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ECOSYSTEM-BASED SERVITIZATION ASSESSMENT FOR THE USE CASE OF BUILDING PERMIT PROCESSES

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SUMMARY*: The construction industry lags behind other industrial sectors in terms of digitalization. The construction sector's slow adoption of comprehensive digital transformation is due to significant fragmentation throughout the building lifecycle and numerous stakeholders with diverse interests and priorities, hindering effective coordination and thus delaying innovative technology implementation. Following a design science approach, we propose and develop a process-oriented analysis framework for servitization based on service-dominant logic and Gaia-X-based ecosystem standards and technologies. The servitization approach is illustrated by applying it to the building permit process in general and described with exemplary services. The novelty of the study lies in combining service-dominant logic with a process-oriented, design-science framework that is operationalised via Gaia-X ecosystem standards and technologies to systematically derive digital service opportunities along the building lifecycle.*

KEYWORDS*: servitization, data space, Gaia-X, building permit, ecosystem, service-dominant logic, BIM.*

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1. INTRODUCTION

In the expansive realm of digital technologies within the architecture, engineering, construction, and operation (AECO) sector, a compelling opportunity for progress emerges against the backdrop of its constrained digital initiatives. A thorough examination, as highlighted in the review of digital technologies in AEC (Baines et al., 2017; Brozovsky et al., 2024a), reveals the sector's fragmentation across organizational, temporal, and information management dimensions. Despite the prevalence of building information modeling (BIM), other integrative technologies such as digital twins, internet of things (IoT), workflow management, customer relationship management, and 5G are labeled as emerging or underdeveloped. The inadequacy of relying solely on BIM is also evident in establishing and sustaining trust throughout the diverse life cycle phases of a building, as evidenced by the 22 trust issues delineated in a study by (He et al., 2023).

On the macro level, the service sector has pronouncedly become the most important sector of all economic activities, typically contributing around 80% to gross domestic product (GDP) and employment: US 78% of GDP (Statista 2023), UK 81% of gross value added and 85% of employment (UK Parliament 2024), and EU 75% of GDP and employment (EC 2024). However, in marked contrast to industries like manufacturing (Kowalkowski et al. 2017; Huikkola et al. 2021) or information technology (ISO 2018, Agutter 2020), where servitization has become integral for innovation and business development, the AECO sector, both in practical applications and research, is yet to fully adopt digitalization (Agarwal et al. 2016, (Brozovsky et al., 2024a) and to integrate servitization (Liu et al. 2022). A sparse number of studies, such as the exploration of “Building-as-a-Service (BaaS)” by (Wildenauer & Basl, 2022), delve into this domain. This research underscores the pivotal role of combining BIM and Service-Dominant Logic (SDL) in the transformation of the AECO sector from a product-centric to a service-centric industry (Wildenauer & Basl, 2022). BaaS, as an approach offering buildings as a service, shifts cost and ownership responsibilities from clients to planners and constructors. However, this transformative shift is impeded by the industry’s traditional mindset, which perceives assets merely as objects, hindering innovations aimed at enhancing long-term efficiency and effectiveness (Brozovsky et al., 2024b; Liu et al., 2022) .

Furthermore, the imperative integration of data ecosystems and spaces with services is crucial for the AECO industry’s advancement, yet it lags behind despite substantial potential. An illustrative case is the inadequately digitized building permit process, marked by diverse and often incompatible software solutions mandated by public authorities. This hampers seamless application integration and cross-application task orchestration, as highlighted in a study by (Fauth et al. 2023). This diversity conflicts with the goals of sovereign data storage and the imperative to prevent information loss (Fauth et al. 2024b). A survey reveals that 86% of participants consider trustworthy data management a critical matter.

Shifting focus to the building permit process, existing research predominantly centers around automated code compliance checking (ACCC) to systematically assess building designs and construction plans using BIM models (Malsane et al., 2015; Nawari, 2019; Noardo et al., 2022). One example is the escape route checking (Fischer et al., 2023) and accessibility compliance verification (Preidel & Borrmann, 2018). Yet, a significant research gap as identified by (Bloch and Fauth, 2024) lies in defining distinct levels of digitalization within the building permitting process and the lack of a common methodology for worldwide comparison, which parallels similar standardization challenges in other related digital construction domains. While prior work largely advances automated code compliance checking and taxonomies of permitting digitalisation, it offers limited guidance on how to systematically derive and prioritise digital service opportunities across the permitting process and stakeholder network. Our study addresses this by introducing a process-based servitisation analysis method grounded in service-dominant logic and operationalised via Gaia-X ecosystem standards. Existing cloud-oriented frameworks, while emphasizing legal requirements and resource effectiveness, raise concerns about data security and loss of control over sensitive data and introduce process-oriented solutions with their own set of inconveniences, including repeated user-registration (Capko et al., 2014; Eirinaki et al., 2016; Fauth et al., 2025; Shahi et al., 2019). Nonetheless there is space of improvement as an empirical study shows, where 38% of German government employees see high automation potential in their own work (Nextpublic. 2023), aligning with international trends where public sector digital transformation increasingly focuses on process automation and service integration with the necessary digital transparency (Matheus et al., 2021).

In conclusion, the AECO industry grapples with challenges in adopting digital technologies and servitization, particularly in the context of the building permit process. Furthermore, there appears to be a disconnect between theoretical servitization frameworks and practical implementation strategies in construction contexts. Existing servitisation studies in construction predominantly argue at the level of general transformation logics (e.g., mindset or institutional barriers) but rarely provide a replicable, process-level method that links value co-creation points to concrete (digital) services and their ecosystem requirements. This paper contributes such a method and demonstrates it for building permitting. As (Liu et al., 2022) emphasize mindset barriers, more recent work by (Coenen et al., 2023) suggests that institutional structures and project procurement models constitute more significant obstacles to service integration. This paper seeks to address these challenges comprehensively, proposing a novel ecosystem approach for more efficient, integrated, and transformative solutions that bridge the gap between digital capabilities and service value creation.

Servitization, in the context of this study, refers to the business model of transitioning from offering products to providing integrated service solutions, a trend that is prevalent in many industries (Baines et al., 2017). In this paper, we distinguish between 'services' in the IT sense - technical services such as cloud-based model checking—and 'services' in the economic sense - business activities such as the building permit approval process, as proposed by (Kowalkowski et al, 2017) in their analysis of service growth strategies. This dual use of the term is important for understanding how digital and automatable services intersect with traditional economic service delivery in the AECO sector, creating what (Coreynen et al., 2017) refer to as “digital servitization” opportunities. The aforementioned digitalization deficits in the AECO sector may be attributed to the lack of a true end-to-end approach both at the IT and the methodological level. New information systems are often restricted to point solutions like BIM authoring software, CDE (common data environments), or compliance checking tools creating what (Woodhead et al., 2018) describe as "technological silos" that impede integrated service delivery. Moreover, even collaborative information technology is often provided as a completely centralized service requiring a high level of trust with a concomitant reduction of participants’ sovereignty. This low usage level of more decentralized IT concepts such as data spaces or service ecosystems makes it seem questionable whether the current digitalization path will scale across the many different organizations engaged in the end-to-end building life cycle. For example, in an end-to-end digitalized building permit workflow, a BIM model generated during design could be securely exchanged and continuously reused and amended across submission portals, automated compliance checking services, authority review processes, construction inspections, and later facility management applications through interoperable ecosystem services rather than repeated manual data transfer and isolated software solutions.

The lack of a holistic approach is also evident in the fragmented methodological situation regarding digitalization projects very often focusing on individual subprocesses or particular stakeholders of the building lifecycle or selected aspects of software development process (e.g., requirements elicitation).

Our preliminary research question addresses how to overcome these deficiencies through the development of a holistic servitization analysis framework for end-to-end digitalization. This framework systematically incorporates both process and methodological aspects of such endeavors while effectively managing the inherent complexities of the information technology domain (we will present a rigorous formulation of our research question in section 3). We define “end-to-end digitalization (eteD) according to (Dallasega et al., 2018; Woodhead et al., 2018) as the comprehensive integation of digital technologies, processes, tools and data management systems across the entire construction value chain, from inital planning through design, planning, permitting, handover and facility management. This shall ensure seamless information flow between all project phases and participants with the aim of eliminating information silos and manual rework, data transfer and human-based controlling while creating a continuous digital thread throughout the assets’ lifecycle.

While both concepts are conducive to digital transformation, it is imperative to differentiate between them. The two approaches differ in terms of their scope and implementation focus. eteD embodies a comprehensive, holistic approach that integrates all phases of a life cycle, while digital services are predicated on specific technology-based offerings that address particular needs or functions during the delivery process of an asset. Nevertheless, these are the fundamental components of end-to-end digitalisation, which can be seen itself as a strategic vision and implementation guide.

As the research problem pivots around the generation and confirmation of certain artifacts in a specific context, we will use a design science approach for structuring our research project, following methodological principles established by (Hevner et al., 2004) and refined for construction contexts by (Kehily & Underwood, 2015). Within this framework, we will turn to service science as the overarching conceptual (meta) model within which we want to address and navigate the whole continuum from (business) processes via (business) services towards IT services. Recognising that any new digitalization approach must address the inherent complexities of the AECO sector, we have selected the building permit process as our use case. This study aims to accelerate digital automation adoption in building permitting through the design of an analysis framework for servitization assessment including the development of and testing with a litmus test. The framework is based on modern data spaces, ecosystem principles as well as service-dominant logic, and should enable ecosystem participants to effectively identify and automate services, while addressing related IT requirements and challenges incorporating emerging concepts of data sovereignty and federated architectures as outlined by (Jarke et al., 2019) and adapted for construction contexts by (Ramu et al., 2022). Since this study was mainly funded through the iECO project, the Gai-X standards and procedures were predetermined as core elements for this research (iECO 2024). Here, Gaia-X provides the standards and software implementation of a universal intra- and inter-ecosystem trust protocol and trust framework allowing ecosystem participants, services, and any other ecosystem resource to be labelled as “compliant” against the backdrop of arbitrary ecosystem governance frameworks. Based on neutral technology standards and the SSI (self-sovereign identity) paradigm, Gaia-X enables (i) so-called (Gaia-X and other) Digital Clearing Houses to attest this compliance and (ii) every ecosystem participant to verify the validity of such attestations in a fully automated way (Strnadl & Del Buono 2026).

