Addressing Complexity of Contexts of IT Solutions for Older Adults

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Abstract. In the last decades a large number and variety of prototyped and commercial IT solutions have been dedicated to older adults with the purpose to make their activities as meaningful and diverse as possible; and to establish the environment around them as comfortable as possible. However, in most cases the requirements for the tools are derived from user surveys or are just a result of some innovative ideas of researchers and practitioners. This might be one of the reasons why the spectrum of possible IT solutions is much larger than the spectrum of actually used solutions. In this paper we propose to view IT solutions that are developed for older adults in the context, which is represented as a socio-cyber-physical system. Enterprise modeling is proposed as a means for context representation and analysis.

Keywords: Older adults, Context factors, IT solutions for older adults, Socio-cyber-physical systems, Enterprise Architecture, ArchiMate

1 Introduction

According to Eurostat data, there is expected a considerable change in the proportion of people in different age groups [1] with more people in the older adult group (65+ years old citizens) regarding both men and women. So the challenge is how to ensure that this group of people can serve the society and be served by the society effectively. The IT solutions supporting older adults are seen as one of the possible options how to meet this challenge. There are already a number of solutions proposed for older adults [2]. However the actual usage of the IT solutions is of much smaller scale than their development activities.

In this paper we consider one of the reasons for relatively law usage of the proposed tools, which is insufficient analysis of context factors. The research question addressed in this paper is "Is it worth and possible to model contexts of IT solutions for older adults as socio-cyber-physical systems?". A socio-cyber-physical system is chosen because we have learned from related work that the use of IT solution depends

on social, cyber and physical factors which all are integrated in situations of the use of IT solutions [2], [3], [4], [5].

To answer above-stated research question we will use the following approach: (1) Learn how contexts of IT solution for older adults are characterized in related work; (2) Analyze what systems are involved in the context of these solutions, in general; (3) Select the modeling techniques for modeling the context; and (4) Evaluate whether the models can simplify context analysis regarding development of IT solutions for older adults.

In this paper general purpose ICT technologies will be considered as contextual factors not as the IT solutions for older adults. Another purposeful abstraction of the paper is that the context issues are only considered with the focus on types of systems to be included in the context. This paper does not aim at analysis of the spectrum of meta-models for context modeling, which is a well developed field itself and deserves a separate discussion.

In Section 2 we discuss the background and related work regarding the spectrum of IT solutions for older adults and review the context factors of usage of IT solutions by older adults. In Section 3 we discuss how the contexts of IT solutions for older adults could be modeled as socio-cyber-physical systems. The gains of modeling contexts as socio-cyber-physical systems, on the basis of an example, are illustrated in Section 4. In Section 5 we provide brief conclusions.

2 Background and Related Work

In this section we will briefly consider the spectrum of IT solutions that are positioned as dedicated solutions for older adults. Regarding these IT solutions we will discuss what context systems are relevant in usage of different IT solutions. The context systems are those systems that surround the IT solution; i.e. the systems that directly or indirectly influence or are influenced by the IT solution. Afterwards we will consider context factors by examining some related works that address contextual issues of IT solutions for older adults.

2.1 The Spectrum of IT Solutions for Older Adults

We have analyzed several surveys on IT solutions for older adults. The information about IT solutions learned from these sources is amalgamated in Table 1. Table 1 does not show a canonic classification of IT solutions. The items in the first column are taken from different surveys and many of them semantically overlap. The purpose of the table is not to demonstrate taxonomy of existing IT solutions. It was created to show that many of established technologies actually require consideration of all three systems: social, cyber and physical. It has to be taken into account that each of these systems is governed by rules characteristic to those systems, and different modeling methods might be needed to understand each type of systems and their interactions [15]. In Table 1 there are only four types of technologies that do not require consideration of physical space. This lets to assume that, in general, the modeling environment

for revealing requirements for IT solutions for older adults must be able to accommodate elements that characterize constituents and laws of all three system types; and the relationships between the systems. It is also important that the use of IT solutions should be considered having a holistic view of activities of older adults, e.g. by considering their daily routines [16], [17]. Modeling daily routines can be done using conventional business process modeling tools [18]. However, when a context is carefully analyzed, the business process models must be linked to other models describing the context of IT solutions.

