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Digital Platform for Circular Economy in AEC Industry

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DIGITAL PLATFORM FOR CIRCULAR ECONOMY IN AEC INDUSTRY

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ABSTRACT

Construction industry counts to the largest global consumers of the resources (sand, building materials) and produces significant amout of waste. Simultaneously it is one of the least digitalised industries. With increasing levels of urbanization, scarceness of resources and lack of landfills, the policy of circular economy is increasingly gaining importance in the construction industry. European Union is obliging material recovery of construction and demolition waste to a minimum of 70% by weight by 2020 for all new construction projects. Simultaneously, digitalization in construction in one of the major goals in EU digitalization action plan.

This paper addresses potentials of digital platforms for enhancement of circular economy in the construction industry, based on our research within research projects: BIM_Material: *Process-Design for BIM based material building pass*, SCI_BIM: *Scanning and data capturing for Integrated Resources and Energy Assessment using Building Information Modelling;* and a case study of digital tools and processes within of a large design and planning company.

Thereby we propose a Digital Ecosystem for Circular Economy (DEEP), integrating various stakeholders and data repositories on inter- and intra-firm level. Therefore the proposed digital ecosystem in our research framework assumes a *hub-spoke network form* where multitude of <u>outside firms and institutions</u> (periphery) are connected to the <u>central platform</u> (core) via shared or open-source technologies. They are modules loosely coupled to the central platform through standardized interfaces, based on graph networks. This platform for the Architecture, Engineering and Construction (AEC) industry would reduce silo thinking in the industry, increase productivity and optimize material usage in the circular economy – from cradle to grave, foster mutual learning and coordination, identify knowledge and intervention gaps.

KEYWORDS

BIM, Material Passport, Eco-Indicators, Resources, Modelling, Urban Mining

INTRODUCTION

Global material resources consumption is increasingly rising as well as the world's population - the future challenge will be to provide sufficient land, material and natural

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resources; as well as to deal with upcoming waste. The increased building activity with some delay triggers the equivalent increase in solid waste generation - its significant increase is to be expected within the next decades.

Building stocks and infrastructures are the largest material stock of industrial economies. It is of long-term importance to maintain or frequently recycle these urban stocks, and in consequence to minimize the use of primary resources and environmental impacts. Designing effective recycling strategies, consisting of concepts and technologies, is required for the realization of a pronounced circular economy in Architecture, Engineering and Construction (AEC). Often referred to as "Urban Mining", such strategies would significantly reduce the consumption of primary resources, environmental emissions and the generation of waste that has to be landfilled.

The traditionally conservative AEC industry is currently experiencing a rapid digital transformation. Digital technologies are revolutionizing collaboration and value co-creation across traditional industry boundaries, thus offering large potentials for the achievement of a circular economy in the construction sector.

Nevertheless, despite the extensive integration of digital tools and technologies, which would require the innovation of practices, the AEC industry tries to apply the new technologies within the traditional processes, thereby lacking complete achievement of the expected economic, technical and processual benefits that new technologies offer. The highly fragmented and heterogeneous AEC industry applies the concept of digital building information modelling and management (BIMM), as one of the most spread new designing and construction methods used. However, the problem of a varying and sometimes even conflicting BIM understanding reflects various requirements and mind sets of numerous professional domains in the AEC industry; such as e.g. exclusive focus on modelling on geometry (without enrichment of non-geometrical properties) or intra-firm instead of inter-firm data exchange and knowledge generation processes.

A holistic framework that would enable continuous data and information flows (without misinterpretation or losses) as well as data processing is lacking, however needed for a) the generation of knowledge and innovation in the digital ecosystem along the life cycle and b) assessment of the environmental performance of buildings, including circular economy aspects. Such framework would offer structured and open data exchange formats for the enhancement of productive processes, including improved engineering, procurement and supply chain management; finally resulting in the creation of new business models and thus innovation in AEC industry.

The principle of modularity applies to the digital platforms for Circular Economy (CE) in AEC on the inter-firm as well as on the intra-firm level.

