2023 European Conference on Computing in Construction
40th International CIB W78 Conference
Heraklion, Crete, Greece
July 10-12, 2023

REQUIREMENTS AND FRAMEWORK FOR GAIA-X-BASED BUILDING PERMIT PROCESSES

Judith Fauth[1,2], Christoph F. Strnadl[3], Hannes Heitzhausen[1], Morris Florek[1], Michael Brenner[4], Sebastian Seiß[4], Pintukumar Nakrani[1], Aurica Pötz[4], Joaquin Diaz[4,5] and Wolfgang Müller[1]
[1]RIB Software GmbH, Stuttgart, Germany; [2]Technische Universität Wien, Vienna, Austria;
[3]Software AG, Vienna, Austria; [4]5D Institut GmbH, Friedberg, Germany;
[5]Technische Hochschule Mittelhessen University of Applied Sciences, Giessen, Germany

Abstract

In the construction industry, processes with many participants are often plagued by information loss during communication events. This, in particular, concerns building permit processes. Data ecosystems, such as Gaia-X, are designed to to enable cross-boundary information exchange with minimal impediments while maintaining data sovereignty for participants. Integrating building permit processes into a Gaia-X environment necessitates a framework which considers both requirements of data ecosystems and requirements imposed on building permit processes. This article aims at creating a process automation framework for Gaia-X-based building permit processes through requirement specifications. The framework serves as a basis for adaption to other use cases.

Introduction

Most kinds of buildings require a building permit. For this reason, the issuance of a building permit is a key process for the successful implementation of a construction project (Bauministerkonferenz, 2020). However, the housing industry, among others, complains about long process cycle times, and many building and civil engineering clients criticize inaccessible procedures for their building permits (Ens, 2022).

In a self-executed survey, building permit authorities in Germany were questioned about digital building permit processes. 171 responses were received from a total of 933 authorities. The interim status (noted Jan. 16, 2023) showed that 88% of the participants already use specialized software in their building permit processes. However, 21 different software solutions are used. In addition, 88% consider trustworthy data storage of data relevant to building permits to be very important or important. The fact that there are numerous different software solutions available leads to isolated solutions, data silos and lack of interoperability within the building permit process. This results in difficulties in sharing information among different participants and stakeholders as well as inefficiencies, and delays.

Taking the building permit process as a suitable digitalization and automation candidate is also suggested by numerous research projects, all centring around the same objectives of making the complex building permit process easier, more transparent, and more efficient. A literature review, however, shows that most research projects limit themselves to automated code compliance checking of digital building models and digitalization of regulations (Noardo et al., 2022).

To be able to automatically check building information modelling (BIM) models against current building regulations, the BIM model must be properly prepared and has to include all necessary information to allow compliance checks (Nawari et al., 2017). Furthermore, natural language building codes have to be translated into a computer-readable format (Lee et al., 2015). Although several applications for BIM-based compliance checks have already been developed, none of them are currently in use. This is mainly due to missing regulations for the preparation of BIM models and rule interpretation (Narayanswamy et al., 2019).

Despite the automation of code compliance checking, Noardo et al. (2022) distinguished further important factors within the digital building permit process that lack maturity and research results, such as the need to change public officers' mindset, scalability, efficiency, interoperability, and solutions to overcome data validation hurdles. Therefore, the development of a single platform for managing the various processes in a unique environment was suggested.

In practice, the building permit process is mostly managed digitally using public administration software complemented by an analogue construction file that contains the building application and all correspondences (Hornung & Suarez, 2016). Citing an example from practice to overcome data gaps evident in the aforementioned approach, the city of Oberursel (Germany) realized a cloud-based building permit service in 2013. All documents within the building permit process are stored in the authority's internal cloud and individual access to the documents can be granted by the authority to all participants (Hornung & Suarez, 2016). By using cloud-based building permit approaches, data loss can be reduced and the collaboration between participants improved because the central data platform supporting the permit process is accessible from everywhere. However, data security, privacy, and sovereignty cannot be fully ensured, because services are running on external infrastructures (Capko et al., 2014).

Besides potential scalability issues, centralized data platforms typically require data providers to upload their data to the cloud platform prior to any data sharing taking

place. While the resulting lack of sovereignty and privacy may be mitigated to a certain extent through appropriate commercial agreements, technically, data providers have abdicated the core control of their own data and relinquished them to the cloud provider and the mechanisms designated in the data platform. Even though this certainly works in particularly trustful environments, to overcome these limits of classical data platforms one needs to turn to other data exchange architectures such as data spaces and data ecosystems (Strnadl & Schöning, 2023).

