Digital Twin Representations of Concrete Modules in an Interdisciplinary Context of Construction and Manufacturing Industry

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Abstract. Based on the knowledge gained from mechanical engineering and research activities in the context of Industry 4.0, innovative, modular building construction approaches based on flow production methods must be based on a real-time life-cycle-oriented management of information about products, production processes and created systems. To enable rapid, individual, precise, and fault-tolerant production of flexible modules made of free-formable high-performance concrete, data from the ongoing production process and data describing the current status of the module must be continuously collected, combined and made available. Based on this information, the individual production steps can be fine-tuned and the utilization of the machines better planned. Furthermore, it can be verified, whether the current status of a produced module still meets the previously defined requirements from engineering. A state-of-the-art literature review and comparison for digital twin concepts from both involved domains, construction as well as production, is presented in the paper. The contribution gives insights of the requirements elicitation for the formal description of the product requirements in terms of function and quality, considering the possible uncertainties in the course of production. Furthermore, it shows a draft concept for the administration shell for digital twins comprising integrated and adaptable data and interaction models for the industrialized production of high-performance concrete modules.

Keywords: Digital twin · PLM · BIM · Construction industry · Smart manufacturing

1 Introduction

Most construction processes are manually performed by construction workers on site and highly depend on external conditions, often beyond own control, as for instance material supply and weather. This causes inaccuracies regarding geometric requirements, workmanship, and material, which often leads to delays and increased costs. There has been progress in terms of modular building and construction methods for the last decades, together with increased use of high-performance materials such as carbon reinforced concrete. These developments are the key to increase the share of pre-fabrication

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in the construction industry and thus tackle the above mentioned challenges. The main idea is to break down each unique building into basic modules that can be pre-fabricated in a highly industrialized manner in order to shift value generation from vulnerable on-site construction to reliable state-of-the-art technology used in manufacturing industry. Furthermore, the idea is to leverage Industry 4.0 approaches, which take advantage of collecting process and operation data by field-sensors at almost any stage of the product lifecycle. Evaluating values with intelligent computer algorithms has become state-of-the-art. A high degree of automation and internet-based communication have established Cyber-Physical Systems (CPS), respectively Cyber-Physical Production Systems (CPPS) [1] if the focus is put on the manufacturing domain.

The project presented in this paper is embedded in the Priority Programme "Adaptive modularized constructions made in a flux: precise and rapid building" [2] of the German Research Foundation and deals with the concept of Digital Twins (DT) in this context. The specific goal of the project is to generate further benefits in terms of digitalization, particularly to enable a digital thread of all planning and building stages, data capturing and processing capabilities, and consistent information flow along the complete lifecycle of a building. Even though DT are considered the virtual counterpart of a physical product, they are more than just data. Digital Twins include algorithms to describe the real product, help to optimize the production process by the processed data, and set the fundamental data basis for operational processes such as predictive maintenance [3]. One major challenge to be tackled in the project is to transfer the concept of CPS, which can describe themselves, are networked, can provide and retrieve services and carry entire data collections over their lifecycle, to the construction industry based on pre-fabricated modules. This includes in particular the representation of specific process modules from concrete construction such as adaptive form-work, reinforcement, concreting and temperature treatment methods with semantic data models.

2 State-of-the-Art and Related Work

2.1 Product Lifecycle View

Comparing construction and manufacturing industry, DT embodies the same thought, but differs in the specific phases of the product lifecycle. The three main phases of the product lifecycle have to be considered adequately for implementing DT concepts. The first phase is the product development phase, or respectively planning phase in construction industry. Here, the focus is put on abstract models on a virtual level, which approximate the real behaviour of a system as accurate as possible. A virtual product model represents the target state and allows early design decisions e.g. through 3D-product review processes. Furthermore, it provides an overview of required materials, estimated costs and time to completion. The most extensive phase with respect to duration is the operation or use of a product respectively building in construction industry. The consideration of the use phase of a product is becoming increasingly important since services in the sense of PSS can leverage additional added value for many companies. In this phase, primarily time series data or sensor-based measured values of a concrete operating state are generated, sometimes with the necessity of real-time data processing. The way in which consistency of information can be ensured, dependencies made transparent and correlations or causal relationships for various issues can be derived, must be conceptually and methodically thought through on a generic level and then implemented in a company-specific manner. In-between planning and operation phase, there is the production respectively building phase, which depicts the transformation from the virtual to the real level. In manufacturing industry, this phase comprises manufacturing an assembly, mostly at a production site, in engineer-to-order processes within plant industry for instance also at customers site. In construction industry, building on-site is predominant but in order to achieve benefits of industrialized production, the share of pre-fabrication is rising.