Based on our previous research conducted within the funded research projects BIMaterial, SCI_BIM and empirical research of inter-firm software platforms within a design and planning company (DPC), we will propose the conceptual framework for a Digital Ecosystem for Circular Economy in AEC Industry (DEEP) that would allow:

- widespread use of Building Information Modelling and BIM based building passports, as fundaments for a material cadastre and thus CE
- information sharing on material resources and their life cycle data,
- information sharing on recycling and re-use of materials,

- creation of a collaborative environment for stakeholders along the value-chain – manufacturers, designers, construction companies and facility managers.

In this research, we will focus on design companies and their specific platforms and modules as example for an intra-firm platform; where the digital platform for CE in AEC is an example of an inter-firm platform, where a number of particular process stakeholder modules needs to be coupled to the platform.

Thus, for the proposal of a conceptual framework for DEEP, coupling and integration of eco-repository data, manufacturers' environmental product declaration and BIM relevant objects properties, as well as digitised public policy regulations need to be organised into a generic structure, allowing data exchange along the life cycle.

This paper is organised as following – first we will introduce, circular economy in construction, together with relevant stakeholders and data models and repositories, as well as the concept of digital platforms as possibility for collective value creation along the life cycle for enhancement of CE. In further chapters we describe the research design, based on three research projects: BIM-Material, SCI_BIM as representatives of inter-firm platforms, and a case study of design and planning company (DPC) as an example of inter-firm platform. Finally, we conclude with the proposal of a digital ecosystem for CE coupling the inter- and intrafirm platforms, and discuss the properties of the proposed framework, which assumes the *hub-spoke network form.*

CIRCULAR ECONOMY

Circular Economy (CE) is currently increasingly gaining on importance in governance and legislation the European Union (EU) as well as by various businesses around the world (Korhonen et al., 2018). CE has its roots in the industrial revolution (1970ies), where through new manufacturing methods, mass production of goods was enabled, which led to huge solid waste generation due to traditional linear extract-produce-use-dump processes (Lieder and Rashid, 2016; Frosch and Gallopoulus, 1989). Additionally, the growth of the world population expanded the demand for resources, wherefore first solutions for minimizing the raw materials consumption were introduced by Meadows et al (Meadows et al., 1972). In contrast to linear economy, the circular economy concept emphasizes the importance of material reuse, remanufacturing, refurbishment, repair, cascading and upgrading (EMAF, 2013). The aim of Circular Economy is to maintain the value of products, materials and resources in the economy as long as possible in order to reach a low carbon and resource efficient economy (COM, 2015). According to the European Commission, circular-economy type economic transitions could lead to annual economic gains up to 600 billion euros in the EU manufacturing sector (COM, 2015; EMAF, 2013).

CIRCULAR ECONOMY IN THE CONSTRUCTION SECTOR

The construction sector is the largest consumer of raw materials (WEF, 2016). 60% of the raw materials extracted from the lithosphere (Bribián et al., 2011) and 40% of CO_2 emissions (WGBC, 2016) are caused by worldwide civil works and building constructions. CE emphasizes the minimization of material resources consumption, waste generation as well as environmental pollution and is a promising solution to the wasteful production processes. The European Union`s action plan for CE aims to minimize of environmental impacts and energy consumption caused by extraction of primary materials, as well as to reduce waste through maximization of recycling rates (COM, 2015). The circulation of resources within the loop would consequently reduce the need for virgin materials (Andersen, 2007). One strategy to keep resources within the loop is Urban Mining. Urban Mining includes in contrast to recycling, the exploration and observation of materials in buildings and infrastructure as well as mining of waste (Klinglmar and Fellner, 2010). The main requirement to enable Urban Mining, is the availability of material information of buildings (Brunner, 2011), which is mostly not the case for the existing stock. The EU-funded Horizon 2020 project BAMB (Buildings as Material Banks) (2016) aims the implementation of CE in the AEC industry through e.g. Material Passports (MP). MPs describe the characteristics of materials in products and buildings and are an essential instrument for implementation of the Urban Mining strategy in the construction sector. Another method supporting CE is LCA (Life Cycle Assessment). Through an LCA the flows of resources and materials are aggregated and analysed throughout the whole life-cycle in order to assess and optimize the environmental impact (International Organization for Standardization, 2006).