After the motivation of our research in general and the selection of the building permit process in particular as our test case (section 2) we carefully describe our approach within a design science research (DSR) paradigm and present an elaborated version of our research question in section 3. Section 4 develops the (theoretical) servitization approach and applies it (practically) to the building permit process as the core of our novel contribution. Due to continuity reasons, the reader will find a complete list of results of applying the servitization method, i.e., the list of the various types of services identified in the building permit process, in the appendix. Results and discussion (section 5) and conclusions with directions for further research (section 6) complete this contribution.

2. STATE OF THE ART

2.1 Service orientation and servitization

With the service sector constituting by far the largest contributor to GDP (gross domestic product) in many developed countries, today’s global economy has shifted from a product- and manufacturing-centric architecture to a service paradigm (Ng et al., 2011; Spohrer et al., 2007), a transformation that (Kowalkowski et al. 2017) characterize as the “servitizitation of society” that extends beyond traditional manufacturing contexts. The realization that a significant amount of research was still concentrated on a manufacturing- and production paradigm led to a “call to action” in 2006 for creating and developing a dedicated science to capture and scientifically address the commonalities of many different service systems (Chesbrough and Spohrer 2006). This initiative marked the inception of a paradigm shift in understanding value creation across economic sectors, as subsequently delineated by (Lusch & Vargo, 2014). This so-called *service science* is now regarded as the (scientific) foundation for a transdisciplinary approach to study, improve, create, scale, and innovate service systems (Spohrer et al. 2007, Spohrer and Maglio, 2008, 2009, Wildenauer, 2022). Already at that time, the critical role of information and communication technologies (ICT) as enablers of this (new) service economy had been clearly identified as witnessed, amongst others, by the (then) newly developing approaches of service-oriented (IT) architectures (SOA) - a design approach where software components offer services to each other over a network - and web services (Chesbrough and Spohrer 2006). Subsequently, it was described (Barrett et al., 2015) as the "digital infrastructure for service innovation", a term which facilitates the development of increasingly sophisticated forms of service delivery across various industry boundaries.

Surpassing the classical product-focused paradigm of exchanging physical goods, service science revolves around the key notions of services and service systems. In distinction to the traditional view of a service as (any) intangible output of a process, service science regards *services* as the fundamental basis of exchange and defines a service as the “application of specialized competences (knowledge and skills) through […] processes, and performances for the benefit of another entity or the entity itself” (Lusch & Vargo, 2014; Vargo & Lusch, 2014). While the classical understanding strongly separates the two roles of service provider and service consumer, service science emphasizes the necessarily inseparable symmetrical nature of these two roles during the course of a service interaction. Accordingly, any such interaction is understood as a form of value co-creation of two (or more) interacting *service systems*. Here, a service system is a "configuration of people, technologies, and other resources that interact with other service systems to create mutual value" (Maglio et al. 2009). In that sense, services may also be regarded as the "offered functionality performed by the interaction of these resources" of the involved service systems (Böttcher & Fähnrich, 2011). This interaction-based perspective, as articulated by (Tronvoll et al., 2020), is pivotal in elucidating the manner in which digital transformation facilitates novel forms of resource integration and service provision within traditionally product-centric industries, such as construction. We therefore stress the fact that this definition is decidedly broader than the classical notion of service delivery systems as it (*scil.*, the broader definition) always includes the customer(s) or beneficiaries of a service (Fromm and Cardoso 2015).

The highlighting of *value co-creation*, i.e., that "value is co-created by multiple actors through the integration of resources in a specific context" (Akaka et al. 2019), is another key difference of the so-called service-dominant logic as important theoretical basis of service science compared to the sequential creation of value as put forward by a goods-dominant logic. Service-dominant logic provides a strong theoretical lens for value co-creation, yet it does not prescribe how to operationalise service identification in complex, multi-actor administrative processes. In construction research, servitisation discussions often remain at a conceptual level (e.g., product-to-service shifts such as Building-as-a-Service) and less frequently translate process interactions into an actionable catalogue of candidate services. We therefore operationalise SDL via a process-based service identification procedure that derives services from resource-sharing interactions within the permitting workflow.

Ever since the installation of the first computer or the first public appearance of an ATM (1969), ICT has played a pivotal role in the proliferation of *digital services* which may be broadly understood as "service systems (with elements, a structure, a behavior, and a purpose) for which the implementation of many of its elements and behavior is done using automation and programming techniques" (Cardoso and Fromm 2015). This term includes all potential forms of technical service delivery or deployment across the whole cloud-to-edge continuum, in particular any form of cloud service such as infrastructure, platform, or software as a service (IaaS, PaaS, SaaS) or in the longterm Building as a service (BaaS). The term "digital service" does not, though, extend into the realm of services as a programming paradigm such as web services, SOA services, or microservices. These (sub-)systems of a digital service system which are directly based on information processing are also called *information services* (Katzan 2008). The latest incarnation of the IT Infrastructure Library, ITIL 4, also puts value co-creation in the core of its definition: A service is a "means of enabling value co-creation by facilitating outcomes that customers want to achieve, without the customer having to manage specific costs and risks." (Axelos 2019). Due to the specific nature of the particular type of resource sharing prevalent in IT, ITIL 4 introduces an asymmetric model of (service) consumer ("A person who defines the requirements for a service and takes responsibility for the outcomes of service consumption") and service provider ("A role performed by an organization in a service relationship to provide services to consumers"). This clearly emphasizes the fact that the two concepts of IT or information services and services as characterized by service science are not contradictory but form a proper subset of the services recognized by service science. Building on this distinction, our contribution connects business-process services (e.g., participation or review activities) to digitised and automatable IT services, and subsequently to ecosystem-exposed services, thereby providing a structured path from theory to implementation.

The move from a product-centric to a service-centric business model and logic can be witnessed in all economic sectors ranging from traditional manufacturers to software companies with the now ubiquitous triad of IaaS/PaaS/SaaS offerings. (Bustinza et al., 2018) identify this as a particularly disruptive phenomenon in industries with traditionally high capital expenditure models, where pay-per-use and outcome-based contracting are increasingly replacing outright ownership. This *servitization* may be understood at its core as "the transition from product to service logic, often involving a complex integration of product-service-software systems, where the ideal–typical form of service logic can be understood as a customer paying for the realized value in use" (Kohtamäki et al. 2021). The concept, first introduced as early as 1988 (Vandermerwe and Rada 1988), has significantly grown and matured in academic research since the early 2000s. A publication analysis 1988-2020 found four prevalent research clusters: customer solutions, servitization, product-service systems (PSS), and service operations (Kohtamäki et al. 2021). This categorisation is complemented by(Zhang & Banerji, 2017) who highlight the increasing intersection between these clusters and sustainability research. This is due to the fact that product-service systems are increasingly recognised for their potential to reduce resource consumption while maintaining or enhancing customer value.

2.2 Digital platforms, ecosystems and Gaia-X

In parallel to the initial waves of digital services – mostly in the form of large mainframe computers – provided solely to users within the same organization, enterprises recognized the optimization potential of interorganizational data sharing – often called *electronic data interchange* (EDI) in a business-to-business context – as early as the 1960s (Schwandt 1997, Jagdev and Browne 1998). The complexities associated with setting up and operating EDI connections with other enterprises due to the fairly elaborated EDI standards (e.g., ANSI X.12, SEDAS, EDIFACT), often limited EDI interactions to large enterprises which could afford the associated higher costs of such a point-to-point (P2P) communication pattern. This led to the development of value-added network services (VANS) providing common platforms specifically supporting EDI transactions, e.g., through identity and access management functions trusted by all participants, by guaranteeing the integrity of the communicated data, or via suitable catalogues (Schwandt 1997).

The advent and proliferation of the World Wide Web (especially in the form of the light-weight HTTP standard and the architectural style REST since the year 2000) supported the establishment of an *API economy* (application programming interface) enabling enterprises to seamlessly expose former internal (IT) services (via their respective API) to any interested and sufficiently legitimated external party (Strnadl 2023a). Like early EDI initiatives, however, this approach also relies on a P2P pattern with its associated inefficiencies.

Under the term *data spaces*, research and practice have been trying to reconcile the advantages of VANS-mediated EDI (especially its shared source of trust) with the ubiquitousness and extremely low transaction costs of the global internet (Otto et al. 2016, Otto 2022). To the best knowledge of the authors, data space research seems to completely overlook this parallelism to VANS-based EDI and (mistakenly) traces back the term to (Franklin et al., 2005; Halevy et al., 2006) who put forward the concept in the context of integrating relational databases within a single organization – which has nothing at all to do with the modern notion of «data spaces». Even though no unanimous definition of data space has been agreed upon, the following definition provides a sound basis for applying this construct in research and practice. A data space is "a coordinated set of technical standards, organizational policies, and core services under a specified governance model to enable and facilitate data exchange between its participants" (Strnadl and Schöning 2023a). The definition of the EU Data Space Support Center (DSSC 2024d) also, albeit only implicitly, recognizes this distinction between organisational governance principles and technical standards on the other hand: "[A data space is an] interoperable framework, based on common governance principles, standards, practices and enabling services, than enables trusted data transactions between participants". Compared to point-to-point API integration or cloud platform solutions, ecosystem architectures lower multilateral integration effort and transaction costs, which is critical for fragmented AECO settings with many SMEs and public stakeholders. This motivates why an ecosystem lens is not merely 'infrastructure context' but an enabling condition for scalable digital services in permitting.

