the differences between them. The reference model is specified, application of tools; the plan and its impact on the company. The outcome is the final architecture.

2.3.5 Phase E – Finding opportunities and solutions

This phase focuses on the implementation the target architecture into the enterprise, using the so-called "Transformational architecture". The aim of the phase is revision of the company's objectives and its preparation for the adoption of the planned changes. The outcome is a plan for implementation and migration of new architecture in the enterprise.

2.3.6 Phase F – Planning migration

Phase deals with the confirmation of a migration plan with prioritization of its implementation. They are evaluated the financial impacts and benefits for the company. The outcome is the creation of a control model of implementation covering all versions of the documentation, requirements, schedule and final transactional architecture.

2.3.7 Phase G to H – Implementation, and Change management

The implementation of EA in the enterprise is finished and followed the realization of the processes for change management in the new enterprise architecture.

2.3.8 Zachmann

The framework was defined by J. Zachmann in year 1980 (IBM), see Tab. 1. The EA is a set of design artifacts or descriptive patterns that are relevant to the description of the object in such a way that it can be produced or maintained throughout its life (A Comparison, 2016).

Tab. 1: Zachmann (A Comparison, 2016)

	Why	How	What	Who	Where	When
Contextual	Goal List	Process List	Material List	Organisational Unit & Role List	Geographical Locations List	Event List
Conceptual	Goal Relationship	Process Model	Entity Relationship Model	Organisational Unit & Role Relationship Model	Locations Model	Event Model
Logical	Rules Diagram	Process Diagram	Data Model Diagram	Role Relationship Diagram	Locations Diagram	Event Diagram
Physical	Rules Specification	Process Function Specification	Data Entity Specification	Role Specification	Location Specification	Event Specification
Detailed	Rules Details	Process Details	Data Details	Role Details	Location Details	Event Details

3. NATO Architecture Framework

The NATO Architecture Framework (NAF) is intended for the design of systems in the NATO C3 (Command, Control, and Consultation) and leads to facilitation of the deployment of communication and information systems (CIS), in line with other systems in NATO (NAF, 2016).

3.1 Architecture Views

The architecture processing must be based on standard practices and models used within NATO. The formation of architecture should be approached from three perspectives (views): the operational, systems and technical view, see Fig. 2.

3.1.1 The operational view

The operational view on architecture is the user view of the system and is used to obtain an overview of its features, functions and behavior, independent of the technology and implementation.

The operational view defines:

- The required operational capabilities.
- Components of the system and their interaction from the user's perspective.
- The specification of the functions of the system.
- Information flows and information exchange requirements.
- Processes supported by information flows.

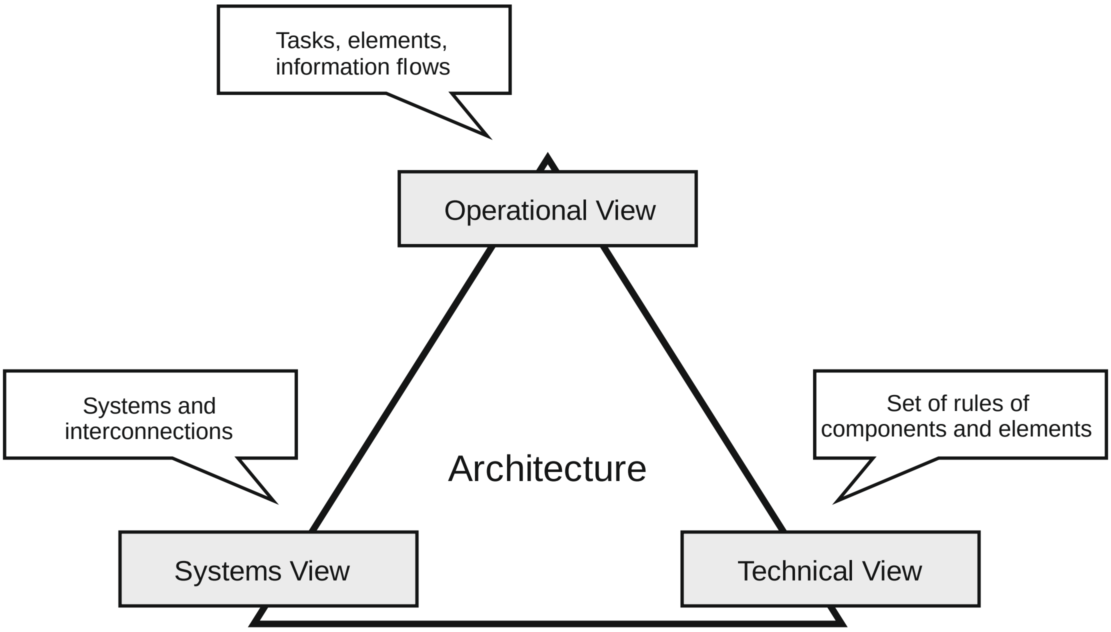

Fig. 2: The architecture Views (authors]

3.1.2 The systems view

The system view on architecture determines boundaries of the system and provides information about its layers and behavior.

The system view includes:

- The system structure (layers) with platforms, features and characteristics.
- Interface of the system components.
- Application and physical resources for the implementation of functions.

