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Towards Respecting Systems of Systems in IT Project Quality Management

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Abstract. Project quality management in general and IT projects quality management in particular has been a research topic for several decades. However, project quality management is usually considered a subpart of project management per se, which includes such activities as project initiation, team formation, responsibilities allocation, and others. In this position paper, we abstract from the abovementioned activities and focus on only one perspective in project management, which, to the best of our knowledge, has not been intensively studied. We propose to focus on the perspective of Systems of Systems in project quality management paying more attention to the systems that are related or belong to a particular IT project. For this purpose, the questions for further research are defined regarding three aspects of IT project quality management, namely, product, process, and inputs of an IT project. The questions are derived based on common features of systems of systems and the enterprise architecture model represented in ArchiMate.

Keywords: Complex Systems, SoS, Quality Management, IT Project, Enterprise Architecture, Requirements Engineering

1. Introduction

Project quality management is part of project management in IT project development. Quality management as such has its application domain independent as well as application domain specific features. For instance, Low and Ong (Low and Ong, 2014) have amalgamated different generic issues of project quality management and developed comprehensive systems of quality attributes for construction projects. In this paper, we focus on the quality management of IT projects that become more and more dependent on requirements for speed, flexibility, and user friendliness of the product in the era of digital transformation.

While project management (including IT projects) and quality management, as the disciplines, and their intersection "project quality management", are under research for several decades (Low and Ong, 2014), the quest for understanding IT projects from the System of Systems (SoS) perspective has attracted wider attention mainly from 2019 when ISO/IEC/IEEE 21839:2019 standard "Systems and software engineering – System of systems (SoS) considerations in life cycle stages of a system" was issued. Ncube and Lim (Ncube and Lim, 2018) explain how the systems (constituent systems) that form the

SoS can be related concerning ownership and operations and how the same constituent systems can belong to several systems. These issues are also relevant in IT project management. For instance, the service developed by company X belongs to the system of its offered services and will also belong to the information systems of user system Y.

The goal of this paper, which extends the discussion started in the initial paper presented during Baltic DB&IS Forum in 2022 (Kirikova et al., 2022), is to explore the scope of questions concerning the SoS perspective on IT project quality management. These questions might be helpful in defining the potential research tasks in developing methods and tools for supporting IT project quality management with respect to the SoS perspective.

The paper is structured as follows. In Section 2, we discuss current trends in IT project management and the quality challenges of IT projects. In section 3, we select and characterize IT project quality management aspects to be considered from the SoS perspective, explore the taxonomy of SoSs, and illustrate the enterprise architecture model used for deriving the questions for further research. In Section 4, we present and discuss these questions in order to facilitate the movement towards addressing the SoS perspective in IT project management. We conclude the paper in Section 5.

2. Current Trends in IT project Management Regarding the Quality

In the IT area, usually, IT project quality management is considered a subset of overall quality management and project management: "IT quality management" ⊆ "IT project management" ⊆ "IT project quality management" (Osterhage, 2014). SoS's perspective on IT project quality management, specifically, has not been largely addressed in research. Nevertheless, IT project quality management has been viewed from the system perspective. For instance, Software Quality Journal has recently published an issue on information systems quality management (Shepperd et al., 2022), that considers a wide range of quality related topics such as temporality of technical debt, a grouping of app reviews, test regression, secured bulk creation, migration to hybrid information systems, generating end-to-end test scripts, the use of sensors, and the impact of human factors in agile projects. The closest to the SoS perspective, in this issue, is the topic of controlling and evaluating the service and transaction dependability of complex IoT systems.

The systemic approach to IT project management is proposed in (Wong et al., 2018). This paper discusses the need for joined effort from both project managers and the technical team in view of organizational level achievement in software quality assurance and provides a general overview of how software change control is carried out in the context of IT project management. Referring to their previous work, the authors (Wong et al., 2018) show relationships between systems development and project life cycles. While, in most cases, the software is regarded as a product of an IT project, this work considers IT products as both software and hardware; and distinguishes also between IT products and services. This helps to see the spectrum of issues to be considered regarding IT project quality management in a systemic way but does not explicitly put these in the context of SoS.