STAKEHOLDER INVOLVED IN THE IMPLEMENTATION OF CE-STRATEGIES INTO THE CONSTRUCTION SECTOR

In a previous study Honic et al. (2019) identified the main stakeholders are involved in the implementation of MPs, as main instruments for enhancement of CE, into the construction sector. These stakeholders also play crucial role for implementing CE-strategies. Designers, planners, construction companies and MP consultants, which are summed up as „AEC organization“, are crucial decision makers regarding material composition of buildings and therefore could enhance the use of materials with high recycling potential and low environmental impact. Eco-inventories and environmental product declarations for materials and building elements needed for LCA and MP are provided by manufacturers („industry“) who therefore represent another important set of stakeholders. Regulative bodies carry great responsibility, through standardisation processes and regulations of e.g. emissions and recycling rates. Governmental or institutional agencies are thereby important digital LCA- or recycling data provider. The European Commission claims an increase of recycling and other material recovery of construction and demolition waste to a minimum of 70% by weight by 2020 (European Union, 2011). These kind of regulations could accelerate the implementation of CE-solutions.

Therefore as the three most important stakeholder sets for implementation of CE in construction sector can be identified:

- AEC organisations (designers, architect, planners, MP consultants)
- Industry – material and product manufacturers
- Regulative bodies and Public Policy

DATA REPOSITORIES

In order to increase resource efficiency in AEC, thus minimising resources consumption and emissions and increasing recycling rates, adoption of predictive modelling, assessment and optimisation tools Life-Cycle-Analysis (LCA) or Material Passports (MP) for buildings are needed already in early design stages. Such assessment and optimisation tools require reliable material information, eco-indicators, and recycling potential data - specific information, which is available from various digital data repositories such as e.g. baubook by IBO (Austrian Institute for Building and Ecology) or ökobau.dat (2019). In general, the required information for LCA and MPs can be summed up as (Honic et al., 2019):

- Data for recycling and LCA, which can be obtained from eco-inventories
- Material composition of building elements, which are available in building elements catalogues
- Product declarations, which are offered by the products manufacturers

DIGITAL PLATFORMS

A platform should offer a needed solution for a broader technological system and solve a business problem for many firms and users in the industry (Gawer and Cusumano, 2014).

The **economic** perspective sees platforms as markets creating network effects, facilitating exchange and generating value for each user of the platform. Value-creating interactions between external producers, consumers and/or users are therefore the establishing features of a platform. These interactions encompass exchanges of information, exchanges of goods and services or the exchange of monetary or social currency, and require an open, participative infrastructure supported by adequate modes of governance (Parker et al., 2016).

The **engineering design perspective** views the platform as a modular technological architecture with stable core components and variable peripheral components. Digital technology has generated this layered modular architecture (Yoo et al., 2010). Standardized interfaces or design rules enable interoperability between these modules (Baldwin and Woodard, 2009). The module is defined as an add-on software subsystem that connects to the platform to add functionality to it (Tiwana et al., 2010) as well as the degree to which a complex product system´s components can be separated, recombined and interconnected in different ways (Schilling, 2000). This loose coupling (Weick, 1976; Orton and Weick, 1990; Sanchez and Mahoney, 1996) of components in a modular architecture reduces complexity of a product system and enables continuous change (Spender and Grinyer, 1995), innovation, flexibility and value creation.

Gawer (2014) conceptualises **technological platforms** through an organisational perspective as evolving organizations or meta-organizations with a focus on agency and structure. Gulati et al. (2012) define the term meta-organization as the specific relational way of organizing legal autonomous entities, weather its firms in a network or individuals, without the use of authority characteristic to employment contracts. These technological platforms appear in different organizational settings, within the firm, across supply-chains and industry ecosystems. For the purpose of our research, we conceptualize the **platform as a digital ecosystem** proposed by Gawer (2014), where the roles of the platform´s constitutive agents, such as the user and complementor can change or expand over time as well as their interactions.

The concept of a platform (within an ecosystem) generates a possibility for collective value creation structured along technological trajectories and is defined "as products, services, or technologies…which provide a foundation upon which outside firms (organized as a "business ecosystem") can develop their own…products, technologies, or services" (Gawer and Cusumano, 2014).

