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Creating a sustainable digital infrastructure: The role of service-oriented architecture

Eli Hustad*, Dag H. Olsen

University of Agder, 4604 Kristiansand, Norway

Abstract

The United Nations' goal of generating sustainable industry, innovation, and infrastructure is the point of departure for our reflective paper. The paper elaborates on the concepts of digital infrastructure, service-oriented architecture, and microservices. It emphasizes the benefits and challenges of creating a sustainable infrastructure based on a service-oriented environment, in which cloud services constitute an important part. We outline the prerequisites for obtaining a sustainable digital infrastructure based on services. Service-oriented architecture (SOA) and recently, microservice architecture, and cloud services, can provide organizations with the improved agility and flexibility essential for generating sustainability in a market focusing on digitalization. The reuse capability of SOA provides a common pool of information technology (IT) resources and qualifies as a green IT approach that impacts environmental protection. Previous research has identified IT and business alignment together with SOA governance as the most critical criteria when implementing SOA. This paper discusses these issues in-depth to explain sustainability.

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Keywords: Digital infrastructure, sustainability, service-oriented architecture (SOA); microservices; cloud services, SOA governance; agility

* Corresponding author. Tel.: +47-38-14-16-21.
E-mail address: eli.hustad@uia.no

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1. Introduction

Developing sustainable digital infrastructures is crucial to ensure technological advances that benefit society. Investment in infrastructure and innovation has therefore become essential for economic growth and global development. This is explicitly emphasized by the United Nations Development Programme (goal 9: Industry, innovation, and infrastructure). It focuses on technological progress in finding sustainable solutions to economic and environmental challenges, such as ensuring growth of new industries with green supply chains and promoting energy efficiency.

Achieving these goals will require considerable effort from contemporary organizations operating in both the private and public sectors. Efficient technological infrastructures are urgently needed to support optimally functioning organizations. Ensuring the sustainable evolution of digital infrastructures that consider environmental challenges will require changes in how infrastructures are designed and utilized, and how the potential reuse of digital resources dependent upon these infrastructures is enabled.

Implementing service-oriented architecture (SOA) is now a well-known approach to enable companies to realize significant benefits, such as increased agility and efficiency, better utilization of existing resources, and more flexibility, and thus be better positioned to respond to market changes [1]. In a fast-developing technological environment, these advantages are urgent for the survival and generation of digital sustainability. Many organizations face architectural challenges arising from complex mixes of legacy systems, enterprise systems, platforms, and applications. To achieve communication among these different systems and applications, point-to-point integration and implementation of middleware solutions (e.g., enterprise application integration) have increased [2]. However, the human and technical resources required to develop and maintain these compound solutions have become extensive and are not beneficial, either for the companies or for the environment. An SOA platform, however, based on module-based architecture and services promises increased flexibility and reusability and can address challenges related to the development and maintenance of demanding and complex information technology (IT) portfolios [3-5]. The focus on services makes SOA unique, and it provides transparency across multiple legacy systems and data sources that are black-boxed. Since the services are defined by open standards, SOA makes a common pool of IT resources available, despite the existence of different IT systems, functionalities, language codes, and platforms [1]. In many cases, organizations want to keep their legacy systems, because they still have business value and support specific business functions and processes [6]; a legacy system is not only a technological artifact—it is a part of the organizational culture crucial for both IT professionals and end-users. SOA may facilitate continuous use of legacy systems and even support better utilization of these systems by adding on business intelligence applications to aid decision-making supported by a digital infrastructure.

Previous research on SOA implementation reveals a gap between theory and practice. Many companies use a more technical approach to SOA rather than focusing on SOA as a catalyst for driving organizational changes to achieve better IT–business alignment and increased agility [5]. Thus, there is a need to study the socio-technical issues accompanying SOA to understand the circumstances for making a sustainable infrastructure.

Specifically, the following questions have guided this research:

(1) How can SOA contribute to a sustainable digital infrastructure?
(2) What challenges must be overcome to make a digital infrastructure sustainable?