A data space can be defined as a decentralized infrastructure for data sharing based on commonly agreed principles (Nagel & Lycklama, 2021). According to the International Data Spaces reference architecture model, data is exchanged via mandatory connectors between data providers (often also holders) and data consumers. All participants and every (data space) connector of a data space must be certified to establish trust (Otto et al., 2021). Data spaces may be regarded as the core constituting elements of data ecosystems that aggregate data from many suppliers, potentially from different data spaces or industries, and build value through the usage of processed data.

In addition to a data ecosystem, an ecosystem as a whole can also contain an infrastructure ecosystem, which is used to provide network and hardware-related building blocks (Heitmann, 2021). It may be characterized as a self-contained community of entities who either directly or indirectly use, create, or deliver information and communication technology and infrastructure-related services like data storage, computation, network services, or combinations of services (Gaia-X, 2022). For brevity reasons, we cannot further elaborate on the economic ramifications of creating and sustaining healthy ecosystems by balancing economies of scale and cooperation opportunities (Abdulla et al., 2021).

Gaia-X is a European initiative to establish such a trusted ecosystem. The main goal is to define and provide the fundamentals and infrastructure for creating value from existing data while data owners maintain data sovereignty, all based on European values (Bonfiglio, 2021). A group of participants 'that directly or indirectly consume, produce, or provide related resources' is called a Federation (GX-22.04AD, 2022). There are currently thirteen Gaia-X Federation Services (GXFS) being developed, acting as technical core services for the ecosystems. The GXFS can be classified into the following categories: Identity and Trust Services, Federated Catalogue, Sovereign Data Exchange, Compliance Services, and the Gaia-X Portal. Even though actual software code implementing core GXFS has already been published, it is far from plug-and-play for use or operations in emerging Federations. Nevertheless, Gaia-X represents the first *ex ante* independent and decentralized approach for technically creating and realizing generic ecosystems.

To overcome the problem of fractured information flows in building permitting, this article proposes a novel data ecosystem-based approach how to automate building permit processes according to Gaia-X principles. Based on suitably extending known requirements specification methods, we derive a new process automation framework explicitly recognizing Gaia-X related artifacts. Both contributions are then validated in a case study by deriving an actual IT architecture for a non-trivial use case.

Research methodology

Concept

The research methodology of the approach is subdivided into three steps as illustrated in Figure 1. Step 1 is the requirements specification based on Poveda-Villalón et al. (2021). The requirement specification is sectioned into three domains: (a) process modelling, (b) digital building permits, and (c) a new explicit Gaia-X context. During process modelling, requirements for processes and their stakeholders are identified. In the digital building permit domain, the requirements for (i) data, (ii) software, and (iii) regulations & standards are considered. The third domain specifies requirements related to the Gaia-X context. This approach represents a novel integration of elements from data ecosystems (i.e., the explicit recognition of data as a relevant object of analysis) and Gaia-X into other (well known) requirements. After the requirements have been elaborated, the process automation framework is developed in Step 2. Finally, the process automation framework is validated in Step 3 using a case study.

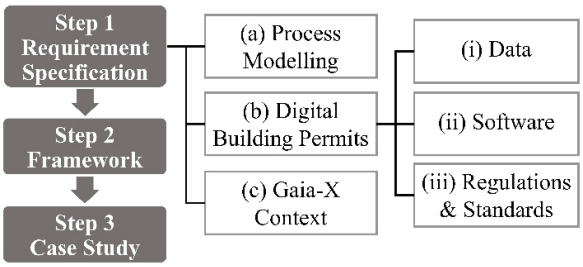

Figure 1: Methodology

The data used for the requirement specification is mainly derived from a literature review. Only limited information about public administration software solutions used in the building permit process was found. Therefore, semi-structured interviews with five German public administration software providers were conducted to gather more in-depth information about the different solutions. The interviews provided the ability to understand the use, functionality, and capabilities of the software applications.

Specification

The following specification is made for the purpose and scope of the process automation framework to be developed. Intended users and use cases are identified as

well as non-functional requirements. Functional requirements are described in section Functional Requirement Specification. We note that the presented requirements are examples only and not exhaustive. Our approach is based on Poveda-Villalón et al. (2021), originally applied to ontologies, which we abstractly use for the requirement specification of the process automation framework development.

The scope of the process automation framework is to develop the Gaia-X based building permit process and to find, evaluate, and integrate services for the individual process steps. The context of the article is limited to the German legislative situation regarding building permitting.

The intended end users include (1) planning parties who prepare and submit building applications, and (2) building authorities who review, approve, or reject building applications. Furthermore, there are (3) other involved parties, such as test engineers, technical authorities, external companies, and agencies of public interest as well as (4) contractors and users who would also profit from the use after the acceptance for commissioning.

The intended use cases are (1) to present a unified building permit process in a Gaia-X compliant way, (2) to show the requirements to be considered and links between them, and (3) to use the process automation framework as a basis for technical implementations.

