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# Digital Platform for Affordable Housing – a Framework Proposal

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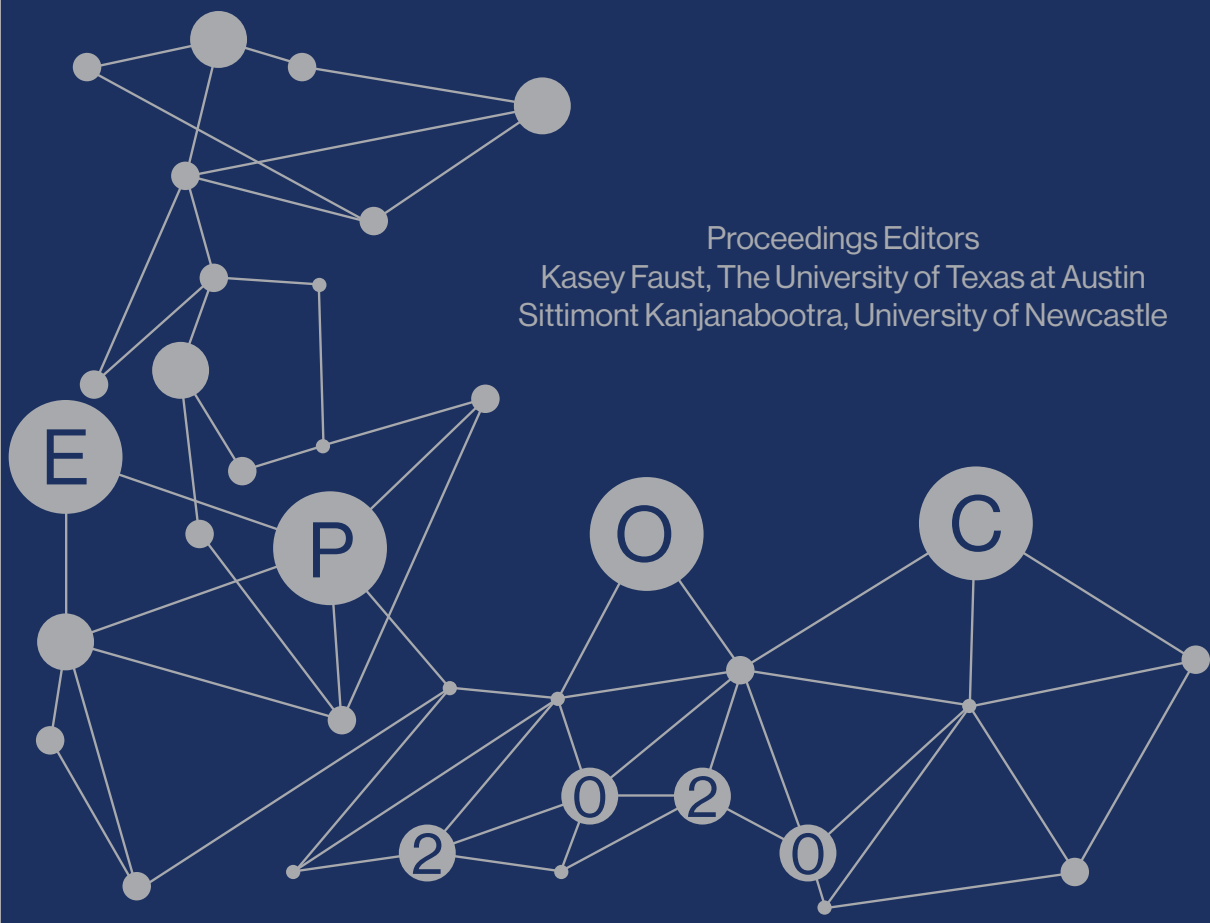


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# DIGITAL PLATTFORM FOR AFFORDABLE HOUSING THROUGH RESEARCH LED TEACHING

Iva Kovacic, Sophia Pibal, Julia Reisinger, Maja Lorbek [1]

**ABSTRACT**

With increasing global urbanisation and thus related increasing housing demand, the need for affordable housing is becoming one of the major societal issues. This trend has led to a resurgence of the modular, off-site housing construction which stands in close relationship with digitalisation and digital fabrication in the AEC industry. However, digital technologies have not yet been fully incorporated in the design and construction processes for off-site modular fabrication, despite their potential for both accelerated as well as cost and material efficient housing construction. As computational tools and BIM enhance involvement of all relevant actors across the value chain, these technologies have significant potential for enabling mass customization and participatory design in the layout of individual dwelling units and the distribution of non-housing uses within multi-storey housing buildings.

