Digitalization of Seaports based on Enterprise Architecture approach

A A Lepekhin[1], A I Levina[1], A S Dubgorn[1], J Weigell[2], S E Kalyazina[1]

[1]Graduate school of Business and Management, Peter the Great St.Petersburg Polytechnic University, Russia
[2] Hamburg University of Technology, Institute of Maritime Logistics, Fraunhofer Center for Maritime Logistics and Services CML, Hamburg, Germany.

Abstract. Global economy and era of digitalization poses great pressure on development of different enterprises. Businesses have to be complied with newest technologies and focus on efficiency of their management system. Seaports are complicated business systems, which are becoming global hubs for different stakeholders to exchange data within complex infrastructure. Digitalization of such complex systems requires a coherent approach, aiming to summon managerial and digitalization goals. The key concept to create a digital-based system of business processes is the concept of IT-services, which are characterized to be a support of business functions. The goals of this research paper is to adapt standard of Enterprise Architecture and create a coherent system of business processes for container terminals and suggest a set of IT-services, which could be further transformed into a complex Applications Architecture of seaport. This Applications Architecture can be further built up with modern digital technologies and information systems of different types.

1. Introduction

This research paper is aiming to provide a coherent overview of existing IT-services for container terminal and hinterland processes and operations and describe the insights of the current state of digital architecture in different container terminals all over the world.

The necessity and additional value of the paper for research and industrial application is caused by a rapid transformation of traditional business models into digital-based models on one hand and the growing role of maritime logistics and increasing vessel dimensions on the other hand. These factors lead to great pressure on container terminal systems: the speed of operations, process efficiency, forms of information exchanges as well as security. Container terminals have to act as global hubs, integrating operations of different stakeholders by providing efficient IT-architecture to support all the existing processes.

The baseline reason of this research project is a result of number of factors, which have changed the operation of container terminals. Overall increase in container shipment operations in global logistics and supply chain management and increasing vessel dimensions caused a significant growth of container turnover and emerging requirements to container logistics processes. The efficiency of container terminals as a part of this supply chain is viewed as a complex issue, which comprises a

variety of different factors. Among those the technological infrastructure of terminal processes is recognized as an important competitive advantage in a view of global digital transformation [1]. This can be explained by speed, efficiency and transparency of information flows, which, being a crucial factor of container terminal functioning, can be significantly improved by information technology. For container terminals the efficiency of information flows directly affect the turnover speed of containers and tackle important operational issues, such as number of empty containers, emission levels, planning of storage areas and thus improving key performance indicators of container terminal.

The development of a competitive IT-infrastructure is represented as a complex task, which starts with high level modelling of business architecture and IT-services landscape. An essential peculiarity of container terminal infrastructure is its high dependability on integration requirements. Different information flows have to be accessible by different stakeholders through different interfaces, which results in growing need of building a high-level model of service structure.

2. Literature review

The current state of globalization affects different industries and processes in a substantial way. It leads companies to relocate the production sites and goods flows, generates new requirements to investments in infrastructure expansion projects and creates a stronger focus on environmental protection and energy efficiency. It brings significant changes in supply chain management due to safety and security requirements in combination with process integration needs. In this context container terminals face new emerging challenges of substantial operations improvement [2].

A container port, which provides the interface between container ships, railroads and road trucks, represents a critical link in global supply chain management. Therefore its efficiency is recognized as an important requirement, which is necessary to be fulfilled by means of different approaches [3]. Current literature considers ports as complex networks, which require a better integration among all the actors involved in operations [4]. Given the complexity of the supply chain, with multiple participants, researchers suggest that there is ample opportunity to increase efficiency and reduce costs by information technology implementation [5]. Currently port community systems are used for concurrent processes on terminals for example Portnet in Singapore, Dakosy in Hamburg or Port Base in Rotterdam. [11],[12],[13].

Information technology support of business processes is a significant competitive advantage of companies and often becomes the determining factor of leadership on the market in different industries. Coherent information infrastructure is tackling the problem of information flows management and integration. Typical problems in container terminals, which have potential to be solved by information technology support, include ship planning and scheduling, berth allocation, stowage planning, crane split, quay-yard movement optimization and yard-gate movement optimization [6].