RESEARCH DESIGN

The proposal for the digital ecosystem for CE is based on triangulation of results of funded research project **BIM_Material:** *Process-Design for BIM based material building pass* ongoing research in follow up funded research project **SCI_BIM**: *Scanning and data capturing for Integrated Resources and Energy Assessment using Building Information Modelling*), as well as on case study analysis of digital tools and processes within large Austrian design and planning company (DCP).

In BIM_Material we developed a workflow for the semi-automatic generation of BIM supported Material Passports, focusing on new construction. Further on, a framework for governance and management of MPs, as instruments for enhancement for CE in construction, based on institutional theory was proposed. Thereby as the central stakeholders were identified: AEC, industry and regulative bodies (public policy) as responsible for implementation, governance and data management.

In SCI_BIM, expands the implementation of Material Passports, focusing on assessment of existing stocks. the aim of optimisation of resources efficiency using MPs is extended to the simultaneous assessment and optimisation of energy efficiency, also involving users; coupling several methods and digital technologies. Thus the scope of stakeholders is extended to the users and relevant data management.

BIM-Material focuses on design of new construction, whereas SCI_BIM on existing buildings.

Thereby the two research projects focus on the interaction of various inter-firm digital data management and stakeholder constellations and requirements, whereas the case study examines the digital inter-firm organisation, and the potentials for data-exchange on inter-firm level.

Based on the findings out of BIMaterial, SCI_BIM and DPC-analysis, the conceptual framework for a Digital Ecosystem for Circular Economy in AEC Industry (DEEP) will be proposed thereby addressing following issues:

- What kind of changes are needed in the organizational architecture and governance?
- How to synchronise interfirm- and intrafirm governance when applying digital platforms?
- How can different degrees of digitalization of stakeholders / processes / value chains be integrated?
- How to establish system boundaries and openness, keeping in mind the ever increasing process complexity and number of stakeholders?

BIM SUPPORTED MATERIAL PASSPORTS

European Architecture, Engineering and Construction industry (AEC) consumes a significant rate of materials such as steel, aluminium, copper and plastics, thus creating a large reservoir on secondary raw materials in buildings. One of the main strategies of EU is to maximize recycling rates in order to minimize environmental impacts and the energy consumption caused by extraction of primary materials. To enable circularity, and in consequence high recycling rates, information about the existing stock is necessary.

The early design stages play a crucial role in the waste reduction, the reusability of building elements as well as in the increase of the recycling potential. New digital design tools such as BIM enable data management along life-cycle, thus bearing large potentials for generating a Material Passport (MP).

Within BIM-Material a framework for BIM-supported generation of Material Passports, based on digital tool chain was developed (Honic et al., 2019). Thereby the potentials of the MP as instrument along a building's lifecycle – as design-optimization tool, material-inventory and as a document on material assets of real estates or building stocks were demonstrated, thus enabling successful implementation of Urban Mining strategies. This project is a central milestone towards standardized, BIM-generated Material Passports. In this project, we developed a concept for the compilation of the MP, as well as a workflow for the semi-automated generation of a MP by coupling BIM to the Material Inventory and Analysis Tool Building One and eco-inventory databases (Figure 1). The proposed methodology allows the assessment of embedded materials in building design as well as simultaneous LCA.

