Proceedings of the 9th International Conference on Civil Structural and Transportation Engineering (ICCSTE 2024)
Chestnut Conference Centre - University of Toronto, Toronto, Canada – June 13-15, 2024
Paper No. 157
DOI: 10.11159/iccste24.157

Synergising Lifecycle Project Management for Sustainability: Towards a Streamlined Approach through different Project Phases

Martin Wogan[1,2], Nijanthan Mohan[1,3], Gertraud Wolf[4], Nazereh Nejat[5], Karsten Menzel[1], Rolf Gross[3]
[1]Chair of Institute of Construction Informatics, Technical University Dresden
Institute of Construction Informatics, Technical University Dresden, 01062 Dresden, Germany
martin.wogan@bmconsult.de; mohan@fh-aachen.de
[2]B/M Consult GmbH
Lampestrasse 3, 38114 Braunschweig, Germany
[3]Chair of Institute of Smart Building Engineering, FH Aachen University of Applied Sciences
Bayernallee 9, 52066 Aachen, Germany
[4]gertraud.wolf@unibw.de, Institute of Construction Management - University of Bundeswehr Munich, Germany
[5]nazereh.nejat@infrakit.com, Infrakit, Finland

Abstract **–** The Architecture, Engineering, and Construction (AEC) industry is transforming project management, departing from traditional linear methodologies. At the forefront of this evolution is the Total Life Cycle Process (TLCP), a paradigm that redefines project management throughout the project lifecycle. Adhering to DIN EN ISO 19650 principles, this innovative methodology utilizes database-supported information models (dIMs), marking a substantial leap towards a fully digital project management system. Unlike conventional methods, TLCP transcends procedural changes by systematically deriving information requirements. This is achieved through meticulous analysis of Information Requirement Matrices (IRMs), tailored to address unique use cases in each project phase. This strategic approach not only enhances communication but also ensures stakeholders have timely access to relevant information, fostering efficiency and collaboration. Critical evaluation and revision of linear processes follow IRM analysis, forming the basis for a robust transition to an agile model. This addresses challenges in project phase transitions, laying the groundwork for a more efficient and integrated project management framework. The overarching goal is to present a cross-phase methodology optimizing resource utilization and adapting to technological advances in the dynamic AEC landscape. The methodology facilitates resource-efficient structure design, construction, operation, and decommissioning. The paper introduces a digital TLCP based on the Level of Information Need (LOIN) framework, embodying the key factors and serving as a practical demonstration. By presenting this digital TLCP, the authors aim to stimulate discussion within the AEC industry, contributing to the evolution of sustainable construction practices. In conclusion, this paper serves as a catalyst for a broader discussion, inviting AEC stakeholders to engage in the ongoing evolution of project management practices. The TLCP approach, emphasizing integration, sustainability, and adaptability, represents a significant stride towards efficiently managing construction projects for a more sustainable and resilient built environment.

Keywords**:** Project management, sustainability, information management, TLCP

1. Introduction

The construction industry has been focusing on resource conservation for several years to achieve the Sustainable Development Goals (SDGs) [1] and the Green Deal [2]. The phrases such as sustainable production and sustainable decisions mentioned in the Green Deal [2] are used as buzzwords to encourage forward-thinking actions and responsible resource management. These terms imply the necessity of future-oriented thinking and mindful use of resources. A detailed vision of raw material management is presented, focusing on saving while also highlighting reuse and reducing surpluses such as construction waste. The sustainability factor involving action and decision-making, which are regarded as fundamental building blocks in the construction industry, though they are not currently receiving as much attention in public debate, plays a crucial factor in achieving the above-mentioned goals.