Despite being recognized as a major contributor to overall efficiency, implementation of modern IT differs at container terminals [2]. Currently there is variety of different software services, which are realized by means of existing software products to support container terminal processes, as well as variety of algorithms and mechanisms, which are in the state of research development [7] [8] [9]. Existing research address either case of existing information infrastructure, or describe opportunities of specific operations optimization, or study specific technology in its appliance to the container terminals [10] [11] [5]. This leads to the need of addressing the service-oriented vision of information infrastructure in a container terminal in order to provide a holistic overview of existing processes and possibilities of their technological support.

The smart port is a promising modern solution that allows to increase competitiveness, customer satisfaction, the level of solving the problems of managing cargo flows, especially in the context of the

globalization of freight traffic. Modern seaports are focused on the integration of automated system solutions. IoT, cloud computing and the ubiquitous availability of networks enable digital transformation of seaports around the world [12]. The smart port is part of the supply chain in the Smart Logistics concept and allows to reduce transaction costs and increase efficiency throughout the value chain. To do this, a modern port should ensure high performance, reliability and efficiency of cargo handling, reduction of the vessel's berthing time in the port and uninterrupted operation. This requires changes in the organization of logistics and the use of modern digital technologies. In the framework of the concept of digitalization and the transition to the concept of "Smart Port", such technologies as driverless cars, IoT, low cost sensor technologies, big data, augmented reality, self-driving vehicles, robots and 3D printing are already in use [13].

There is an experience of using simulation modeling of the port terminal at levels associated with the movement of ships, with the handling of ships on the terminal quay, and with the handling of containers at the terminal. This allows to optimize the use of terminal resources, improving its performance, and reduce the impact on the environment [14]. The ports of Hamburg and Rotterdam can be cited as examples of the integrated application of technologies. The single platforms used unite the automation of traffic flows, infrastructure and the flow of goods and offer solutions for shippers, freight forwarders and traders who want to increase their understanding of all the complexity of logistics chains and control them.

For a wider application of advanced digital technologies and port digitalization, a logistic digital infrastructure and a number of digital changes are required, which requires investments in IT solutions, reorganization of internal activities in accordance with the rules of the digital world and retraining of specialists.

3. Materials and methods

A container terminal is viewed as a complex system, which includes various stakeholders, processes and services. In order to represent that complex system in scopes of the current research project, an enterprise architecture concept is intended to be used.

The enterprise architecture model is designed to connect the management technologies of various aspects of a business to create an integrated management system. The enterprise architecture in its modern understanding appeared as a response to the problems of aligning the requirements of business and IT infrastructure. This concept is quite close to the objective of current project and can be applied as a baseline method for creating the models of container terminal IT-infrastructure [15].

Currently, there are various methods for the formation and evaluation of the enterprise architecture. Among them The Open Group Architecture Framework (TOGAF) standard focuses on the business mission and uses the Architecture Development Method (ADM), which describes the process of transition from a basic architecture to a target in accordance with business objectives [16] [17].

TOGAF represents the enterprise architecture in the form of 3 basic layers.

- Business Architecture - system of business processes and functions of the organization, basic business units, organization locations, organizational structure.
- Applications Architecture - application components, application functions, integration components of applications and IT services.
- Technological Architecture - internal networks of the organization, server component of applications, databases, etc. [18]

Conceptual provisions of the approach to the formation and development of the architecture TOGAF ADM formed the basis for the language of modeling the architecture of the company – ArchiMate,

which would be applied in current research as modelling notation [19]. This modelling language and supportive software (Archi 4.0) will be used in scopes of the current research paper.

4. Results

The analysis of processes structure of container terminals showed that there could be two baseline types of business-processes to be derived:

- Administrative Level processes (which refer to general management and legislation issues)
- Operational Level processes (which refer to container-shipping functionality)

Administrative level processes include:

- Terminal security
- Bay planning and development
- Empty containers transportation
- Licensing
- Customs inspection
- Insurance

The processes landscape for administrative level is demonstrated in the Figure 1. It also demonstrates potential IT-services, which are part of Applications Architecture. The services are demonstrated as «application-independent», which means that we focus only on their benefit to specific business-process.