This paper is organized as follows. First, the concepts of digital infrastructure, service-oriented architecture, and microservices are examined. Second, the benefits and challenges of creating a sustainable infrastructure based on a service-oriented environment are discussed. Third, we outline the prerequisites for obtaining a sustainable digital infrastructure based on services. Finally, we offer concluding remarks and recommendations for future research.

2. The concept of digital infrastructures, benefits and challenges

2.1. Digital infrastructures and SOA

Digital infrastructures are important foundations to ensure digital transformation of organizations that want to enhance the potential of new digital technologies. A digital infrastructure consists of both technical and organizational components, processes, and networks. It comprises the social environment of users of digital tools and the designers and systems developers connected to the infrastructure. In current research literature, a digital infrastructure is conceptualized as an interconnection of different system collectives, including the software, hardware, standards, the Internet, platforms, and humans, very unlike standalone information systems [7]. Digital infrastructures are becoming indispensable for sustainable operations in both public and private sectors, and their emergence and growth are increasing across different industries (pharmaceutical, health care, manufacturing, energy, marine industry, and governmental institutions). Enterprise social media platforms [8], knowledge intranets at universities [9], enterprise architecture in the education sector [10], service-oriented architecture in public administration [11], and the infrastructure of e-health services [12] are examples of the different variants of crucial digital infrastructures for growth and development. Three growth mechanisms have been identified as critical to stimulate the evolution of digital infrastructures: adoption, scaling, and innovation [7].

In this paper, we focus mainly on SOA, which is an essential infrastructure for companies that want to pursue a sustainable digital transformation and who must tackle a complex IT portfolio. From the technical perspective, SOA is software architecture based on key concepts from a front-end application, services, a service portfolio, and a service bus (the glue binding the different systems to be integrated). A service consists of a contract (description of the service interface), one or more interfaces, and implementation from a business perspective. SOA is a business concept, an idea, or an approach to how IT functions can be planned, designed, and delivered as modular business services to gain business benefits [13]. Vital to SOA is a set of open standards that define the service, as well as how to find it, communicate with it, and use it. The location of data and the functionality of services facilitate reuse and easier reconfiguration and allow improving and changing the services without compromising the overall functionality. Developing a set of such services requires an overall architecture that specifies design principles. These principles should be rooted in an organization's business needs for the services [14].

Recently, microservices are becoming another approach for service-oriented environments. Microservices are developed on the same principles as SOA, with respect to service development and deployment, but they consist of more and smaller services [15], and their architectural style structures an application as a collection of small autonomous services modeled around a business domain [16]. The approach supports individual business capabilities and offers several benefits, in terms of loose coupling, maintainability, and scalability. If a service is too large, it should be split into two or more services supporting a single business capability [17]. Further, each service in microservice architecture is operationally independent from other services, which increases the flexibility. Despite less coordination across development teams being needed for microservices (teams of functional and infrastructure services), compared to SOA (teams of functional, enterprise, application, and infrastructure services) [16], more formalized control is needed in microservice architecture to get a complete overview of all the services and updates. Microservices are also said to increase the cognitive load for architects [18]. Microservices have been criticized as being an immature approach, to date, lacking development principles and resulting in high costs for mistakes, especially when migrating monoliths [19]. Specific recommendations are advisable for handling the complexity. As regards sustainability, the SOA infrastructure may seem to be more efficient, but several companies combine these architectures and have invested in skills to tackle the complexity to achieve a sustainable and evolutionary software development process [20].

In the following section, we discuss the infrastructure of SOA. Although SOA and microservices are likely to be combined, we see the microservice architecture as a possible approach in conjunction with SOA in the service-oriented environment.

2.2. SOA benefits

According to existing SOA literature, companies can gain several benefits by implementing SOA. The most important are increased changeability and efficiency, reduced integration costs, improved agility and flexibility, better utilization of existing resources, faster time to market, easier possibility to make changes and continuous improvement of business processes, and improved return on investment (ROI) [e.g., 21, 22, 23]. The following paragraphs explain these benefits in more detail.