The non-functional requirements arise from the FAIR (Findable, Accessible, Interoperable, Reusable) principles. In analogy to scientific data, Gaia-X must enable findability through publication (findable), usability and retrievability through standardized formats/protocols (accessible), interoperability through machine readability (interoperable), and reusability through detailed descriptions (reusable) (Wilkinson et al., 2016). Additionally, Costin & Eastman (2017) described requirements for the development of ontologies in the context of the construction industry. According to these, data models should (1) be described with clear and consistent terminology, (2) be sufficiently linked to high-level/generic data models, avoiding inconsistencies and duplicates, (3) ensure extensibility and reusability through standardized methods while integrating existing data models into their own conception and development, (4) establish reliability and ensure security by publishing a permanent identifier so that changes cannot be made by unauthorized parties (Costin & Eastman, 2017).

Functional Requirement Specification

Process requirements

The building permit process is a sovereign administrative act that consists of many procedural steps and, depending on the scope of the project, may involve many parties. The legal requirements for the building permit process in Germany are multifaceted. Moreover, the building requirements are regulated at different levels (e.g., planning law at national level, and building codes at state level, ancillary building laws at different levels, statutes, or by-laws at municipal level). In addition, other laws influence the process as well, for example public administrative regulations, and construction, implementation, and data protection requirements which can also be derived from technical areas.

A simplified building permit process is introduced in Figure 2. The process considers two main domains: applicant and authority. All parties within both domains are connected via a data space for communication and data exchanging purposes. The applicant domain represents all stakeholders on the applying side such as building principals, designers, and engineers while the authority domain presents all public entities such as building permit authorities, agencies of public interest,

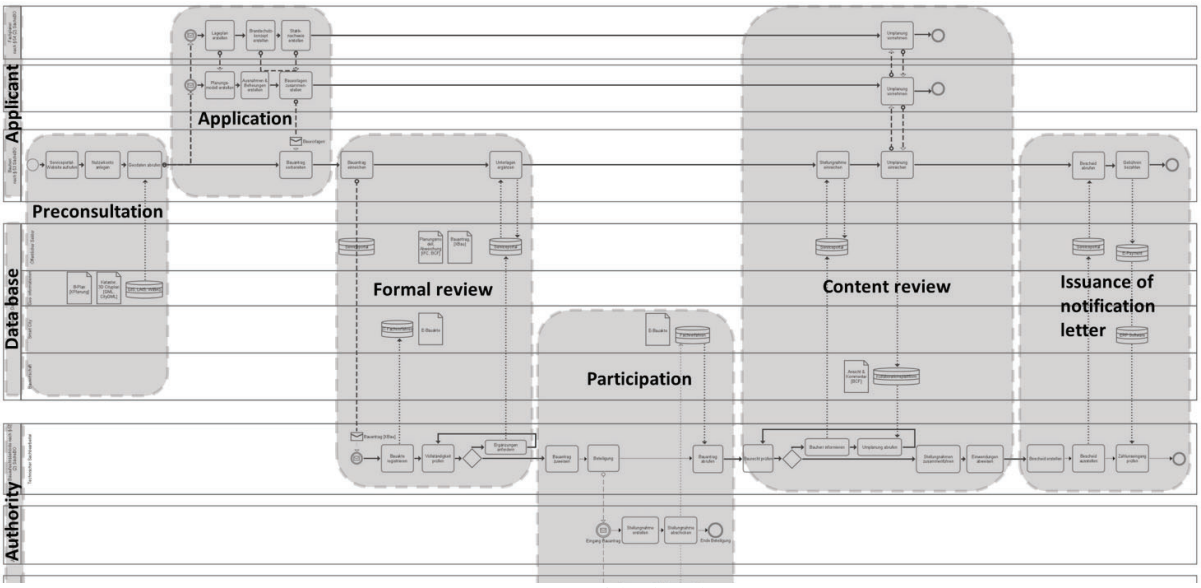

Figure 2: Main process steps of the digital permitting process

and neighbours. Starting with pre-consultation, the first exchange takes place between the building permit authority and the applicant, during which general questions can be clarified. Once the building application has been prepared, it is submitted to the responsible building permit authority in the next step. After receiving the building application, the formal review within the authority begins. Incorrect information or missing documents should be identified and, if necessary, requested. Subsequently, all relevant stakeholders in the building permit process are involved in the participation subprocess. Participants may be other specialist authorities, agencies of public interest, or neighbours. The participants submit their comments, which are coordinated and acknowledged by the building permit authority. The actual review of the content of the building application takes place in parallel. If the construction project can be approved, a positive decision is issued. If the project conflicts with regulations, the applicant has the option of adjusting the application; otherwise, the application will be rejected. After a successful review, the applicant receives the building permit and can begin the construction phase. It needs to be noted that Figure 2 cannot represent the entire complexity of the building permit process due to space issues.