Table 1. IT solutions for older adults (based on referenced sources).

Type of IT solutions	Source	Types of systems interacting with the IT solutions
Robotic technologies (social and physical assistants, including monitoring robots, falling protection robots, intelligent environments, etc. With respect to robots as such, we found about 60 robots dedicated for older adults [7]	[6], [7], [14]	Social, cyber, physical
Smart homes (defined as regular homes which are augmented with various types of sensors and activators)	[2]	Social, cyber, physical
Mobile and wearable sensors	[2]	Social, cyber, physical
Applications: health and activity monitoring tools, wandering prevention tools, and cognitive orthotics	[2]	Social, cyber, physical
Home assistive technologies: physiological monitoring, functional monitoring/emergency detection and response, safety monitoring and assistance, security monitoring and assistance, social interaction monitoring and assistance, and cognitive and sensory assistance	[8], [14]	Social, cyber, physical
Sympathetic design framework based devices for socialization, eating, leisure activities; and sharing the products older adults have made	[9]	Social, cyber, physical
Games	[10]	Social, cyber, physical
Robotic pets	[11]	Social, cyber, physical
Healthcare and active aging and healthy lifestyle support tools(includes also rehabilitation and assistive technologies)	[12], [14]	Social, cyber, physical
Financial activity support tools	[13]	Social, cyber
Special purpose machines	[14]	Social, cyber, physical
Social networking platforms	[14]	Social, cyber
Messaging services	[14]	Social, cyber
Information services	[14]	Social, cyber

2.2 The Context of IT Solutions for Older Adults

Necessity of context modeling has been well recognized in the area of IT solutions for older adults, e.g. context modeling is performed to identify which data should be considered by sensors [2]. However, in most of cases the modeling is based on just interviews or questionnaires without thorough consideration of each involved system and relationships between the systems. In Table 2 we have amalgamated issues of dedicated IT solution usage by older adults that we have found in related research. For each issue we point to system type(s) the issue belongs to and the enterprise(s) (systems of activities, organizations, institutions, companies) that relate to the issue.

Table 2. Contexts of IT solutions for older adults (based on referenced sources).

N	Context issue	Source	Type(s) of systems the issue belongs to	Enterprise(s) related to the issue
1	*Neighborhood* (transportation, housing, accessibility, gathering space, etc.)	[4], [5], [17]	Physical	City planning, Gardening, Road management, etc.
2	*Family* (family values, family structure)	[17]	Social, physical, may be also cyber	Family as an enterprise.
3	*Individuality*	[3], [17], [18]	Social, cyber, physical	Daily routines of older adults, properties, proficiency.
3	*Work outside the home*	[17]	Social, cyber, physical	Company or institution where an older adult is employed or associated with.
4	*Health support services*	[4]	Social	Healthcare system
5	*Community support services*	[3], [4]	Social	Municipality and private enterprises for older adults, home care providers.
6	*Respect and recognition*	[4]	Social	Enterprises involving older adults (e.g. associations).
7	*Communication and information*	[4]	Social, cyber	ICT infrastructure and general purpose software application provision for older adults: ICT companies, Social networks.
8	*Home interior*	[3], [14]	Cyber, physical	Accommodation management.
9	*Funding availability*	[3]	Social, may be also cyber	Funding agencies.