3.1.3 The technical view

The technical view on architecture is based upon NATO standards, IS od the the public administration and departmental normative documents. Technical view defines the layout of system components.

Technical view specifies:

- Technological components.
- The layout, interface and component's interdependencies.
- Rules, standards and tools.

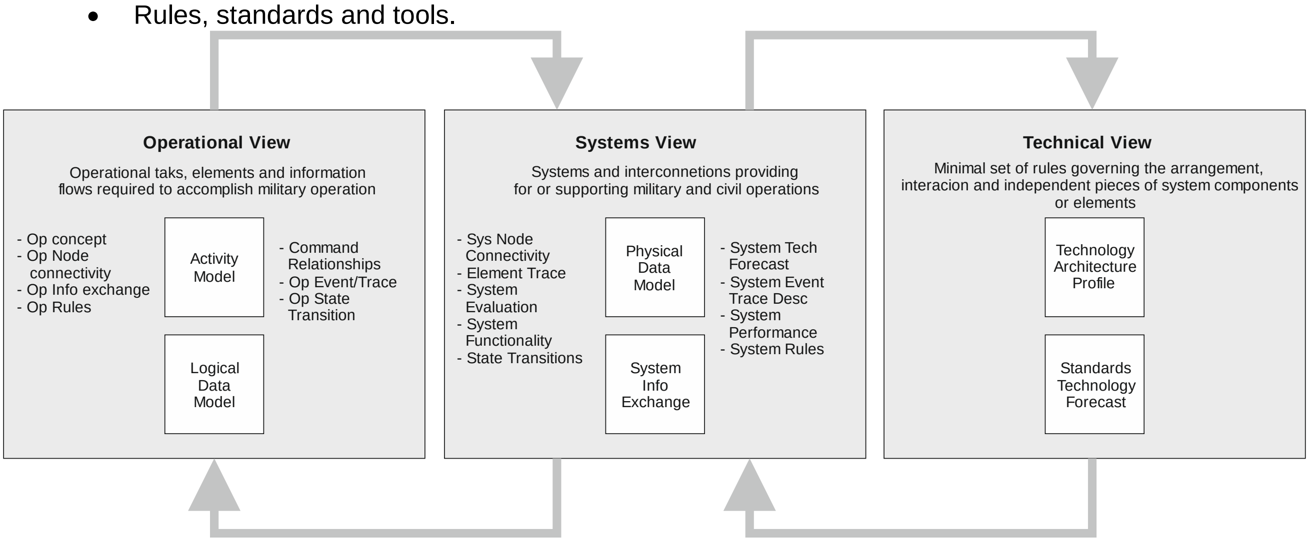

Fig. 3: Operational, systems and technical view (authors)

3.1.4 Relations between views

The relevant architecture is composed of a logical combination of operational, systems and technical view. Relations between operational, systems and technical view, including their content, are expressed in Fig. 3. An integral part of architecture development is also addressing the requirements for the system security. Ensure confidentiality, integrity, availability of information, and accountability of the users are the basic requirements of the architecture design (Methodology CIS/ACR, 2010).

3.2 Procedure for designing architectures

The design process architectures by NAF is listed in the Methodology CIS/ACR (2010) and includes 5 stages. Phase's content is filled with successive steps:

1. ***Determination of the intended use of architecture:*** Architecture is always created for particular purpose. Before starting the description of the architecture is by designer to determine its specifics, requirements and expectations of users and issues that must be addressed.

2. ***Scope of architecture, relations, system environment and other conditions****:* It is determined the scope of the architecture, its elements and level of detail. The architecture describes the system environment, operational scenarios, project costs and available resources for its creation.

3. ***Determination of requirements that should be in the architecture fulfilled:*** It means a range of demands, leading to fulfill the purpose of architecture and future use.

4. ***Selection, creation and processing templates:*** According to the results 1-3 steps of architecture design are chosen templates that will be used. It is necessary to gather data to create them. The result is a set of consistent and interconnected templates of the architecture.

5. ***Creating Architecture:*** Processing the resulting architecture using the selected templates. Presentation of architecture in an understandable form.

4. Using NAF in development the system optimization of the transport service

NAF is a complex, but rather complicated design tool for development CIS applications. Architecture by NAF includes several views and in each of them is available a number of templates. Not all of the templates meet specific application requirements, is an important stage of their selection.

When solving the experiment in design the system "Optimization of the transport service (OTS)" using the NAF has been one of the objectives how the NAF to apply such for solution a specific problem. Authors followed the methodology in Section 2.2 and the results are described in this chapter. Using for OTS the NAF aims to prepare the ease of applying the system in the NATO environment..

4.1 Template NAV-1: Overview and Summary Information

The template is used in the initial phase of development of architecture as a planning guide. After completing architecture provides summary information on system solution and facilitates the quick orientation. It includes identification information; the purpose of the system and its scope; environment of deployment and findings from the discussions.

4.2 NAV-2 Integrated Data Dictionary

Data Dictionary contains definitions of terms used to describe architecture with links to sources of information. It is formed during the formation of architectures to preserve semantic integrity.

4.3 NOV – The operational view templates

The selected templates of the operational view describe system OTS from a user perspective.