The state of disrepair in infrastructure [3] has been a matter of public concern for some time. The extensive list of causes for the recent failures lays bare the industry's structural flaws, which neglect to consider the life cycles of infrastructure like bridges, roads and railways. It is crucial to deeply comprehend the temporal importance of structures and their connections with sustainability. Instead of perceiving infrastructure as disposable objects, it is vital to view them as part of a repeating cycle instead of objects that are forgotten once they have been built. Adherence to academic convention, objectivity, and formal register is paramount. In this regard, the object life cycle can be divided into five phases: initiation (0), planning (1), execution (2), operation (3), and optimised initiation renewal (4). However, as the physical existence of the object is limited to phases 2 and 3, the term project life cycle is used to highlight its position within the broader process. Alongside recognising models as temporary structures, sustainability also warrants attention in project management, which encompasses the overall execution of projects. In particular, project management provides a more robust framework for considering sustainability than the project life cycle.

This study aims to establish connections between temporal processes and contemporary digitisation techniques. Furthermore, a novel approach will be introduced to develop project-specific temporal processes, resulting in unambiguous tasks that improve project management in the construction industry. The ultimate objective is to contribute to the German construction sector's long-term sustainability and future prospects in the form of a TLCP.

2. Definition of sustainability in lifecycle processes

2.1. Sustainability in the project lifecycle

In recent years, sustainability has become a more developed method, often subdivided into the three areas of economy, ecology and social issues [4]. Contemporary research primarily focuses on the question: How can the whole and, in detail, the now and the later, the economic, ecological and social dimensions of work systems be thought of together in a way that supports joint action? This concept is referred to as the sustainable polygon. These approaches and methods demand thorough comprehension of the underlying processes, requiring on-the-job development and analysis for practical suitability [5].

Specialist planners must responsibly utilise all resources at their disposal to achieve the most cost-efficient building possible and ensure it is geared towards the entire lifecycle. This encompasses materials, processes, and a keen eye on the responsible use of resources throughout the building's lifespan. The *Honorarordnung fuer Architekten und Ingenieure* (Fee scale structure for architects and engineers, HOAI) further subdivides these phases mentioned in Figure 1 in Germany, resulting in up to ten phase levels, with phase (0) serving as an initialisation or preliminary feasibility study.

Fig. 1: Phases in project lifecycle.

This approach to project accounting has developed over time in Germany as a practical means of calculating costs for construction projects. Considering the recurring life cycle of products and advancements in technology and related methods, such as model-based computer systems and Building Information Modelling (BIM), it is not appropriate to plan based solely on self-contained service phases, as this can result in breaks and losses of information during project execution.

Several factors contribute to this practice [6]:

- Public clients must comply with legal requirements.
- Social needs take precedence over technically optimised solutions.
- Prolonged life cycles often lead to the oversight that initialisation precedes operation (operation until failure). While mobility is the backbone of society, it is not always acknowledged as such, as evidenced by deteriorating roads and bridges.
- Addressing challenges like the absence of digitalisation, transparency, and effective communication is essential.

2.2. Sustainability in project management

According to German national standard (DIN) 69901-5 [7], project management is the totality of all management tasks, organisation, techniques and means for the initiation, definition, planning, control, coordination and completion of projects and thus concerns phases (0)-(3) in the product life cycle according to Figure 1. In phase (3), however, the responsibility only applies until the end of the warranty of the commissioned services. Internal or externally commissioned project management acts in the client's interests. Project complexity is coordinated by project management and supported by cooperation with the parties involved.

A project can only be sustainable if the principles of sustainability are also integrated into the project management process. The consideration of economic efficiency, the selection of materials or the social aspects are essential points that must be considered together [8].

For example, it may be necessary to carry out a product life cycle analysis during the planning phase in order to assess the impact of measures on the three pillars of sustainability. At this point, project management either analyses the effects of the measures or coordinates them [9].

According to [10], the processes of sustainability can be categorised in project management in three areas:

- Internal processes
- Management of projects
- Project-specific processes

Sustainability in project management means having a broader perspective on the project, coordinating the overall process, networking internal and external influences, and knowing and applying the advantages of the known principles of sustainability. The focus here is on conserving resources. Networking also applies to the communication structure and the dissemination of information. Project management should provide targeted communication structures and ensure the transparency of the required information. [11].