When implementing SOA, the IT infrastructure is broken down into different services. These independent sets of interactive services offer well-defined interfaces that enable interaction with other services. The services can represent a business process or a part of one. This architecture enables reuse by linking services to create new ones. A service may comprise one or more specific features by which it can be used wherever this functionality is required. The service works for itself and may be used in other applications through the service interface. The SOA allows new applications to be put together quickly so that the services can be reused everywhere. This is valuable for a business when there are market changes, making it easier to respond to new demands. The company's IT staff must always consider reuse while improving the reusability of functionalities [21, 24-27].

Reuse supports the entire organization's operations and processes while reducing costs. Moreover, reuse is indirectly influenced by the culture (reusing instead of making) in the IT community and is directly affected by different departments' ability to collaborate and interact [28]. To be able to use old systems in the new architecture, the functionality of these systems becomes encapsulated in different services with interfaces, so this functionality can also be reused, thus avoiding creating completely new applications from scratch. The existing functionality in the old systems is thus transformed into services that create more value for the business [29]. In addition, the reuse method supports the so-called "green IT" approach, as it involves more efficient use of computer resources. In addition, SOA has proven to be an energy-efficient infrastructure for enabling an architecture of the Internet of Things [30].

The benefits of green IT relate primarily to reduced energy consumption, which in turn reduces CO_2 footprint—central to sustainability and a lower environmental impact [30]. For example, to become green in terms of hardware, reductions in consumption of non-renewable resources, pollution, and waste-efficient management are recommended. To become green in terms of software, it is recommended that negative influences on the environment of software development be minimized and that the complete life cycle of sustainable software systems engineering be supported. SOA can support these demands for organizations that have a green mindset and contribute to environmental protection through green IT development practices [31].

To make the best of existing resources, it is important to create stability in the interface of the services. This means that the services work, as much as possible, in isolation from their implementation, which reduces the scope of changes and the costs associated with subsequent changes. Reuse avoids the costs of introducing new services or changing the functionality of existing services. Allowing reuse and better utilization of existing resources will, in turn, improve the organization's agility, in addition to reducing the need for software maintenance. Reuse enhances organizational flexibility by allowing existing services to be used in new ones [32]. Being agile can be defined as being fast, resourceful, and adaptable. Agile organizations can respond more quickly to market changes, be more resourceful, and, to a greater extent, adapt to their surroundings. A flexible organization can thus respond more rapidly to customer requests, market dynamics, and new technological opportunities. It can manage its internal resources better—its people, technology, processes, and knowledge—and be able to respond and act more effectively in the midst of changing demands, threats, and opportunities [33].

Defined as the extent to which an organization's IT infrastructure resources are portable and reusable, IT flexibility is an indispensable strategic goal and one of the main reasons to adopt SOA. An SOA is flexible in that it offers an adaptable data structure that facilitates the introduction of new services and products. Characterized as interoperability, this means that services can be developed on different platforms using various software languages; at the same time, they have the capability of communicating with each other. The three criteria for flexibility in SOA are (1) connectivity, which enables components to link to each other; (2) compatibility, which allows interconnected components to interact and share information; and (3) modularity, which involves isolating and standardizing as many business and system processes as possible [26, 32, 34]. The SOA has emerged as a conceptual framework to facilitate changes that allow smooth business processes to adapt flexibly to a changing market. The framework's goal is to develop flexible and robust IT-based services capable of responding effectively to business needs. The SOA can provide more agility and a more responsive infrastructure; for this reason, it can also offer a solid foundation for the organization's agility and adaptability. The SOA increases operational flexibility and should provide more leeway in choosing the implementation of technologies and selecting locations for service providers and consumers. The services' abstract interface enables suppliers and consumers to develop services independently of each other, as long as the interface is stable [32, 1, 35].

Improved agility and flexibility are often long-term benefits in an SOA project. Only when a company focuses on key business goals will it foster the creation of an SOA that is designed to promote flexibility and agility. It is often difficult to quantify improvements in flexibility, but to achieve it, IT systems should be process-driven and quick to respond to changes in business affairs [25].