4.3.1 NOV-1 Operational conceptual diagram

The operational conceptual diagram illustrates the operating environment on a global level. The used schemas are depicted in a free format. The icons present different element classes or functions, the links between icons show the exchange of information and the possible relation between element classes or functions, see Fig. 4.

4.4 NOV-2 Schema of interconnections between operational nodes

The schema of interconnections between operational nodes is the image of nodes, links and activities, required to carry out those activities. A scheme is more focused on physical nodes, rather than on abstract activity or connections between them and characteristics of the information exchange. Further comprising a description of data, see Fig. 5.

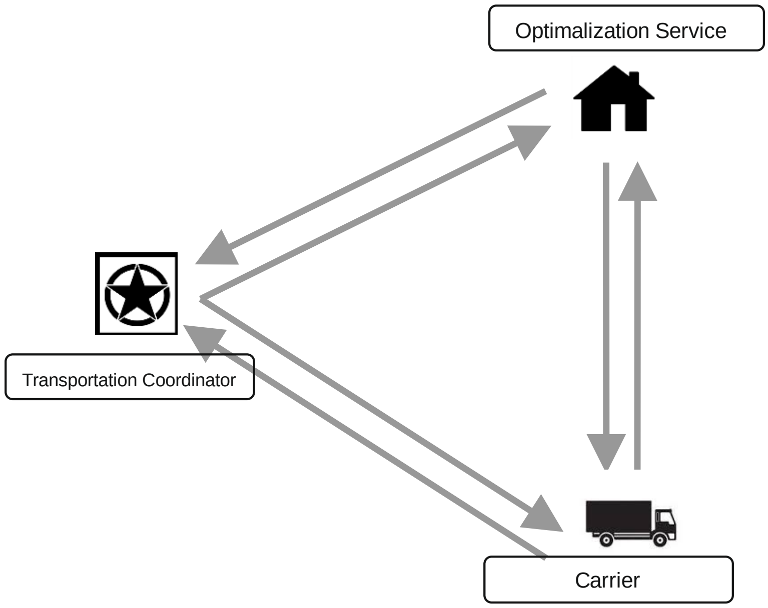

Fig. 4: NOV-1 Operational conceptual diagram (authors)

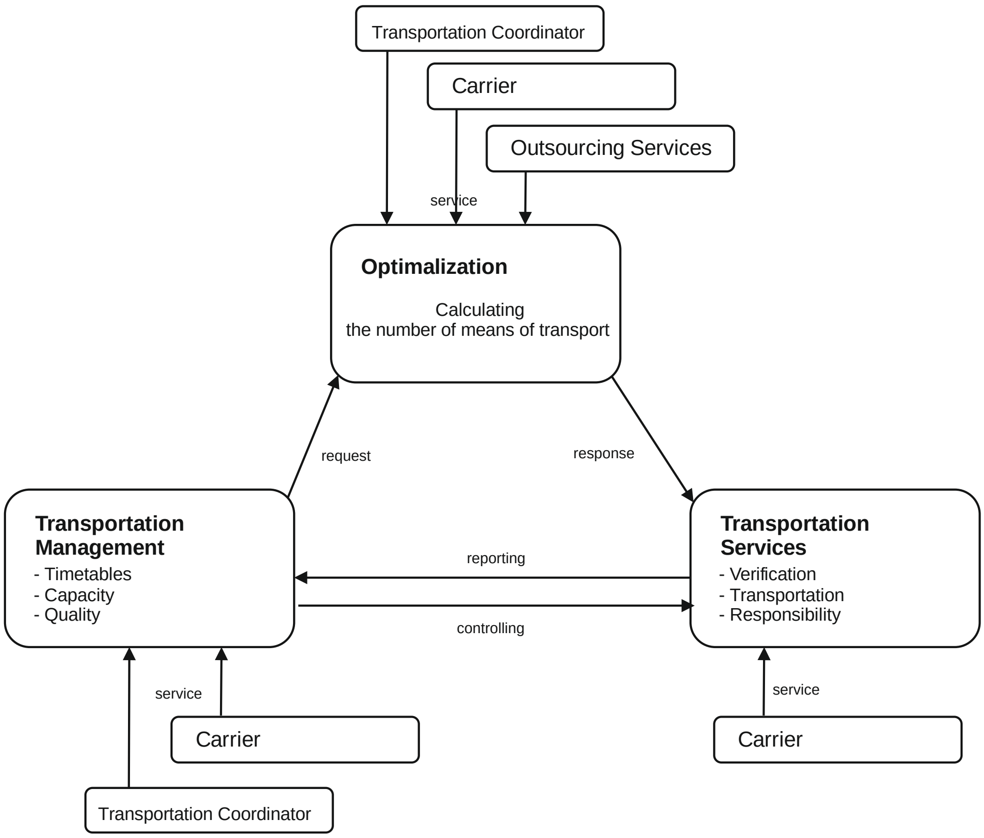

Fig. 5: NOV-2 Schema of interconnections between operational nodes (authors)

4.4.1 NOV-3 Matrix of information exchange according to operational requirements

The template defines relationships between three basic entities (tasks, elements and information flows) from an operational perspective. The matrix identifies the information required to certain activities, see Tab. 2.