IT project quality in the context of quality standards is discussed in (Shen et al., 2018). Here, both the product quality model and the quality in use models are presented; and software internal and external quality and the quality in use are considered

systematically in relation to requirements specification and evaluation. In (Shen et al., 2018), the product is viewed on three layers: software, computer system, and system; and SoS issues are also, to some extent, considered in it. Nevertheless, the authors do not go beyond the borders of software engineering in their research.

Indirectly, IT project quality management is discussed in recent works on problems regarding agile IT projects. The most comprehensive report on these problems and possible treatments is given in (Kasauli et al., 2021). Analysis of these issues can lead to the conclusion that knowledge management has to be addressed with new tools and processes in IT projects (Kirikova, 2022). Research on agile projects emphasizes the essential role of requirements in achieving high quality results in software systems development. Not surprisingly, requirements engineering is an area comparatively intensively addressed from the SoS perspective (Duarte et al., 2018; Hallerstede et al., 2012; Ncube and Lim, 2018). However, the available research results are rather a concern for suggestions for the research agenda than a report on proposed and validated methods.

IT projects related to digital transformation are one more area where project quality management has to take into consideration the SoS perspective (Papavasiliou and Gorod, 2022). This relates to recognizing disrupted processes and ensuring the consistency of newly created systems (Hawryszkiewycz, 2022).

Another area where the SoS perspective becomes a concern is the restructuring of organizations or organizational ecosystems, such as mergers and acquisitions (Lace, 2022).

As discussed in this section, the SoS perspective directly or indirectly is recognized in different IT project management settings. However, it is not yet explicitly addressed by corresponding models and methods. In this paper, we will discuss the areas where research is needed to address IT project quality management from the SoS perspective by illustrating different aspects and project settings for a better understanding of the depth and breadth of the topic. The goal to explore the scope of questions concerning the SoS perspective on IT project quality management was achieved using the method which sequentially aimed at the following milestones:

i. The main quality aspects of research are identified,
ii. The concept of SoS is explored,
iii. An SoS and identified aspects compatible enterprise representation is selected,
iv. Based on this representation, for each identified quality aspect further research questions are defined, and some project settings are illustrated.

3. SoS Related Aspects of IT Project Quality Management

In this section, we discuss the backbone for deriving questions for further research (milestones i, ii, and iii listed in the previous section). In Sub-section 3.1 we identify the aspects of project quality to be further analysed with respect to the SoS perspective. In Sub-section 3.2 we provide models of the SoS perspective and select the depth and breadth of the concept for consideration in this research. In Sub-section 3.3, we select a model which can help to derive and illustrate the challenging question of further research regarding the SoS perspective of IT project quality management.

3.1. Selected Aspects of Quality

When discussing the SoS related aspects of IT project quality management we will distinguish between three essential quality aspects (Figure 1): the quality of the product, the quality of the process, and the quality of the materials (inputs to the process) while leaving the quality of performers of and equipment used in the process out of the scope of the discussion.

The first quality aspect is the quality of *a product* (in the case of an IT project, the IT solution that is to be developed). The quality of IT solutions has a long history of research in such areas as software engineering and requirements engineering where many quality characteristics have been proposed and standardized (Mendoza et al., 2019; Zhao et al., 2021). Also, various methods for testing the quality are available (Zhao et al., 2021) and have been evaluated (e.g., (Chen et al., 2019; Staegemann et al., 2022)). Besides generic standardized quality characteristics, specifics of such solutions as IoT (Fizza et al., 2021), service systems (Lee and Lee, 2019), and artificial intelligence solutions (Lenarduzzi et al., 2021) have been considered. While the importance and complexity of achieving high quality IT project products are well understood, the role and the systemic relationships from the SoS perspective are less analysed, modelled, and methodologically addressed.

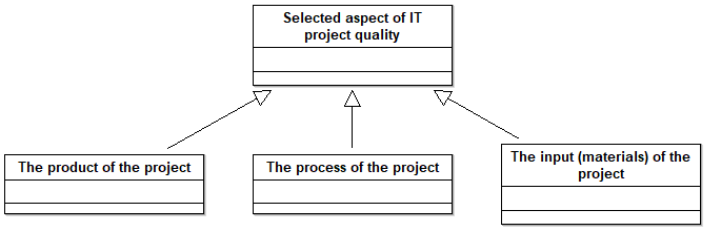

Fig. 1. Selected aspects of quality.