The context factors shown in Table 2 are revealed in social science studies. When the context has to be sensed by IT solutions, the smaller granularity context factors may

be considered such as medical history, residence layout, etc. [2]. For handling these factors some situation modeling languages and ontologies are developed as referenced in [2]. These languages and ontolgies are beyond the scope of this paper. The needed level of details of a context of IT solutions depends on the purpose of modeling and the stage of IT solution creation (whether it is necessary to develop a vision, a prototype, a commercial product or other considerations). Hereby we address only types of systems to be modeled, not the details of different contexts.

In Table 2 we can learn that, regarding contexts of IT solutions for older adults, there are different system types and many different enterprises involved. We also can notice that the aspect itself can be represented with less systems than the enterprises related to the aspect (e.g. the aspect in Row 1 is just a physical system, but the enterprises caring for this aspect are social systems that obviously use also information technology and thus the cyber systems are to be considered, too). So, the modeling techniques for context representation have to be able to represent social, cyber and physical systems as well as the relationships between these systems or their elements.

3 Enterprise Models for Context Representation and Analysis

From the previous section we can conclude that the enterprises models for contexts of IT solutions for older adults, in general, must represent elements from all types of systems, namely social, cyber and physical ones; and they should be able to represent several enterprises simultaneously. There is a number of enterprise modeling approaches (methods, methodologies) available with different modeling languages associated with these approaches [19], [20], [21]. There are specific architecture frameworks developed for business systems (e.g. TOGAF [22]) and cyber physical systems (e.g. RAMI4.0 [23]). In this paper we will discuss enterprise modeling of contexts of IT solutions for older adults using enterprise architecture representation language ArchiMate [24]. This language is aligned with TOGAF framework. It allows representation not only of business but also physical systems.

ArchiMate language has its own framework which consists of 6 layers (strategy, business, application, technology, physical, and implementation and migration). Each layer can be modeled from three aspects: passive structure, behavior, and active structure. This is an essential characteristic of the language, because availability of modeling elements for these aspects at several layers gives an opportunity to show functional issues (what is transformed by what or whom) of social, cyber and physical systems. Additionally, there is one more aspect that can be related to all layers – motivation. Further in this section we will discuss modeling elements of business, application, technology, and physical layers regarding passive structure, behavior, and active structure elements. We will not consider strategy layer and implementation and migration layer as these layers are representing rather changes in the systems (enterprises) than the systems themselves. The motivation aspect is also left out of the discussion, as it is rather change oriented than just a representation of IT solution contexts. However, we admit that in enterprise modeling all ArchiMate elements are useful as

strategic, implementation and motivation issues are and should be considered in the context models. These issues are just not in focus of this paper.

In Table 3 we show how ArchiMate modeling language suits for the representation of context aspects and enterprises revealed in Table 2. We can see here that, theoretically, the ArchiMate language suits well for the representation of contexts of IT solutions for older adults.

Table 3. ArchiMate's capacity to represent contexts of IT solutions for older adults.

N	Context issue	Enterprise(s) related to the issue	ArchiMate elements for aspect and enterprise representation
1	*Neighborhood* (transportation, housing, accessibility, gathering space, etc.)	City planning, Gardening, Road management, etc.	Aspect: All physical layer elements (**behavioral elements missing**) Enterprise: All Business, Application, Technology layer elements
2	*Family* (family values, family structure)	Family as an enterprise	All ArchiMate elements
3	*Individuality*	Daily routines of older adults, properties, proficiency	All ArchiMate elements (**more developed business modeling possibilities would be desired**)
3	*Work outside the home*	Company or institution where an older adult is employed or associated with	All ArchiMate elements
4	*Health support services*	Healthcare system	All business, application, and technology layer elements
5	*Community support services*	Municipality and private enterprises for older adults, home care providers	All business, application, and technology layer elements
6	*Respect and recognition*	Enterprise involving older adults (e.g. associations)	Business layer elements, but **there are no specific elements to show respect and recognition**
7	*Communication and information*	ICT infrastructure and general purpose software application provision for older adults: ICT companies, Social networks.	All business, application, and technology layer elements, but at the business layer **there are no elements to show social networks that are not related to IT**
8	*Home interior*	Accommodation management	All physical layer elements
9	*Funding availability*	Funding agencies	All business, application, and technology layer elements