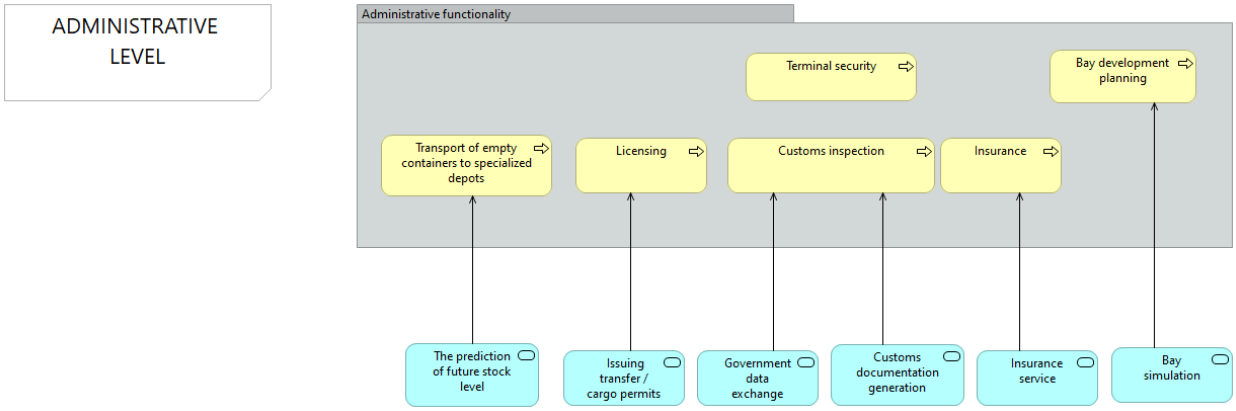

Figure 1. Administrative level business processes and IT-services

Operational processes have wider range than Administrative and have been split into three groups:

- Vessel
- Terminal
- Hinterland

This grouping allowed to provide deeper analysis of each group and design the models of business-processes landscape and potential IT-service to support them.

Vessel-related processes group includes two baseline processes: Berth planning and Stowage planning. Both processes can be supported by IT-services, related to Data-exchange issues. The model of this group is demonstrated in Figure 2.

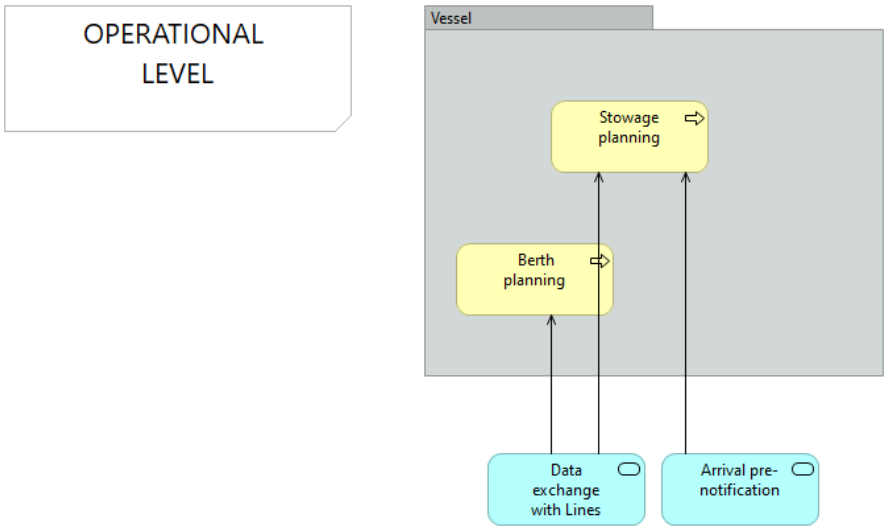

Figure 2. Operation (vessel) level business processes and IT-services

As for Terminal processes group, there are four baseline processes: Crane scheduling, vessel unloading/loading, horizontal transport and gantry cranes assignment. The most interesting from the point of IT-services support is Horizontal transport process. There as potential to implement such IT-services as: Dispatching, Containers identification, Routing of transport, Modelling topology of container yard and other. The model of this group is demonstrated in Figure 3.