The pronounced emphasis on data sharing or data exchange in data space conceptualizations – as opposed to data or generic processing or the provisioning of arbitrary (information) services – is complemented by the Gaia-X initiative focusing on the enablement of *service ecosystems*. This strategic shift is characterised by Baur 2025 as being essential for the creation of sustainable digital infrastructure that balances innovation with European values of privacy, security, and interoperability. The EU Data Act is a notable exception defining "common European data spaces" as "purpose or sector specific or cross-sectoral interoperable frameworks for common standards and practices to share or jointly process data" (EU 2024). Coordinated by the Belgian not-for-profit Gaia-X European Association for Data and Cloud AISBL, the mission of Gaia-X is to "enable trusted decentralized digital ecosystems" (Gaia-X 2024a). Centering around the core notions of a "service offering", Gaia-X develops the technical and organizational standards of a trust framework realizing a trustworthy hybrid multi-cloud service ecosystem. So-called "Gaia-X Credentials" provide the necessary elements establishing trustworthiness between participants in a service exchange (Gaia-X 2025). Data exchange is just one potential type of service realizable using Gaia-X standards. While Gaia-X adopts a considerably libertarian conceptualization of ecosystem (which are essentially regarded as any collection of economic actors "operat[ing] under a commonly defined governance", (Gaia-X 2025), recent economic analysis suggests to explicitly require a value proposition shared between ecosystem participants to ensure its stability (Eustache et al. 2024). There, *ecosystems* are regarded as the "alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize" (Adner 2017). Building upon this definition, (Kapoor, 2018) underscores the significance of governance mechanisms that orchestrate complementary activities, eschewing the rigid hierarchical control structures that are hallmarks of traditional supply chains. Under some circumstances, a clear distinction from two- or multi-sided platform-based ecosystems can be drawn by requiring the ecosystem participants to provide "varying degrees of multi-lateral, non-generic complementarities that are not fully hierarchically controlled" (Jacobides et al. 2018).

It is important to note that the functional scope of some data spaces is restricted to the mere sharing of data assets such as those based on the International Data Spaces Reference Architecture Model version 3 or 4 (IDSA 2019). The recent conceptualization of the EU Data Spaces Support Center also puts data in the center of its metamodel leaving services almost as an afterthought when defining a "data product" as a "data sharing unit, bundling resources (data and/or data services) and metadata that describes the license terms, the resources, and other information in a machine-readable way" (DSSC 2024a). This is also evident in the "building blocks" comprising "description[s] of related functionalities and/or capabilities that can be realized and combined with other building blocks to achieve the overall functionality of a data space" (DSSC 2024b). There, data models, data exchange, provenance, and even APIs center around the data shared within the data space (DSSC 2024c). We need to stress, though, that the last version 3.0 of the DSSC Blueprint now recognizes more generic so-called "value creation services", that is "services aimed at creating value out of the data shared in the data space", as almost equal concepts of a data space (DSSC 2024e). One cannot help but notice that this concept still pivots around the data circulating within a data space. Such a limitation prohibits the usage of these conceptualizations for implementing ecosystems encompassing generic services amongst data due to the incompatibility of their respective metamodels. Typical properties of data such as provenance, traceability, or data quality are simply not applicable to services. This also applies *vice versa*, for instance for attributes such as service level, service times, service availability, or observability. Consequently, approaches centred primarily on data asset exchange are insufficient for systematically deriving and exposing end-to-end permitting services that include non-data attributes (e.g., service levels, orchestration, observability). Gaia-X is therefore adopted in this study because its trust framework and service-offering model directly support the registration, policy enforcement, and consumption of business and IT services across organisational boundaries.

Both types of ecosystems, data spaces, and Gaia-X-based service ecosystems, share the technical characteristic of a "flat" access and usage mechanism following the "service bus" pattern: Ecosystem members need to implement and maintain the respective identity, access, and (ecosystem) usage mechanisms only once irrespective of the number of other members they want to interact with (Strnadl and Schöning 2023b). This feature results in excellent scalability at a very low level of transaction costs rendering this type of ecosystems well suited for the AECO sector with its large proportion of SMEs.

2.3 Digitalization of the building permit process

Prior digital building permit research has predominantly focused on specific functional islands such as automated compliance checking, e-submission portals, or country-specific procedural implementations. While these strands advance important components, they do not provide a method to identify, cluster, and prioritise services across the entire permitting workflow and its stakeholder network. Our study complements this body of work by applying a process-based servitisation lens to derive a structured service domain for building permitting, including criteria for digitalisation, automation, and ecosystem exposure.

The building permit process is in nature a highly complex construct involving multiple disciplines and sectors including public administration. To reach a common language, (Fauth et al. 2024a) developed a taxonomy defining concepts with building permit systems on a high level. One of the subsystems comprises the procedural systems providing the process steps involved in building permitting including: *pre-consultation, submission, administrative check, assignment, content check, participation of other agencies, participation of the public, issuing building permit, inspection, post decision, and archiving.* The aim of the building permit process is to ensure that a planned construction project complies with public law requirements and regulations.

In the process-oriented consideration after the legally compliant procedure there are many participants to whom the processes are linked (Fauth et al. 2024a). There are different main roles other than the building permit authorities, where the actual content check of the building application takes place, that must be taken into account in order to develop services. The applicant side, including the architect and the client, interacts with authorities during many process steps. For a holistic view, not only the processes inside authorities are examined but also upstream processes such as pre-consultation or submission of a building permit application, which includes the applicant's view. After the submission the building permit process affects neighbors or the public in general; these stakeholders must be informed and involved if required by law. Furthermore, specialist authorities or inspection engineers are consulted if, for example, nature conservation, monument protection or fire protection must be observed. Courts or other agencies of public interests may also be involved (Fauth et al. 2024a). The explained and illustrated process steps (Figure 1) can be confirmed by several other publications such as (Braholli et al., 2023; Yeung et al., 2023; Sonntag & Wimmer., 2003). Even if details change within a country or municipal context, the shown main characteristics can be considered as generally established.

In terms of data ecosystems, Fauth et al. (2023) proposed a framework for a Gaia-X-based building permit process considering different domains of requirements. Requirements for processes and stakeholders involved in building permitting are considered as well as the digital building permit requirements including data requirements, software requirements, and regulations like building codes and laws. It is also discussed how to implement specific Gaia-X requirements in a basic way. It is stated that the necessity for such a framework arises from customer complaints about long process cycle times, inaccessible procedures, and non-transparency. Software applications in building permit review are used to streamline the processing and review of building applications by officials in approval authorities. Communication between different participants is also to be facilitated. A fragmented landscape of software solutions, at least in Germany, emphasizes this approach. The software applications also provide platforms for data sharing and collaboration among various stakeholders involved.

Figure 1 shows a schematic overview of how a data ecosystem interacts with the stakeholders involved in the building permit process based on the process visualization in (Fauth et al. 2023) and supplemented by the terminology within the taxonomy in (Fauth et al. 2024a). The depicted processes were validated in 17 European countries (Fauth et al. 2024b).

Building permit processes are public administration services that bridge public management and the AECO industry. They involve administrative workflows for service delivery. According to (Kuhlmann et al. 2021), services in administration include financial assistance, consultations, and rule enforcement.

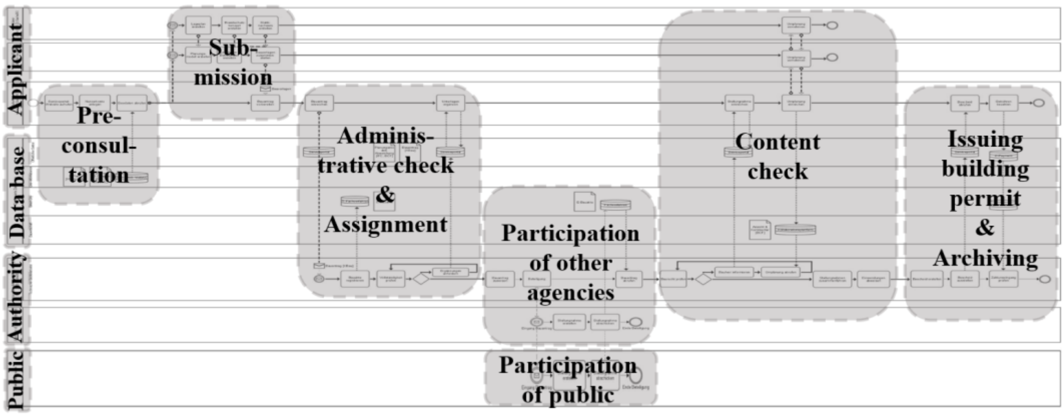

Figure 1: Overview of the building permit processes.

2.4 Synthesis: gap and positioning

Taken together, prior work contributes (i) conceptual servitisation and SDL foundations, (ii) digitalisation and ecosystem infrastructure concepts (data spaces, platforms, Gaia-X), and (iii) building permitting digitalisation efforts often centred on individual subprocesses (e.g., compliance checking) or local implementations. However, the literature provides limited methodological guidance on how to move from an end-to-end permitting process to a set of well-defined, reusable digital service candidates, and how to assess their suitability for ecosystem-based exposure under sovereignty and trust requirements. This paper advances the state of the art by offering a replicable, process-based servitisation analysis method grounded in SDL and operationalised via Gaia-X, thereby linking business process interactions to automatable IT services and to ecosystem service feasibility.

3. METHODOLOGY

Design science research (DSR) has been successfully applied in the study of information systems (IS) for two decades with (Hevner et al. 2004) as seminal paper) as a prescriptive supplement to other more analytical or deductive research methods (Johannesson and Perjons, 2021). With its explicit focus on constructing, validating, and evaluating artifacts in contexts relevant to certain stakeholders, it is an excellent fit for the purpose of our contribution, i.e., the analysis framework for servitization assessment as the artifact satisfying a particular set of business and IT requirements (= context) for organizations within the AECO industry (= stakeholders).