To illustrate the SoS perspective regarding the IT project product (a developed IT solution), we give here an example of the key information systems for a company in a utility segment. The company could be a provider of water, heat, energy, or waste management services in a particular city or country. It is assumed that these key information systems are Asset Management System, Accounting System, Customer Relationship Management System (CRM), Field Service Application, and Customer Portal. The main role of each system is given in Table 1.

From the SoS perspective, it is essential to analyse the system interactions. The diagram in Figure 2 shows all the systems, and the directed links show where interactions exist to understand that all the systems mentioned in Table 1 are, in essence, the systems of systems and they all are interrelated constituents of an overall organizational information system. This consideration is only regarding the information systems domain. Other domains, such as business, physical, etc., will be discussed in the further sub-sections. But, even considering only information systems as SoS, we can see that their interrelationships play an important role in their expected functionality. The one line connecting the two systems, in Figure 2, means many different data flows between them. Moreover, the significance and quality of each data exchange depend on

the overall SoS context in which the data exchange takes place. Thus, to assess the quality of system performance, it is essential to evaluate it from the perspective of SoS.

Table 1 The roles of information systems.

System	Key roles
Asset Management System	Asset accounting, asset life cycle management, asset maintenance planning, depreciation calculation
Accounting System	Accounting of the provided service, invoicing, payments, client's balance, processing of debtors
Customer Relationship Management System (CRM)	Customer information management, contract register, customer service event register
Field Service Application	Receipt of work orders, registration of issued assets, registration of work performance, control of meter readings
Customer Portal	Customer self-service, concluding contracts, updating personal data and contact information, reporting meter readings, receiving invoices, applying for service, and registering complaints.

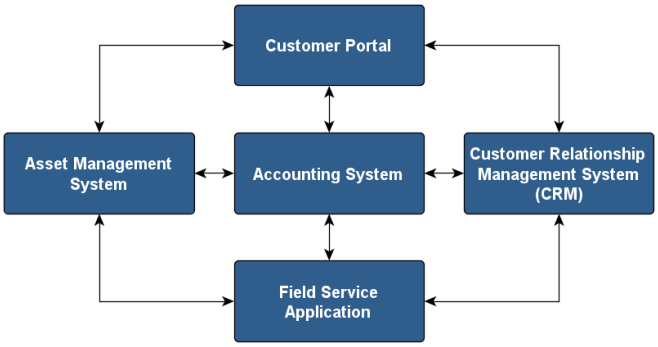

Fig. 2. Information systems and their interactions.

To illustrate further the importance of the SoS perspective, we will analyse in more detail the Accounting System. Figure 3 and Figure 4 present two diagrams demonstrating how the role of the Accounting System changes in the context of SoS in different scenarios. Then, in Table 2, we illustrate how the requirements for Accounting System interactions vary and thus what the differences are in their quality indicators.

In Figure 3, the contract signing scenario is represented where the Accounting System is directly related only to the Customer Relationship Management System. In Figure 4, the invoicing and payment scenario is reflected, where the Accounting System is related to several other systems.

The representations of scenarios show that, in different SoS contexts, the Accounting System performs different activities, uses different inputs, and produces different outputs. Thus, each SoS setting yields different quality expectations from the Accounting System. This is illustrated in more detail in Table 2, where the Accounting System's environment (related systems from Figure 4), inputs, outputs, and quality

characteristics are shown for one scenario next to another. From this example, we can see that if the Accounting System was a target product of a particular IT project, the understanding and achievement of its quality would depend on a good understanding of its role in different SoS contexts (scenarios). This illustrates why the SoS perspective is so important when considering the product aspect of an IT project quality management.