This paper presents the ongoing research project "WOHNEN 4.0"[2] – which aims to develop a digital platform **"Housing 4.0";** based on coupling of various digital tools and databases, as well as on **integration of processes and actors** involved in the design, construction and use of multi-storey housing, including architects, construction companies, housing associations and property developers and inhabitants in Austrian context. Thereby, the potentials of BIM for modular, off-site housing assembly in order to improve planning and construction processes, reduce cost and construction time and allow for mass customization will be explored.

The digital platform **"Housing 4.0"** is based on coupling of digital applications "**BIM4D2P" (BIM for Design to Production)**, "**PHD" (Parametric Habitat Designer),** with a joint digital knowledge base containing all relevant parameters for design and construction. "BIM4D2P" acts as an interface between design and construction and enables interdisciplinary BIM data exchange without data losses, as it is based on common data structures. "PHD" is designed to generate and visualise floor plans and buildings automatically and to calculate investment cost and return of investment. Additionally BIM-modules (digital object libraries) and joint data structures for data-exchange across the value chain will be provided; as well as systematical categories of parameters for off-site modular construction types and requirements for adaptability and flexibility in modular fabrication. The novel approach in this project is user-involvement; which has been neglected in recent national and international projects on off-site, modular construction supported by digital technologies.

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**Keywords**: Social Housing, BIM, Digital Prefabrication, Modular construction

## INTRODUCTION

With rapidly rising urbanisation - 66 % of world population will be living in mega cities till 2050 (UN DESA 2015) - the need for affordable housing is urgently increasing. Industrial prefabricated construction is thus currently experiencing a renaissance. Industrialized housing has long tradition, usually related to the unpopular anonymous image of mass-produced concrete pre-fab elements (Plattenbau Siedlungen) and lack of individualization. However, the last generations of modular, prefab multistory housing, are characterized through more participative and individual design enabled through the digitalization of design and fabrication process (Meuser 2019).

In order to ensure efficient process along the value chain, the interface between planning and fabrication requires particular attention already in the early design stages. BIM based design to fabrication bears thereby high potentials for achievement of efficient digital design to fabrication process, as the digital building element catalogue can be transferred in the digital production (Pasetti Monizza at al. 2018). Through the serial, industrially digitally fabricated housing significant saving effects can be achieved through use of standardized building elements in high number; however with individual floorplans according to users' needs.

The increasing impact of digitalisation will lead to a crucial transformation in the AEC industry while the demand for affordable housing has led to a resurgence of the modular, off-site housing construction. However, digital technologies have not yet been fully incorporated in the design and construction processes for off-site modular fabrication, despite their potential for both accelerated as well as cost and material efficient housing construction. As computational tools and BIM enhance involvement of all relevant actors across the value chain, these technologies have significant potential for enabling mass customization and participatory design in the layout of individual dwelling units and the distribution of non-housing uses within multi-storey housing buildings.

This paper introduces the Integrated Framework for digital platform **"Housing 4.0";** which aims to support designers, planners, developers, housing associations and users in creation of affordable housing, thus integrating processes and actors.

**"Housing 4.0"** consists of several interlinked applications: "**BIM4D2P" (BIM for Design to Production)** and "**PHD" (Parametric Habitat Designer),** and a joint digital knowledge base containing all relevant parameters for design and construction of affordable housing in Austrian context. "BIM4D2P" acts as an interface between design and construction and enables interdisciplinary BIM data exchange without data losses, as it is based on common data structures. "PHD" addresses promarliy the users and developers, and is designed to generate and visualise floor plans and buildings automatically and to calculate cost. Additionally BIM-modules (digital object libraries) and joint data structures for data-exchange across the value chain will be provided; as well as systematical categories of parameters for off-site modular construction types and requirements for adaptability and flexibility in modular fabrication.

Thereby, the potentials of BIM for modular, off-site housing fabrication in order to improve planning and construction processes, reduce cost and construction time and allow for mass customization will be explored. The novel approach in this project is user-involvement; which has been neglected in recent national and international projects on off-site, modular construction supported by digital technologies.