Even though the product lifecycle is often represented as a linear sequence of successive phases, in reality industrial companies have a multidimensional and complex network of different information processing requirements due to parallel product development projects, parallel customer and production orders in the value-added network or development network and parallel operation of machines or plants in the sense of the PSS concept [4]. With the foundation laid in the early phases of the product lifecycle, the DT particularly serves as a basis for an extended service. Therefore, it is essential, to also have the model representation of the product in operation, i.e. the current usage data and in addition, the continuous documentation of all changes or MRO operations (maintenance, repair, overhaul) of the product or building in operation. This must necessarily happen at the level of the product instance, i.e. a DT exists for each individual product, enhances the digital model representation which is created in the development phase and can be continuously fed and enriched with data from production and later use. In this way, changes in operation and the context of use are taken into account accordingly. One major challenge is to keep the DT permanently up to date over the lifecycle to track changes and enable full traceability. In order to optimize the operation of a product, data is generally recorded by Internet of Things (IoT) devices with sensors or available in the control software used for the DT.

When it comes to planning activities or tasks (engineering phase), e.g. for service operations, for the replacement of plant components, for the introduction of additional safety or supply equipment or for the dynamic simulation of space conditions and collisions with moving parts, sensors and IoT devices are not sufficient for data acquisition. Instead, a spatial representation of the system with its components must be acquired and components must be identified on the basis of geometric or other features. With a lifetime of 30 years or more, this is a permanently recurring task. This is particularly necessary because in industrial practice there are usually deviations between planning and execution, i.e. the information “as designed”, “as planned”, “as built” and “as maintained” must be compared with each other in order to keep the DT representation up to date.

Building Information Modelling (BIM) is the current state-of-the-art for a digital integration of all relevant information regarding the object, processes and stakeholders in the construction industry. As more than 90% of the value creation within the construction industry takes place on construction sites, digital tools only play a major role for planning and documentation but not during the actual value creation. The guideline

VDI-2552 specifies the fundamentals of BIM, e.g. model-based target-costing, data management, processes and qualification for construction projects [5]. According to this guideline, a usage of a digital representation of a desired product before production helps to reduce project risks and to determine completion date, costs and quality. In particular, visualization and related analyses can optimize operative costs and energy efficiency concepts for the product. The preview of product usage is taken into consideration during early stage of planning and documented within the BIM. This should enable an optimal initial operation of the product and reduce the cost of rework. Moreover, BIM gathers all relevant product information to increase project transparency and is accessible to each project party (Fig. 1).

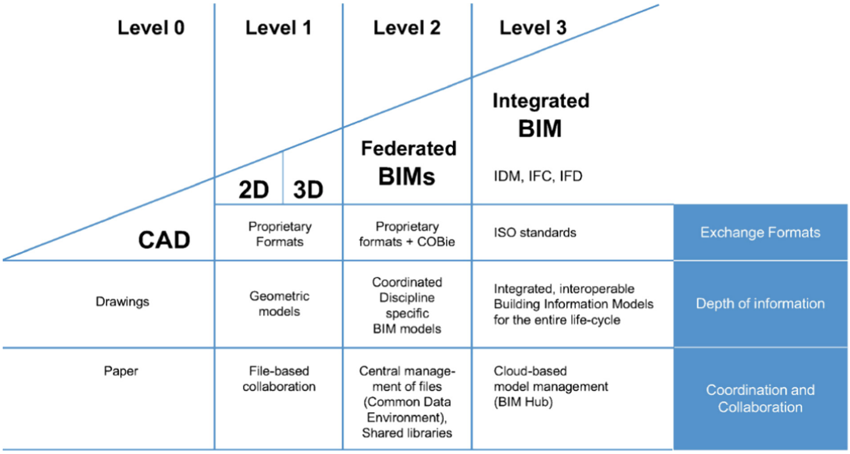

Fig. 1. Performance levels of BIM integration [7]

BIM comprises a set of IT tools and methods to integrate all CAD-design activities, relevant product information like size, material or weight and project parties. However, there are differences regarding the performance level of BIM. VDI-2552 therefore specifies four levels of performance to emphasize the use of different software and data integration intensity. The first level (level 0) stands for cooperation within a project between two or more stakeholders with only individual, data exchange of mainly 2D CAD geometric information without any process tools. Level 1 describes standardized processes regarding the exchange of 2D and 3D geometry as part of a common data environment. In level 2, this 3D-BIM is extended by the information of time (4D) and costs (5D) implemented as attributes within CAD-models. The currently highest performance level of BIM (level 3) represents an integrated digital working environment. That includes a shared model server among all project parties with standardized collaborative digital workflows.