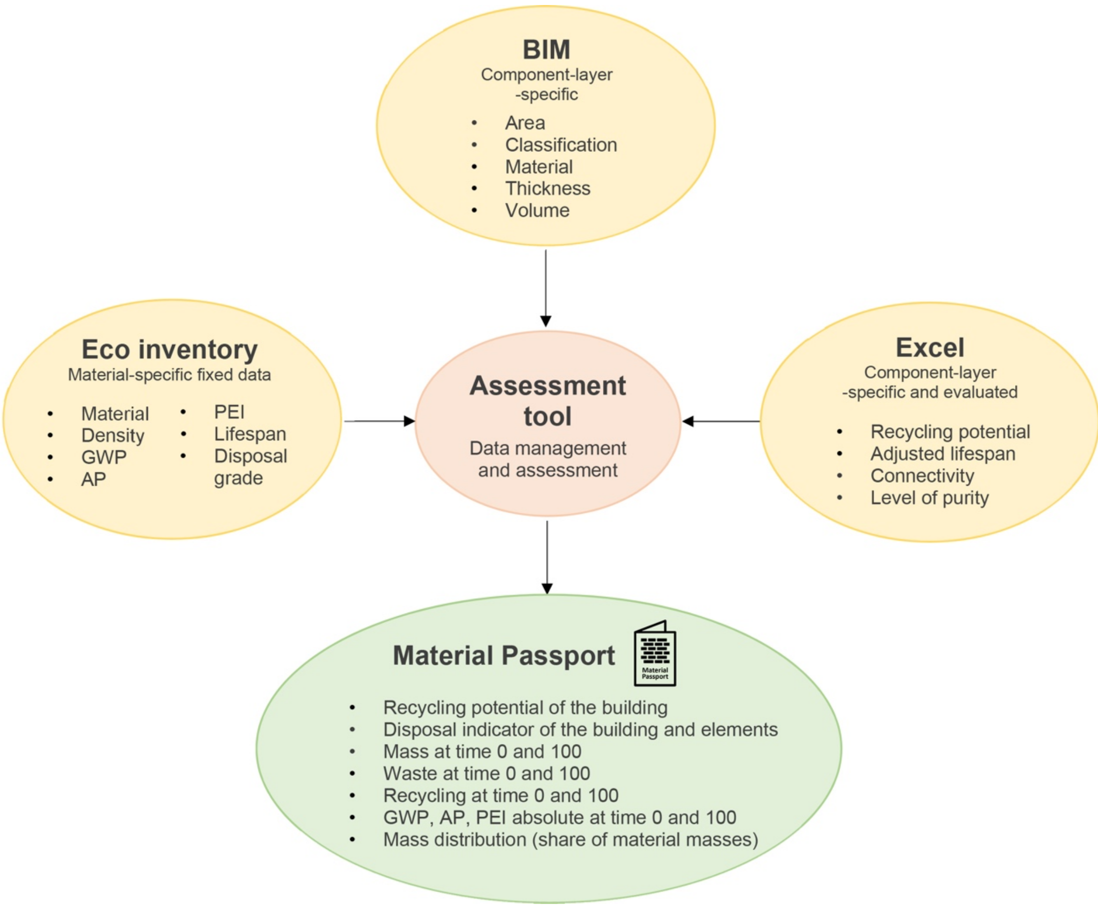

Figure 1: Framework for BIM based Material Passports

Digital Tool Chain for Assessment of Building StocksBuilding stocks and infrastructures are the largest material stock of industrial economies. These total material stocks on the global scale are about as large as reserves of primary resources in nature. It is of long-term importance to maintain or frequently recycle these urban stocks, and in consequence to minimize the use of primary resources and thus the dependency on imports – a strategy labelled as "Urban Mining". Simultaneously, buildings consume worldwide 40% of energy and produce about 30% of global CO_2

emissions. With a construction rate of only 2%, building stocks are crucial for minimization of energy consumption. Due to worldwide rapidly increasing consumption of resources and land, as well as growing generation of waste, increasing of recycling rates and reuse of materials, next to reduction of energy consumption is of highest priority for achievement of sustainability.

The ongoing research within multidisciplinary, funded research project **SCI_BIM** aims to increase both resources and energy efficiency of existing buildings through coupling of technologies and methods for capturing and modelling (as-built BIM with geometry and material composition) of buildings and assets and finally using gamification concept for the as-built model management by users.

It is planned to develop the Integrated Data Assessment and Modelling Method (Figure 2) on a real case of existing building. The capturing of geometry will be conducted via laser scanning and photogrammetry, and capturing of material composition via Ground Penetrating Radar (GPR). The suitability of GPR for material capturing and modelling via semi-automatic Scan to BIM process for generation of information-rich as-built BIM from a Point-Cloud, will be evaluated in terms of usability and costs and benefits. Such as-built BIM models should in a further step enable an efficient generation of Material Passports or BEM - Building Energy Modelling. In addition, the maintenance of BIM models in the life cycle is challenging for facility management. Currently, there is no automated way to transfer changes in the operational stage of a building to as-built BIMs. In SCI_BIM, a concept which enables the assessment of changes on buildings through the commitment of users based on gamification, is to be developed for the maintenance of BIM models. This innovative gamification concept allows assessment of the structural changes (users take photo via smartphone, which is uploaded in the photogrammetric as-built BIM within the gamification platform) and of user behavior (such as open windows or lighting) through user participation. Through implementation of user data, the as-built BIM is updated. On the one hand, the structural changes will be captured (static data) and on the other, the user behavior model for operational building automation (dynamic) will be compiled.