4.4.2 NOV-5 Model of operational activities

The template describes the organizational level and the basic role of the system; organizational and managerial ties from an operational point of view (Fig. 6). The organizational levels and their links in the model are in relation to operational nodes defined within the template NOV-2.

Tab. 2: NOV-3 Matrix of information exchange according to operational requirements (authors)

Supported Operational Tasks	**Operationals Elements**		**Descritption of Information**
	Information Consuming Node	**Information Producing Node**	
Transportation Management	Carrier	Transportation Management	Determination of transport activities
Optimalization	Carrier	Carrier	Optimization of transport performance
Optimalization	Optimalization Service	Carrier	Optimization of transport performance
Optimalization	Optimalization Service	Transportation Coordinator	Optimization of transport performance
Transportation Services	Carrier	Transportation Coordinator	Implementation of transportation

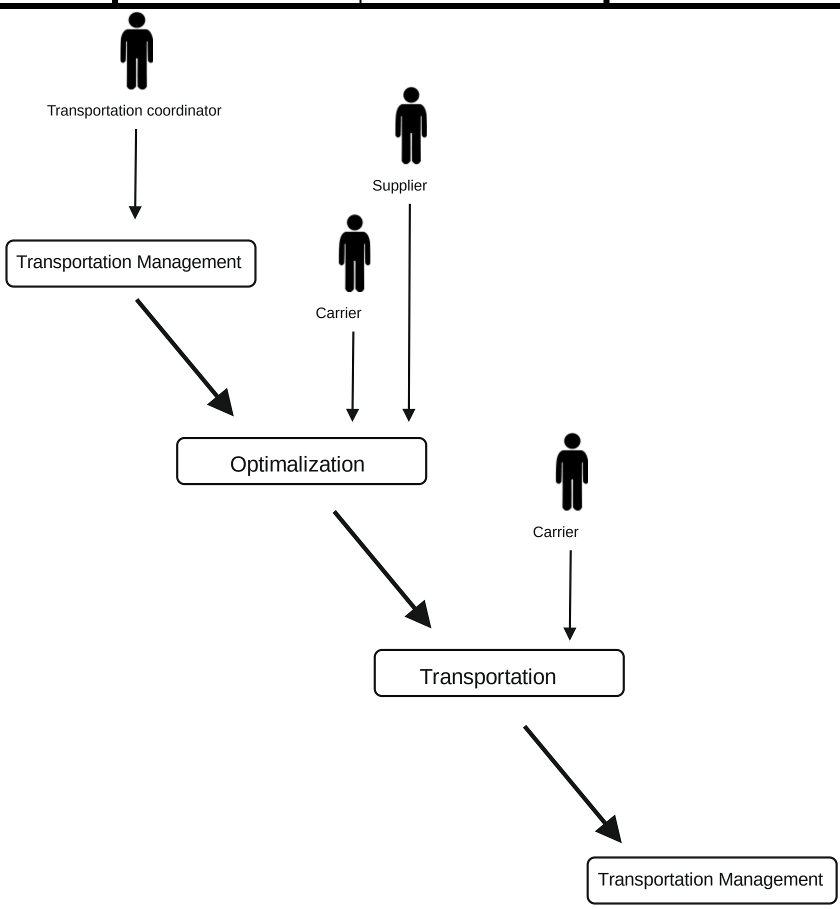

Fig. 6: NOV-5 Model of operational activities (authors)

4.4.3 NOV-6 Conceptual data model

The conceptual data model describes the data and the relationships between them at a conceptual level (see Fig. 7, Class Diagram) and provides a basis for design at logical level to support operational requirements.

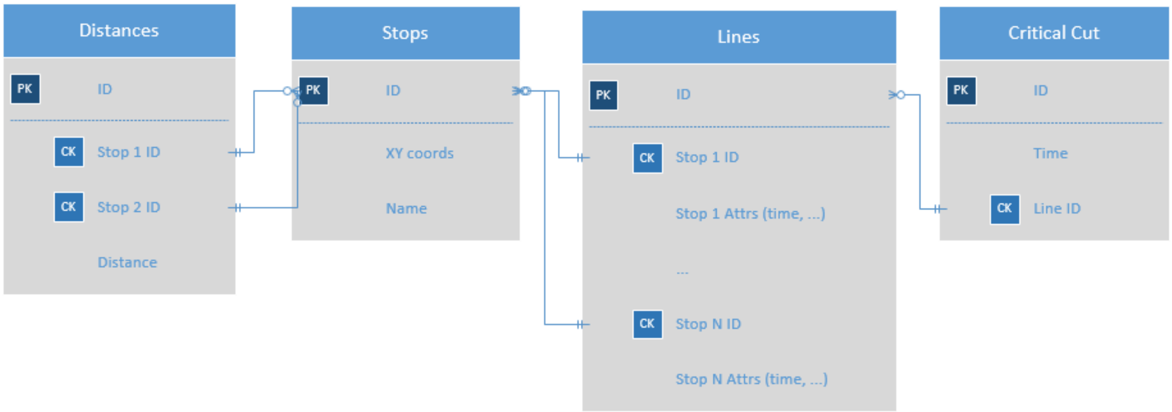

Fig. 7: NOV-6 The Class Diagram (authors)

4.5 NSV – The systems view templates

The selected templates of the system view show the structure of OTS.