Even though BIM offers a variety of advantages for construction planning, it is also criticized for a need of IT-experts to deal with a high technical burden and a huge amount of work to run these digital tools [6]. BIM is used as a documentation rather than a real time facility management tool. Potential benefits of BIM usage in the operation and maintenance phase have been an unaddressed issue in practical use. Yet, there have been few recent studies about using BIM as a digital basis for facility management. The positive effect of a real time data model for maintenance is shown by an example, where the integration of the internet of things (IoT), BIM and computer aided facility management technologies resulted in better and more intuitive maintenance decisions [8]. Considering that 80% of the total lifecycle costs are generated when the building is in operation [9], this seems to offer an enormous space for improvement.

Process and product data are key to assure a cost-efficient production and high-quality products meeting all predefined requirements. Therefore, gathering data from all phases of the product lifecycle can provide technical insights and act as a starting point for process control and improvement [10]. Product Lifecycle Management (PLM) is a strategic management approach which consists of integrated methods and tools to create, analyze and store all product relevant engineering information along the product lifecycle[11].

At production stage, the state-of-the-art includes two different construction concepts. The first one is the pre-fabrication of modules with simple geometry made out of normal concrete. The second is the construction within the construction zones manually performed by construction workers. The first approach does not apply for complex and unique product structures and modern high-performance materials, whereas the second falls short on using modern production technologies, causes a long time to completion, and relies on factors like weather conditions or personal skill and experience of the workforce. BIM can support this stage by providing all relevant process data. Yet, it cannot directly control the manual process of constructing and is highly dependent on a manual data transfer of current work progress.

Within the phase of product development BIM and PLM are quite similar concepts enabling a common product understanding for design review and decision making. One difference may result from collecting even more data at the stage of production and usage from smart industrial products along the product lifecycle. This allows to optimize production flow and the way a product can be used. From CPPS, insights from production can automatically be transferred to product development. The process of realization thus can become smart and connected – resulting in short production times and reduced loss of production. The concept of modularity is a key factor for modern industrial products and well implemented within the context of Industry 4.0. Many production flows are designed to produce modular products using IoT technologies to establish a real time communication within an autonomous workspace. This allows a pre-fabrication of modules for a final assembly at a later production stage and shortens the lead time for products. Enabling modularity and the technology to manage an intelligent and autonomous production flow, the manufacturing industry seems to be ahead of the construction industry in this regard. An intelligent production system for modular construction products including complex product structures does not exist within the construction industry. By integrating sensors or identification labels to the pre-fabricated modules within the construction industry, the process of assembling will be faster and more structured.

2.2 Digital Twin Model Representation

The fundamental base for digitization of industrial processes is an appropriate information base, respectively a model representation that covers on the one hand side the specifics of particular sub processes and on the other hand side covers the digital thread throughout the lifecycle. The following subsections present the state-of-the-art for the two addressed domains.

Industry Foundation Classes and Model View Definition

In construction industry, the Industry Foundation Classes (IFC) standard DIN EN ISO 16739 [12], specifies schemata developed for exchanging and sharing data for BIM. IFC is not one specific data format but can be encoded in different formats. The IFC schema architecture is divided into Domain layer as the highest layer, Interoperability layer, Core layer and Resource layer, the lowest layer. In the Domain layer, entities are defined that are usually assigned to a specific discipline and used for intra-domain exchange. The Interoperability layer defines entities for products, processes or resource specifications that are used in more than one discipline and exchanged between different domains. The most generic entity definitions are included in the Core layer. A globally unique ID is assigned to every entity that is defined in the Core layer or above. The Resource layer includes all schemata of resource definitions. The standard is continuously updated for a better description of complex buildings or constructions [13]. The current IFC version 4.2 does not include infrastructural constructions like bridges, but IFC5 will support this infrastructural domain as well.