3. Optimisation of phase transitions in the project life cycle

The current legal landscape and contracting practices within the German construction industry present substantial impediments to efficient and collaborative project execution. The segmentation into nine performance phases and unclear interfaces is further exacerbated by prevalent contracting norms. A notable instance is the routine handover of printed documents during the planning-to-construction transition, a practice considered outdated in contemporary contexts.

3.1. Challenges in the phase transitions

The complexity of navigating phase transitions in the German construction industry is multifaceted, influenced by regulatory constraints (HOAI) and operational practices such as the prevalence of the design-bid-build contracting process [12]. Despite the increasing adoption of BIM in the German AEC sector, the lack of standardised workflows is a major challenge. This deficiency hinders the effective implementation of BIM and leads to complexity and additional work in later project phases. As a result, the occurrence of unusable models becomes a significant concern. The lack of well-defined transition points in project workflows adds another layer of complexity. This is particularly evident in the routine handover of printed documents without transparent processes, leading to operational inefficiencies. This hampers project efficiency and highlights the need for a more streamlined and digitally integrated approach. These multiple challenges underscore the complex nature of phase transitions in the German construction industry and the urgency for comprehensive solutions [13].

Not only are transition points challenging in infrastructure projects but also transition processes and transferring relevant information from one phase to another or from one stage to another is a huge ambiguity in the entire life cycle of the projects. That is due to the lack of a reasonable information chain, a clear definition of information needed in each phase indicating related or not related to the next phases, understandable prerequisite information for the following phases, query and filter processes for data and information transition with information buffers, as well as archive and accessibility possibilities in the nested information in the information models.

These factors are spread among various project parties, service providers, and technology vendors, which raises the complexity of linking the information and changes the harmony of the information at each stage. Each of these key indicators is a major role player in the TLCP to set a clear flow for data and information transfer along the project life cycle.

As all project participants have different starting points, it is essential to have a defined digital knowledge transfer to ensure accurate and transparent information transfer.

3.2. Potential through implementation of TLCP

A holistic view of the product lifecycle can be achieved through a centrally implemented dIM for the structured capture, management and exchange of project-relevant information, ensuring the availability and quality of information and supporting efficient communication, transparency and collaboration between all project stakeholders. In the dIM, information can be updated in real-time and made easily accessible, leading to improved decision-making and planning accuracy [14]. As mentioned in the previous section, one of the key challenges is to capture all relevant information in a structured way and manage it in a standardized database. This requires clear information standards and formats as well as close coordination between project stakeholders. Against this background, the following Table 1 and Figure 2 depict the Information Requirements Matrix (IRM) and the elements included in it, such as Level of Geometry (LOG), Level of Information (LOI) and Documentation (DOC), which forms the Level of Detail (LOD) that will serve as the basis for developing and managing the dIM.

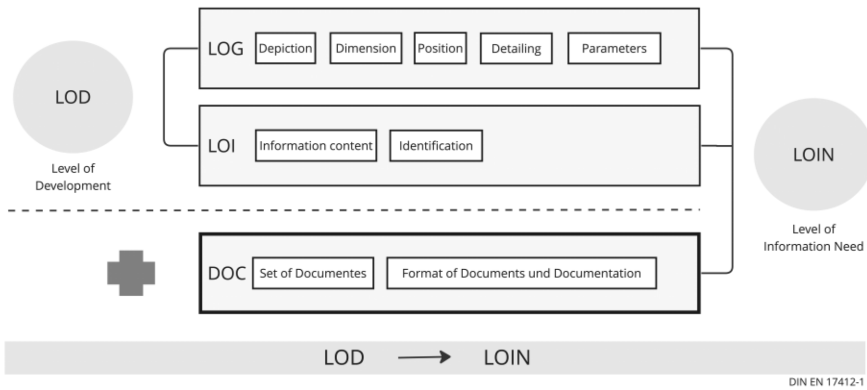

Fig. 2: Level of Information Need (LOIN) [15].