Digital building permit requirements

In this section, the functional requirements for the digital building permit process are described. Figure 3 shows an overview of identified functional requirements with respective examples. The functional requirements are categorized in three different domains: data, software, and regulations & standards.

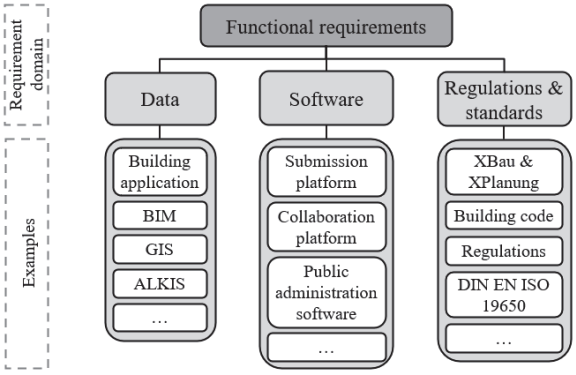

Figure 3: Functional requirements of the digital building permit domain with examples

The data domain contains relevant data which are necessary for processing and issuing building permits. Building application documents include construction drawings (or BIM models), a building description, a site map, an extract of the real estate map, construction certifications, if applicable, an application for deviation or exemption, etc. (Musterbauvorlagenverordnung, 2007). Geographic information systems (GIS) are computer-based systems that allow the storage, management, manipulation, analysis, and visualization of spatial data. In connection with the building permit process, GIS data can be helpful for example to analyse and evaluate the impact of construction projects on the surrounding environment (Wieczorek & Delmerico, 2009). Furthermore, BIM data representing the building to be approved with all needed information for the building permit process and also ALKIS data could be of interest for the building permit process as well. ALKIS (Amtliches Liegenschaftskatasterinformationssystem) is a German database system that provides information about real estate properties, including their location, ownership, and physical characteristics (Wandinger, 2002).

In the domain software, software applications are listed that are used for the execution of building permits. They include for example submission platforms that are usually hosted by the government and provide all necessary information and templates regarding building applications. Further, the platforms offer the possibility to submit building applications (Federal Ministry of the Interior and Community, 2021). Collaboration platforms, on the other hand, can be seen as a project room where all participants can communicate and share data with each other (Ma et al., 2018). One also encounters model checkers, software applications which check specific regulations against the building data automatically (Hjelseth, 2015). In addition, public administration software is used by building officials in building permit authorities to process and review the building applications (Kapteinat, 2021).

The domain regulations & standards contains guidelines that are taken into account during processing building permits. It includes, for example, the German standards XBau and XPlanung which aim at improving digital planning and building permit processes. The XBau standard deals with the communication between different participants in a building permit process. It defines the structure and content of each message that is required during the building permit process. XPlanung is a data standard that supports the lossless exchange and provision of spatial planning data (Krause, 2023). Other standards could be relevant such as ISO or DIN norms (e.g., DIN EN ISO 19650:2018 for organization and digitalization of building information). As mentioned in subsection process requirements, a varying number of regulations needs to be considered for building permitting. Building codes, municipal by-laws, or ancillary building laws such as environmental regulations are just examples.

Gaia-X requirements

Considering the context of Gaia-X with regards to functional requirements, the GXFS contribute the essential aspects for establishing a trusted environment. Enabling participants to collaborate in a Gaia-X (compliant) data ecosystem (also called a Federation) will be achieved by implementing and operating certain subsets of the GXFS at a designated entity acting as the