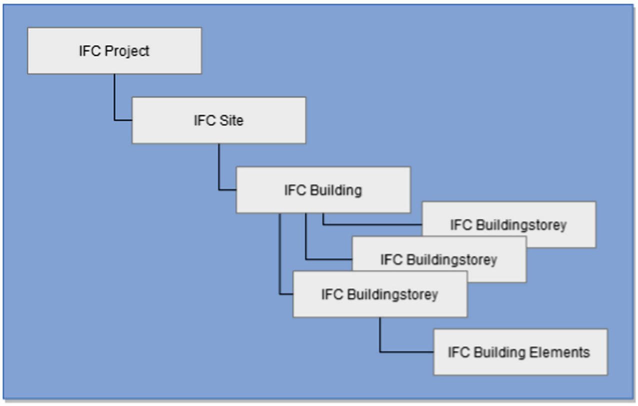

Fig. 2. IFC Tree-View [14]

In an IFC file, a building is structured into subsets. The subsets are arranged in a tree structure (cp. Fig. 2). Every IFC file has to contain one project and at least one site. It is possible to include more than one building in such a structure, but usually there is only one. Every hierarchy element lower than building is project-based and exists in more than one place in the file (for a better overview only one Building Element is pictured).

For each kind of building element, there is an entity that contains standard attributes and relations for describing the element. Due to this semantics, the building is structured and every single element with its attributes can be identified. A transferred or exchanged model cannot be changed or adapted, it is only a reference model. For exchanges, the creator of the IFC-file needs to change the model and export as well as re-distribute the new IFC-file again [15]. To cover prefabricated components IFC4precast [16] was introduced. The ifcElementAssembly is an element aggregated from different ifcElements. ifcElementAssembly includes attributes like the assembly place. With IFC4precast, a strong connection between CAD, MES and the production system can be realized.

When the exchange of models is required, usually the exchange file does not need to include every single information in detail. To limit the exchanged data, the concept of Model View Definition (MVD) defines the required data for a specific use case or workflow. Within MVD exchange specifications for IFC4 are given. There is a limited amount of official MVDs that are used as international standards. For the coordination of design between architects and structural domains there is a different MVD than for estimation of energy usage and costs of the building [17].

Reference Architecture Model for Industry 4.0 (RAMI 4.0)
The RAMI 4.0 standard DIN 91345 [18] specifies all essential terms around the reference architecture model. For a basic understanding, especially the terms asset, administration shell and service are essential. Asset is defined as any uniquely identifiable entity with value to the organization, whether it is an object, software, service or design. Thus, an asset does not have to be a physical object. Every asset in RAMI 4.0 is designed, created, used and disposed of and is therefore subject to a lifecycle according to the common understanding as described in the section above. But in this respect, the definition corresponds to the concept of the unit under consideration from the field of maintenance DIN 13306 [19]. Identification can be performed using indicators according to ISO 29002-5 or as a URI in the URN namespace according to RFC 3986 [20].

The information about an asset is digitally stored and provided in the so-called Asset Administration Shell (AAS), so that an Industry 4.0 (I4.0) component is created as a combination between an asset and its administration shell [21]. This relationship is illustrated in Fig. 3. The administration shell of an asset thus represents the holistic digital representation of an asset. Since the administration shell is also uniquely identifiable, an Industry 4.0 component is also uniquely identifiable as a composition of both elements, whereby a one-to-one relationship exists between the asset and its administration shell. The administration shell is divided into a manifest and a component manager-managed part. The basic idea of recursive asset description is also continued within the administration shell, as each administration shell contains the identifications of the asset and the administration shell itself in the so-called header. In addition, the identification and characteristics list for all submodels are part of the manifest part. Proprietary data models (CAD data, source code, etc.) are managed by the component manager, which can also provide interfaces in the form of services for other I4.0 components based on the submodel manifest.