Table 1: IRM concept based on LOIN use case with consideration of TLCP [14].

Key Data	Content
Use Case	Why is the information required?
Milestone	When is the information required?
Objects	What / *Which Information* is required? (LOG/LOI/DOC)
Actors	Who required the information? ***Who delivers the information?***

Based on the BIM methodology, this research framework assumes consistent information management among project stakeholders or for further processing. Effective communication, which is crucial for the success of construction projects, is often constrained by limited cross-project phase and cross-stakeholder interaction. The development of the TLCP is heavily influenced by insights gained from past and current projects, highlighting the need for standardised information requests. In order to tackle analogous processes within similar project structures, the approach defines appropriate LOIN use cases, creating an organised information delivery system for inter-project phase processes and reducing the likelihood of unnecessary iteration loops and information gaps. The forthcoming web-based dissemination of LOIN use cases will be supported while following the requirements set out in DIN EN 17412-1 [15]. A LOIN use case's fundamental principle, which corresponds with the queries in Table 1, is strengthened by insights from the TLCP: Actor - Who delivers the information? Precision in determining crucial junctures in the information delivery process for the TLCP guarantees consistent scrutiny of procedures, encompassing the obligation to deliver information. This strategy promotes an interdisciplinary viewpoint that spans phases.

4. Integration of TLCP in current practices

Implementing TLCP in the current process relies on key factors, including adherence to national and international standards, digitalization through information models, systematic derivation of Information Requirements, cross-phase methodology, agile transition, process optimization, and fostering discussion and exploration.

Table 2: IRM for Infrastructure se case with consideration of TLCP.

Key Data	Information Requirements Matrix (Infrastructure)
Use Case	Position of road alignment
Milestone	Preliminary Design to Conceptual Design
Objects	LOG: Geology, hydrography data, environmental constraints, protected areas details, As-is information, information from previous phases (As-is, Feasibility, alternative variations) LOI: Weather data, socio-economic aspects related information, cost-time analysis, infrastructure and utilities, national standards and guidelines, material details, construction phase considerations DOC: Explanatory report, soil report, construction phase line report, safety report
Actors	From Preliminary Design (Who delivers): Owner (Public/Private), Legal& state bodies such as state-approved surveying and information department, specialist/consultant, Fire protection expert, energy suppliers In Conceptual Design (Who requires): Planners, Owners, state authority, civic bodies, energy suppliers

In the course of the study, it emerged that various approaches have developed in the different phases, which require different information requirements. One example from infrastructure planning depicted in Table 2 is that the information from the planning phase must be prepared in such a way that authorisation is possible based on the applicable technical and legal requirements.

Efficient integration of the TLCP process requires a meticulous consideration of not only the primary criteria for information requirements but also the often-overlooked sub-criteria and sub-sub-criteria. Failure to inspect these finer details can result in significant time loss. By adopting this comprehensive approach, TLCP has the potential to evolve beyond a mere project standard to become a standardized practice within the entire organization. This shift ensures a thorough and consistent application of TLCP principles, enhancing overall efficiency and effectiveness across diverse projects and initiatives.