## POINT OF DEPARTURE

A steadily increasing demand for affordable housing in central urban locations represents the major challenge for the housing sector. In order to meet this demand, industrially fabricated housing is again becomming a hot topic in research and construction in European as well as in global context. In contrast to the serial, typologised prefabricated buildings from the 1970s ("Plattenbauten"), which were discredited through monotony, todays innovative housing projects rely on modular structures and modular design systems as well as on sustainable mostly timber based constructon technology. In this paper we use the terms modular construction, which stands for both room modules and building set systems based on particular modules or elements. The modular merhod will be selected in consultation with the planners and construction companies involved and with regard to the greatest possible flexibility and adaptability.

The high level of prefabrication – as a characteristic element of modular structures and building set systems – enables significant increase in the quality of constrution, and reduction in construction time and costs, in particular due to economies of scale. In Austria there are already specialized providers for modular (wood) structures as well as realized multi-storey housing blocks. However, the potential of digital technologies has neither been used in planning nor for realization of modular housing in Austria or in the D-A-CH area (Germany, Austria, Switzerland) to date. The use of digital tools in modular multi-storey housing enables the optimization of planning and construction processes as well as the validation of the individualization and adaptability of modules and buildings in various construction systems (e.g. concrete or timber).

Digital building models allow quick design reviews and generation of several variants for flexible and quickly adaptable layouts in a variation of different structures.

Demographic change, spatially disparate development, migration and re-urbanization lead to an increased demand for affordable, immediately available housing in metropolitan areas. Newly arriving, highly mobile professionals from Austria and abroad as well as newly established households (young families, couples after the family phase, young and older single households) compete for a very restricted segment on the housing market: private rental apartments in old building stocks and used apartments.

New housing units appear only after construction period of two years on the market. The continous zuzug in the growing cties, affordable leases as well as competition between private developers and housing associations lead to steadiliy increasing prices at purchase of new as well as existing real estates and building slots (Mundt and Wagner 2017, Statistik Austria 2018).

The issue of "affordable housing" is highly relevant in the growing urban agglomerations. Due to the trend towards joint housing – such as joint building ventures (**Baugruppe** in German), co-housing and cluster apartments – participation is becoming increasingly important even with more traditional forms of housing. By individualizing the particular housing units and buildings, the trend towards participation – as one of the most important "housing trends" – can be anticipated. Sustainable use of resources as well as the steady change in household constellations and changes in user preferences require greater attention to adaptability and flexibility during the life cycle of new housing structures.

## STATE OF THE ART

The AEC industry is currently undergoing a digital transformation. The processes in the real estate industry (planning, building, operating) are increasingly digitalized along the value chain. However, in order to be able to use the full potential of information and communication technologies, it is necessary to integrate and couple the particular digital processes as well as all stakeholders. Especially the coupling of planning and construction - from design to production - has the potential to revolutionize one of the most important challenges of our time and one of the basic needs of our society - the creation of affordable housing. The use of Building Information Modeling (BIM) and digital tools in planning and industrialised construction should enable significant reduction of the construction costs and time, as well as ensure the increasingly required flexibility and adaptability of the layouts and buildings.

Industrialized construction is currently experiencing a renaissance due to the increasing urbanization and the growing need for affordable housing in central urban areas.

According to Li et al. (2019) Prefabricated Housing Production (PHP) has potential to overcome the low productivity and poor environmental performance of the AEC industry (Wu et al. 2017) by using the idea of industrialisation during the construction's lifecycle.

Industrial housing underwent in its development five generations (Ågren and Wing 2014). The first four identified generations are building, building section, housing unit and component catalog (Meuser 2019). The last, the fifth generation of industrial housing is based on the individual design, which is then divided into prefabricated elements (Meuser 2019). Individualization, which is becoming increasingly important especially in the field of multi-storey housing, though means less automation and a retardation of the planning process (Lidelöw 2017). The digitalization of the planning processes based on digital platforms and the use of parametric modeling enables a participative and individualized design in modular, prefabricated multi-storey housing. According to Nasereddin et al. (2007) "modular construction should produce a higher quality home delivered to the customer faster at lower cost".

In industrial prefabrication digital production techniques are standard in most companies. However, this increase in production efficiency requires time-consuming data preparation. The exchange of data between production companies and planners is usually associated with more time and higher costs, since information is often not created compatibly and has to be elaborately reworked. Often the data even has to be regenerated. In order to be able to guarantee an efficient, digital data chain, special attention must be paid to the interface between planning and production in the early planning phase. This can be achieved through 3D models and BIM as planning method, since all building elements (digital twins) to be produced can be forwarded directly to digital production (Matcha and Ljubas 2010).