As significant innovative contribution of this project the semi-automated recognition and generation of BIM-Objects from the Point-Cloud, as well as the use of gamification for reduction of energy consumption together with automated update of as built-BIM4FM can be identified. The need for research lies in the evaluation of the usefulness of such information rich BIM models for the optimisation of resources efficiency on the one hand and of energy efficiency on the other.

Thereby a research gap is addressed – the capturing and modelling of geometry is already well explored, however the methods and tools for capturing and modelling of material composition of buildings are largely lacking. Through this method the automated generation of Material Passports at both throughout and at the end of the lifecycle will be enabled, thus delivering useful information for the material cadaster as well as for the assessment of the material value of a building.

The first experiments in material assessment via GPR and the semi-automated Scan to BIM process - generation of the as-built BIMs on the basis of scan data (point clouds, voxels, material information) have shown that attributing the exact material properties to the scanned data (point clod) is difficult, as the standardised or structured material data repositories for this purpose are lacking. Therefore, in order to obtain information-rich BIM models, providing comprehensive knowledge base that includes both geometry and parametric attributes such like layer structures (building materials and building elements) and their thermal properties, requires further data repositories with structured information on historic materials and relevant properties.

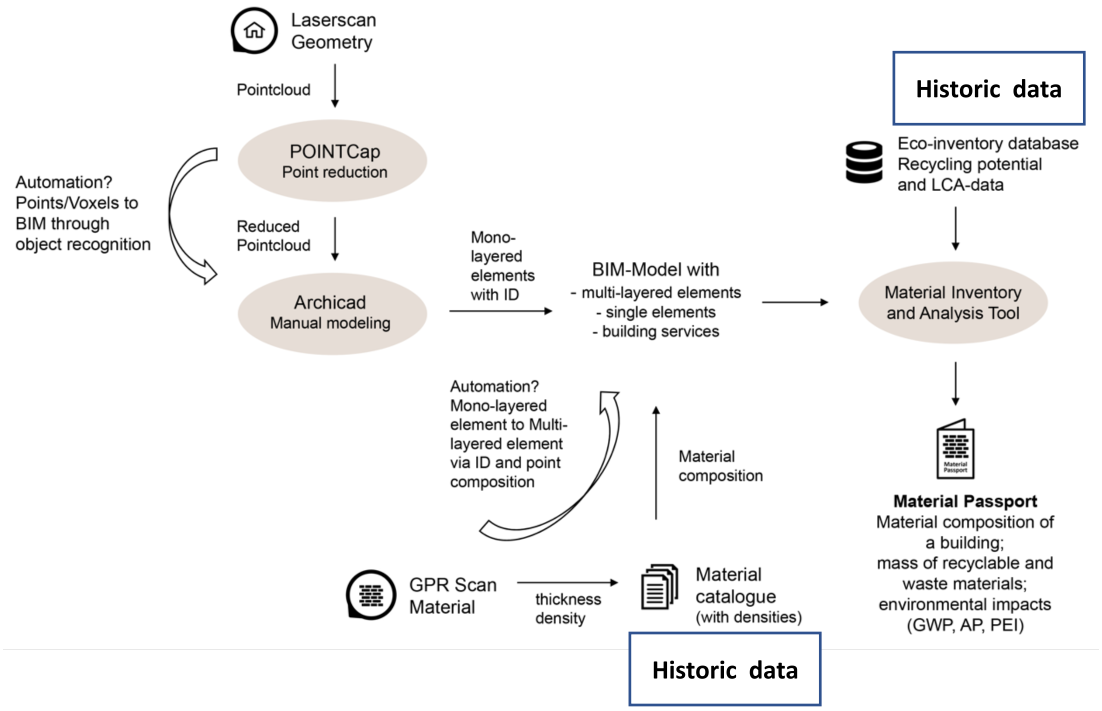

Figure 2: Framework for coupling of digital tools for semi-automatic geometry and material assessment of existing stocks

DIGITALISATION IN DESIGN AND PLANNING COMPANY

Nearly every planning firm faces problems of lack of productivity and sometimes poor quality. This is often attributed to the lack of innovation as well as to the low level of digitalisation in the AEC industry. Especially in terms of interoperability many weak points can still be identified. As these problems are ubiquitous in the AEC industry, there is still great need for action on issues such as increasing interoperability within a company and digitization in general.