Basically business layer elements are for representation of social aspects; application and technology layer elements cover cyber aspects; but physical layer elements correspond to physical aspects of the contexts. However, in some cases ArchiMate language is not sufficient for representation of the contexts. So in Row 1 of Table 3 the behavioral elements of the physical layer are missing; in Row 3 better business process modeling possibilities are required; in Row 6 there are no simple means how to represent respect and recognition; and in Row 7 there are no means how to represent social networks at the business layer. The missing elements are pointed to in bold in the third column of Table 3.

Business, application and technology layers have almost the same modeling elements in ArchiMate (except there some more network related elements in the technology layer). However, at the physical layer there are no behavioral elements. Absence of behavioral elements hinders a possibility to fully represent the physical context. From this follows that context representation would be more successful if all types of passive, active and behavioral elements (or their substitutes) would be available in all discussed layers (business, application, technology, and physical). For representation of respect and recognition some elements from a motivational layer could be borrowed. For business process modeling, the ArchiMate language could be combined with some business process modeling tools supporting BPMN [25].

4 Onion Smartwatch Example

In this section we will use an example of visionary IT solution for older adults to show how enterprise modeling of a context as a socio-cyber-physical system facilitates IT solution development. The example stems from documented daily routines of about 70 years old visually impaired woman living in Latvian countryside [7].

Let us consider the excerpt of activities documented on Wednesday, 08.05.2019. There will be a sequence of observed activities with the time for start and the end of an activity: Put on barn closes (06:30-06:40); Go to barn (06:40-06:43); Feed rabbits (06:43-07:12); Feed cats (07:12-07:15); Go home (07:15-07:18); Take shower (07:18-07:28); Have breakfast (07:28-07:45); Prepare a working suit (07:45-07:55); Go to work in the museum (07:55-08:00); ... ; Go to home (17:00-17:05); Have lunch (17:05-17:30); Put on barn closes (17:30-17:37); ... ; Go to garden greenhouse (18:47-18:50); Take tools (18:50-18:53); Go to the field (18:53-18:54); Propel the furrows (18:54-19:53); Put the fertilizer in the furrows (19:53-20:20); **Plant onions** (20:20-20:55); Close the furrows (20:55-21:05); ... ; Sleep (22:46-06:50).

When planting onions it was observed the woman has a difficulty to see, which an upper part of an onion is and where the root part of it is. On the basis of this observation the idea of an onion smartwatch was generated. The onion smartwatch is the wearable device that is taught to recognize things when they are shown to it; – in this case to give an approval sound if an onion is in a right position and the warning sound if an onion is in a wrong position. The device may be trained also for other functions depending on the needs of a particular older adult. Device as such could also be used by younger people facing similar problems. However, to make a technology feasible

for older adults the context of usage of this technology by older adults must be taken into account, i.e. not only technical features of an IT solution matter, but also social factors are to be taken into account.

The primary context aspect here is Individuality (see Row 3 in Tables 2 and 3), so all ArchiMate modeling elements can be used, and also the business process modeling with BPMN can be applied. Additional contexts refer to how the IT solution can be produced, funded, and obtained by the individual. So, several enterprises are to be considered as a context of the IT solution (onion smartwatch).

In Fig. 1 a simplified enterprise model is shown represented in ArchiMate language. The model shows 5 enterprises, namely, the individual process of onion planting using the smartwatch; the IT company that can produce smartwatches; the research institution that comes up with the idea of the smartwach and seeks IT companies cooperation regarding their production, simultaneously requesting funds for the IT company from the Funding organization. Also a municipality is represented in the enterprise model as the distributor of produced smartwatches.