To merge numerous requirements of customized housing, Benros and Duarte (2009) propose an integrated system which allows to easily visualize a model and automatically generate the information required for production.

In serially produced, industrialized housing, the production of large numbers of the same products offers significant potential for savings. Also the "invention of a new detail" can be omitted. By using BIM as planning method, long-term cost reductions can be achieved due to the omission of constant adaptation in planning in the planning process. Planning and production optimization can be achieved at best with

independent open source systems and thus real industrialized construction (TU Munich 2018).

## REALISED MODULAR PILOT PROJECTS

In Austria there is already a number of providers for modular structures, even in multi-storey housing. Examples for realized buildings are among others Kaufmann Bausysteme (2020) based on wooden room modules (room cells) One of the most important system providers for timber constructions is Lukas Lang Building Technologies (Lukas Lang 2020) which is based on prefabricated, small-scale components.

Several comprehensive studies on industrial housing, such as by Meuser (2019) or Albus (2018), provide an overview of different technologies and case studies of multi-family housing in Europe, Russia and Asia. In both studies the topic of digitization of planning processes is barely discussed. Albus focuses on automation in production without a connection to planning, while Meuser points out the potential of the individually configured building using BIM, but the use of parametric modeling when presenting realized projects is not described systematically.

Especially in Germany there are significant improvements and innovations in modular structures today. This is referable to the general agreement on new construction of multi-storey housing blocks in serial and modular structure between the Federal Ministry of the Interior, Building and Community (BMI / formerly BMUB) and the GdW, the umbrella organization for the housing industry, planners and the construction industry (GdW 2018).

The study "Serial housing" (“Serieller Wohnungsbau”) (Hauptverband der Deutschen Bauindustrie e.V. 2017) assesses a large number of realized projects, showing that BIM was only used in few projects and was partly limited only to the planning process and not to the whole value chain.

In the research project "Building with a far-sighted system building set for industrialized social housing" (TU Munich 2018), focused on assessment of BIM based digital planning methods for modular structures in terms of cost, quality and time potentials. It was found that "only a specific system building set (e.g. precast concrete structure) is developed, since structural design, building physics and fire protection properties of different building systems differ greatly and a complete parameterization cannot (yet) be managed" (Winter et al. 2018).

## BIM FOR PREFABRICATION

There is still little research on BIM implementation in industrial fabrication in the AEC industry and a knowledge gap for BIM for production (off-site production). Previous research has focused on the topic of BIM objects and their graphic and non-graphic content. BIM application and the workflows within the production companies, the interfaces and interfirm data exchange functionallities have not been discussed to date (Dawood et al. 2016).

In a study Hamid et al. (2018) at first showed how BIM objects can be embedded with fabrication semantics and then utilized to facilitate the workflow between designer and manufacturer. The developed knowledge-rich BIM objects – generated in the first step through using the domain knowledge of the fabricator – support the designer as well as the manufacturer by providing automated activities within the workflow. Thereby it, among others, reduces the need for design reviews and automating part list calculation.

Mostafa et al. (2018) state in the Australian context that BIM has an enormous impact on the AEC industry, but the use of BIM for prefabrication is minimal. According to the study authors, the minimization of planning errors, agreement between planning and execution, early involvement of crucial stakeholders in the processes and mass customization are the main advantages of using BIM in prefabrication (Mostafa et al. 2018). The study, which is based on a survey of key stakeholders in Australia, also found that BIM was already appreciated as a visualization tool and knowledge database when prefabricating housing blocks in Australia (Mostafa et al. 2018).
Pasetti Monizza et al. (2018) considered the potentials and problems of parametric and generative design techniques in off-site production (mass production) in AEC industry by means of the glued laminated timber (GLT) industry. The results show that through using parametric algorithms in GLT manufacturing improvements in manufacturing efficiency and also in production efficiency can be determined. Due to the lack of industry 4.0 approaches in the conventional GLT value chain, restrictions also had to be taken into account
Also in the field of timber – in this case cross-laminated timber (CLT) – Bianconi et al. (2019) developed a web-based design space catalog with an intuitive interface which enables customers who are not typically into programming and computation to model and find forms taking into account defined parameters. Like Pasetti Monizza et al. (2018) they also see limitations in sharing information of wooden construction sector through heterogenous software.
Besides the timber construction sector, research is currently conducted in the field of using a wider range of experimental materials – like glass casting (McGee et al. 2012) or clay forming (Friedmann et al. 2014) – and new manipulation techniques (e.g. robotic metal forming (Shobe et al. 2013, Raspall 2015)).