Moreover, DSR methods have been successfully applied to a variety of problems in the construction sector such as for developing innovative procurement strategies (Oyegoke and Kiiras, 2009) or using blockchain technology to improve supply chain efficiency (Tezel et al., 2021). In particular, design science methodologies have recently been productively employed in digitalization contexts in the AECO sector, for instance, regarding digital twins , e.g., supporting the whole building life cycle management including internet of things (IoT) sensors (Khajavi et al., 2019), enabling facility management strategies using the lean optimization methodology based on an enterprise BIM approach (Mbabu et al., 2022), selecting an optimal level of sophistication of digital twins (Agrawal et al., 2022), or developing a digital twin framework for integrating BIM and data mining supporting advanced construction project management (Pan and Zhang, 2023).

More specifically, DSR was used in the context of servitization (Schenk et al. 2021) and concrete automation of the building permit process (Reinhardt and Mathews 2017; Soliman-Junior et al. 2020, 2021) as well.Our research objectives pivoted around designing an analysis framework taking into account the dimensions of business processes, and information technology. Observing the methodological proposal of (Wieringa 2014), we reframe it as a design problem within a specific context, addressing particular requirements to help stakeholders achieve defined goals. The following research questions (RQs) were developed based on these observations:

Research Question

1. *How can potential ecosystem participants reliably identify business services?*
2. *To what extent can these services be automated in the form of ecosystem-based IT services?*
3. *What are the related data ecosystem requirements challenges that participants need to address?*

The methodological approach is depicted in the form of the following design science canvas (Johannesson and Perjons, 2021) in Figure 2.

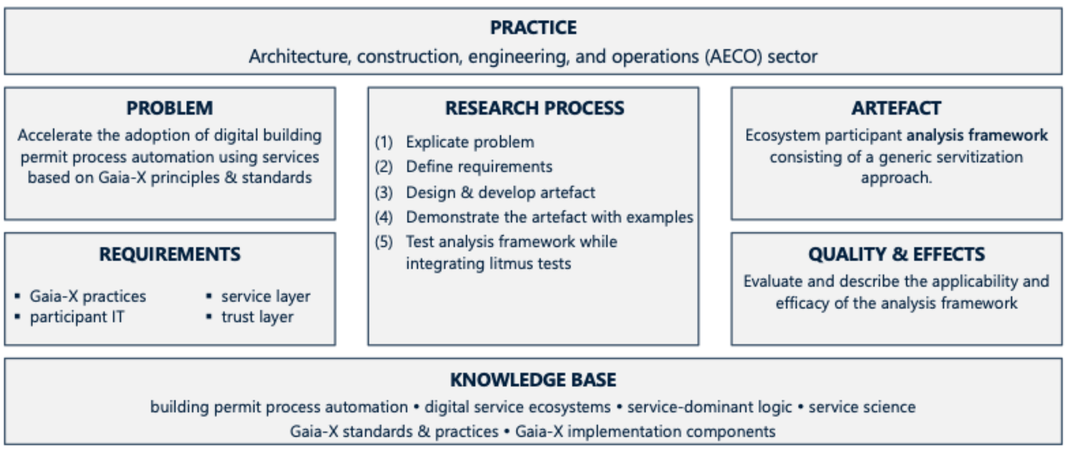

Figure 2: Design science research methodological approach.

The proposed artefacts were iteratively developed and refined within the iECO project environment between March 2022 and October 2023. Requirements, service structures, and implementation assumptions were discussed and prioritised in interdisciplinary workshops involving stakeholders from software development, AECO practice, and ecosystem governance. Following the design science paradigm (Wieringa 2014), validation focused on the applicability and plausibility of the framework in a complex real-world domain, that is "justify[ing] that it would contribute to stakeholder goals if implemented" This was explored through the systematic derivation of candidate services from the building permit process and through an illustrative BIM model-checking use case representing an automated ecosystem service.

Within engineering disciplines, evaluation, that is the "investigation of a treatment as applied by stakeholders in the field", is typically accomplished *after* the deployment of the solution into use (Wieringa 2014). Due to the complexity of such an endeavor, it was not included in this research. A first approach towards actual implementation is presented in the Discussion.

4. SERVITIZATION APPROACH OF THE BUILDING PERMIT PROCESS

4.1 Approach overview

In this section, we describe how to identify services within an existing business domain or area. Our approach uses a process-based service identification in comparison to resource-based identification (e.g., data-based, knowledge-based, human resource-based). This means that we start with identifying suitable existing processes and then detail them to the level where we can identify individual services. The processes and services within the illustrations in this chapter were modeled using the ArchiMate 3.2 specification, a standard developed by the (Open Group 2023).

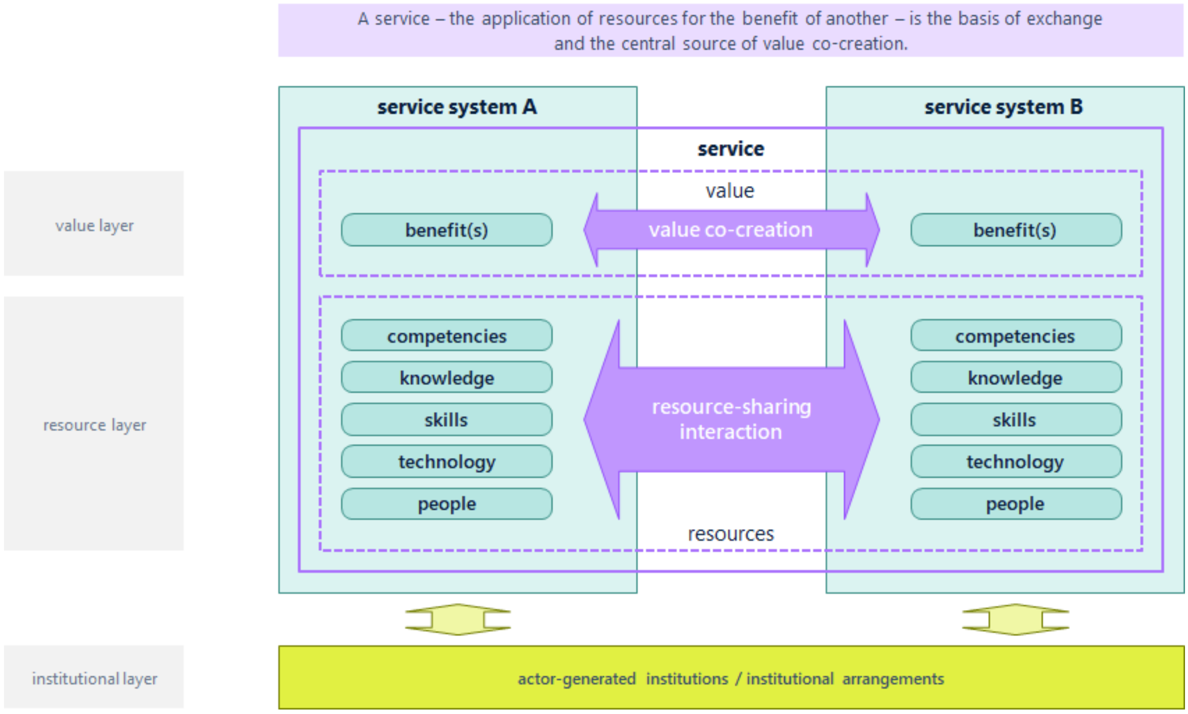

Figure 3: Definition of a service, own diagram after (Akaka et al. 2019).

For service identification, we follow the methodology of Frost et al. (2019) starting from the basis that value co-creation for any entity (including oneself as a service provider) during a service interaction is accomplished via a suitable sharing of resources, as illustrated in Figure 3. This approach overcomes the (wrong) claim that "a process *is* a service" (where only sub-processes would be recognizable as services) and replaces it by the proposition "a process *implements* or *realizes* a service"; for instance, plan checkers at a public institution *realize* or *accomplish* the review of the building application. It also does not matter if the service is required by law or not, or if it is rendered against a fee or provided without any consideration. As we will see later, the definition of a certain service may also be given with complete disregard to the actual implementation, for instance, whether the service is fully or partly digitized or whether it is performed manually.

Drawing on the paper's process-based service identification logic, we propose to derive service opportunities through the following four consecutive steps: first, represent the building permit process using process diagrams (section 4.2); second, pinpoint activities in which value is co-created, e.g., compliance checking or neighbour participation (section 4.3); third, specify the resources and outputs shared in each activity (section 4.3); and fourth, translate these shared resources into candidate services, for instance, a compliance-checking service enabled by sharing legal expertise (section 4.4).

The following subsections explain the steps of this novel approach through the actual application to the building permit process. A summarized overview of the results can be found in the Appendix.

4.2 Identification of services within the process

Before any service may be digitalized it is necessary to first understand actual and potential services in a given business context. As services in general always involve the interaction of two service systems, service identification starts by recognizing all interactions between different actors in a process. Using a suitably detailed process diagram (in our example the building permit process) we first identify all interactions between different process actors and, secondly, cluster those into different services where a common set of resources are shared between the actors.

Figure 4 illustrates schematically the overall building permit process including sub-processes and shareholders (Fauth et al. 2024a). The figure prominently shows numerous (here still analog) clusters (= services) of resource sharing interactions between different actors identified within the building permit process.