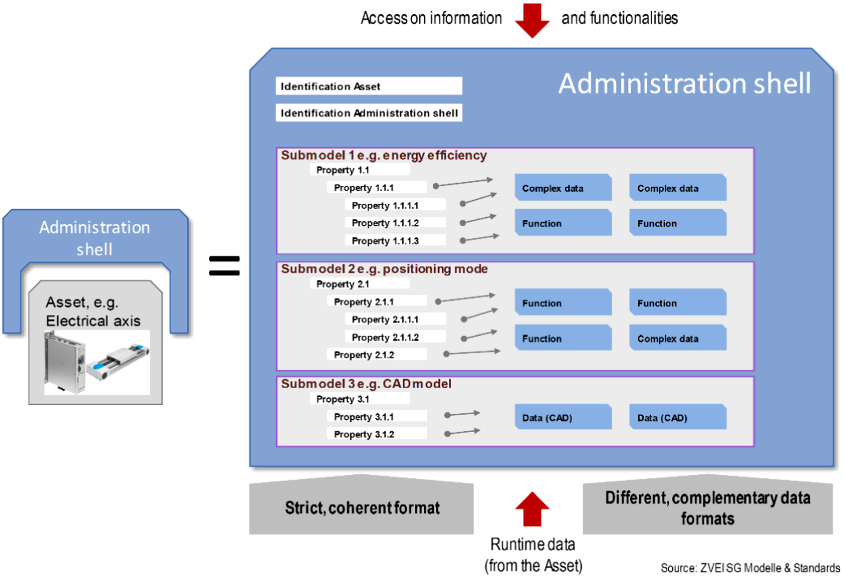

Fig. 3. Basic structure of the Asset Administration Shell - in reference to [22]

In this context, a service is a delimited set of functions that can be offered by an entity or organization via interfaces (APIs) with defined Quality of Service (QoS) properties.

The way an object is managed and thus, its publicity in the information system is independent of the object's ability to communicate. For example, an important device in a system can be managed as an entity even if it is not capable of communication. The tracking of its states in the lifecycle must then be done by external measurement and identification systems or by people themselves and stored in a separate, yet associated way.

Table 1. CP-classification for objects [23]

Communication	Publicity
4 - Service system-compliant communication	4 - administered as an entity
3 - actively able to communicate	3 - known individually
2 - passively able to communicate	2 - anonymously known
1 - not able to communicate	1 - unknown

Following to the notation in Table 1, the Communication/Publicity-classification (CP) of CP33 corresponds to an individually known entity with active communication capability, e.g. a classic field device with fieldbus connection. An entity that is monitored and managed in its lifecycle but has no communication capability whatsoever would have a CP class of CP14. An "I4.0 component" must conform to CP24, CP34 or

CP44. The combination of I4.0 components creates a new I4.0 component with its own comprehensive administration shell. This results in a recursive asset description that is capable of achieving any level of granularity, from simple components to a complete factory plant, as shown in Fig. 4.

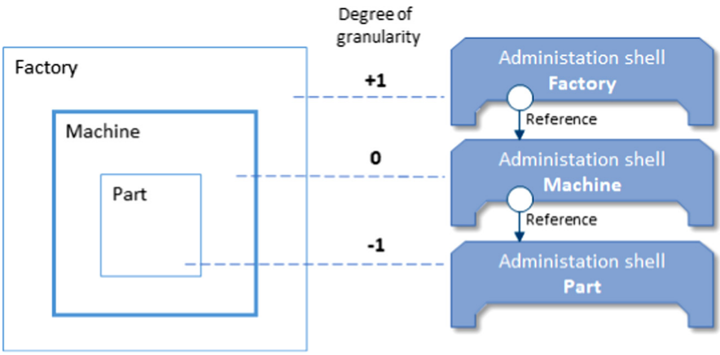

Fig. 4. Work on system design can be started at any level of granularity, structured in reference to RAMI 4.0 [24]

3 Domain-Specific Requirements

Modular construction methods with freely formable high-performance materials are the key to enable integration in industrialized flow process fabrication. Modules have high repetition rates and scalability, making them ideal for industrialized series production in modern flow processes. The advantages of series production known from manufacturing industry can be leveraged. i.e. production speed, geometric and material accuracy, durability and resource conservation through optimization. At the same time, buildings become changeable over their lifetime by exchanging or adding modules. Construction projects that utilize industrialized manufacturing and pre-fabrication processes impose different and extended requirements on DT concepts, particularly model representation and lifecycle information management that go beyond the current scope of BIM in the construction domain and PLM in the manufacturing domain.