4.1 Implementation and integration of TLCP in a web-based information modelling tool

Implementing and integrating life cycle processes in a web-based information-modelling tool is achieved following the steps shown in the process picture (Figure 3) below:

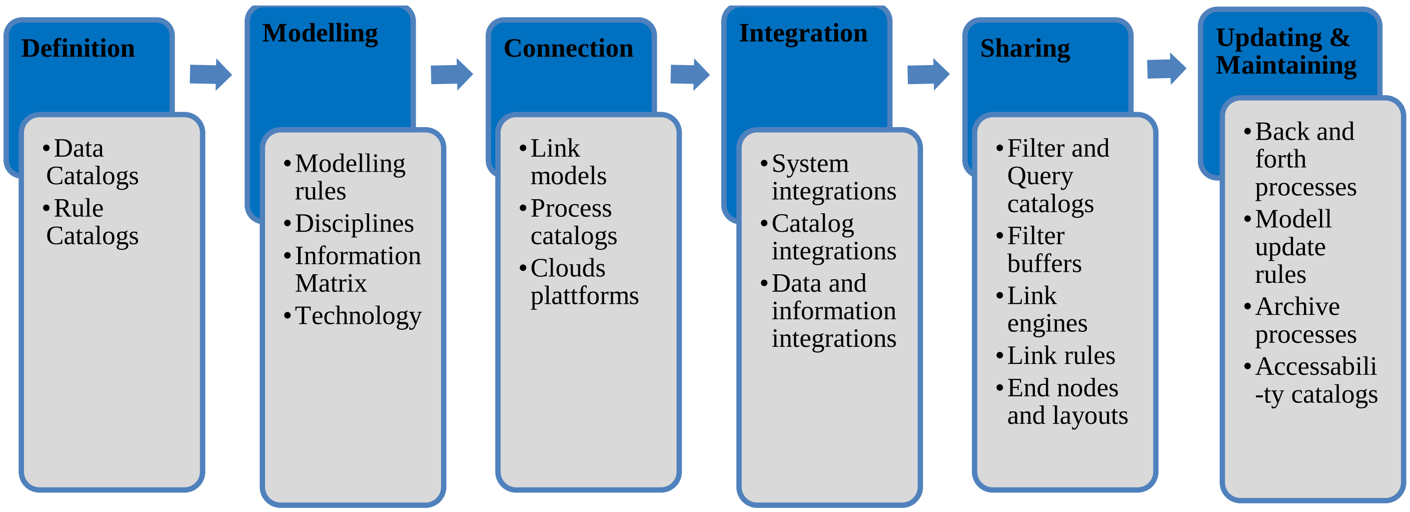

Fig. 3: Integration of TLCP in a web-based information-modelling tool.

The first step towards implementation of TLCP in a web-based information modelling tool involves identifying and defining all the life cycle processes that are relevant to the project, tailor-made for each life cycle phase, such as preliminary, conceptual, and detailed design, construction, maintenance, renovation, and demolition, among others. In this step, as listed in Table 2, the impacts, input and output, object types and actors with all inter- and outer relations must be defined in *data and rule catalogues*. Once the processes have been defined, they are to be modelled in the information modelling tools. After this stage, as shown in Figure 4, the data and information among the entire life cycle of the project would typically look like various islands, which in some cases are connected, and, in some cases not, in which the data and information flow is not guaranteed during the entire life cycle.

In Figure 4, the bigger orange circles represent various systems such as Project Management Software, BIM Systems, Construction Management Software, Document Management Systems, Collaboration Platforms, Supplier and Vendor Portals, Geospatial Information Systems (GIS), Quality Management Systems, Safety Management Systems, Regulatory Compliance Platforms, Client and Stakeholder Portals involved during the entire life cycle of the projects. The green circles are sub-systems, and the data level is demonstrated with grey dots. The grey two or one-headed arrows with their direction show the typical information flow, which is not guaranteed completely. The next step is to establish connections between the different processes. This is typically done through a process flow diagram or a similar tool that shows how the processes interact with each other and with the building model in so-called *process catalogues*.