### AUTOMATED FLOOR GENERATION

For the development of automatic floor generator tool (PHD) the Visual Computing und layout generation and optimisation will be used. Parametric design of architectural models is mainly used in computer games, VFX in films and in advertising. The most important methods for exterior facades are based on split rules (Wonka et al. 2003) integrated into symbolic shape grammars (Müller et al. 2006). Müllers CityEngine has developed as an industrial standard for generating large-scale city scenes. The basic idea was later enhanced to represent more complex forms (Krecklau et al. 2010, Schwarz and Müller 2015).
User-friendly operation remains still a major issue (Lipp et al. 2008, Silva et al. 2013). Previous research on BIM-based off-site production (ODP) is mainly focused on the process optimisation through reduction of cost and time while neglecting user requirements regarding adaptability and flexibility, nor integrating the principles of participant design. Previous projects, mainly conducted by construction companies and producers of off-site modular elements, thus lack to integrate both the user perspective as well as the perspective of architectural design, which enhances spatial, functional and social qualities.

## FRAMEWORK PROPOSAL

Research project "Housing 4.0" focuses on the integration of digital technologies in planning and fabrication of modular, however according to users' through lifecycle changing needs, flexible and adaptable multi-storey housing. Next to the exploration

of potentials of digital technologies for design and fabrication of modular structures in multi-storey housing, this project is based on exploration as well as on nhancement of cooperation of various actors in realization of housing projects - planners, construction companies and manufacturers, as well as users, housing associations and developers. Thus the involved project partners include next to academic partners also construction companies from housing sector, a large design and planning office, a specific user group – a **joint building venture association (**to be reffered as **Baugruppe) -** and an consultant **-** coordinator of the **Baugruppe.** Through cooperation and input of specific domain knowledge (design, fabrication, usability) the plattorm should satisfy the actors' needs in terms of both usefulness and usability as the tools will be optimised by actors as both co-creators and testers.

As particular focus is on participatory design together with flexibility and adaptability of housing units during the whole life cycle, a particular user group, simultaneously acting as a client was chosen – a joint building venture association.

The joint builing venture association stands for a joint housing form, where a group of citizens in joint effort designs and builds own habitation space and environment in participatory manner. There are numerous examples of sucessfull realized joint building venture projects in Germany and increasingly in the city of Vienna, as a form of subsidised housing. There are numerous, mostly complex models regarding delivery of such projects – where as the association can act as investor, and a building is in joint ownership; or a housing developer is found as an investor, and the group is a client and future tenant. Currently, the most challenging issue represents the accessibility to affordable building sites, therefore the city of Vienna explicitly dedicates parcels within new city developments, thus supporting this housing form (Gemeinsam Wohnen 2020). The joint building venture association was chosen as a user group with the highest requirements for participatory design in order to assess of the housing- and construction-specific requirements and restrictions.

Digital platform "Housing 4.0" (Figure 1) consists of several interlinked applications: "BIM4D2P" (BIM for Design to Production) as design, planning and fabrication support-tool; "PHD" (Parametric Habitat Designer), as visualisation and habitat generation tool for users and developers; and a joint digital knowledge base containing all relevant parameters for design and construction of affordable housing in Austrian context.

