IT and technological architecture of healthcare organization

I V Ilin¹, A A Lepekhin¹², A S Ershova¹, and A D Borremans¹

¹ Peter the Great St.Petersburg Polytechnic University, Polytechnicheskaya 29, 195251 St.Petersburg, Russia

E-mail: lepekhinalexander@gmail.com

Abstract. The healthcare industry has changed significantly over the past few years. This is largely due to widespread digitalization, as well as a shift in the emphasis of medical care towards patient focus. This led to the emergence of approaches such as value-based and personalized medicine, as well as the concept Health 4.0. An increasing number of medical organizations are striving to follow the indicated trend, but this becomes impossible without the provision of proper information support. In this regard, most medical organizations are faced with the need to reorganize the existing information and technological architecture. The main goal of this article is to develop methodological principles and an algorithm for the formation of an IT architecture and technological infrastructure of a medical organization that plans to implement the principles of value-based and personalized medicine using modern digital technologies. The methodological basis for the ideas proposed in the article was the concept of enterprise architecture, as well as the TOGAF architecture description standard.

1. Introduction

In recent years, digitalization and automation have become one of the main trends in the world. Almost all areas of life have undergone digital transformation to some extent. It also touched upon the healthcare sector.

Modern medical organizations are influenced by two powerful external factors - global (digital transformation) and industry (value and personalized medicine) values. The need to take into account global and industry trends in business development is a matter of survival, competitiveness and efficiency for companies. Medical organizations in the modern world are also forced to adapt to both the development trends of the healthcare industry and the overall digital transformation of business and reality.

All these trend modern trends in the development of healthcare dictate the need to develop methodological principles and a sequential algorithm for building an information and technological architecture of a medical organization that implements the principles of value-based and personalized medicine.

This paper is aimed at:

- study of leading concepts in medicine: value-based, personalized medicine, Health 4.0, as well as the concept of enterprise architecture;
- creation of a reference model of information and technological architecture and development of principles for its formation;
development of a methodology for the phased formation of the architecture of a medical organization that implements the principles of value and personalized.

2. Methodology and literature review

The modern health care system is actively developing under the influence of various global trends. The most significant of them today are the concepts of value-based and personalized medicine, as well as the concept of digitalization of medicine – Health 4.0.

Value-based medicine is a medical practice that aims at maximizing value, specifically desirable or positive value in every step of a patient’s medical management [1][2]. This concept assumes, first of all, a competent assessment of the value from the point of view of not only a truly medical effect, but also from the point of view of the patient, his environment and society as a whole. From these positions, the most valuable interventions are those that not only prolong life or inhibit the development of the disease, but also significantly improve the quality of life of a particular patient and meet their goals. The second component and downside of the value of medical care is its cost. From the point of view of any health care system, it is necessary to achieve an optimal balance of effect (medical, patient-centered and social) and cost. At the same time, this concept assumes a change in the financing of medical care according to its ultimate value. It is the achievement of the most valuable effect of medical intervention for the patient in combination with the rational use of resources that is the main criterion for the effectiveness of the work of a doctor, institution, and the entire system as a whole [3][4].

Personalized medicine is another ideological basis for building a management system for a medical organization. It assumes that comprehensive medical care is provided in accordance with the individual characteristics of a particular patient. In this case, such characteristics are understood not only to all well-known clinical signs, such as age, sex, physique, lifestyle, but to a greater extent the molecular characteristics of the patient’s body, such as data from genomic and post-genomic studies [5][6][7]. The goal of personalized medicine is to find the right drug for a specific patient, and in some cases even to develop a treatment regimen for the patient in accordance with his individual data. The need for this is due to the fact that traditional drugs created for the treatment of a specific disease are ineffective for 30–60% of patients, along with a high incidence of side effects [8][9].

Adherence to the principles of value-based and personalized medicine in the modern world is extremely difficult to ensure without the use of information and digital means. In this regard, the concept of Health 4.0 has become widespread today.

The Health 4.0 concept represents the industry medical focus of the Industry 4.0 concept. This means the application of all Industry 4.0 technologies - IoT (Internet of Things), Cloud computing, Big Data, Artificial Intelligence, Machine Learning, Blockchain, 5G (mobile technologies), visualization, predictive analytics - in the field of medicine to achieve goals set for medical organizations in the framework of solving problems of value-based, personalized medicine, telemedicine, etc [10][11][12].

Thus, the introduction of the principles of value-based, personalized medicine and Health 4.0 allows a medical organization to become an integrated center, capable of providing a patient with personalized services with the participation of the patient as an active subject.

Implementing said principles of value-based, personalized medicine and Health 4.0 requires medical organizations to build their enterprise architecture accordingly. This is done to ensure organization’s ability to adapt to proposed changes and in order to help manage business transformation processes.