4.5.1 NSV-1 Description of the system interface

The template identifies the interface between nodes and elements of the system. It combines operational and systems view assigning systems and their interfaces to operational nodes shown in the diagram linking operational nodes NOV-2, see Fig. 8.

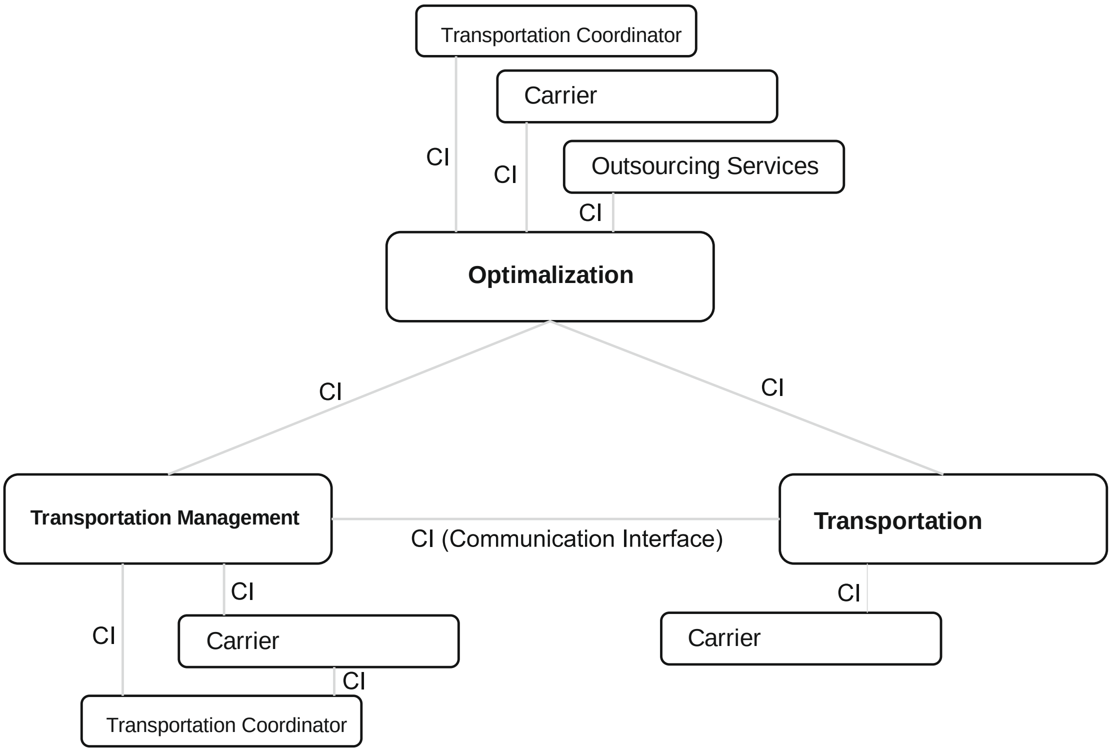

Fig. 8: NSV-1 Description of the system interface (authors)

4.5.2 NSV-2 Description of the system communication

The template identifies the communications infrastructure in which the system nodes carry out their connections. Description is focused on the physical aspects of the information connection, see Fig. 9.