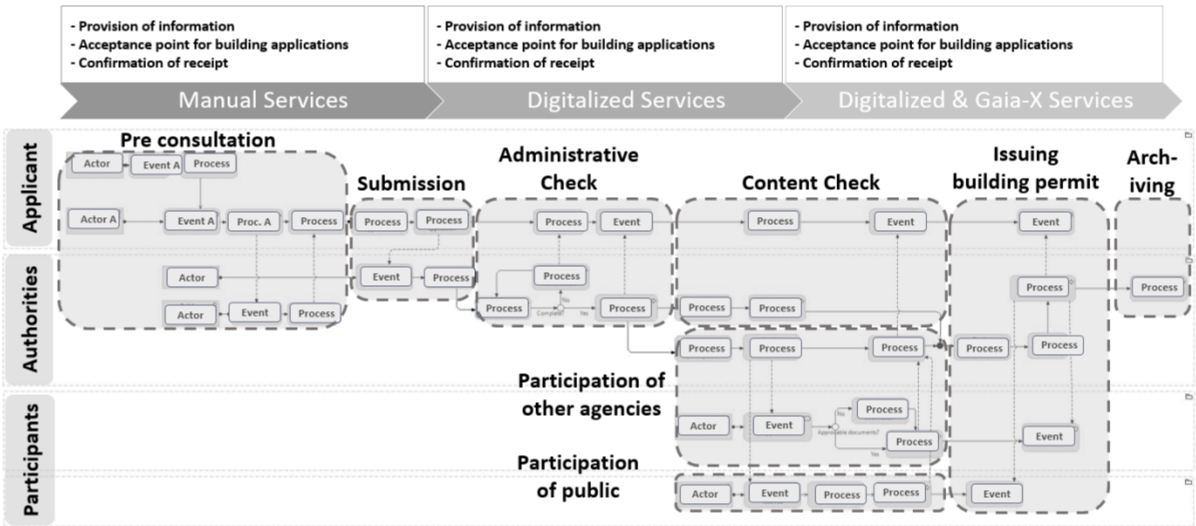

Figure 4: Schematic overview showing exemplary manual services in the building permit process.

For better understanding we use two examples of services describing them in more detail (for each of the following process steps): (a) the content checking service and (b) participation of the public.

Content checking is typically realized as a process which can be defined as “the examination of the submission against substantive planning and building law” (Fauth et al. 2024a). Considering the service elements, the building permit authorities provide the service of a comparison of the submitted building documents with the legal requirements in terms of planning law and building technology. The medium the building documents are based on is not relevant at this stage. The process of participation of the public refers to the involvement of interested or concerned people (Fauth et al. 2024a), often seen as the affected neighbors (Churghulia 2020). As in some projects more people are affected than others (e.g., through emissions, noise pollution, shading), the definition of who is an affected neighbor and how they are affected differs widely. Some countries even tend to omit the neighbor participation as they can only hand in an objection once the permit is granted or even the building is finished (Fauth et al. 2024a). Other countries, like the USA, offer a hearing for the public: Anyone who has an interest in the project for any reason can attend and make a statement of their thoughts regarding the project. The hearing procedure only occurs when a deviation is intended for the building (Fauth and Soibelman 2022). The way in which neighbors are informed also varies from country to country: An official announcement may be posted in a newspaper or on a website, or sent by letter.

Looking at the service perspective in some countries (such as Austria), the affected neighbors have the option to visit the authorities' offices and view the submitted plans and documents. A building official also needs to set up a viewing appointment and will answer questions if needed (Urban 2022). In order to provide the concerned neighbors with comprehensive information, not only the applicant's documents must be kept available but also higher-level plans and information. In this way it is possible to check whether sufficient distance is maintained from structures on adjacent properties or for example whether distances for planting are observed to avoid shading (Hök 2012). This procedure can lead to multiple manual exchanges between the authority officials and the neighbors at the authority office. The result is the neighbors' consent or objection. As illustrated in Figure 5, two services can be derived from this. The "neighbor viewing service" allows the neighbors to view documents that are relevant to them and that may give rise to objections. The "neighbor complaint service" describes the subsequent handling of the neighbors' objections or statements during the participation process.

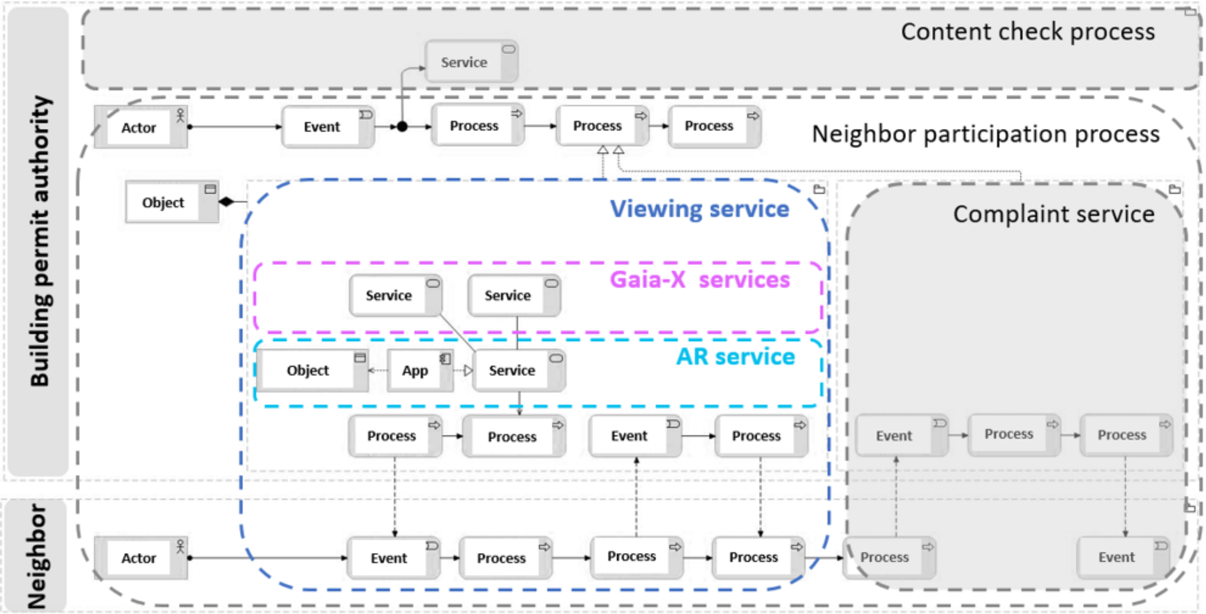

Figure 5: Detailed representation of neighbor participation process including manual neighbor services.

As can be seen in Figure 5, the relationship of a service (here: "neighbor viewing service") to a process (here: "neighbor participation process") is not one of replacement but one of realization: A service realizes parts or the whole of a process. Typically, complex processes invoke several different services in order to accomplish their goal, as depicted in Figure 5. In these cases, services accept certain input from earlier (completed, upstream) process activities before they are rendered. Service output (if any) will then be consumed in later (downstream) process activities.

We also infer from Figure 5 that services themselves may be composed of or realized by certain (sub-) processes. This mutual "realization" relationship between services and processes may be further analyzed, such as in the ArchiMate standard where processes "realize" services, but services "serve" one or more processes (Open Group 2023). This subtle semantic discrimination, though, does not make any difference at the current level of modeling.

4.3 Identification of digital and automatable services

Not all such services are *only* possible through digitalisation; rather, digitalisation often enables new levels of scalability, automation, timeliness, traceability, and cross-asset integration. Accordingly, we define digital and automated services as services that are partially supported by technology (Section 2) and that typically require digital data infrastructures to deliver their full value. Examples include lifecycle-based information management for assets through BIM (ISO 19650), data-driven quality management systems for customer satisfaction (Milakovich, 1995),, and structured information management that improves asset quality through standardised, searchable, and interoperable datasetsas Figure 6 shows numerous digital services within the building permit process based on the manual services shown in Figure 4.

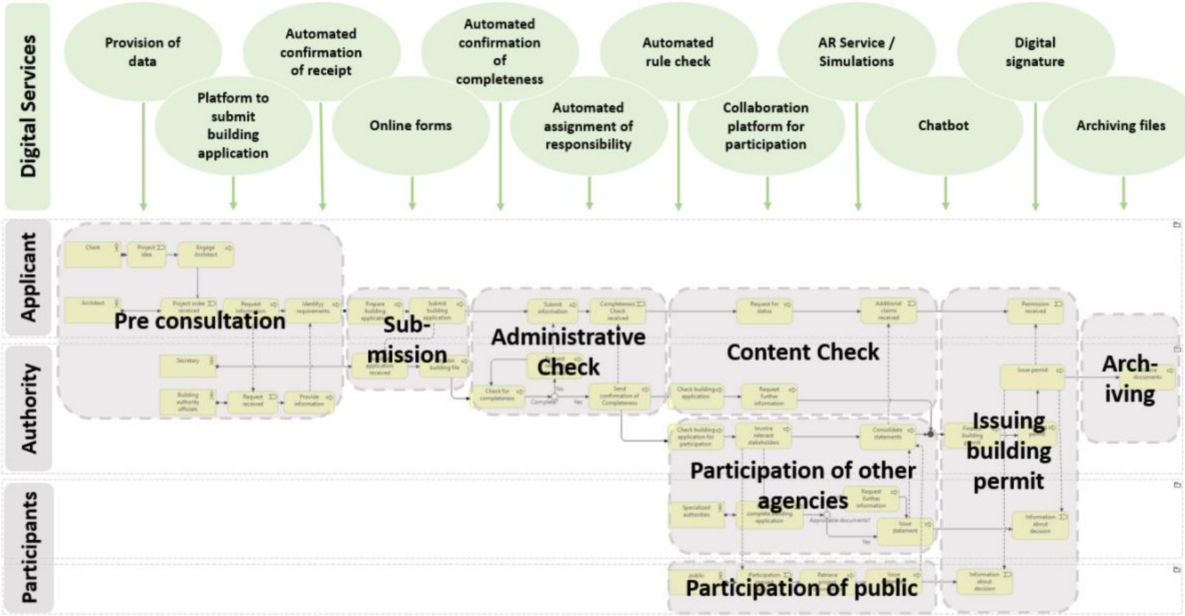

Figure 6: Schematic overview showing exemplary digital and automatable services within the building permit process.