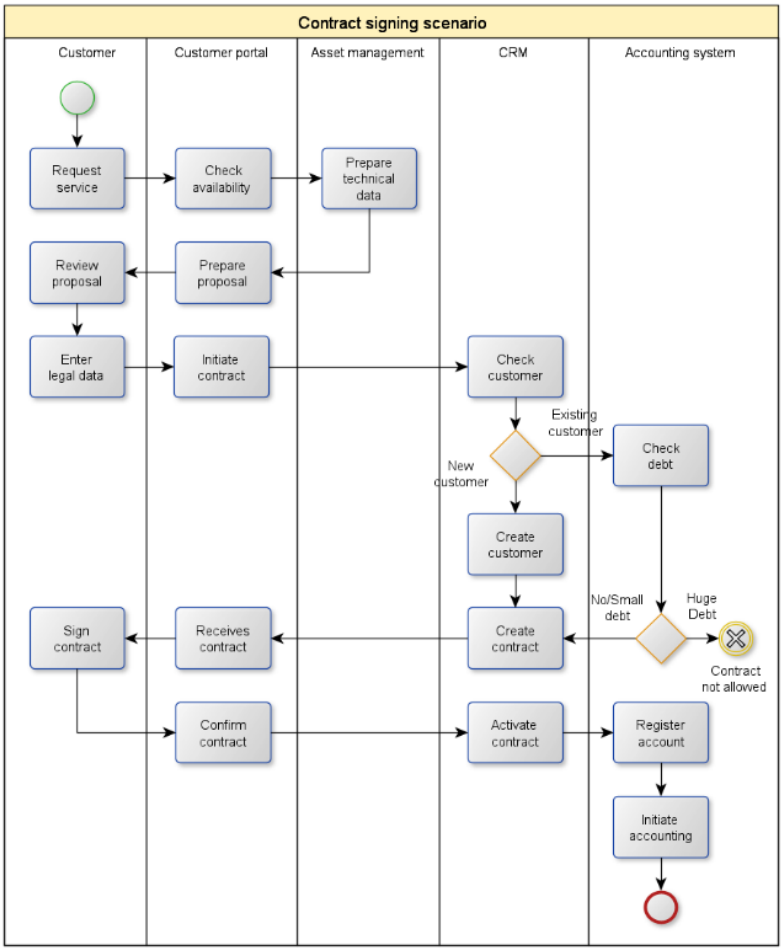

Fig. 3. Contract signing scenario.

Another quality aspect to be considered is the *process* aspect. The IT project's process is a network of activities that are performed to achieve the project goal. Due to the variety of possible systems development life cycles (Klunder et al., 2021), the sequence and iterations of the activities of the process can adhere to different quality characteristics (for instance, rooted in agile manifesto principles (Poth et al., 2017)), however, traditional metrics still appear to be applicable in many life cycle variations (Jinzenji et al., 2013). Thus, the IT project process, as a process in general, can be evaluated, as suggested in (Krogstie, 2016) and (Shrestha, 2018), using such common

process metrics as effectiveness, efficiency, usability, compatibility, and other characteristics. The SoS perspective requires viewing the IT project process in concert with other processes that take place in the related systems if any identifiable influences exist. First of all, it refers to other information technology development processes in these systems where several IT projects are ongoing simultaneously (Martinsuo and Ahola, 2022). However, different business processes of the related systems (including quality management processes) as well as an overall system of enterprise's activities must also be respected.