Requirements, which have to be regarded and mapped in the sense of a consistent digital thread can be divided into the following categories that reflect the key unique characteristics of the process under consideration:

- Modularity
- Adaptability
- Material
- Manufacturing and pre-fabrication process
- Transport and assembly processes (on construction site)

Modularity: The idea of modularization is based on the possibility of realizing a large number of product variants at low costs using semi-finished components under the criteria of standardization and interchangeability. Modularization brings inherent variability. Modular development attempts to present an external variety of products to the customer, while at the same time limiting the internal variety of product solutions and technical systems. The principle here is the multiple use of subsystems in different configurations. Two approaches are possible: Construction of the structure from known modules (bottom-up) and modularization of the support structure into parametric modules with explicit characteristics (top-down). i.e., either the shape of the overall structure is determined depending on previously defined basic modules or the overall structure is broken down into similar basic elements.

Both ways impose demands on variant management within the DT and require furthermore the implementation of the product type and product instance concept.

Adaptability (Including Scalability and Compatibility Aspects): As mentioned above, modularization is the division of a whole into individual components (modules, segments, building elements), which interact via their interfaces (for building elements: physical points of contact and joints). Modular building structures will become increasingly adaptable over time, i.e., individual elements can be exchanged or maintained. Structures that can be changed by means of minimally invasive structural adjustments according to plan will be created in order to be able to react to changes that were not expectable at the time of planning, e.g. climatic conditions, traffic increases or the necessity for expansion. Equipped with sensory intelligence, these cognitive module systems can for instance communicate their stress or degradation characteristics during use phase. Furthermore, active building structures with the possibility of transient optimization and adaptation over their lifecycle can be created.

The DT has to consider this adaptability aspects, lifecycle spanning in the forward and backward direction. The model representation has to cover both, the prevailing boundary conditions (load assumptions, material properties, manufacturing tolerances, installation quality), which are often subject to uncertainties, as well as the phase time series data capturing actual conditions and reflecting deviations between planning and use phase.

Material: High-performance concretes with carbon or glass fibre reinforcement offer a high potential for freely formed, weight-minimized components and enormous durability high corrosion resistance. Compared to conventional concrete construction, it can take higher loads or save material significantly. Furthermore, improvement strategies are available to do justice to the new material through a targeted material distribution as well as structure or topology optimization. This leads to better material utilization and less waste.

On the other hand, proper material modeling within the DT plays a vital role, since high-performance on the one hand side also means high dependability of the material properties and composition. Quality assurance does not only comprise geometrical aspects but also material micro structure, cavities, particle distribution etc. This has to be reflected in the DT as well as for instance heat treatment.

Manufacturing and Pre-fabrication Process: The state-of-the-art building process has a largely handcraft character. Therefore, it is error prone, associated with long construction times and exposed to high geometrical and material scatter and thus inaccuracies due to weather conditions. Faultless series production with a high degree of individuality of the assembled end product can only be achieved with the consistent digital interlocking of all production steps. The entire value-added chain has to be supported by means of intelligent and digitally networked systems, which also includes the subsequent use phase of the building. CPPS are able to optimize themselves through a continuous flow of information and thus, in complex processes with high tolerance and precision requirements they can recognize errors early on and avoid waste and defective products. Today, BIM and IFC are already frequently used in industrial prefabrication of components in stationary production facilities (e.g. steel construction, form work construction, automatic bending machines, welding robots, etc.). Within Computer Aided Manufacturing (CAM), individual manufacturing steps for automated production are defined on the basis of digital component models.

Nevertheless, a major challenge is the efficient definition of the CAM processes for special and individual components with the required modular precision, particularly the linking of all process steps in the DT, starting at the design level up to production with reduced losses due to manual interfaces. This includes concepts of concreting and form work with high demands on precision and re-usability in production, adaptivity and scalability both at module level and component level (reinforcement). The representation of the required semantics in the DT, based on existing IFC constructs or similar concepts is required.

Transport and Assembly Processes (On Construction Site): As the core idea is to reduce individual building structures to scalable basic modules, i.e. to combine uniqueness with adaptive series production, the construction activity on site should be minimally short and be reduced to the assembly of the modules to the structure. Keeping this in mind, special attention is paid to the interfaces between individual modules, i.e. the formation of joints. Depending on the modularization method, different force transmission requirements are made via these contacts using different geometric shapes (e.g. rectangle, finger joints, undercut toothing (puzzle), etc.) reflecting the particular load and use demands as well as pairing strategies and tolerance compensation approaches.