According to the definition proposed by Mark Lankhorst enterprise architecture is a set of holistic principles, methods and models that are used in the design and implementation of the organizational structure of the enterprise, business processes, information systems and infrastructure [13].

Nowadays there are several basic standards and methods for building enterprise architecture, but only one of them contains an architectural design method that answers the question of “how?”. That standard is TOGAF, The Open Group Architecture Framework, developed by The Open Group.
consortium. At the core of TOGAF is the Architectural Development Method (ADM), which describes a step-by-step cyclical approach to developing an overall enterprise architecture.

Table 1 shows every phase of an architecture development method offered in TOGAF.

| Phase      | Description                                                                                                                                 |
|------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Preliminary phase | Describes the preparation and initiation of the activities required to create architectural capabilities, including the adaptation of TOGAF and the definition of architectural principles. |
| Phase A    | Reflects the initial phase of the architecture development cycle, during which an architectural vision is created, captured in document called “Architecture Vision”. Developing a vision involves working with stakeholders, defining their main interests and project goals. The results that need to be achieved are indicated, as well as the actions that need to be done for this. An enlarged description of the basic and target architecture takes place, as well as an assessment of the organization’s readiness for the proposed changes and a preliminary risk assessment. |
| Phase B    | Describes the development of a business architecture that supports the architecture vision.                                                                 |
| Phase C    | Describes the development of an information systems architecture and/or data architecture.                                                  |
| Phase D    | Describes the development of a technology architecture.                                                                                     |
| Phase E    | Consolidates the gap analysis between the baseline and target architecture from Phases B, C, and D. The main goal of the phase is to collect all the architectural elements to be converted and compare alternative ways to implement the target architecture, taking into account applicability and practicality. |
| Phase F    | Describes the development of a detailed implementation and migration plan that is designed to move from the source architecture to the target architecture, taking into account the identified priorities. |
| Phase G    | It assumes the implementation of “architecture governance” by a team of architects of the currently implemented projects. The results of Phase G are solutions put into production that match the given architecture. |
| Phase H    | Establishes change management procedures in relation to the new architecture.                                                                |

ADM also involves combining the described phases into four iterations:

- iteration of setting architecture management practice (preliminary and A phases);
- architecture development iteration (phases from B to F);
- iteration of scheduling transition from current to target state (phases E and F);
- architectural guidance iteration (phases G and H).

The concept of iterative development is important for TOGAF ADM and is applicable to three entities: the cycle itself, which is iterative, to four dedicated iterations, and to each phase separately, given that the implementation of steps is also usually iterative [14].

3. Results
Since the implementation of the principles of value-based and personalized medicine in a modern medical organization is inevitably associated with the use of information technologies, it seems
expedient to develop a number of methodological principles that will make it possible to form the correct IT and technological architecture.

When creating an information and technological architecture, first of all, a medical organization must make sure that the technologies being implemented support the achievement of long-term goals and the solution of operational business problems [16]. It is a fundamental principle that will enable an organization to maximize the benefits of information technology.

It is important to keep in mind, however, that building an enterprise architecture is not an easy task. The organization may simply not consider all the necessary elements. In this regard, the following principle states that when building an information and technological architecture, one should rely on ready-made reference models that have been developed by specialists for a specific field. An example of such a reference model is shown in Figure 1.

Figure 1. Medical organization information and technological architecture reference model.

This model presents the main classes of systems that are definitely needed by organizations planning to follow digitalization trends, as well as the principles of value-based and personalized medicine. These include ERP, MIS, BI.

ERP is a class of information systems designed for enterprise resource planning. A medical organization with the help of the ERP can automate activities for personnel management, procurement of medical equipment and consumables, logistics, marketing, and financial activities, as well as project management.

Perhaps the most important for medical organizations is the MIS system. Medical Information System (MIS) is a complex software product, the purpose of which is to automate all the main processes associated with the work of medical institutions of general and narrow specialization. Automated medical information systems allow you to establish electronic document flow quickly and efficiently, flexibly arrange work with patients, keep an operational record of the work of administrative personnel, etc [17].

The BI system is no less important for the organization. BI (Business Intelligence) technologies are based on the analysis and organization of end-user access to data and information structured and quantitative in nature. Users of the BI system, having access to data and their analysis, can then form conclusions on their basis, find relationships and make forecasts for making effective decisions [18][19]. The use of BI systems in medical organizations largely allows a personalized approach to be implemented: all decisions regarding the appointment of therapeutic or preventive measures are made based on the results of the analysis of a large amount of patient data, which is carried out by the BI system.