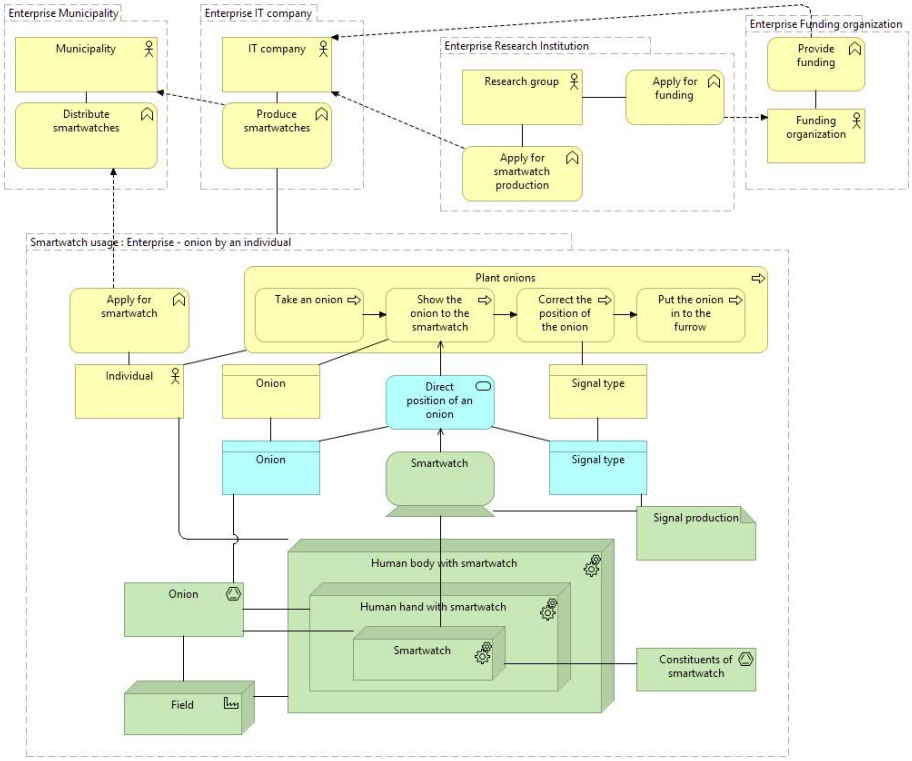

Fig. 1. Enterprise model for onion smartwatch and its context

The enterprise model in Fig. 1 represents all three types of systems (social, cyber and physical ones). Different level of detail of representation would be needed for different purposes of modeling. For instance, to develop requirements for smartwatch,

it would be necessary to examine on which part of a human arm the watch should be located, taking into account dust level of the ground, convenience of showing an onion to the equipment (or device), weight of the device and other parameters. Regarding the enterprises, some collaboration elements might be introduced to specify how they perform activities together.

Nevertheless, even from this simple model we can conclude that enterprise modeling in the socio-cyber-physical context is possible; and it is beneficial for the design of IT solutions for older adults, because it gives an opportunity to model IT solutions taking into account issues of all three types of systems and it gives an opportunity to see the relationships between different enterprises involved in the context of an IT solution. So it allows addressing a full scope of the complexity of the context.

A peculiarity of these models is that one and the same object can have several representations in the enterprise model. For instance, a smartwatch will be the device at the technology layer and the equipment at the physical layer; an individual will be a role at the business layer and equipment at the physical layer; and an onion will be data at the application level and a material at the physical layer. We can assume here that a possibility to reflect (if needed) any object in all layers would be a desirable feature of a modeling language. To achieve this, the ArchiMate language should be extended with new elements so that practically all layers have the spectrum of elements that is a union of semantics of element types of business, application, technology and physical levels.

The model present in Fig. 1 is very simple. Real enterprise models can grow quite large and their maintenance can be time and effort consuming. Therefore it is necessary to develop tools for smooth enterprise modeling and analysis for IT solutions for older adults.