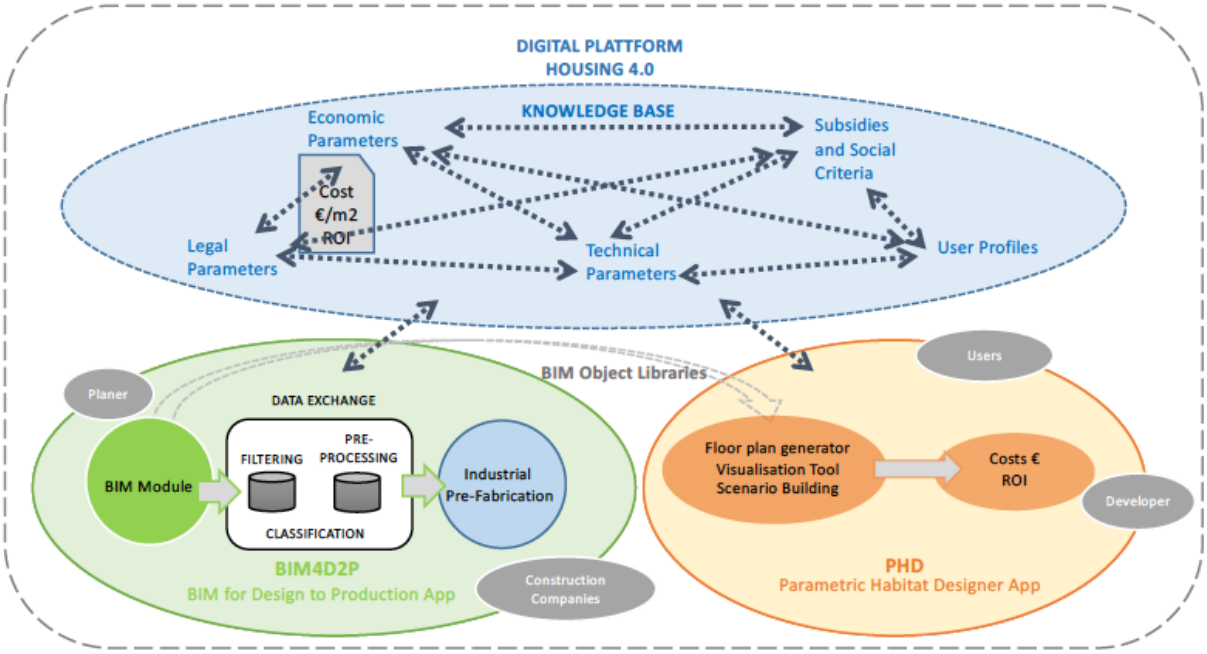


Figure 1: Digital platform Housing 4.0 with modules BIM4D2P; PHD and a joint Knowledge Base

- Knowledge Database
  Affordable, social housing is spanned within numerous, complex interactions of policy making regarding city planning and social sustainability, constructability in terms of both building codes and economic dependencies (subsideis, financiability, returns of investments) and finally, user preferences and lifestlyes and changing requirements along lifecycle. The Vienese social housing model is rnown across the world, however represents a complex system of regulations, reflcted in spatial, social and economic interactions.
  Therefore an extensive database consisting of numerous parameters offers information on the one side, and represents constraints and rule sets for additional apps on the other.
  Thereby the Viennes building code and further legal parameters (energy efficiency directive and technical directives (OIB 2020), quantitative requrements regarding subsidies and regulations (eg. max. allowed number of rooms according to the number of inhabitants, max. incomes etc.), regulations and restrictions regarding maximal construction costs, and user profiles (as defined by subsidy policy) will be assessed and reflected in stored in the knowledge base as qualitative and quantitative information. Thereby the quantitive parameters build a base for the algorithm of automatic floor generator within PHD tool.
- “BIM4D2P” acts as a planning and fabrication support application and an interface between design and construction. Thereby interdisciplinary BIM data exchange without data losses, based on common data structures should be enabled. The joint data structures will allow interdisciplinary data exchange of

the BIM-Modules as digital object libraries. These digital object libraries for planners and industrial fabrication are intended to support a largely optimized and semi-automated production of housing modules and components.The framework and methodology for the **BIM4D2P App** form the basis for the digitization of the design-build-operate process.

- BIM-modules in form of digital BIM modules and components (digital object libraries) reflect the modularity concept, an object standing either for room module or an building element such as slab, wall, pillar. BIM-modlues and their characteristics: parameters (geometry) and attributes(properties) will be created in harmonisation with buildingSmart Data Dictionaries (BSDD 2020) Joint data structures for data-exchange across the value chain will be provided; as well as systematical categories of parameters for off-site modular construction types and requirements for adaptability and flexibility in modular fabrication. An essential goal is the conception and creation of digital object libraries (BIM modules) including relevant parameters and data structures, which enable semi-automated data transfer to PHD as well as the development of the methodology for the automated generation of floor plans.
- The **PHD (**Parametric Habitat Designer) App allows automated generation of floorlayouts and visualization is aimed at both users and real estate developers and is also. The algorithm for the PHD as an automated layout generator and a visualization tool builds up on the needs of the users, is linked to the BIM4D2P object libraries and components thus obtaining geometry and parametrics of the BIM objects; and extracting knowledge base generated rule sets from the legal, and technical parameters acting as constraints.
  PHD generates the layouts and the distribution of the housing units as well as non-residential uses in the building, taking into account the parameters (technical, legal-normative requirements and restrictions) and the user requests. Thereby planning optimization for the needs of specific user groups as well as checking the adaptability during the life cycle of the building (changing the housing mix, hybrid uses, etc.) using parametric variants is enabled. The PHD App with layout variation and usage distribution in the building is linked to the cost benchmarks. Both rapid visualization of user needs as well as cost optimization allow increasing the return on investment for real estate developers.