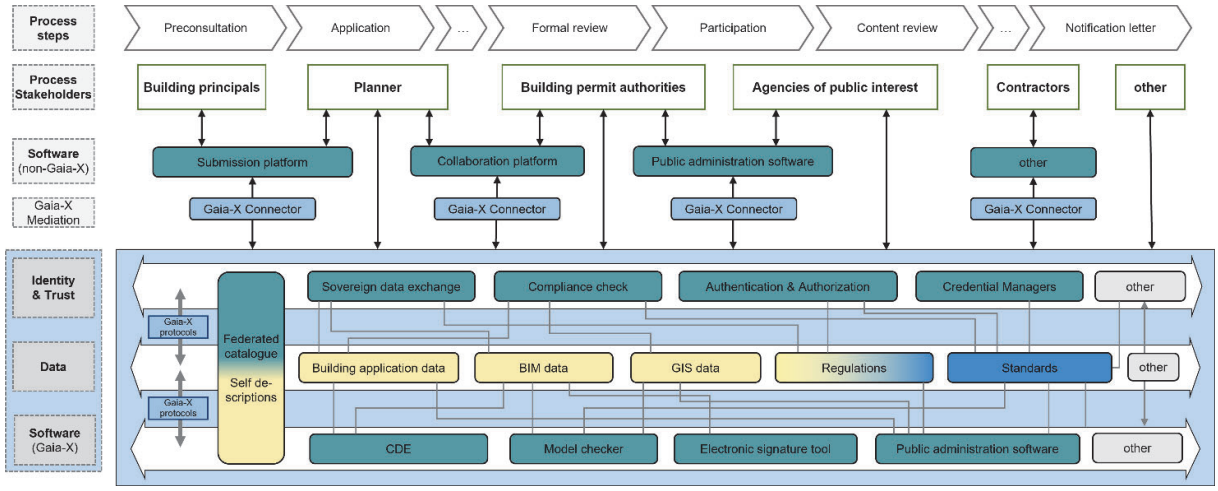

Figure 4: Process automation framework for Gaia-X-based building permit process

ecosystem Federator and (different subsets) under the governance of the participants.

Standardized Gaia-X self-descriptions constitute the core mechanism how Gaia-X ecosystems create and maintain trust between participants and their services and data offerings. Self-descriptions contain various claims about any relevant entity within a Gaia-X Federation such as participants, service and data offerings, and any other resources. Automatic compliance checking mechanisms provided either through GXFS itself or by other entities (e.g., Gaia-X AISBL or trust anchors) then establish the required trust level within the Federation.

The Federator will implement and operate the Gaia-X Federated Catalogue and the Portal of the Federation as well as provide links to the required Gaia-X Compliance Service which attests identities and the conformity of the various claims associated with Gaia-X self-descriptions to applicable Gaia-X standards and trust levels.

The Federated Catalogue serves as a central repository of a Federation, allowing participants to browse, search, and find data and service offerings from other participants via the self-descriptions provided. The Gaia-X Portal acts as an example integration layer, exhibiting the GXFS and offering convenient access to them. It will facilitate participant onboarding and accreditation, highlight service discovery, and provide examples of service orchestration and provisioning. GXFS provide the basic software artifacts needed to create Federated Catalogues (FC.CCF, 2021) or Portals (CP.NOTAR, 2021).

Participants themselves need to operate suitable Credential Managers which securely store the cryptographic Gaia-X identities of organizations and persons in the form of decentralized identifiers. An Authentication & Authorization service then mediates the native and trustworthy Gaia-X identities with their internal identity management systems. The choreography of these GXFS thereby closes the trust gap typically existing in other loosely coupled ecosystems (IDM.TSA, 2021).

Initially, we foresee that a large proportion of existing software applications will not (yet) implement Gaia-X native authentication and authorization protocols (see 'Software (non-Gaia-X)' layer in Figure 4). For those applications, suitable so-called Gaia-X Connectors, either operated by the participants themselves or offered by other participants (e.g., in the form of Software as a Service), will provide convenient coupling and integration logic to overcome this gap. Eventually, we expect more and more ecosystem-specific applications to natively recognize and implement Gaia-X protocols (see 'Software (Gaia-X)' layer in Figure 4).

Framework representation

During the phases of the building permit process many stakeholders with different roles such as building principals, authorities, and contractors are involved. As shown in Figure 4, the stakeholders use Gaia-X-certified software as well as non-Gaia-X software ('Software […]' layers in Figure 3). The data needed for the building permit processes like BIM data, and GIS data, or regulations is stored in the Gaia-X data space. Gaia-X-compliant parties can access the data space directly, while other participants have to rely on third parties. To ensure the accessibility to the stored data in a Gaia-X data space, the used software either connects via an offered connector or accesses the data and services directly. The use of data is being recorded by a Sovereign Data Exchange service. What kind of data or service is being offered in the data space is collected in a Federated Catalogue. The services and applications within the data space provide this information in the form of self-descriptions. To enable trust in these self-descriptions, a Notarization API and other trust and identity mechanisms are used. For this purpose, initial trust anchors must be chosen by the Federation. Permit stakeholders in this process automation framework most likely do not include