The geometric definition within the DT has to cover and represent semantics of such joint definitions. Regarding transport, sequencing strategies for component delivery, based on data or the pre-fabrication process is required, taking into account batch and cargo capacities, which are often the limiting factor in construction industry.

4 Draft Concept for the Administration Shell for Digital Twins

As seen in Sect. 2, there has been huge progress regarding standardization in both mentioned industries. On the one hand, the IFC standard for BIM data exchange currently provides four layers for data structuring. Furthermore, the state-of-the-art for BIM data models comprises five dimensions (3D-CAD, time, costs) as shown by the performance levels of BIM integration. On the other hand, RAMI represents a generic approach to cluster technology in the context of Industry 4.0. This reference architectural model is based on a variety of industrial standards. The three-dimensional cube of RAMI characterizes modern industrial technology by different hierarchy levels (IEC 62264, IEC 61512), the lifecycle and value stream (IEC 62890) and six layers to describe the digital information model on an abstract level [21].

The classic product lifecycle in construction industry is a unidirectional approach without digitally providing information from the lifecycle back to the early phase of development. Moreover, the RAMI model differentiates between type data (development) and instance data (after development) in order to establish an efficient flow production by creating many instances from a single type. For construction products this relation is very different. Due to the uniqueness of each project there will usually be only one instance with one type data set of the product itself.

As stated earlier, the goal of the proposed approach is to use a streamlined production for modules made of high-performance concrete that combined form individual structural parts, which would otherwise be produced monolithically on site. Figure 5 shows an example for a wall element ("Building Element 001"), which consists of several concrete modules. Through this approach, each module will have an identifiable type with several unique instances. This way, modularity enables an industrial flow production for individual construction projects.

Yet, the classic PLM approach for construction projects needs to be adapted in order to implement digital consistency through the use of an Asset Administration Shell (AAS).

The AAS must consist of integrated and adaptable data and interaction models, e.g. services, and provide semantics by structured and standardized methods via its component manager (cp. [21]). IEC 61360 specifies four main types of data properties (identification, semantic, value, relational). ZVEI uses these properties to make a proposal for the structure of a digital AAS and defines specific data-wise requirements, e.g. the AAS must consist of a minimum number of properties [21].

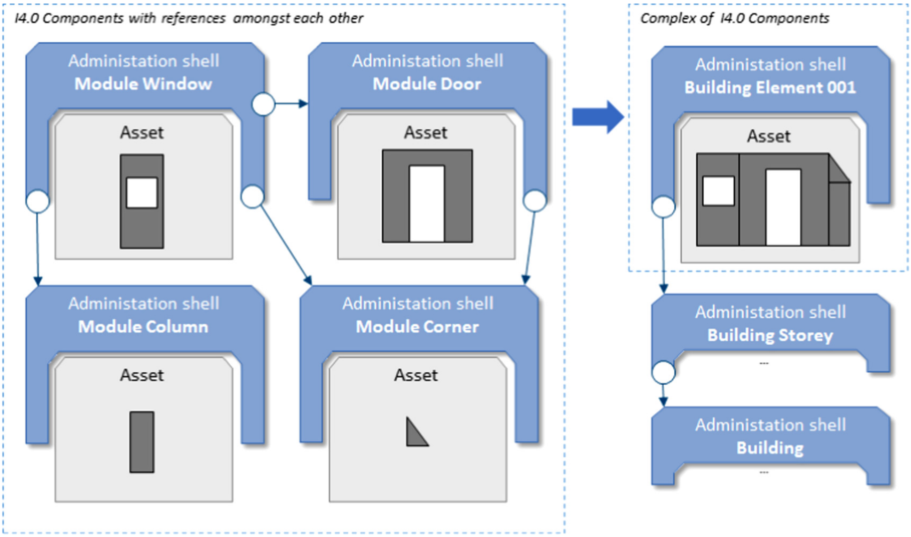

Fig. 5. Exemplary building element made of prefabricated modules - in reference to [24]

To structure data objects, four property classes are derived (basis, obligatory, optional, free) and references from each property to at least the data and functionality within its AAS are mandatory. These ideas act as a set up guideline for an AAS for the DT of construction assets. To manufacture concrete modules efficiently, data properties can be stored in digital containers within their individual AAS. The AAS then contains an arbitrary amount of submodels. These submodels describe different aspects of the asset. The details and information of every submodel is specified by various specifications. To apply the AAS for construction industry, some more specifications need to be considered. IFC with its entities and attributes helps to describe every single element of a building. This information is necessary for different submodels of the AAS. For example, the attributes of a wall specified in ifcWall are relevant for submodels of a building, e.g. energy efficiency, configuration, engineering. All specific attributes need to be considered in submodels.