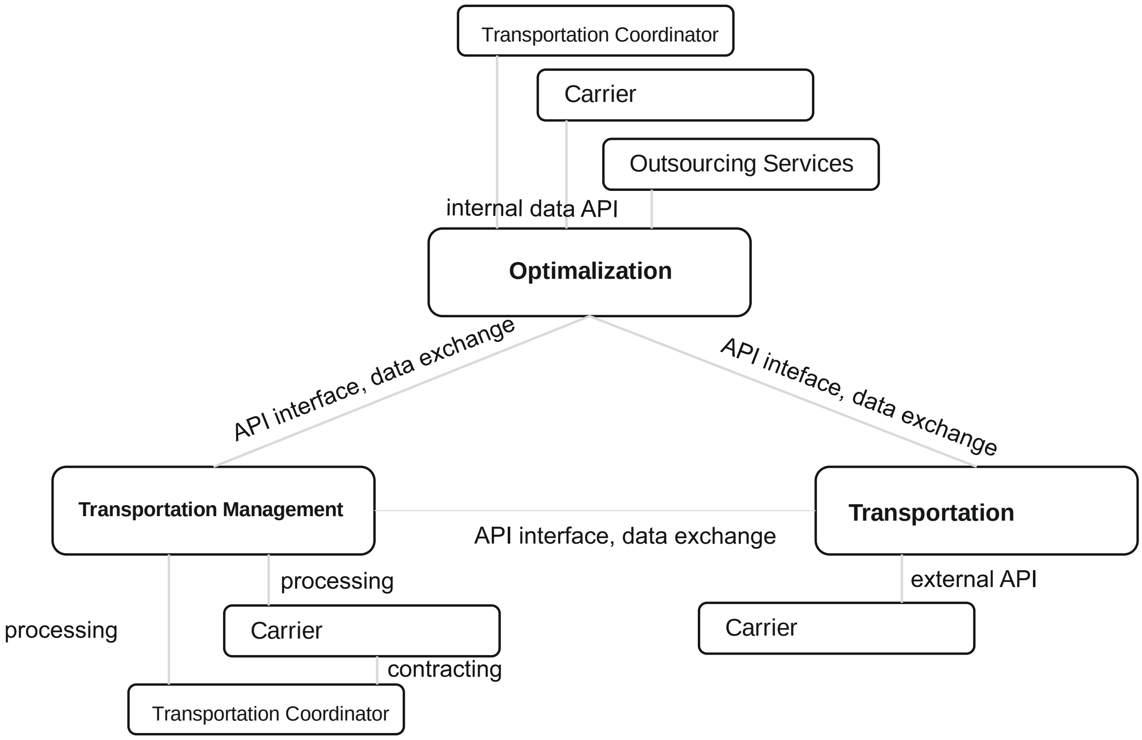

Fig. 9: NSV-2 Description of the system communication (authors)

4.5.3 NSV-4 Description of the system functions

The template is intended to describe the functions of the system and the data flows between them, see Fig. 10.

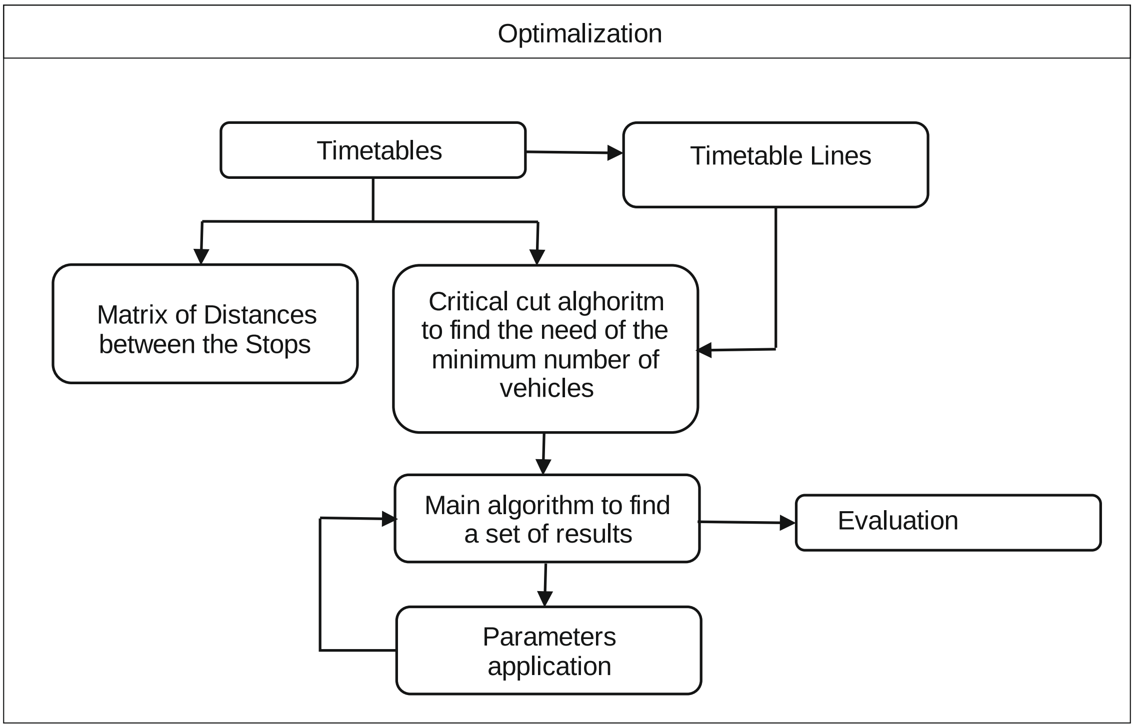

Fig. 10: NSV-4 Description of the system functions (authors)

4.5.4 NSV-7 Matrix of the system performance parameters

The table provides an overview of current and desired performance characteristics of each system within the specified time. It is processed to optimize up to 100 connections.

Tab. 3: NSV-7 Matrix of the system performance parameters (authors)

System	Time without algorithm	Time with algorithm
Creation of Distances Matrix	>24 hrs.	<10 mins
Citical Cut Method	>24 hrs.	<10 mins
Optim. Data Processing	>24 hrs.	<10 mins

4.5.5 NSV-8 Description of system development

Diagram shows the timetable for the development or modernization of OTS in an allotted time (M = month), see Fig. 11.

4.6 NTV – The technical view templates

Selected templates of the technical view define the technical part of the system OTS.

4.6.1 NTV-1 The system standards profile

The template contains a set of rules which solves system implementation and operation. In describing the architecture with a smaller amount of templates can contain an appropriate portion of the existing technical documentation, guidelines, standards or products description. Template recommends and puts into the architecture the technical standards that have been or will be implemented.