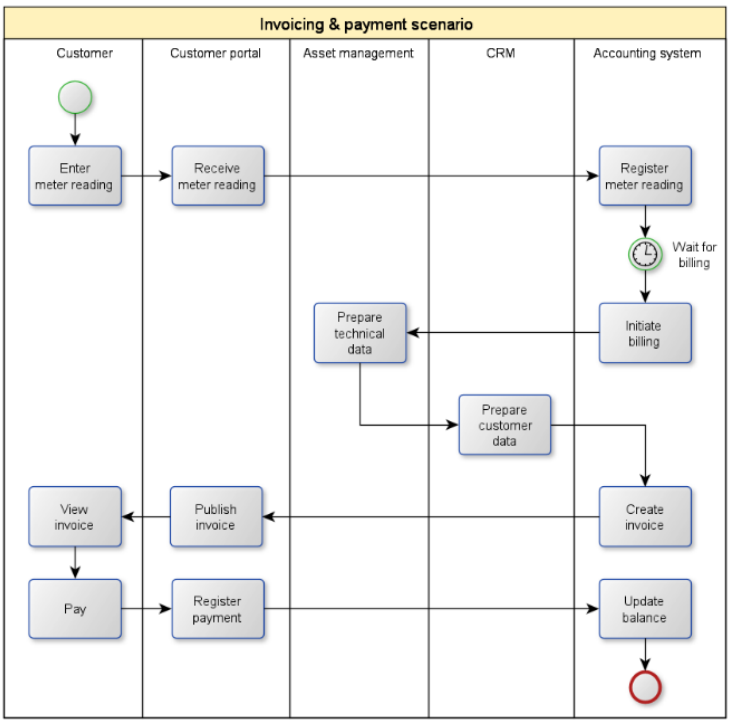

Fig. 4. Invoicing and payment scenario.

The third quality aspect, discussed in this paper is the quality of *inputs* of the process. In manufacturing processes, it would mean the quality of materials (e.g., the quality of the wood in the production of the furniture). In IT projects these inputs are requirements specifications and information (data) used in the system (Krogstie, 2016). As Table 2 illustrates, the SoS perspective is very essential to being able to state the right set of requirements and to identify needed inputs and outputs. While requirements and data themselves have standardized and well-known quality metrics (comprehensively amalgamated in (Krogstie, 2016)), these can be successfully applied only if all relevant SoS relationships are respected.

As mentioned above, in this paper we explore only three (product, process, and input) aspects of IT project quality management and do not pretend to cover all the

aspects of quality management variety and complexity of which are well characterized in (Zikra et al., 2017).

Table 2. Comparison of scenarios from SoS perspective.

Issues	Contract signing scenario	Invoicing and payment scenario
Accounting system's environment	• Customer Relationship Management System (CRM)	• Customer Portal • Asset Management System • Customer Relationship Management System (CRM)
Accounting system's inputs	• Request for Customer Debt • Request to create an account	• Request to register meter reading • Service point technical data • Customer data • Payment
Accounting system's outputs	• Balance • Account number	• Request for technical data • Request for customer data • Invoice • Payment confirmation • Balance
Accounting system's quality characteristics	• Accounting system is on-line and accessible from the CRM system • Accounting systems provide service for debt amount/balance • Accounting system correctly calculates the debt amount/balance • Accounting system provides service for account creation • Accounting system correctly creates an account • Accounting system assigns a unique account number	• Accounting system is on-line and accessible from Customer portal • Accounting system has scheduled the start of the billing • Accounting systems provides service for meter reading registration • Accounting system correctly registers meter reading • Accounting system request and update technical data • Accounting system request and update customer data • Accounting system correctly creates an invoice • Accounting system publishes invoice • Accounting system provides service for payment registration • Accounting system correctly registers payment • Accounting systems provide service for debt amount/balance • Accounting system correctly calculates the debt amount/balance

3.2. The SoS perspective

SoS perspective is well recognized in research and acknowledged by international standard ISO/IEC/IEEE 21841(2019), which defines 4 different types of SoS, namely, directed, acknowledged, collaborative, and virtual. The same standard, in its appendix, acknowledges also other SoS taxonomies, for instance: (i) chaotic, directed, and collaborative; (ii) physical, conceptual, social; and (iii) organizational, federated, coalition. Following the explanations provided by (Ncube and Lim, 2018), we can see the commonalities and differences between several types of SoS in Figure 5.

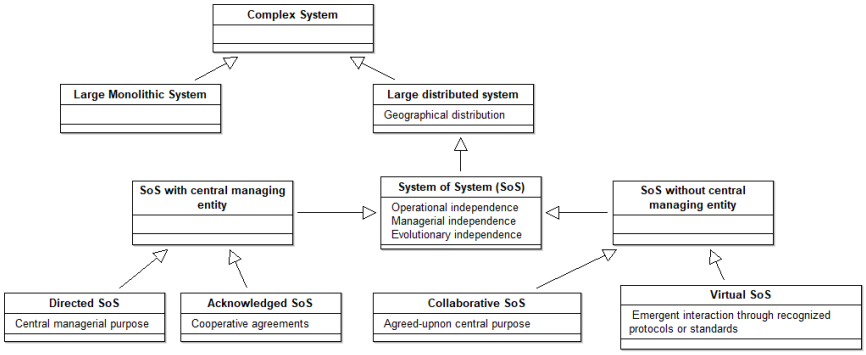

Fig. 5. Taxonomy of SoS.