Referring to the aforementioned examples of a) content check and b) neighbor participation, the following describes the same services but as digital services.

A) Compliance checking through BIM model checks

Model checking involves an automated examination of regulations using a BIM model where geometric, semantic, and interconnected information are assessed for compliance with building regulations, among other criteria. The two challenges associated with automatic model checking lie in (i) translating these regulations into a language interpretable by computers and (ii) applying these regulations to a concrete construction project. It is evident that this task requires a well-structured data model as a foundation. To the extent that such data models are also *standardized*, they allow to apply the model checking functionality to arbitrary construction artifacts at scale. In other words, standardized data models may lead to servitization of functions (here: model checking) on such data sets. This, *inter alia*, is one of the benefits outweighing the substantial complexity and effort required to create such a data model with detailed component and element descriptions. Model checking has numerous applications, for example the scrutiny of country-specific building regulations as part of the building permit process (Arantes et al. 2022). A model checker can assess information derived from numerical or alphanumerical data, primarily focusing on quantitative aspects. Currently, it is of limited capacity to conduct checks involving qualitative data (Nawari 2018).

In this study, we consider model checking as a service provided by a software application that is used to check compliance with quantitative parameters. We assume that a data model (BIM) is provided as a source of reference. Note, that in this automated form, model checkers are paradigmatic examples of SaaS (software as a service).

B) Neighbor participation using augmented reality (AR) service

In terms of digitalization of the example of the involvement of neighbors or the public, we refer to an augmented reality (AR) service developed by Schranz, Urban and Gerger (Schranz et al. 2021). The AR solution can be described as a service replacing the Neighbor *Viewing* of the building application information. The solution focuses on the integration of AR with BIM to enable authorities to more effectively check compliance with regulations and assist non-experts like neighbors in visualizing the building impacts. Furthermore, the solution can facilitate communication and understanding among stakeholders by presenting complex BIM data in a more accessible and interactive manner by providing a collaboration feature where participants share the same view with different end devices and can highlight parts of the model.

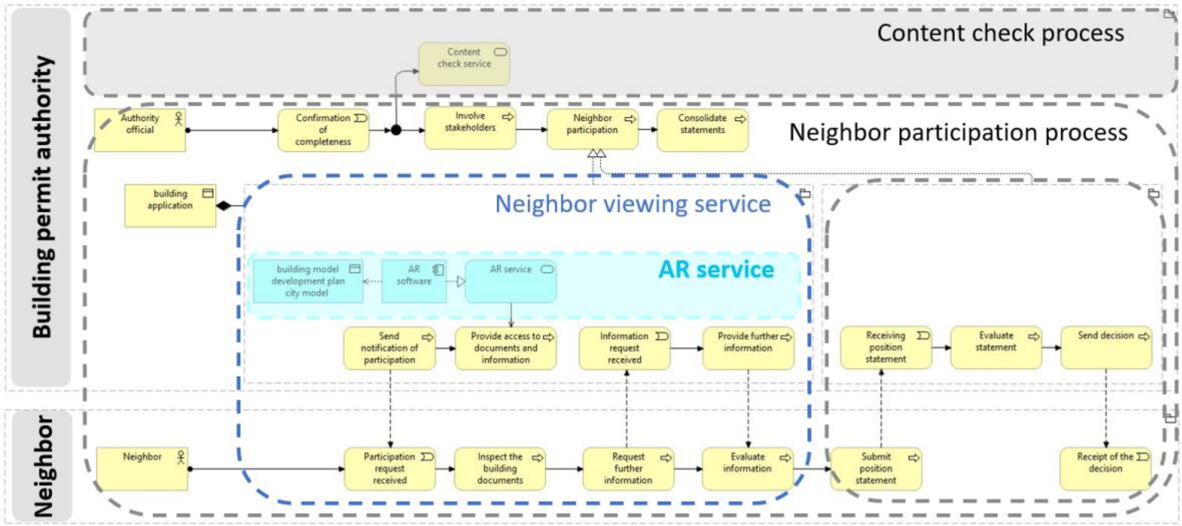

Figure 7: Detailed representation of neighbor participation process including digital AR service.

Figure 7 shows where digital services can be integrated into the process. In addition, digital services can be integrated into repetitive process steps and used by multiple stakeholders.

As an interim conclusion, we observe that digital services can be (more easily) reused in other steps or by other parties, as discussed in the literature for the pre-content check (e.g. Krischmann et al. 2020, König et al. 2023). That means that the model check can be processed by the applicant before the submission of the building application or during the content check by the authority, or as a combined service. In this context, the pre-content check serves as a quality and compliance check.

In addition, and compared to manual services, digital services may support (manual) services in various different ways, for instance, they can be introduced before the manual service to provide additional functionality to the service consumer (e.g., notification service), they may augment and support the manual service (e.g., visualization service), or they may fully replace a manual service with a new approach in terms of stakeholders involved, chronological sequence, or resources used (e.g., automated data exchange service). Appendix 1 shows more examples.

Even though digital services reap benefits (such as timesaving), they are usually still disadvantaged by partially proprietary characteristics (i.e., the solutions are limited to a specific area).

4.4 Identification of ecosystem services

4.4.1 Generic ecosystem service litmus test

The first wave of digitalization and automation is typically focused on services provided by and used within a single organization. However, the advent of data and service ecosystem standards such as for common European data spaces (DSSC 2024d) or Gaia-X now permits the efficient realization and consumption of services for different entities belonging to an ecosystem. In order to differentiate this type of shared services from internal services, we will call the former "*ecosystem (business) services*" because they are provided within the organizational and technical governance of a particular ecosystem. The Model Check or AR service introduced earlier are prototypical examples.

As described in Section 2.2, ecosystem services are based on digital and automated services. Appendix 1 and Section 4.2 provide further examples. The key task here is to identify services which are suitable to be exposed to the (Gaia-X) ecosystem using (Gaia-X) ecosystem provided technologies and standards. Recognizing that this problem is similar to that of identifying suitable services for a service-oriented architecture (SOA) (Erl 2005, chapter 12; Krafzig et al. 2005, chapter 5; Erl 2008, Appendix B; Josuttis 2008, chapter 6; Zhang et al. 2007, chapter 9; Engels et al. 2008, chapter 5.3; Dodani 2008) we have developed the following ecosystem service litmus test.

Table 1: Ecosystem service litmus test.

ELEMENT	DESCRIPTION
Input	(description of) a fully automated service For services which are not (yet) fully digitized, only the digitized parts may be subject to the ecosystem service litmus test.
Output	Decision (“YES”| “NO”) whether it is economically feasible to expose the service as an ecosystem service using technologies and standards provided by the ecosystem.
Test	
Test procedure	**IF** Does the service potentially benefit any other ecosystem participant? **AND** Does the service benefit from Gaia-X operand and/or operant resources? **AND** Are any (initial) ecosystem integration costs and expected transaction costs less than the expected benefits (including any fees levied for the consumption of the service)? Also see (Strnadl 2023b) for a first mathematical formalization of ecosystems. **THEN** **RETURN** “YES” **ELSE** **RETURN** “NO”
END	(* end of ecosystem service litmus test *)

The Ecosystem Service Litmus Test begins by evaluating a fully automated service - or its digitized components if not fully digitized - to determine its viability as an ecosystem service. The decision-making process involves three key steps: First, assess whether the service benefits any other ecosystem participants. If it does, proceed to evaluate whether the service leverages Gaia-X operand and/or operant resources. Should this criterion be met, the final step involves a cost-benefit analysis to ensure that the initial ecosystem integration and transaction costs are outweighed by the expected benefits, including any applicable service fees. If all conditions are satisfied, the service is deemed economically feasible, and the test returns a “YES.” Otherwise, it results in a “NO.”

To assist the determination of the answers to the second and third condition, we have developed a Gaia-X ecosystem value contribution assessment depicted in Figure 8. Incorporating service-dominant logic, it is grounded on (i) certain operand and operant resources provided by Gaia-X-based ecosystems (cf. the Gaia-X resource layer in Figure 8) and (ii) on the fact that value co-creation is based on resource sharing between the different service systems in the ecosystem at the actor level in Fig 8. Benefits, i.e., value co-created through the sharing of one or more of these resources, may arise directly at the service interaction layer or indirectly at the service ecosystem layer. As direct service interaction benefits, we discriminate the reduction of transaction costs (Dahlman 1979, Change and Ive 2000) and the four domains where information use can make a difference to business entities (Marchand 2000). For convenience, we have added a few typical examples of concrete benefits.

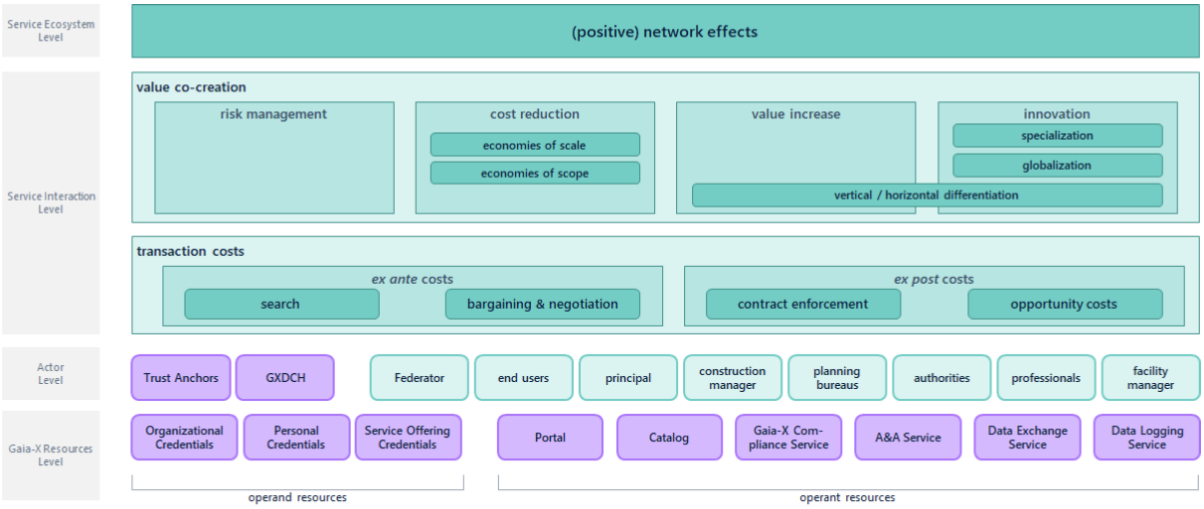

Figure 8: Gaia-X value contribution assessment.