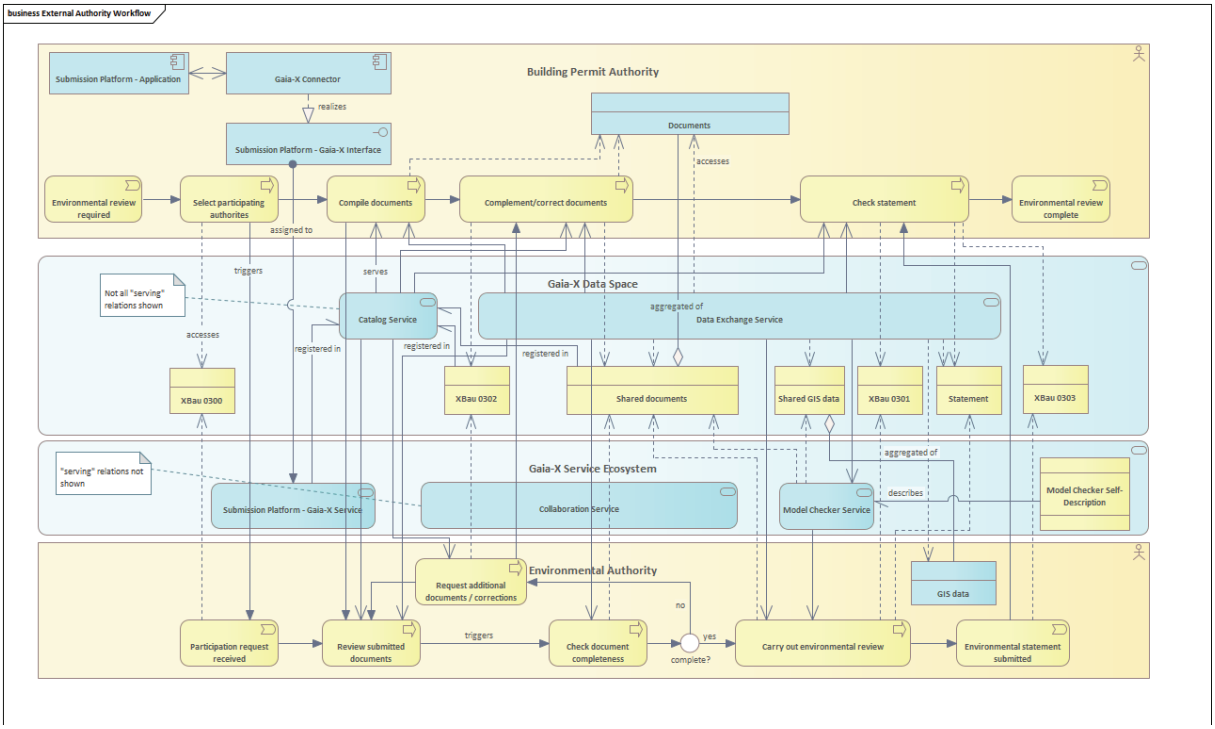

Figure 3: Gaia-X-based IT architecture for the participation of an environmental authority

participants of the Federation who offer the services displayed on the identity & trust layer or the 'Services & Applications' layer, but who possess or hold significant amounts of data from the 'Data' layer. The process automation framework shown in Figure 4 does not list all possible stakeholders, providers, services, etc. who might participate in the proposed ecosystem as they differ in concrete building permit use cases.

Case study

In this section, the earlier mentioned functional requirements and process automation framework are validated by developing a Gaia-X-based IT architecture for the environmental approval process, a subprocess of the building permit process involving the building permit authority and a suitable environmental authority. The resulting process- and service-based IT architecture is modelled in Archimate 3.2 and depicted in Figure 5.

Several (but not all) model elements from our framework are directly mapped to the corresponding IT architecture such as process stakeholders, the respective process steps, and *ex ante* Gaia-X-compliant software ('Collaboration Service' and 'Model Checker Service'). To avoid complexity in this publication (in reality one cannot circumvent it), we only show a single Gaia-X Self-Description for the 'Model Checker Service' (modelled as Archimate 'Contract') fully cognizant of the prerequisite that all entities of the Gaia-X conceptual model need such a binding description.

With regards to an actual IT implementation, we have to stress that it needs to take into account the following three refinements (as incorporated into Figure 5) to fully achieve Gaia-X compatibility:

1) Shared data ('Shared Documents' and the various 'XBau 030X' messages may be conveniently located in the 'Gaia-X Data Space' domain in the IT-architecture – as intended in the process automation framework. Technically, though, only references to the real data assets are stored in a (service and data) catalog via the 'Catalog Service'. Only upon actual data access or retrieval, a corresponding 'Data Exchange Service' will retrieve or provide the actual data from the respective participant ('Documents' inside the 'Building Permit Authority' actor or 'Shared GIS Data' accessing the locally available 'GIS Data' of the 'Environmental Agency' actor). Note that this necessary technical decision has (deliberately) not (yet) been made for the various XBau-messages – clearly evidenced by the lack of reference of the (yellowish Archimate) 'Business Objects' to any technical realization in the form of (blue Archimate) 'Data Objects'.

2) Non-Gaia-X-compliant software ('Submission Platform – Application') can be exposed in a Gaia-X-compliant way by using a suitable 'Gaia-X Connector' and exposing a suitable API – all within the control of a Gaia-X participant (modelled as actor). On the service abstraction layer, this interface will be assigned to a corresponding Gaia-X service duly registered in the 'Catalog Service'.