SoSs, according to (Ncube and Lim, 2018), are regarded as complex systems of distributed (usually geographically) nature. They can or cannot have a central managing entity. In case there is a central managing entity, it can act based on central managerial purposes or based on cooperative agreements. If SoS is without a central managing entity, they may have the central purpose they have agreed upon; or they may be involved in emergent interaction through recognized protocols and standards.

Being aware of the type of SoS may help to choose appropriate IT project processes so that they can comply with the nature of SoSs related to the project. In the case of IT projects, several SoSs of different types may need to be analysed to perform the project without the loss of relevant information. Consequently, it is an ecosystem of different types of SoSs that influences IT projects and is the context of IT projects (Graciano Neto et al., 2020; Tsai et al., 2022). This ecosystemic view on SoSs will be used in the rest of the paper when discussing independence, distribution, emergence, and evolution, which are the common characteristics of all types of SoSs, and which pose certain challenges to the IT project quality management.

3.3. The Model for Research Question derivation

We assume here that any IT project takes place in an enterprise or in an enterprise ecosystem (or digital business ecosystem (Tsai et al., 2022)). One of the well-founded ways of considering an enterprise as a system is using enterprise architectures (Dumitriu and Popescu, 2020; Gampfer et al., 2018; Henningsson and Toppenberg, 2020; Kamogawa and Okada, 2005; van den Berg et al., 2019). Therefore, we will use

ArchiMate (The Archimate, 2023) enterprise architecture representation language framework for illustrating the chosen SoS related aspects of IT project quality management (product, process, and inputs as discussed in Sub-section 3.1). Research on these aspects may lead to new solutions that may help to deal with such challenging attributes of SoSs as *independence*, *distribution*, *emergence*, and *evolution* (Ncube and Lim, 2018) in the quality management of IT projects. We will use the full ArchiMate meta-model with simplified relationships, extended with the physical layer, to illustrate the system aspects inside the enterprise (Figure 6).

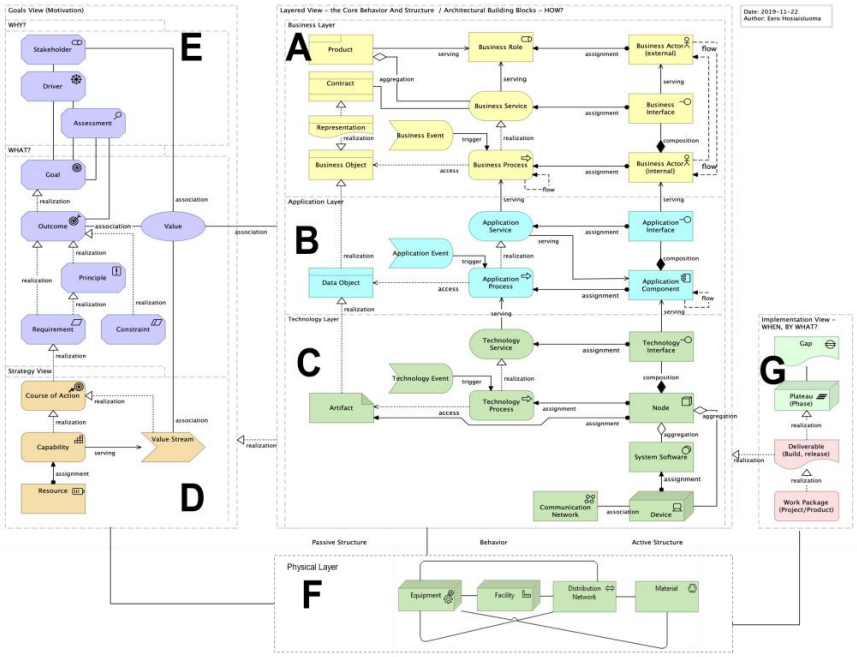

Fig. 6. Constituent systems A-G of an enterprise (A, B, C, D, E, and G parts adopted from https://www.hosiaisluoma.fi/blog/archimate-metamodel/)