Therefore, in the next step, an integration platform should be designed to establish integration between different systems, such as project management systems or cost estimation tools for additional functionality. Web-based platforms are one of the best examples of such smart services in which nested information can be kept, interconnected and analysed based on *integration catalogues.*

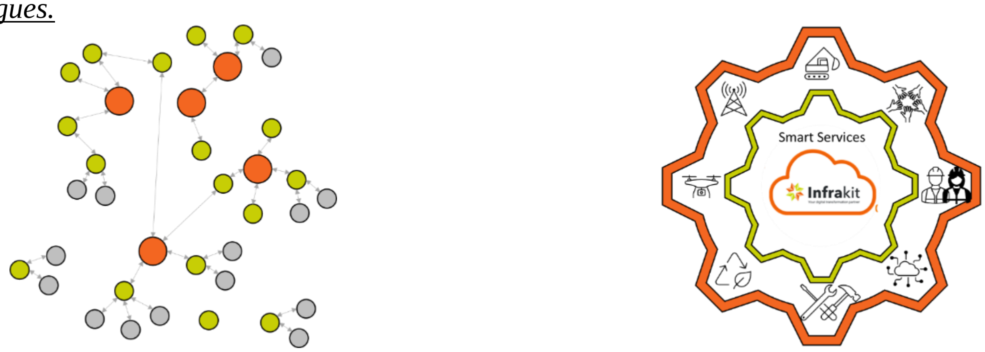

Fig. 4: Information data points [16].

Such web-based information modelling environments are from one side capable of parsing data and models, and interlinking information, and from the other side connect them to resources from manpower to machinery and collaboration between human and technology using Artificial Intelligence (AI) methods. By establishing such connections between various sources, a comprehensive overview of the project lifecycle not only in the planning and design stages but also in the construction, operation and maintenance is ensured. Once the integration platform is set, different layouts can be designed to host the query and filter catalogues and apply them to the nested information based on the profile specs along phases or in the transition processes. These layouts define which data are to be shared with whom and when based on what expectations and with which results. Thus, information sharing between stakeholders and parties involved in the project is in a targeted way so that process-oriented information flow, collaboration and relevant communication is guaranteed. Such layouts can be purposed to target design, construction, operation and maintenance processes; transition processes; machine, human, and technology processes; or sustainability processes. The smart platforms have the capability to keep the information regularly updated and maintained to reflect changes over time with versioning and archiving mechanisms which is crucial especially in the operation, maintenance or renovation processes

In conclusion implementing and integrating TLCP in a web-based information modelling tool improves collaboration, provides more efficient processes, and better management of the project over its entire life cycle.

4. Conclusion and Outlook

The integration of diverse data sources and information models grounded on the TLZP is paramount for enhancing efficiency and ultimately advancing sustainability in the construction field. The applied information management enables systematic fact-based decision-making across planning, construction and management domains, ensuring seamless data exchange and communication among multifarious project stakeholders across phases. To enhance information flow and ensure system interoperability, industry players must collaborate more and establish uniform standards and data exchange formats. One promising option is the incorporation of artificial intelligence and machine learning, which could provide the potential for automating analysis and decision support systems in the future. Further research and pilot studies, along with a more extensive application in practice, will propel the advancement of this methodology and enhance its beneficial effects and practical suitability.

Acknowledgements

We would like to thank the Institute of Construction Informatics at TU Dresden for their support throughout our research journey. Special thanks goes to the Institute of Smart Building Engineering – the team of project Diggitwin funded by the Ministry of Research North Rhine-Westphalia, Germany, at FH Aachen for their collaborative spirit, which enhanced the depth of our work. We would also like to express our gratitude to B/M Consult GmbH, Haydn Ingenieure GmbH & Co. KG, Institute of Construction Management – University of Bundeswehr Munich, Infrakit and Wilhelm Theis GmbH for their indispensable support and expertise, which played a key role in enriching the value of our research.