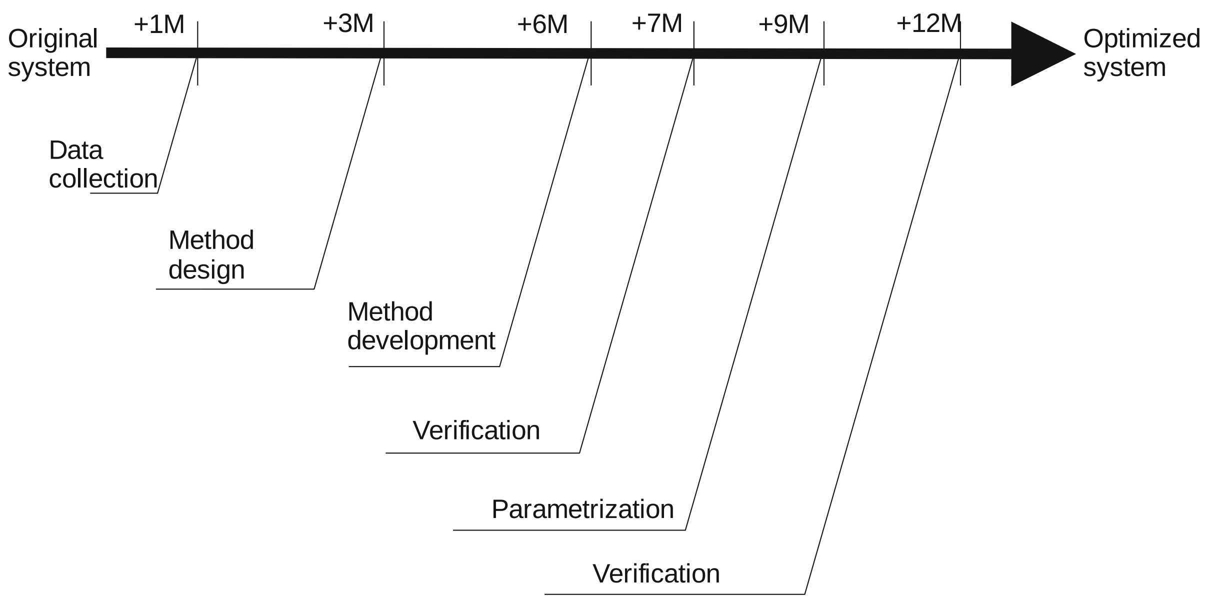

Fig. 11: NSV-8 Diagram of system development (authors)

4.6.2 NTV-3 Technical configuration

The technical configuration describes the standards for the functions defined in the functional configuration. The template describes the configuration of user workstations, specifically for network services, kernel services, infrastructure services and common application security, see Fig. 12.

4.6.3 NTV-4 Software configuration

The configuration of software includes a set of products for defined standards in the technical configuration. The template describes the configuration of user workstations, specifically for network services, kernel services, infrastructure services and common application security, see Fig. 13.

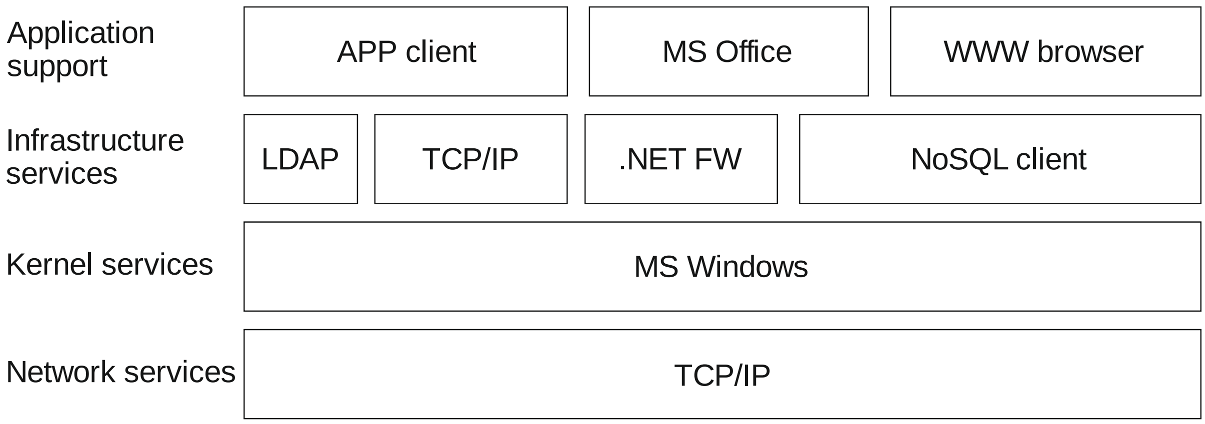

Fig. 12: NTV-3 Technical configuration OTS (authors)