In order to identify potentials for improvement of the interoperability of companies in the AEC industry, in order to increase efficiency, but more over to enable life-cycle oriented design and planning thus enhancing resources and energy efficiency and CE-strategy, we conducted a case study. Thereby analysis of digital ecosystem of large design, planning and engineering company (DCP), with more than 800 employees and eight offices across Europe, as an early BIM adaptor, was conducted.

In particular, this work focuses on possible interfaces between the various tools of the in-house platform, thus achieving a possible improvement in interoperability.

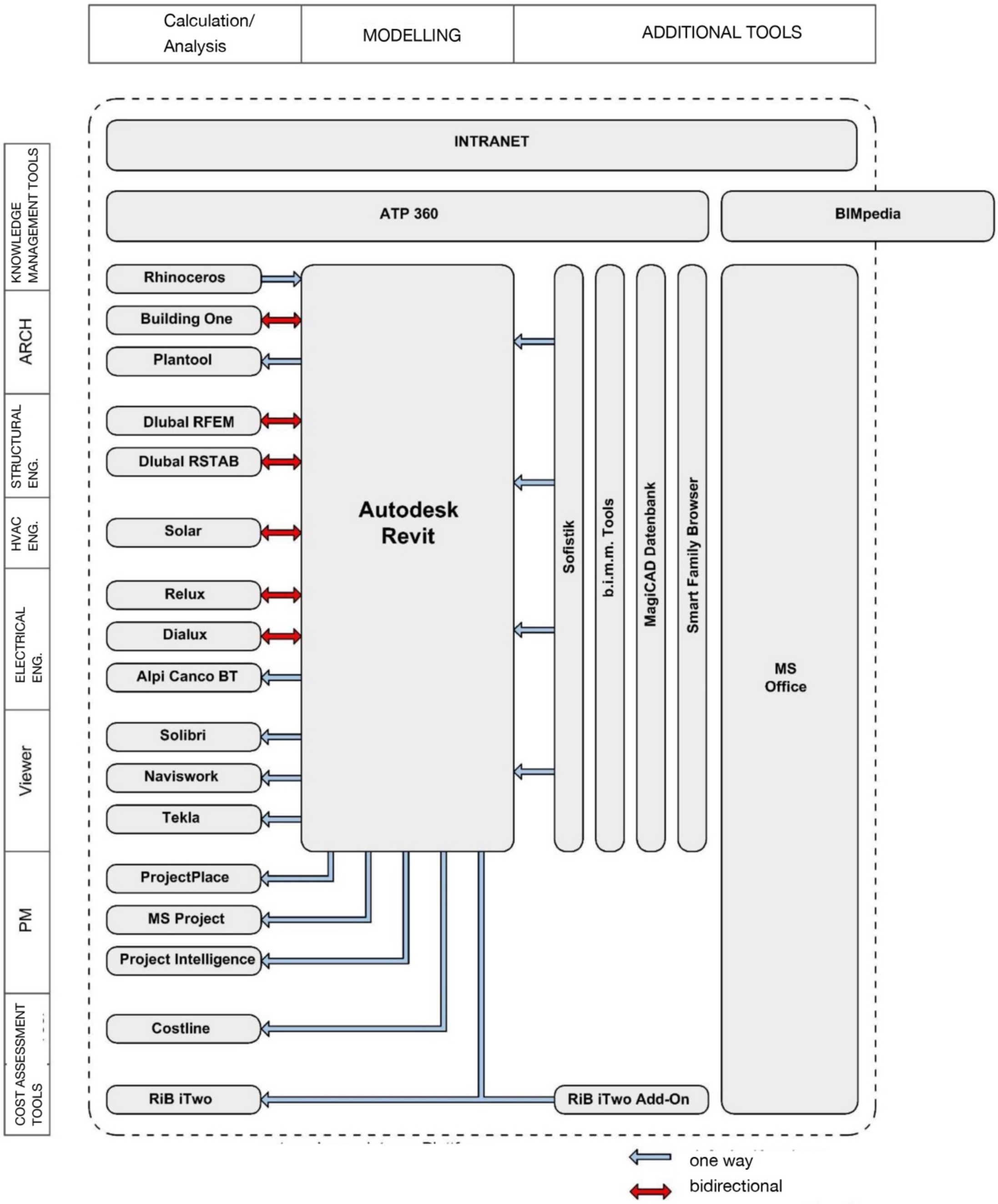

Figure 3: Intra-firm digital ecosystem of the case study DPC

Figure 3 displays the digital ecosystem of the tools and interfaces employed at DPC. As central platform BIM authoring tool Autodesk Revit delivers central model, data and information for specific domains of: Architecture, Structural-, HVAC-, MEP-Engineering, Cost Calculation and Project Management.

Next to BIM (Revit) there is a number of supporting modelling tools such as Rhino which is used in architectural competitions, delivering wireframe graphics for further processing in higher Level of Development in Revit.

Each of the partaking professional domains also employs domain specific tools for e.g. structural (Dlubal) or energy and light (Solar, Dialux), cost assessment (RIB iTwo) or project management.

As general knowledge management tools BIMpedia (web of knowledge on intrafirm BIM modelling standards, as well as on national and international BIM standards) as well as own inter-firm intranet offers a knowledge base of e.g. standard architectural details, corporate design and layouts, building codes, regulations, and standards; as well as news site with insight into new projects or current corporate events.

Through conducted analysis and interviews with seven experts in the company (structural engineers, architects, BIM manager, CEO of DPC's subsidiary IT company) following deficits were identified: large number of employed domain specific software tools next to the central BIM authoring tool requires significant effort for creation of proprietary interfaces and workarounds in order to enable smooth data exchange. Most of the data exchange is still one way exchange, most of the experts are stressing the necessity for bidirectional exchange in the future. Significant amount of data gets lost in this way, in particular the data on personnel costs (man-hours) and construction costs needs higher level of coupling in order to enable more efficient planning of future projects as well as cost assessment in early design stages.