3) Identity and trust from Figure 4 need to be absorbed into the actual service invocation mechanism or the 'Gaia-X Connector' and are, consequently, no longer directly visible at the abstraction level used in Figure 5.

Finally, note that while the previously introduced requirement domains software and data are directly represented in the IT architecture, regulations & standards have already been realized in the form of a compliant process and standards based (XBau) messages thereby blurring the boundaries between the domains.

Discussion

The article shows that the requirements specified and analysed are feasible and reasonable for the process automation framework development even if they cannot be considered comprehensive. The study also shows that the proposed process automation framework needs to be checked in a frequently updated iterative mode as long as the GXFS and the underlying IT-architectural decisions are being developed. In particular, how standards and regulations are integrated in such a process automation framework needs to be considered in future studies. For example, laws and regulations could soon be offered by a participant-created service and would then switch from domain regulations & standards to data (Figure 3). However, the methodology used for requirement specification was successful.

Furthermore, the process automation framework needs to be validated and tested in a real-world scenario. However, the process automation framework and the requirement specification serve as basis for a Gaia-X-based building permit process as well as a starting point for other Gaia-X-based use cases in the architecture, construction, and engineering industry.

Summary and conclusion

In this article, a process automation framework is developed to provide initial guidance for Gaia-X-based building permit processes. The process automation framework proposes a basis for a digital building permit process to enable transparent exchange between the parties involved. For this reason, integrated software applications (either Gaia-X-compliant or Gaia-X-connected) can contribute to collaborative working methods and homogenize currently heterogeneous process landscapes. Authorities can ultimately use digitized data and processes to make the process more efficient. Review processes can be automated, content can be made accessible more quickly, and the procedure itself can be analysed and optimized. Furthermore, the article shows that a requirement specification (including processes, digital building permit requirements, and Gaia-X requirements) is a suitable method for framework developing in this context.

In future research, a prototypical demonstrator needs to validate the proposed process automation framework. Moreover, as Gaia-X is a European project, future studies need to focus on expanding the process automation framework on an international level.

Acknowledgments

The presented study is part of the research project iECO (intelligent Empowerment of Construction Industry) which is supported by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and monitored by the Bundesnetzagentur.

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag

References

Abdulla, A., Janiszeska-Kiewara, E. & Podlesny, J. (2021) Data ecosystems made simple. McKinsey & Company. [Online] [Accessed on 13th January 2023] Available: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/tech-forward/data-ecosystems-made-simple.

Bonfiglio, F. (2021) Vision & strategy. [Online] [Accessed on 6th December 2022] Available: https://gaia-x.eu/wp-content/uploads/files/2021-12/Vision%20&%20Strategy.pdf.

Capko, Z., Vukmirovic, S. & Babic, A. (2014) ICT and certification as factors influencing development of intelligent cities on cloud computing strategy. Economy of Eastern Croatia Yesterday, Today, Tomorrow, 3, pp. 235-244.

Costin, A. & Eastman, C. (2017) Requirements for ontology development in the AECO industry. Lean and Computing in Construction Congress (LC3): Volume I Đ. Proceedings of the Joint Conference on Computing in Construction (JC3), Vol. 1.

CP.NOTAR (2021) Software requirements specification for GXFS Compliance Notarization API CP.NOTAR. [Online] [Accessed on 9th December 2022] Available: https://www.gxfs.eu/specifications/

Ens (2022) Housing industry complains about too long building permit procedures. Association of the Housing and Real Estate Industry in Niedersachen and Bremen e.V.

FC.CCF (2021) Software requirements specification for GXFS Federated Catalogue Core Catalogue Features FC.CCF. [Online] [Accessed on 9th December 2022] Available: https://www.gxfs.eu/specifications.

Federal Ministry of the Interior and Community (2021). Digitale Baugenehmigung – Mecklenburg-Vorpommern geht voran. [Online] [Accessed 10 th January 2023] Available: https://www.onlinezugangsgesetz.de/SharedDocs/kurzmeldungen/Webs/OZG/DE/2021/02_bauvorhaben_online.html.

Gaia-X (2022) Gaia-X architecture document 22.04. GAIA-X European Association for Data and Cloud AISBL. [Online] [Accessed on 11th December 2022] Available: https://gaia-x.gitlab.io/technical-committee/architecture-document.

Heitmann, B. (2021) D2.6 Architecture design and technical specifications document I. [Online] [Accessed on 6th December 2022] Available: https://www.trusts-data.eu/deliverables.

Hjelseth, E. (2015). BIM-based model checking (BMC). Building Information Modeling–Applications and Practices, p.pp. 33-61.