## DEVELOPMENT OF DIGITAL PLATTFORM PROTOTYPE

The digital platform “Housing 4.0” development is structured in several phases:

- Concept and modelling of Knowledge Base and PHD Modules,
- Pilot Use Case for generation of BIM-objects and parameters
- Testing and evaluation of PHD through user group
- Implementation of BIM4D2 module
- and finally Testing and Evaluation of the Platform “Housing 4.0”

Currently the project is in the second stage, where as the Use Case has just been completed and evaluated.

## CONCEPT AND MODELLING OF KNOWLEDGE BASE AND PHD

In the first phase, the focus lies on conception and modeling of the joint knowledge
Thereby an extensive review of the building code and subsidy regulations was conducted, and coding of relevant building codes was undertaken. As Vienese building code, as most of the building codes was not designed to be machine readable, there are difficulties with more qualitative, intuitive pararaphs. Easier to code has proven to be the technical and energy efficiency guidelines as these already provide either concrete key performance indicators or standardized calculations procedures.
Using a pilot case – the real housing project of the joint building venture association (Baugruppe) called Gleis 21 - the BIM models according to the functional specification and space program of the association and particular user needs, as well BIM modules were generated.
By using a real project specific restrictions, such as the respective building regulations, requirements of the area zoning plan, country-specific regulations with regard to subsidized housing etc., come into effect.
For design and generation of BIM models and BIM modules of the particular use case Research led Teachnig Approach with students was applied – thorugh interdisciplinary BIM Design Studio:BIM_Home.

## PILOT USE CASE

The process-analysis for **BIM-modelling** of modular digital object elements and **parametric modelling** of rule-sets for PHD was conducted on a Pilot Use Case within Research led Teaching Platform „Interdisciplinary BIM Design Stuido“ in a one-semester course and simultaneously student competition called **BIM-home.** Through this approach, we continue and extend the methodological framework for Research led Teaching developed within Integrated Design Studios (Filzmoser et al. 2016, Filzmoser et al. 2017).
Based on particular requirements, real site and a client brief of a real housing project (Gleis 21) of the Baugruppe as client and user, as described above, the students developed design proposals for modular housing with requirement for maximal flexibility and maximal degree of prefabrication in future use. Figure 2 displays one of the student project-proposals for the pilot case, as BIM model.

Figure 2: Pilot Case, Project example BAUM home

Within 8 student projects proposals the digital object library for the modular, prefab digital elements was generated. Figure 3 displays the BIM objects and modules of the student-project BAUMHome.

Figure 3: Pilot Case, BIM Objects of Project example BaumHome

Further, based on the real use case the parameter catalogue for the technical and legal rule-sets and constraints for PHD was generated by the research team.
To guarantee for quality of obtained projects as well of BIM modules and to support the selection of BIM Objects and Modules for further processing, BIMhome is conducted as a student competition, with an independent jury. The evaluation and selection criteria are:

- Flexibility, defined as the ability of the primary structre to allow changes inter/and intra housing units throughout the lifecycle
- Spatial quality
- Grade of prefabrication
- Constructability and technical quality

The generated BIM objects will be enriched through cost information, eco-indicators, and recyclability and reusability information.

**TESTING OF PHD**

PHD will be tested for the integration of participatory design and the embedding of user requirements in the planning. To test and evaluate the PHD the Baugruppe including the involved architect will give feedback to the generated projects within IDS BIM_Home in particular regarding flexibility. Further on, these actors will also test the Beta version of the tool, thus generating floor layouts according the own needs.

The PHD can also visualize the representation of different housing combinations (housing mix) for housing associations and real estate developers.