Also, in addition to information systems, the presented model also indicates the software of medical equipment and the equipment itself. Moreover, as you can see, the equipment is represented
not only by nosocomial installations, but also by personal wearable devices. The use of personal wearable devices is a significant part of value-added and personalized medicine. First, patients tend to be more comfortable using wearable devices than being monitored in a hospital, which adds value to the patient. And secondly, wearable devices collect individual data to form the most effective treatment strategy. And in this regard, another principle is being formed: all equipment (both inside the clinic and outside it) must be integrated into the information and technological architecture. This will allow collecting more information about each patient, and, as a result, will provide a personalized approach to each patient based on his individual characteristics.

It is important to understand that the created architecture will function effectively only if the necessary connections are built between the systems and technological elements and information exchange is established. Ensuring systems integration is the next principle to be followed when developing IT and technology infrastructure. Such integration will allow automating many functions (for example, data from medical sensors will be automatically transmitted and stored in the electronic medical record of the patient).

The principle of ensuring the maximum level of data security is also especially important for medical organizations, since a huge amount of personal data is stored in the systems of a medical organization, protected by medical secrecy and medical ethics. Therefore, it is necessary in some parts of the landscape to use systems with clearly declared and customizable roles, as well as with the ability to isolate these systems from the "outside" world, without interrupting the interaction with other systems used in the landscape [20][21].

Thus, following the listed methodological principles will allow a medical organization to create an information and technological architecture that will support the principles of value-based and personalized medicine.

The proposed algorithm for implementing said principles in a medical organization in based on TOGAF ADM. During Preliminary Phase a thorough research of a medical organization is conducted. That involves correctly identifying stakeholders and setting guidelines for organization’s way of operation. For a medical organization stakeholders typically include its top management, suppliers of various medical equipment and medicine, sometimes insurance companies and government are also included in this list. Guidelines vary for every enterprise depending on its size, set of medical services provided and many other factors.

The purpose of Phase A is to create an enterprise architecture concept. Based on the analysis of the driving forces of the medical organization, its enterprise architecture goals and objectives are formulated, descriptions are created for the base and target environment. At this stage The Statement of Architectural Work is created and it becomes a blueprint for the assignment and defines the scope and conditions of the enterprise architecture.

Phase B involves creating a detailed business architecture. This means building models of the existing and desired enterprise architecture of the medical organization, as well as modeling all business process models, including the main ones, such as healthcare itself, and management and support processes needed to keep the organization running. This is conducted taking into account the views of stakeholders.

During Phase C the architecture of data and applications for information systems is created, the foundations for building a technological infrastructure are determined. This involves figuring out the software components needed to support medical and all the other processes conducted in the clinic, as well as IT services that ensure the proper practice. In a clinic it is integral to include a medical information system into the information systems architecture and develop an algorithm of cooperation with the rest of the systems implemented in the organization to provide medical services of highest quality.

During Phase D the technological architecture is created. Based on business and information systems architectures developed during Phases B and C, the requirements for technological equipment needed are set. For such an enterprise as a medical organization technological architecture wouldn’t only mean server and LAN architecture but also various medical machinery. It is critical to create a
durable technological architecture that would withstand emergency situations, as for a clinic an 
equipment failure can literally result in a life or death situation.

Phase E involves identifying the gap between the current and target architecture, and exploring possible ways to achieve said target architecture. For a medical organization this would mean defining how different its architecture is from architecture suitable for conducting practice according to the principles of value-based and personalized medicine, and finding ways to bridge those differences. During this phase the strategy for implementation and migration is created, as well as high-level implementation plan, and project list.

During Phase F the transition from the current state of the architecture to the target is planned. A plan for implementation and transition is developed and priorities between various projects are set. This phase includes assessing the dependencies between projects and minimizing their final impact on the functions of the enterprise. The implementation and transition plan is detailed down to the level of work packages, which can help estimate the cost of the entire transition as a whole.

Phase G includes coming up with recommendations for the implementation projects, as well as creating an Architecture Contract that will guide those projects. This will help to ensure accordance of transformation processes to the level of quality required for an enterprise of such a field as healthcare.

During Phase H architecture change management process is set up around the new enterprise architecture that was implemented during all the previous phases. Since medical field is ever-evolving it is very important for a clinic to monitor new developments in technology and methodology.

Using this implementation algorithm will ensure the creation of an enterprise architecture supporting the principles of value-based and personalized medicine, as well as having a built-in system for further development.

4. Conclusion

Today, the vast majority of organizations strive to follow modern trends, as this allows them to remain competitive in the market. For the healthcare industry, such trends are digitalization (Health 4.0), value-based and personalized medicine. However, in order to fully follow these trends, it is not enough for organizations to simply take note of them or be guided by them exclusively ideologically. There is a need to fundamentally rethink the organization's work and architecture at all levels.