Hornung, G. & Suarez, F. (2016) Das Baugenehmigungsverfahren in der behördlichen Cloud wird sukzessive in immer mehr Baubehörden praktiziert. Der Prüfingenieur, Vol. 49, pp. 39 -43.

IDM.TSA (2021) Software requirements specification for GXFS Trust Services API IDM.TSA. [Online] [Accessed on 9th December 2022] Available: https://www.gxfs.eu/specifications.

Kapteinat, S. (2021). ProBAUG Baugenehmigung und Mehr. Available: https://www.prosoz.de/wp-content/uploads/2022/10/Pro_2021_ProBAUG.pdf.

Krause, K.-U. (2023). Handreichung XPlanung - XBau, 2. Auflage. Available: https://xleitstelle.de/sites/default/files/2023-01/Handreichung_XPlanung-XBau_2_Auflage.pdf.

Lee, H., Lee, S., Park, S. & Lee, J. K. (2015) An approach to translate Korea building act into computer-readable form for automated design assessment. International Symposium on Automation and Robotics in Construction, Vol. 32, pp. 1-8.

Ma, Z., Zhang, D., & Li, J. (2018). A dedicated collaboration platform for Integrated Project Delivery. Automation in Construction, 86, p.pp. 199-209.

Musterbauvorlagenverordnung, MBauVorIVO § 3 (2007).

Nagel, L. & Lycklama, D. (2021) Design principles for data spaces. Position Paper Version 1.0, doi: doi.org/10.5281/zenodo.5105744.

Narayanswamy, H., Liu, H. & Al-Hussein, M. (2019) BIM-based automated design checking for building permit in the light-frame building industry. International Symposium on Automation and Robotics in Construction, Vol. 36, pp. 1042-1049, doi: doi.org/10.22260/ISARC2019/0139.

Nawari, N. O. & Alsaffar, A. (2017) The role of BIM in simplifying construction permits in Kuwait. AEI 2017, pp. 855-866, doi: doi.org/10.1061/9780784480502.072.

Noardo, F., Guler, D., Fauth, J., Malacarne, G., Ventura, S. M., Azenha, M., Olsson, P.-O. & Senger, L. (2022) Unveiling the actual progress of digital building permit: Getting awareness through a critical state of the art review. Building and Environment, 108854, Vol. 213, doi: doi.org/10.1016/j.buildenv.2022.108854.

Otto, B., Alina R., Etiel, A., Teuscher A., Scleimer A.M., Lange C., Stingl, D., Loukipoudis E., Brost G., Böge G., Pettenpohl H., Langkau, J., Gelhaar, J., Mitani, K., Hupperz, M., Huber, M., Jahnke, N., Brandstädter, R., Wessel, S. & Bader, S. (2021) GAIA-X and IDS. International Data Spaces, doi: doi.org/10.5281/zenodo.5675897.

Poveda-Villalón, M., Fernández-Izquierdo, A., Fernández-López, M. and García-Castro, R. (2021) LOT: An industrial oriented ontology engineering framework. Engineering Applications of Artificial Intelligence, Vol.111, doi: 10.1016/j.engappai.2022.104755.

Strnadl C. F. & Schöning H. (2023): Datenplattformen, Datenräume und Datenökosysteme. Moderne IT-Architekturen zur Datenmittlung. In: Weber, B. (ed.), Data Governance. Berlin: Springer, to appear.

Wandinger, M. (2022) Amtliches Liegenschaftskatasterinformationssystem (ALKIS). Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland (AdV). [Online] [Accessed on 8th December 2022] Available: https://www.adv-online.de/AdV-Produkte/Liegenschaftskataster/ALKIS/.

Wilkinson, M.D., Dumontier, M., Aalbersberg, I.J J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J.-W., Da Silva Santos, L.B., Bourne, P.E., Bouwman, J., Brookes, A.J., Clark, T., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C.T., Finkers, R., Gonzalez-Beltran, A., Gray, A.J.G., Groth, P., Goble, C., Grethe, J.S., Heringa, J., Hoen, P.A.C.'t; Hooft, R., Kuhn, T., Kok, R., Kok, J., Lusher, S.J., Martone, M.E., Mons, A., Packer, A.L., Persson, B., Rocca-Serra, P., Roos, M., van Schaik, R., Sansone, S.-A., Schultes, E., Sengstag, T., Slater, T., Strawn, G., Swertz, M.A., Thompson, M., van der Lei, J., van Mulligen, E., Velterop, J., Waagmeester, A., Wittenburg, P., Wolstencroft, K., Zhao, J. & Mons, B. (2016) The FAIR guiding principles for scientific data management and stewardship. Sci Data (Scientific Data), Vol. 1, doi: 10.1038/sdata.201