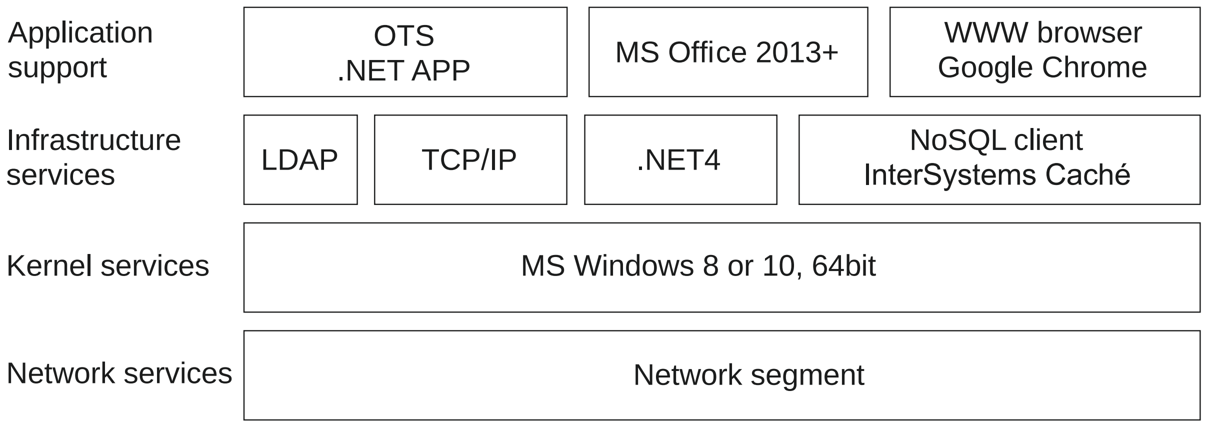

Fig. 13: NTV-4 The configuration of software OTS (authors)

5. Conclusion

The EA allows a good orientation in large enterprise systems. Introduction of standards facilitates communication at all levels of the company, both between management and IT staff, and between the company and its customers. The EA describes every business process, making it easy to identify, maintenance and necessary development. The EA is not a product that can be purchased, but it is primarily a process that needs to be developed and actualized according to the requirements of the company and its surroundings.

Modeling a software project by NAF reflects the way in designing an application in which are used standardized techniques for understanding the intention of the system among NATO members. The templates structure in NAF is leading software architects in a clear and conspicuous manner, eliminating any doubts about the desired and expected functionality of the system.

The specifications and analysis of requirements for OTS software development, was using templates NAF designed its solution. For a project dealing with the optimization of public transport were selected such a template architecture NAF, which are especially useful for software projects. Of the existing templates in the NAF they were used not only all the required templates, but was selected optional templates (NSV-2, 7-ASP, ASP-8 3-NTV, NTV-4); due to a better understanding of results of software project.

It can be stated that the most difficult in the design using the NAF is its comprehensiveness. Basic documentation NAF v3 has about 1,000 pages of text, how to approach the design and use of templates. In such a range of documentation is not possible for an individual to present a complete description of solutions using detailed templates including UML diagrams, it is rather a task for large structured project team. Working in the NAF must be supported by the relatively long phase of training and study. But after mastering theoretical training, then work with NAF is realistic and applicable for the creation of ICT systems.

References

A Comparison of the Top Four Enterprise Architecture Methodologies, 2016: Available at https://msdn.microsoft.com/en-us/library/bb466232.aspx

EA Approaches, 2016: Available at http://internationaleainstitute.org/ea-approaches/

Foorthuis, R. & van Steenbergen, M. & Brinkkemper, S; at al., 2016: A theory building study of enterprise architecture practices and benefits. *Information Systems Frontiers*, Volume: 18, Issue: 3, pp. 541-564; DOI: 10.1007/s10796-014-9542-1

Institute for Enterprise Architecture Developments: Enterprise Architecture, 2016: Available at https://ea.ist.psu.edu/about/what_is_ea

Methodology CIS/ACR: management of the architecture development in Ministry of Defence ACR, 2010, Brno: University of Defence

NAF-NATO Architecture Framework, 2016: Available at http://www.berner-architekten-treffen.ch/archiv/18/2_RUAG_NAF.pdf

Narman, P. & Holm, H. & Johnson, P; et al., 2011: Data accuracy assessment using enterprise architecture. *Enterprise Information Systems*, Volume: 5, Issue: 1, pp 37-58; DOI: 10.1080/17517575.2010.507878

Niemi, EI. & Pekkola, S., 2016: Enterprise Architecture Benefit Realization: Review of the Models and a Case Study of a Public Organization. *Data Base For Advances In Information Systems*, Volume: 47, Issue: 3, pp. 55-80; DOI: 10.1080/17517575.2010.507878

Nosková, M., 2012: *Application of the project management in Enterprise Architecture.* Prague: University of Economics. Available at http://www.vse.cz/vskp/33496_aplikace_projektoveho_rizeni-v%C2%-Enterprise_architecture.

Novotný, M., 2006. Enterprise architecture IT. *System ONLINE*. Available at http://www.systemonline.cz/sprava-it/enterprise-architektura-it.htm

Isom, P. & Miller-Sylvia, SL. & Vaidya, S., 2010: Intelligent Enterprise Architecture. *IBM JOURNAL OF RESEARCH AND DEVELOPMENT*, Volume: 54, Issue: 4, Article Number: 6; DOI: 10.1147/JRD.2010.2051750

Ross, JW. & Weill P. & Robertson D., 2006: *Enterprise Architecture as Strategy: Creating a Foundation for Business Execution.* Boston: Harvard Business School Press

TOGAF-The Open Group Standard, 2011: The open group architecture framework. Version 9.1, Document Number: G116. ISBN: 978-90-8753-679-4

Weill, P., 2007: Enterprise Architecture by MIT Center for Information Systems Research, as presented at the Sixth e-Business Conference, Barcelona Spain

Zeman, K., 2016: *System for optimization of the transport service* (dissertation). Brno: University of Defence

JEL Classification: L91, M15