It must be respected that we shall not neglect that the SoS goes beyond one enterprise and may concern similar enterprise architecture elements in other enterprises. The enterprise architecture representation used further in this paper reflects several constituent systems of the enterprise. The technology layer (C) illustrates computing infrastructure that includes hardware and operating systems; the application layer (B) illustrates software systems from the enterprise-user perspective; the business layer (A) stands for business execution system, the motivation view (E) and strategy view (D) stand for decision making system, physical layer (F) stands for physical environment system, while implementation view (G) stands for project management and execution system. IT project quality management aspects address the elements of these systems, and we can see that, in general, every element in one system is related to elements in other systems. Thus, it is essential to see when, how, and which relationships are to be considered when addressing the product of an IT project, the process of IT project management, and the inputs of the project.

The constituent systems identified in Figure 6 are not the only way how to identify the constituent systems. For instance, there can be systems identified by departments, systems identified by process classes, or using other criteria. In cases where several companies have to be considered by one and the same IT project, the SoS may be meta-classified by their role in a supply chain, or by their position in a corporative structure (Lawall et al., 2014). Images of organizations proposed by G. Morgan (Morgan, 2006), also could be consulted in the identification of SoSs relevant to the IT project and IT project management.

4. Three IT project Management aspects from the SoS Perspective

As we have discussed in the previous sections, the importance of the SoS perspective is recognized in research and standards, however, it is not clear yet how this perspective could be methodologically addressed in IT projects in general, and in IT project quality management in particular. In this section, using the ArchiMate modelling language-based model, and viewing an enterprise as an SoS with constituent systems A-F as represented in Figure 6, we will derive the questions for further research, which might help to focus the research efforts towards the models, methods, and tools that would help to address the common attributes of SoSs, such as independence, distribution, emergence, and evolution.

4.1. IT Product from the SoS Perspective

Depending on the project, an IT artifact can be regarded as just software or also as software and hardware (Wong et al., 2018). Thus, in Figure 6, the product can be represented with System A, or with System A&B. We can see that these systems themselves can be regarded as SoSs, as we can distinguish between data systems, service systems, package systems, etc. A and B are constituent systems of an enterprise as a system. Therefore, the IT project's product must also be viewed from at least business and decision-making perspectives. Consequently, for the product aspect of IT project quality management, we shall find the answers to the following questions:

- What tools and methods should be used to identify product scope and relationships in systems A or A&B?
- What tools and methods should be used to identify relationships between the constituents of the product and the rest of the systems (C-G) in enterprise architecture?
- How to ensure continuous estimation of an expected product quality respecting changes in the related elements in all related systems?
- Looking at the product as an SoS, how can its independence, distribution, emergence, and evolution be modelled and analysed?
- Looking at the product as a constituent system, how does its independence, distribution, emergence, and evolution may impact other constituent systems and a parent SoS?

Concerning product quality per se, many methods are proposed for quality assurance and control, part of which are well automated (Shen et al., 2018; Shepperd et al., 2022; Wong et al., 2018). These methods are beyond the scope of this paper. Nevertheless, in

further research, these methods can be analysed from the SoS perspective and may help to answer the questions stated above.

4.2. IT Project Process from the SoS Perspective

IT project as a process can be situated in system G of Figure 6. Knowledge-wise it is related to all other systems. In the case of in-house development, on the one hand, this process is a constituent system of processes of an enterprise that will use the product, but, on the other hand, it can also be a constituent system of processes of a developer enterprise. As a process, it might be a subject of the same quality characteristics as the enterprise business processes (Heinrich, 2014), including the quality of business process models (Krogstie, 2016). Similar to the product aspect, the project process itself can be viewed as an SoS. Therefore, the following questions regarding it are relevant from the SoS perspective:

- What tools and methods should be used to identify the project process and dependencies among its constituents in System G?
- What tools and methods should be used to identify relationships between the constituents of the IT process and the rest of the systems (A-E and F, if applicable) in enterprise architecture?
- How to ensure continuous estimation of an expected process quality respecting changes in the related elements in all related systems?
- Looking at the process as an SoS, how can its independence, distribution, emergence, and evolution be modelled and analysed?
- Looking at the process as a constituent system of other enterprise processes, how does its independence, distribution, emergence, and evolution may impact other constituent systems and a parent SoS?