References

[1] United Nations. (2023, December 05). The Sustainable Development Goals Report (Special edition) [Online]. Available: https://unstats.un.org/sdgs/report/2023/The-Sustainable-Development-Goals-Report-2023.pdf

[2] European Commission. (2023, December 05). Der europäische Grüne Deal [Online]. Available: https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0021.02/DOC_1&format=PDF

[3] Norddeutscher Rundfunk. (2023, December 05). Marode Infrastruktur: Deutschland bröckelt [Online]. Available: https://www.ndr.de/fernsehen/sendungen/extra_3/Marode-Infrastruktur-Deutschland-broeckelt,extra21932.html

[4] M. von Hauff and A. Kleine, "Methodischer Ansatz zur Systematisierung von Handlungsfeldern und Indikatoren einer Nachhaltigkeitsstrategie - Das Integrierende Nachhaltigkeits-Dreieck," Discussion Report, Technical University of Kaiserslautern, Germany, 2005.

[5] F. Flemisch, M. Preutenborbeck, J. Wasser and N. Herzberger, "Vom Teufelsquadrat zum nachhaltigen Vieleck (Engelsdiamant) und holistischen Bow-Tie-Modell: Denkanstöße zur Methodenentwicklung für die Analyse, Gestaltung und Entwicklung von nachhaltigen Arbeitssystemen," in *Proceedings of the Frühjahrskongress 2023*, Hannover, Germany, 2023.

[6] B. Weber-Lewerenz, "Die unternehmerisch verantwortungsvolle Digitalisierung im Bauwesen/Corporate Digital Responsibility (CDR) in Construction Engineering," Bauingenuier, vol. 2/2021, pp. 20-21, 2021.

[7] Beuth Publications. (2023, December 05). DIN 69901-5: Project management - Project management systems - Part 5: Concepts [Online]. Available: https://www.din.de/en/getting-involved/standards-committees/nqsz/publications/wdc beuth:din21:113428752?destinationLanguage=&sourceLanguage= .

[8] G. Silvius, R. Schipper, J. Planko and J. van den Brink, *Sustainability in Project Management*. Farnham, England: Gower Publishing, 2017.

[9] Project Management Institute, *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)*. Project Management Institute Inc., 2021.

[10] U. Holzbaur and M. Fierke, *Nachhaltiges Projektmanagement*. Wiesbaden, Germany: Springer Gable, 2021.

[11] M. Stumpf and M. Brandstaetter, *Nachhaltigkeit im Projektmanagement – Bedeutung der Integrierten Kommunikation in der Innen- und Außendarstellung von Projekten*. Germany: Springer Publications, 2012.

[12] N. Mohan, M. Ebbers, R. Gross and F. Theis "Design-Build-Verfahren aus Sicht der TGA – Wie können klare Verantwortlichkeiten und die konsequente Anwendung der BIM-Methodik helfen, Planungs- und Bauleistungen besser ineinander zu integrieren?" Build-Ing, vol. 2/2022, 2021.

[13] A. Vaatz, A. Hamdan, N. Al-Sadoon, M. Wogan and K. Menzel, "Integration of semantic temporal information in BIM using ontologies," in *Proceedings of the European Conference on Computing in Construction 2023*, Crete, Greece, 2023.

[14] N. Mohan, G. Wolf, M. Wogan, J. Beilfuss and R. Gross, "Auf dem Weg zu einem ganzheitlichen Lebenszyklusmanagement von Bauwerken für nachhaltiges Bauen: Eine vorgeschlagene Methodik zur digitalen Transformation durch datenbankbasierte Informationsmodelle," in *Proceedings of the 34. Forum Bauinformatik*, Bochum, Germany, 2023.

[15] Beuth Publications. (2023, December 05). DIN 17412-1 Building Information Modelling - Level of Information Need - Part 1: Concepts and principles; German version EN 17412-1:2020 [Online]. Available: https://www.beuth.de/en/standard/din-en-17412-1/327868247beuth:din21:113428752?destinationLanguage= &sourceLanguage =.

[16] N. Nejat, "Effiziente Infrastrukturprojekte," Intergeo 2023, Infrakit, Germany, 2023.