5 Conclusions

This paper concerns IT solutions for older adults and their context. A specific of this type of IT solutions is a necessity to consider not only information technology per se, but also social and physical issues of usage of IT solutions. Therefore we examined here the spectrum of currently available IT solutions for older adults and tool usage contexts to identify what type of enterprise modeling approaches could be applicable for modeling contexts of IT solutions for older adults. After brief theoretical analysis, the ArchiMate language was chosen for enterprise modeling and simplified enterprise model shown for envisioned IT solution. Regarding the research question whether it worth and possible to model contexts of IT solutions for older adults as socio-cyber-physical systems, the theoretical considerations and practical experiments allow us to conclude the following:

1. For many IT solutions for older adults, their contexts require consideration of three types of systems (social, cyber and physical). There are few solutions that require consideration of two only or just one type of systems. Therefore it is worth to model the contexts as socio-cyber-physical systems.

2. ArchiMate language is appropriate, in general, for representing socio-cyber-physical systems, however, it cannot cover all issued and therefore it is suggested to extend this language so that business, application and technology, and physical layers would have the same representative power. It would give an opportunity to:

- represent transformations at physical layer and
- represent networks at business layer.

3. Enterprise modeling of socio-cyber-physical systems is partly possible with ArchiMate; and it is beneficial, because it allows representing several enterprises of the context of an IT solution and showing and analyzing the relationships between the elements of these enterprises.

The research work presented in this paper is devoted to IT solutions for older adults, and all literature used here comes from that domain. However, the necessity to model simultaneously all three system types of socio-cyber-physical systems is important not only in the context of IT solutions for older adults, but also in more general contexts, such as robotics, Internet of Things and others.

In this paper we analyzed the contexts of IT solutions as enterprises. One of directions of future work is to consider the contexts in line with the analysis of capabilities [26] (or changes of capabilities) of older adults and compare or/and integrate these results with those obtained in the research reflected in this paper.

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References

1. Eurostat: statistics explained, available at https://ec.europa.eu/eurostat/statistics-explained/index.php/Industry_and_services, last accessed 12.06.2019
2. Rashidi, P., Mihailidis, A.: A Survey on Ambient-Assisted Living Tools for Older Adults. IEEE Journal of Biomedical and Health Informatics, 17 (3), 579-590, May (2013).
3. Peek, S. T.M., Luijx, K.G., Rijnaard, M.D., Nieboer, M.E., Voort, Cl.S., Aarts, S., Hoof, J., Vrijhoef, H.J.M., Wouters, E.J.M.: Older adult's reasons for using technology while aging in place. Rereontology: Regenerative and Technology Section, 62, 226-237 (2016). doi:10.1159/000430949
4. Brooks-Cleator, L.A., Giles, A.R., Flaherty, M.: Community-level factors that contribute to First Nations and Inuit older adults feeling supported to age well in a Canadian city. Journal of Aging Studies, 48, 50-59 (2019). doi.org/10.1016/j.jaging.2019.01.001
5. Chaudhury, H., Campo, M., Michael, Y., Mahmood, A.: Neighbourhood environment and physical activity in older adults. Social Science & Medicine, 149, 104-113 (2016), doi.org/10.1016/j.socscimed.2015.12.011
6. Shishehgar, M., Kerr, D., Blake, J.: A systematic review of research into how robotic technology can help older people. Smart Health, 7(8), 1-18, June (2018).
7. Muceniece, A:. Analysis of the Spectrum of Robotized Technologies for Older Adults. Bachelor Thesis, Riga Technical University (2019) (in Latvian).
8. Demiris, G., Hensel, B.K.: Technologies for an Aging Society: A Systematic Review of "Smart Home" Applications, IMIA and Schattauer GmbH, 33-40 (2008).