While process quality is a very well researched topic (Heinrich, 2014), the traditional methods do not directly address the above-stated questions. Therefore, additional research is needed to see how existing approaches could be used and/or extended to be applied in the SoS context.

4.3. IT project "Materials" (Inputs) from the SoS Perspective

The main IT project "materials" or inputs are requirements. In Figure 6, requirements are situated in System E and are related to all other systems (A-D, F (if applicable), and G). Requirements can themselves form an SoS. Problems, challenges, and some of the possible solutions regarding requirements in SoS are discussed in (Kirikova, 2022). Respecting the related work in (Kasauli et al., 2021) and (Kirikova, 2022), the following questions can be considered as relevant concerning requirements quality from the SoS perspective:

- What tools and methods should be used to identify and maintain the dependencies between the requirements so that they might be considered as a system?
- What tools and methods should be used to identify relationships between the requirements and the rest of the enterprise architecture elements?
- How to ensure continuous estimation of the expected requirements quality respecting changes in the related elements in all related systems?

- Looking at the requirements as the SoS, how can requirements independence, distribution, emergence, and evolution be modelled and analysed?
- Looking at the requirements as a constituent system of other enterprise systems, how may the requirement system's independence, distribution, emergence, and evolution impact other constituent systems and a parent SoS?

The related work (Kasauli et al., 2021; Kirikova, 2022) shows that requirements quality may depend on project knowledge management quality. However, knowledge management in SoS is itself a scarcely researched topic.

Regarding the "inputs" aspect, it is also necessary to consider data quality (Krogstie, 2016) which will be used by the developed IT system. Caring about the data quality, however, can be the task of the IT project itself. Therefore, from the SoS perspective, the main question here is to identify correctly which data are needed and what can influence its quality for being able to scope the project correctly, i.e., so that the data quality would be under control.

5. Conclusion

This paper amalgamated open questions when considering IT project quality management from the SoS perspective. We looked at three main aspects of IT project quality management, namely, the quality of the product (software and/or hardware), the quality of the project process, and the quality of requirements and data (input of the process). Looking at the questions stated for each quality management aspect, we can see that the scope of questions is similar. For each aspect, the methods and tools are needed that support considering the aspect as a SoS (e.g., in terms of new modelling approaches for IT artifacts, project processes, requirements, and data); and discovering the relationship between this SoS and other SoSs, which might be at the same or different levels of the systems' conceptual hierarchy. Additionally, for all aspects, the methods for identifying and handling SoS related attributes, such as independence, distribution, emergence, and evolution, are needed. It is also essential to be able to see the relationships between all identified SoS at the level of their constituents.

This work is limited only to the questions that arise when looking at IT project quality management from the perspective of SoS. Further research is needed to get satisfactory answers to these questions, which have become more and more important in different digital transformation projects in enterprises' digital ecosystems. The future research to model project management using the SoS approach is intended towards the investigation of morphological and functional structures for SoSs with and without central management entity and how to apply these to IT project quality management aspects. The systems which compile SoSs, for several case studies, will be identified and the corresponding structural models will be constructed, analysed as well as decomposed, and the result of decomposition, namely, constituent elements will be described from the static and the dynamic point of view based on systems thinking considerations. The next step will be the cause-consequence analysis of relationships between components to understand the antecedents of project quality and the various criteria for its assessment with respect to the essential SoS attributes. The overall research strategy will be focused mainly on collaborative and virtual SoSs where the use of the multiagent systems paradigm seems to be a perspective issue regarding the practical implementation of the proposed approach. At the same time, the directed and

the acknowledged SoSs also may be studied from the same perspective using the basic ideas of the hierarchical systems theory.

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