The table in Appendix 1 provides a list of identified ecosystem services for the building permit process. Our analysis yielded three different types of ecosystem services as further explained in Table 4.

Table 2: Ecosystem service types.

SERVICE TYPE	EXAMPLES / DESCRIPTION
(Ecosystem) Core service	These services are intrinsically required for the operation of any Gaia-X-based ecosystem and are all provided by Gaia-X Digital Clearing Houses (GXDCHs). They provide core standardized functionality in the following areas: • *Common identification and authentication services for organizations and employees* • *role-based or attribute-based access and usage policy enforcement services*
(Ecosystem) Federation service	These optional services are also standardized by the Gaia-X initiative but, strictly speaking, not required for a minimal Gaia-X-based ecosystem. However, they feature a very large potential of re-use e.g., around data sharing or data transactions and will be provided by either GXDCHs or suitable other entities ("federators"). They typically include • *data exchange service – data provider "sends" or "pushes" the data asset to the data consumer* • *data access service – data provider exposes an endpoint where the data consumer can access and retrieve ("pull") the data* • *data storage service – lower-level PaaS/IaaS service for storing data assets* • *data notarization service – for digitally notarizing external real-world events or facts* • *(digital) clearing house – for tamper-resistant non-repudiable logging of data and service transactions*
(Ecosystem) Business service	This service type pertains to the (most prevalent) situation where a fully digitized business function is simply exposed as a Gaia-X-compliant and Gaia-X-registered (business) service to any other ecosystem participant.

We also want to stress the fact that not all digital/digitized services identified when applying our servitization process have to become ecosystem services. The two most prevalent reasons for this are explained in Table 5 with additional examples depicted in Appendix 1.

Table 3: Prevalent reasons for not exposing a business function as Gaia-X-compliant service.

SERVICE TYPE	EXAMPLES / DESCRIPTION
Other IT solution prevalent	Other, non-Gaia-X or non-ecosystem-related IT tools or solutions are readily available and economically more attractive for solving the underlying business need. Examples include • *classical e-mail* • *corporate (communications and team-work) platforms such as Microsoft Teams, Google Meet, Slack*
Internal service	Many IT functions are not intended to be shared with parties or people outside the original organization. In these situations, exposing this type of service to the outside world simply does not make any business sense. Typical examples include • *(internal) finance and accounting tools* • *ERP tools* • *(internal) workflow management tools* In the building permit process, the following services fall into this category (cf. Appendix 1): • *capacity checks* • *specialist area checks* • *application of discretion* • *case-by-case examinations* • *request statements from other entities* • *finalizing official documents (such as the building permit)*

4.4.2 Ecosystem service litmus test examples

As an example application of our ecosystem service litmus test, we take the neighbor hearing service. It clearly passes step 1 by construction.

Step 2 requires a matching to be made between Gaia-X operand and operant resources and any service candidate. We perform this based on the process diagram of the digital building permit process and an explicit representation of available Gaia-X resources as depicted in Figure 9.

Figure 10 shows the outcome of a matching workshop where we performed this exercise identifying the following ecosystem services (highlighted in light and dark blue in the diagram):

- *Ecosystem core and federation services: data access service and data exchange service*
- *Ecosystem business services: AR service*

Figure 10 shows the interactions between the building permit authority and neighbors using selected Gaia-X federation services (here: data access service and data exchange service) and the “AR service”, a Gaia-X business service. The neighbor's process flow (i.e., the number and sequence of tasks) does not change in principle but only in the way it is executed, namely digitally. To view information, neighbors no longer have to visit the authority but can use a chatbot or even have additional opportunities to evaluate the project and its documents regarding their position statement using the AR Service. On the authority side, digital services can now be used to automate process steps which means fewer resources are required. Also, authority's services, such as chatbots or AR services, can be offered around the clock without having to rely on opening hours or the presence of officials. This is intended to reduce process loops that inevitably arise in the manual service or process view due to service actors not being constantly available.

Gaia-X core and federation services enable common identification and authentication for organizations and their employees as well as access and usage policy enforcement services which also could reduce such dependencies. These services are typically used by Gaia-X business services that provide the actual business or economic benefit to process participants as illustrated in Figure 10.

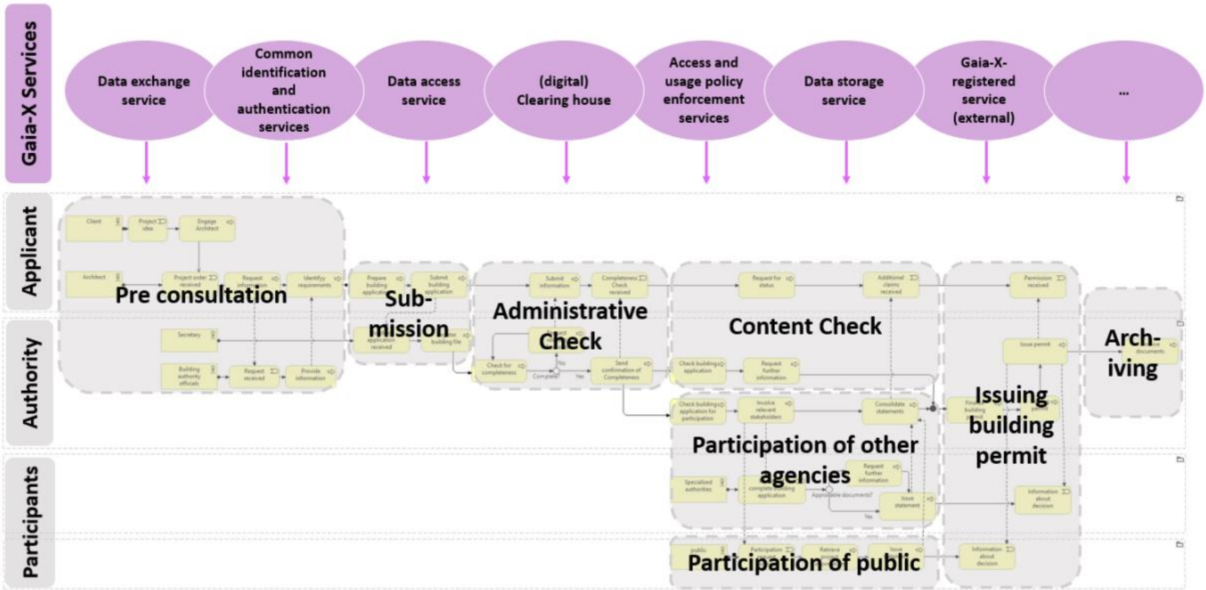

Figure 9: Schematic overview showing exemplary digitizable and automatable Gaia-X services within the building permit process.

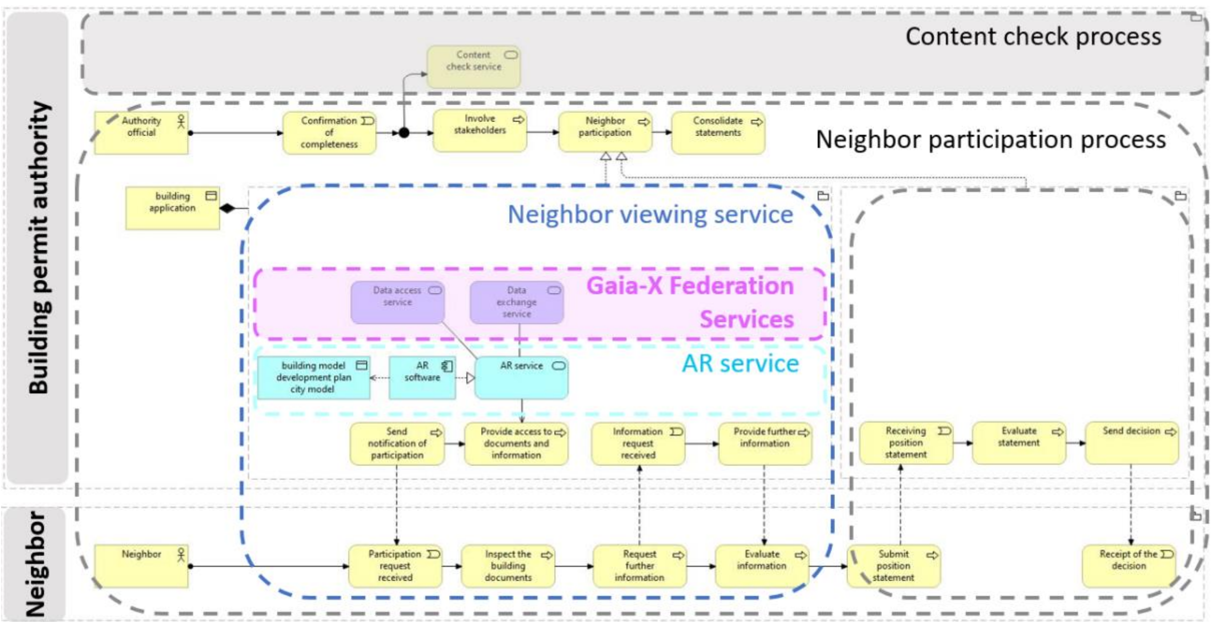

Figure 10: Detailed representation of the of neighbor participation process including Gaia-X Ecosystem services.