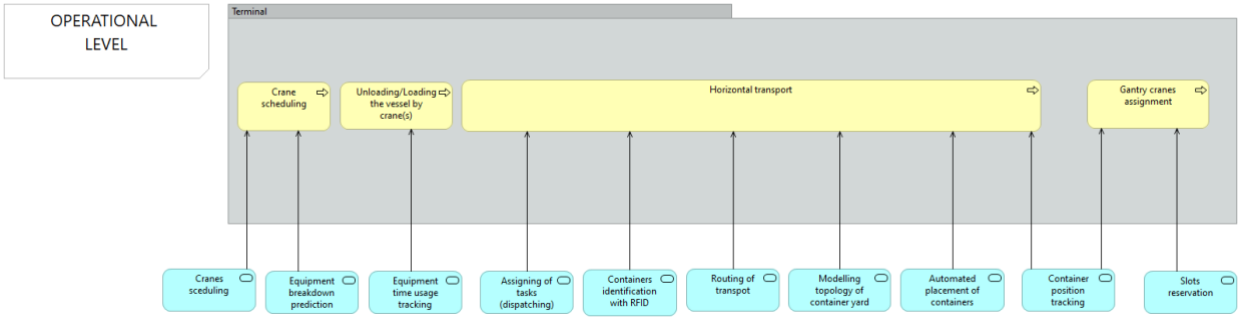

Figure 3. Terminal (vessel) level business processes and IT-services

Hinterland processes group stands for processes, related to hinterland transport management, including such processes as: dispatching of trucks, routing, freight status management and others. The model of this group is demonstrated in Figure 4.

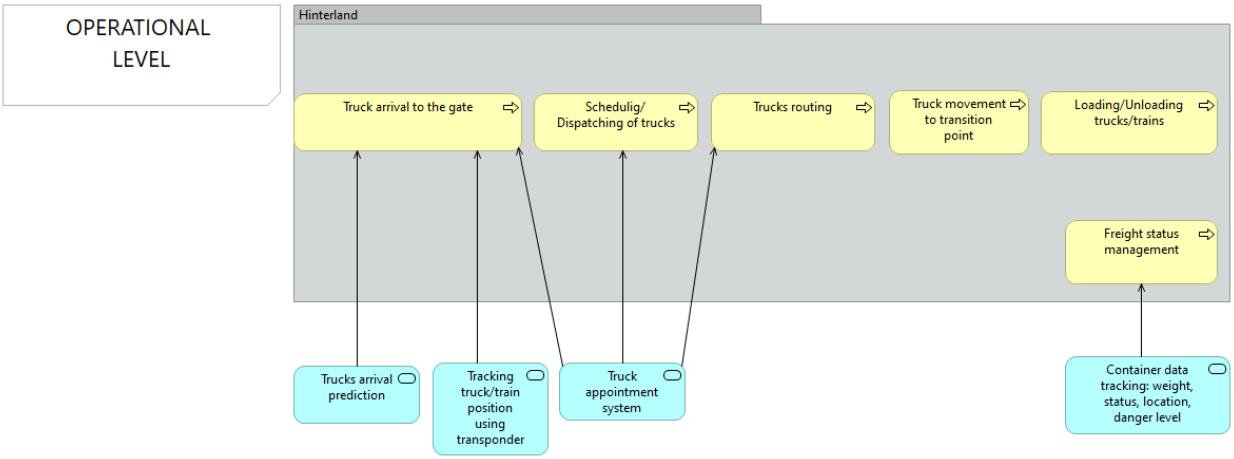

Figure 4. Operation (hinterland) level business processes and IT-services

The results of performed analysis can be divided into two groups. Firstly, this is an attempt to create the processes landscape of container terminals based on TOGAF standard and Archimate modelling language for Enterprise Architecture [20]. Secondly, we provided potential set of IT-services to support processes landscape. IT-services is a starting point for creation an Applications Architecture, they can be realized by variety of applications and technologies.

5. Discussion

The container terminal processes, which are included in scopes of the current research, as well as IT services supporting them, have initial constraints. The set of processes, which is included in scopes of the current research paper, refers only to import, export and transshipment operations. The research paper does not focus on specifics of functionality, which could realize the described IT-services. The essence of IT-service in scopes of current research is the ability to support and enhance business process. The development of different Application Architectures for the described IT-services structure could be a topic for future researches.

6. Conclusion

According to the latest research estimates, the volume of the world market for container shipments is growing due to globalization of economics. This can be potentially driven by the fact that the main advantage of containers is their standardization and mobility.

Containers are easily reloaded from ships to railway platforms, from platforms to a truck and back. Thereby the key factors for a container terminal are the efficiency of the stacking and the transport of containers to and from the ship's side. High productivity and container throughput from quayside to landside and vice versa at low costs are vital for a terminal operator in terms of being competitive. Different information flows have to be accessible by different stakeholders through different interfaces in order to improve the operations efficiency of container terminal. This can be realized by corresponding IT-infrastructure. A competitive IT-infrastructure is represented as a complex task, which aligns business architecture and IT-services landscape.

In scopes of current research we have developed a business-processes landscape of container terminal and proposed a set of IT-services to support this landscape. The described models can become a basis for development of Applications Architecture of Smart port based on modern digital technologies.

7. Acknowledgements

The reported study was funded by RSCF according to the research project № 19-18-00452.

8. References

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