Organizations that operate in silo structures face problems with duplication of functionality and data, which leads to high integration costs when new systems are implemented. The SOA has features to address this problem. In the case of new business requirements, the cost of improving and creating new services will be significantly reduced by the SOA. The reason is partly the ability to reuse existing services. The learning curve for the systems developer team is also lower, since they are already familiar with the existing system components. The loosely-linked services facilitate outsourcing IT functions and limit IT costs. At the same time, it is important to develop a shared view on reusable SOA resources within the organization to prevent redundancy and duplication of system development (SD) tasks [22, 36].

The SOA is supposed to enable faster adaptation to changing market conditions arising from unforeseen events. Reusing existing services and components can significantly reduce the time to market. The use of existing services decreases time spent on design, development, testing, and distribution, in line with green thinking. Over time, with an SOA approach in place, a company will develop an increasing number of services that contribute to a broader and greener ecosystem, which facilitates building on complex applications rather than developing new ones, leading to faster time to market [21, 26, 37]. Due to the reuse of IT resources that SOA affords; an organization's ROI of its existing IT systems continually increases over time.

Combining SOA with cloud computing can increase sustainability by becoming greener on a long-term basis. Companies do not need to invest in physical hardware resources, and companies pay for their actual use of software application resources and transactions [38]. The cloud vendors have large economies of scale because of the multi-tenancy feature and will therefore contribute to reducing the use of energy-demanding physical resources. Services are provided for shared, virtualized resources (infrastructure and platform virtualization). For instance, platform as-a-service (PaaS) offers cloud-based resources for developers so they can develop, deploy and operate software in a more efficient manner to address uncertainty and software quality [39].

To succeed with cloud-based services, however, SOA is a crucial prerequisite before organizations migrate business applications to the cloud, enabling the process "SOA using cloud computing" [40]. As described in the above, SOA repairs broken architectures in organizations with complex IT portfolios and may visualize which services that are most suited for being handled by external cloud providers, extending SOA outside of the enterprise.

The benefits of SOA are amplified when selected IT solutions become cloud-based services. IT resources provided over the Internet increase the elasticity and scalability, which again can intensify the flexibility and agility of enterprises operating in rapid-changing environments [41]. These features are crucial for creating a sustainable infrastructure.

2.3. Critical factors to render SOA efficient and sustainable

The literature points to several critical success factors (CSFs) when implementing SOA. The most discussed are IT–business alignment, SOA governance, SOA awareness, and process-driven IT–Business Process Management (BPM) [42-44, 35, 45, 46]. SOA awareness in the organization strengthens SOA governance, which in turn reinforces IT–business alignment, also enhanced by process-driven IT–BPM. This paper primarily focuses on IT–business alignment and SOA governance which are crucial for sustainability.

IT–business alignment is highlighted as important for enabling the implementation of efficient services. Additionally, effective communication between IT and business units is essential to promote their knowledge exchange, which leads to a balance of their respective desires. It is also crucial for developing sustainable business processes that flow smoothly without inefficient bottlenecks, before they are automated or digitized into services. Better knowledge exchange between IT and business also appears to increase the flexibility of IT projects [47]. Further, the SOA team, complexity, communication, and clear goal-setting in implementing SOA have been identified as important factors to succeed in SOA adoption projects and for achieving alignment between IT and business [48]. IT and business alignment is important for limiting the cultural diversity in SOA development projects; the lack of such focus has caused coordination challenges across teams and misalignment in SD processes [49].

Organizations with effective communication structures, particularly between IT and business departments, will have a greater chance to obtain SOA benefits, in terms of the requirements of flexibility and reuse. This is because effective communication reduces problems and misunderstandings [35, 27].

Furthermore, "fostering a partnership culture between the business and the IT" is highlighted as a CSF when implementing SOA [35, p.129]. This is closely related to the IT–business alignment and underscores the importance of a close relationship between the business and the technical processes in a culture characterized by trust and cooperation. It has also been posited that establishing a partnership culture as such is crucial for the successful management of joint IT–business projects [50].