5. RESULTS AND DISCUSSION

Within a design science methodology, our research developed an analysis framework for complex business domains based on service-dominant logic and Gaia-X-based ecosystem standards and technologies. The analysis framework consists of the specific artifact of a generic servitization approach that identifies and evaluates potential digital services with the use case of building permitting.

The analysis framework success in accelerating the digital automation of the building permit process can be seen in its ability to enable ecosystem participants to reliably identify business services, addressing the first research question. The servitization method allows the identification of generic, digitized, or digitizable services within any business process and is complemented by a serviced litmus test indicating whether it is of economic benefit to expose thus identified digitized services in a larger ecosystem or not. The structured approach to mapping out processes and services allows for clearer identification of services that can be automated. Our technical implementation method prescribes the architecture and implementation steps for integrating and exposing arbitrary (digital) services as Gaia-X-compliant services in any Gaia-X-based ecosystem.

The design of our methodological approach, grounded in modern data spaces and ecosystem principles, address the second and third research questions. We demonstrated its applicability to the AECO sector by applying it to the building permit process, a particularly complex workflow within this domain. Here we identified several services of varying degrees to which they can be automated. The study demonstrates how key business services can be automated as ecosystem-based IT services. Furthermore, it identifies critical IT requirements, such as data management protocols and integration challenges, which must be addressed to ensure successful implementation. This renders this article one of the first (if not *the* first) to apply service-dominant logic to a complex business process within the AECO sector to derive a concrete and actionable list of services as opposed to remaining on a superficial or generic level (such as “building-as-a-service”). The analysis framework not only identifies services that can be automated but also provides practical insights into the IT requirements and challenges that need to be addressed, aligning with the third research question.

A complete evaluation, that is, investigating the performance and interactions of our methodology in productive environments (Wieringa 2014), was out of scope of the present research due to its complexity. Nevertheless, we were able to implement into working software a first prototype of a “BIM Model Checker Service” for the Saxonian building code) where, for instance, users of a classical BIM authoring tool are able to invoke external “model checking” and “rules checking” services.

Moreover, our holistic approach extends the earlier ideas of service-oriented architectures from simply bridging the intra-organizational business and IT-divide (Strnadl 2006) towards a realm where services are shared beyond the confines of one’s own organization, *viz*., ecosystems. Our research thus also proposes a solution for handling the fragmented nature not only of the building permit process in particular, but also of the whole AECO sector in general with different participants using different technologies.

In future, the encapsulation of isolated pieces of work into self-contained services also opens the way towards the manageable outsourcing of parts or even the whole building permit process – in times of a decreasing supply of skilled workers, support by software or additional human resources is crucial. Within building permit authorities, it is rare that processes and tasks are outsourced to other resources. In some countries (such as Germany), the current law prohibits the involvement of third parties (such as software, consultants, or independent architectural offices) to make a decision within the review. Other countries, for instance the USA, outsource part of the review. Countries like Israel even created a new profession in outsourced offices (so-called building control offices) which checks specific parts of the building documents. The question arises why outsourcing should not be used more intensively in the building permit process in other countries or at a global scale to overcome challenges like the need for highly qualified staff in authorities, not enough staff available for the amount of building permits or fluctuating workload. Furthermore, outsourcing could lead to more streamlined processes since standards are needed to work with external partners. Public authority employees could focus more on their core business and could thus spend more time on the often-mentioned missing communication (Fauth et al. 2024b).

While our study provides specific instances of servitization within the building permit process, we want to stress the fact that our servitization method is completely generic in nature and is not confined to the building permit process in any way. This might be used in future research and industry initiatives to pave the way towards creating a comprehensive building permit service ecosystem. This generality may even be extended to any other industry sector beyond the AECO sector, e.g., Manufacturing-X, European Health Data Spaces, or European Mobility Data Spaces initiatives. Of course, our technical implementation architecture is bound to Gaia-X standards and technologies and may not be fully compatible with other data space or service ecosystem approaches such as IDS RAM or FIWARE data spaces (DSBA 2023).

We acknowledge some limitations of our study that warrant consideration. Firstly, it does not include tangible elements from actual IT implementations, thus presenting a gap in its representation of real-world scenarios. Additionally, certain crucial aspects, such as its focus on a single ecosystem, or the establishment of the ecosystem, have not been thoroughly examined. The workshop conducted for the research involved only one partner, indicating a need for broader evaluations to enhance the study's robustness. We acknowledge that validation involving a broader range of stakeholders is necessary to fully confirm its effectiveness. Future research should extend the validation approach to include more comprehensive evaluations across larger scales and diverse business-to-business contexts, complementing the current focus on business-to-government and government-to-citizen interactions. Another limitation lies in the differentiation of service identification between digitalization and automation, raising questions about the clarity and specificity of the categorization. Lastly, the list of potential services provided in the article is not exhaustive; instead, it offers illustrative examples, as evident in Appendix A. It is also possible that not all services that will ever be possible can be found with our method, but the most important ones for the respective use case can be determined. These limitations collectively underscore the need for further refinement and expansion in future research endeavors.

6. CONCLUSIONS AND FUTURE WORK

Our servitization approach, i.e. the re-formulation of a (business) domain in terms of services and interacting service systems, is based on a three-step procedure. We first identify all possible business services – understood in the sense of service science as the application of resources for the benefit of another – in the underlying business process. Then we extract all existing automated or potentially automatable services amongst these business services. Finally, we categorize these digital services according to the extent they may either benefit from Gaia-X core and federation services (such as data sharing or data notarization services) or may be exposed as Gaia-X business services to other ecosystem participants. This is accomplished by a novel ecosystem service litmus test grounded in a multi-level Gaia-X value contribution assessment combining transaction costs reductions with benefits evaluation specifically recognizing positive information management and ecosystem effects.

Future work may extend the framework and deepen our understanding in the dimensions of service ecosystems and technology implementation. Regarding the former, more deeply addressing the legal impacts of the European Data Governance Act or the European Data Act may prove valuable, e.g., the mandatory separation of data intermediation from business service providers, or the proper inclusion of citizens in the building permit process (e.g., making available suitable and legally required subsets of building data for collecting feedback from the affected neighborhood).

Technology-wise, a complete evaluation of our methodology in a real-world context willl be able to complete the full lifecycle of our DSR approach. Due to the complexity and novelty of our approach, classical observational case studies to that effect could be complemented by technical action research, where the services and software *under test* are not being used independently from a research context. Additionally, the integration of our concepts into various forms of digital twins (e.g., a design twin resulting from the architecting or engineering phase, or an operational twin used for the operations phase of a building by facility management organizations) will certainly expand the positive impact of ecosystems thinking for the whole AECO sector.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AUTHOR CONTRIBUTIONS

Judith Fauth: conceptualization, investigation, methodology, project administration, writing – original draft, visualization, supervision

Christoph F. Strnadl: conceptualization, investigation, methodology, resources, validation, visualization, writing – original draft, writing – review and editing

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APPENDIX

Processes	Manual Services	Digital Service Concepts	Gaia-X Service Concepts
Pre- Consultation	communication and answering questions	exchange	[1]
	provision of information	exchange	[2]
			[3]
Submission	acceptance point for building applications	upload	[4]
			[5]
	identification and authentication	identification and authentication	[2]
			[6]
			[7]
	confirmation of receipt	automated notification	[6]
			[7]
	completeness check	rule checker	[8]
		workflow/case management system	[8]
Administrative check	confirmation of completeness	automated notification	[8]
	status request	automated notification	[8]
	verification of the status "Authorized to issue building permits"	external database interface	[8]
	request for missing information	exchange	[8]
			[9]
Assignment	notification of the responsible contact person	automated notification	[7]
	capacity check	capacity check	[10]
	specialist area check	specialist area check	[10]
Content Check	review of building planning and building regulations law for correctness	rule checker	[8]
		workflow/case management	[8]
	application of discretion/case-by-case examination	decision support	[10]
	inspection of the property	visualization	[8]
	examination of exceptions & exemptions	rule checker	[8]
Participation of other agencies	requests for statements from specialist authorities and agencies of public interest	exchange	[10]
	provision of information on the building application documents	exchange	[2]

			[3]
			[7]
	signature	digital signature	[4]
	consolidation of the statements	upload	[2]
			[3]
			[7]
Participation of the public	provision of information	exchange	[2]
		visualization	[3]
			[8]
	submission of statement	online forms	[8]
Issuing building permit	signing and stamping	digital signature	[4]
	dispatch of building permit	exchange	[7]
	issue an invoice	digital payment	[7]
			[8]
			[9]
Inspection	inspection and acceptance of construction work during regular or irregular site inspections	digital site monitoring	[2]
			[7]
	approval for operation/usage by human people	rule checker	[7]
Post-decision	provision of information on the building application documents	exchange	[3]
Archiving	archiving the construction file	storage and access	[11]
			[3]

Notes:

[1] Accomplished with classical IT tools without the need for specific Gaia-X-related tooling

[2] Accomplished with classical IT tools without the need for specific Gaia-X-related tooling

[3] data access service (Gaia-X federation service)

[4] common identification and authentication services for organizations and their employees

[5] role-based or attribute-based access and usage policy enforcement services

[6] data notarization service (Gaia-X federation service)

[7] (digital) clearing house service (Gaia-X federation service)

[8] expose externally as Gaia-X-business service

[9] use Gaia-X service orchestration mechanisms

[10] Service completely internal to an organization. Therefore, Gaia-X principles and standards do not further support internal applications.

[11] data storage service (Gaia-X federation service)