Each submodel needs to be allocated in the basic's views with attributes, data or functions. The basic views are Business, Constructive, Performance, Functional, Local, Security, Network view, Lifecycle and Human. In construction industry MVD specifies standard views and the attributes, data and functions of every element in construction industry for specific usage. To cover all basic views, MVD needs to be added to the basic views of DIN SPEC 91345 to apply the AAS for construction industry. In Fig. 6, an example of AAS with certain submodels and relevant specifications is shown. Based on ZVEI's figure, the previous mentioned specifications were added.

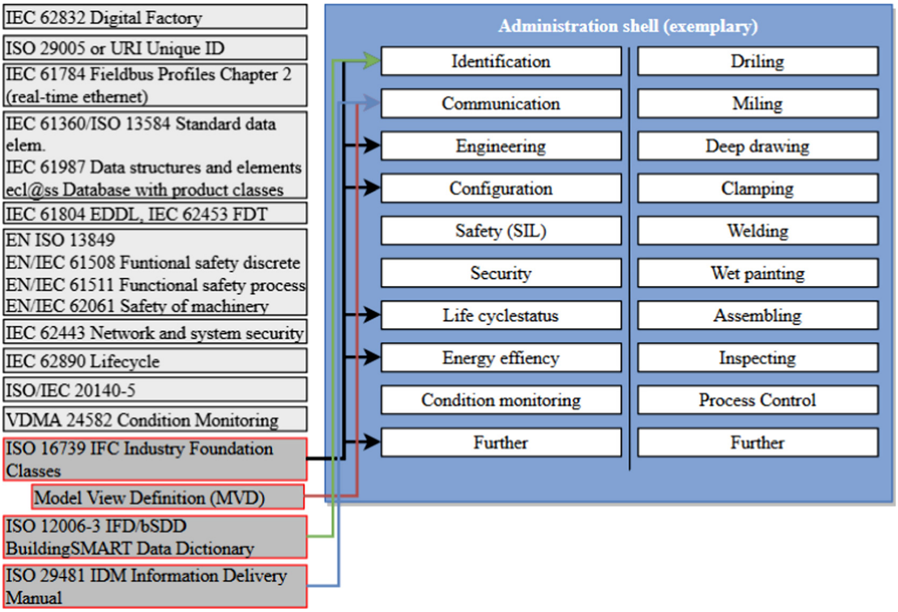

Fig. 6. AAS with submodels and relevant specifications - in reference to [24]

During construction phase, the AAS acts as a reference model to realize a fast and efficient building process in order to save time, foster transparency and reduce costs. At the stage of product usage, the administration shell represents an integrated, updated, digital model of the product, enables a formal and structured way of storing and adapting product data, as well as turning a building or bridge into a cognitive product-service system.

5 Conclusion and Outlook

Industrialized pre-fabrication of modules made from high-performance concrete materials open new opportunities for construction industry in terms of cost and time savings, quality and sustainability. The presented paper provides a technological insight of the construction and manufacturing industry regarding engineering and production processes as well as the product lifecycle management. While construction industry is dominated by individual engineering to order processes, manufacturing industry faces any kind of engineering and production order from one piece to mass production. In order to successfully apply the approach of pre-fabrication of modules from manufacturing to the construction industry, an interdisciplinary technology transfer needs to be considered. Therefore, industrial standards and guidelines for digital information management from both industries must be analyzed from an integrative perspective to set up a modern concept of a DT representation model. More precisely, RAMI and its AAS need to be merged with standards in construction industry like IFC.

One scientific contribution of the work in the mentioned project will be the development of a product lifecycle concept including the creation of an AAS for concrete modules in construction industry under the mentioned requirements. The first step of is to identify a reasonable number of generative modules for the construction of a high number of buildings and bridges. The second step is to set up a digital AAS for each module and establish a digital data transfer between different AAS. This will include the elaboration of an ontology for digital representation models. While modularity allows mass production, the DT of these modules establish digital data management and a more efficient engineering and production process in the construction industry.

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