When legacy systems are migrated into SOA, systems developers who work with different legacy systems may resist their transfer to SOA, as this requires changes in ad-hoc work routines and the introduction of new governance mechanisms [11]. Moreover, SD in silos will no longer be feasible. It is important that the whole SD team be included early in the migration phase to achieve a smooth changeover while aiding the process by allowing knowledge transfer. Achieving a successful migration phase requires a committee made up of several groups, each with its own responsibility in the migration process. Typically, there will be groups that focus on alignment and coordination of business and IT strategy and on coordination of business goals and the IT architecture. Thus, it is crucial for the different departments to be represented. It is also vital to involve systems developers with technical expertise in legacy systems [51, 37].

The establishment of effective SOA governance mechanisms is necessary for success in SOA adoption and implementation [28, 25, 26, 1, 35], but including SOA governance in a firm's existing IT governance structure is not a straightforward endeavor. It requires new competence to understand and develop appropriate structures and processes for SOA governance in order to support the module-based approach and manage the new service layer between existing business processes and IT applications [45].

SOA governance, an item on Lee et al.'s (2010) list of CSFs for obtaining successful SOA adoption, includes an effective policy management process, roles, and responsibilities, and well-defined and strictly coordinated development of services [35]. Thus, efficient portfolio management is important for sustainability, setting priorities and controlling the project's scope. Moreover, the focus on SOA SD practices is ranked as critical due to the need for combining top-down and bottom-up approaches, as well as different development patterns and guidelines.

When SOA is combined with cloud services, IT governance mechanisms are even more influenced. Organizations may need to rethink how they utilize their internal IT staff resources, and new roles might be necessary to address both internal IT needs and external requirements due to maintaining cloud-based solutions [52]. Besides, cloud services are handled by vendors outside the organizational boundaries, and new competencies are needed to tackle SLAs and security issues [53]. These changes can be resource-demanding to tackle but can create a more efficient and sustainable IT governance approach over time.

Table 1 summarizes the characteristics that make SOA a sustainable digital infrastructure. Challenges for achieving sustainability are also highlighted.

Table 1. SOA as a sustainable digital infrastructure

Sustainable characteristics of SOA	Sustainability challenges
Keeping legacy systems	Inefficient legacy systems that are kept, user resistance
Reuse of resources and services	Difficulties in prioritizing the services to be implemented
Flexibility and agility	Too chaotic, lacking overview, governance challenges
Supporting green IT approach	The reuse opportunities are not optimized, not managing to reduce power, inefficient engineering approaches, lack of skills among systems developers, microservices creating problems
Business processes – renewal	User resistance, difficulties in making improved processes
Cost efficiency	Goal not achieved; more resources are used than predicted
Less maintenance	More governance is needed than expected
Possibilities for extending SOA outside of the enterprise with cloud computing services	Difficulties with combining SOA and cloud services, selecting wrong services for the cloud
IT and business alignment	Lack of a good communication culture between IT and business, alignment is not achieved
Efficient SOA governance mechanisms, efficient SD culture	Challenges of establishing efficient SOA governance, systems developers are not aligned across teams, challenges with IT governance when SOA is combined with cloud services

3. Conclusions and future research

This paper has elaborated on the topic of digital infrastructures and has highlighted the sustainable characteristics of a service-oriented environment. The concepts of digital infrastructure, service-oriented architecture, microservices, and cloud-based services are expanded, and the benefits and challenges of creating a sustainable infrastructure based on a service-oriented environment have been explored. We have outlined the prerequisites for achieving a sustainable digital infrastructure based on services. The most important qualifications relate to reuse capabilities, flexibility and agility, IT and business alignment, and efficient SOA governance mechanisms, which can help establish a green IT approach. SOA, as a sustainable digital infrastructure, provides digital advancement for seeking sustainable solutions to economic and environmental challenges. Future research should focus on evolution processes for digital infrastructures to understand the circumstances that may contribute to both sustainability and innovation.

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