### IMPLEMENTATION OF BIM4D2

The module BIM for Design to Producton should enable data transfer from planning into digital fabrication and manufacturing without data lossess. Thereby expert interview with manufacturers, construction companies and planners will be conducted in order to gras the processes and software used, as well as the needs regarding interfaces. Thereby joint data structures will be developed as wllas data exchange preocedures according to building smart, in oder to enable Open BIM workflows.
Using the generated BIm objacts in the previous steps, the workflows will be tested and opimized.

### TESTING OF DIGITAL PLATTFORM

Finally,through further use case – a new Baugruppe project at different location with different users, the digital platform “Housing 4.0” should be tested and evaluated by a) project partners from planning and construction companies as well as by b) users of the Baugrupe.
In a joint workshop with all actors feedback will be assessed, and the platfom optimised according to reported needs.

## DISCUSSION AND CONCLUSION

The presented framework for Digital Plattform “Housing 4.0” should allow for realization of affordable, prefabricated housing thereby considering user needs. Coupling of various digital technologies for planning and fabrication should allow more time and cost efficient construction.
The expected project results are:

- The framework for the digital platform "Housing 4.0" and as well as tested and evaluated BIM4D2P and PHD prototypes
- Information-rich digital object libraries (BIM modules)
- Integrated planning methodology and digitized design-built-operate process
- Systematically created parameter knowledge base for prefabricated modular multi-storey buildings
- Parameters for the requirements of flexibility and adaptability for modular structures based on the evaluation of pioneering layout typologies and on the basis of the participatively generated design from the case study
- For the pilot case, it was assumed that the constructional implementation of modular multi-storey buildings would be carried out by general contractors in close cooperation with the planners. General contractors are more able to exploit economies of scale than individual, highly specialized companies. This assumption is based on the hypothesis that, in contrast to specialized construction companies, general contractors would rather rely on the openness of the digital platform (interoperability). Long-term business relationships between general contractors and subcontractors therefore also promote the indirect participation of small and medium-sized companies on the digital platform. Therefore, for the proof of concept, cooperation and joint parametric modeling by planners and general contractors is analyzed in more detail.

> However, the conceptualization of the digital platform should enable equal participation of companies and planners, regardless of company size.

The first results show that for the coding of legal rules is needed for PHD and automation of floorplan generation is challenging and facing numerous difficulties regarding the interpretation of legal codes.
Furter on, the Baugrupe, as the housing form wit highest degree of participation represents a very specific user profile, which is not representative for housing market at large, and also requires a set of own legal rules and exceptions.
The projects and models generated in the pilot use case have shown that prefab timber construction shows numerous advantages in terms of ressources afficiency and reduction of emissions, however displays several deficits regarding constructive properties in terms of acoustics, in dealing with moisture and finally fire protection. In order to satisfy the current standards and also to guarantee for the performance, additional constructive measures must be undertaken (e.g. Vorsatzschalen for acoustics) which cause additional cost, thus disabling cost optimisation in terms of affordability. Currently the technical codes as well as building codes are mostly based on the prescriptive approach which leads to more expensive solutions – the question arisies if the simulation based approach could be more cost saving allowing for "non-standardised" solutions?
As the integraated planning is still scarcely implemented in the planning practice and the efficient design to industrial fabrication processes (off-site production, prefabrication) are not yet established. Thus, the objective of Housing 4.0 is both the development of an integrated method and the optimization of the BIM-based planning and construction processes by creating common data structures, open interfaces and the standards for the creation of common object libraries (BIM objects) for design-built-operate processes in close cooperation between planners and construction companies.
Thus, the Housing 4.0 platform offers a model digital process for the conception and production of **affordable, modular housing on a large scale**, **with shorter construction times** and with **architectural qualities** due to the **individualization**.
The demands of different stakeholders (from planning, AEC industry, housing associations and end users) will be assessed and evaluated with the aim of defining a requirement profile for the planned digital platform. Industrialization and digitization of the AEC industry are not only a technical challenge, but also require complex solutions that have to take social, economic and political restrictions into account (Ågren and Wing 2014). By analyzing the AEC and housing industry, housing policy and the legislative framework in the Austrian context, the opportunities and obstacles for digitization of the housing sector will be identified and thus enablig sdevelopment of strategies for successfully overcoming of the barriers and efficiently exploiting the potential.

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