This article has focused on the information and technology architecture of the enterprise of a healthcare organization that seeks to follow value-based and personalized medicine. The following tasks were completed:

- studied and analyzed the distinctive features of value-based and personalized medicine;
- features of digitalization of the healthcare sector are described;
- presented the IT and technological architecture of a medical organization, which combines nosocomial equipment and personal devices of patients;
- formed the basic methodological principles and consistency, allowing to create this architecture correctly.

Thus, this article clearly demonstrates how enterprise architecture evolves and changes depending on various conditions and factors.

Acknowledgements

The reported study was funded by RFBR according to the research project № 19-010-00579.

References

[1] Ammar A 2019 Values-Based Medicine (VsBM) and Evidence-Based Medicine (EBM). In: Larrivee, D. (eds.) Neuroethics in Principle and Praxis - Conceptual Foundations, IntechOpen,

[2] Bae J M 2015 Value-based medicine: concepts and application. Epidemiol Health 37
Shlyakhto E V, Konradi A O 2018 Value-based medicine is a new paradigm in healthcare. Remedium Privolzhye 3 (163), 4-8

Fulford K W M 2004 Ten principles of value-based medicine. Schramme, Philosophy and Psychiatry, pp 50-80. De Gruyter, Berlin

Deegan P E 2005 The importance of personal medicine: A qualitative study of resilience in people with psychiatric disabilities Scandinavian Journal of Public Health 33 (66), 29-35

Rabinovich S A, Vasiliev Yu L 2014 Individual approach to the patient in dentistry as a link in personalized medicine. Russian dentistry 7 (3), 12-14

Horne R 2017 The human dimension: putting the person into personalised medicine. New Bioethics 23 (1), 38-48

Hamburg M A, Collins F S 2010 The path to personalized medicine. The New England Journal of Medicine 363 (4), 301-304

Deedov I I, Tyul’pakov A N, Chekhonin V P, Baklaushev V P, Archakov A I, Moshkovskii S A 2012 Personalized medicine: State-of-the-art and prospects. Annals of the Russian academy of medical sciences 12, 4-12

Iliashenko O 2018 Formation of a smart hospital business reference model based on 4P and Health 4.0 concepts. Science and Business: Ways of Development 2 (80), 56-60

Estrela V V, Monteiro A C B, França R P, Iano Y, Khelassi A, Razmjooy N 2018 Health 4.0: applications, management, technologies and review. Medical Technologies Journal 2 (4), 262-276

Mueschenich M, Wamprecht L 2018 Health 4.0-how are we doing tomorrow?. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 61 (3), 334-339

Lankhorst M 2009 Enterprise architecture at work: Modelling, communication and analysis, Springer

Arzumanyan M Yu, Kudryavtsev D V, Zaramenskikh E P 2016 Moving from Enterprise Architecture Management to Information Systems Development: Aligning Standards. In: Telnov, Yu.F. (ed.) Collection of scientific papers of the XIX scientific and practical conference “Enterprise Engineering and Knowledge Management”, pp 162-171 Plekhanov Russian University of Economics, Moscow

A Brief Introduction to TOGAF Architecture, https://marcus-aurelius.ru/netcat_files/multifile/1325/Kratkoe_vvedenie_v_arhitekturu.pdf, last accessed 2020/09/13.

Kozin E G, Ilyin I V, Levin A I 2016 Service-oriented approach for architecture solutions analysis. St. Petersburg State Polytechnical University Journal. Economics 4 (246), pp 162-172

Gusev A V 2009 The review of the market of complex medical informs systems. Physician and information technology 6, 4-17

Mogilko D Y, Ilin I V, Iliashenko V M, Svetunkov S G 2020 BI Capabilities in a Digital Enterprise Business Process Management System. In: Arseniev D., Overmeyer L., Kälviäinen H., Katalinić B. (eds) Cyber-Physical Systems and Control. CPS&C 2019. Lecture Notes in Networks and Systems, vol 95

Ilin I, Levina A, Lepekhin A, Kalyazina S 2019 Business Requirements to the IT Architecture: A Case of a Healthcare International Scientific Conference Energy Management of Municipal Facilities and Sustainable Energy Technologies EMMFT 2018. Advances in Intelligent Systems and Computing, vol 983

Ilin I V, Iliashenko O Y, Iliashenko V M 2019 Architectural approach to the digital transformation of the modern medical organization. In: Proceedings of the 33rd International Business Information Management Association Conference, IBIMA 2019: Education Excellence and Innovation Management through Vision pp 5058–5067

Ilin I V, Levina A I, Lepekhin A A 2020 Reference Model of Service-Oriented IT Architecture of a Healthcare Organization Cyber-Physical Systems and Control. CPS&C 2019. Lecture Notes in Networks and Systems, vol 95