9. Rebola, Cl.B.: Sympathetic devices: designing technologies for older adults. In SIGDOC 13 proceedings of the ACM International Conference of Design of Communication, 151-156 (2013).
10. Gerling, K, Livingston, Nacke L., Mandryk, R.: Full body motion-based game interaction for older adults. In proceedings of the SIGCHI Conference on Human factors in Computing Systems, ACM, 1873-1882 (2012).
11. Lazar, A., Thompson, H., Piper, A.M., Demiris G.: Rethinking the design of robotic pets for older adults. In proceedings of the 2016 ACM Conference on Designing Interactive Systems, 1034-1046 (2016).
12. Piper, A.M., Cambel, R., Hollan, J.D.: Exploring the accessibility and appeal of surfae computing for older adults health care support, Proceedings of SIGCHI Conference on Human Factors in Computer Systems, 907-916 (2010).
13. Maqbool, S., Munteanu, C.: Understanding Older Adults' Long-term Financial Practices: Challenges & Opportunities. In DesignCHI'18 Extended Abstracts, April 21–26, 2018, Montreal, QC, Canada, Paper No. LBW546 (2018).
14. Bastardo, R., Pavão, J., Martins, A.I., Queirós, A., Rocha, N.P.: The Design for All Paradigm in the Development of Applications to Support Older Adults: A Review. In proceedings of the 8th Int. Conf. on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion, 337-343 (2018).
15. Thuy, N.: Modeling and simulation of the dynamics of complex socio-cyber-physical systems and large scale systems of systems all along their lifetime. Complex Systems Design and Management, G. Fanmuy et al. eds. 71-81 (2017).
16. Chung, J., Ozkaynak, M., Demiris, G.: Examining daily activity routines of older adults using workflow. Journal of Biomedical Research 71, 82-90 (2017).
17. Ludwig, F.M.: How routine facilitates wellbeing in older women. Occupational Therapy International. 4(3), 215-230 (1997).
18. Kirikova, M., Kolkowska, E., Soja, P., Soja, E., Muceniece, A.: Towards aligning IT and daily routines of older adults, accepted for the BITA 2019 workshop of BIS 2019, to be published by Springer (2019).
19. Kaidalova, J., Seigerroth, U., Persson, A.: Enterprise modeling for business and IT alignment – a framework and recommendations, Complex Systems Informatics and Modeling Quarterly, CSIMQ, 12, 66–85, ISSN 2255-9922 (2017). doi.org/10.7250/csimq.2017-12.04
20. Seigerroth, U.: The Diversity of Enterprise Modeling – a Taxonomy for Enterprise Modeling Actions. Complex Systems Informatics and Modeling Quarterly, CSIMQ, 4, 12-31. ISSN 2255-9922 (2015). doi:10.7250/csimq.2015-4.02
21. Sandkuhl, K., Stirna, J., Persson, A., Wißotzki, M. Enterprise Modeling: Tackling Business Challenges with the 4EM Method, Springer, (2014).
22. The TOGAF® Standard, Version 9.2 Overview, https://www.opengroup.org/togaf, last accessed 2019/03/17.
23. Pisching M.A., Pessoa M.A.O., Junqueira F., Miyagi P.: PFS/PN Technique to Model Industry 4.0 Systems Based on RAMI 4.0. 2018 IEEE 23rd International Conference on Emerging Technologies and Factory Automation (ETFA), 1, 1153-1156 (2018).
24. ArchiMate® 3.0.1 Specification, an Open Group Standard (2017), http://pubs.opengroup.org/architecture/archimate3-doc/, last accessed 2019/03/17.
25. Business Process Model and Notation, available at https://www.omg.org/bpmn/, last accessed 2019/06/07.
26. Zdravkovic, J., Stirna J., Grabis, J.: A Comparative analysis of using the capability notion for congruent business and information systems engineering, Complex Systems Informatics and Modeling Quarterly, CSIMQ, 10, 1–20 (2017). doi.org/10.7250/csimq.2017-10.01