Despite of the relatively high level of digitalization and process integration on intra-firm level, the concept of synchronous data exchange with further consultants or construction companies (inter-firm) has not been addressed in the digitalisation strategy of DPC. With upcoming initiative on BIM based digital permit by City of Vienna building authorities BIM by 2020 the issue of inter-firm digital data exchange and integration is gaining on importance.

Further, the CE approach and ressources efficiency has not been considered as the scope of work DPC yet. However, with upcoming regulations from the European Commission, recycling or material recovery of construction and demolition waste has to account to a minimum of 70% by weight by 2020 (European Union). Therefore the integration of CE solutions into the existing digital ecosystem of DPC will be necessary.

PROPOSAL OF A DIGITAL ECOSYSTEM FOR CE

Based on the conducted research where inter-firm and inter-firm data exchange processes, stakeholders and data repositories were analysed under perspective of enhancing the CE in construction, we developed a proposal for digital ecosystem for CE – DEEP (Figure 4).

Thereby as particular data domains are identified:

- Institutional Domain: upcoming digital buildings permit process, which requires bidirectional data exchange, incorporating digital cadastre available to the planners; digital data exchange standards (such as CEN, BIM ÖNORM etc.), and finally digital repository of national building codes and standards.
- Industry and Manufacturer Domain addresses the data delivered by the industry: such manufacturer product declarations, BIM Objects etc.
- CE Public policy Domain, such as environmental agencies or regulating bodies; which deliver eco-inventories, generic environmental declarations, waste and recycling data.
- AEC companies, with their intra-firm platforms.

- Users – data collected through users, or user behaviour, regarding material use and energy performance

Thereby data availability, reliability and accessibility plays crucial role; for which a consens and commitment of all partaking stakeholders is needed.

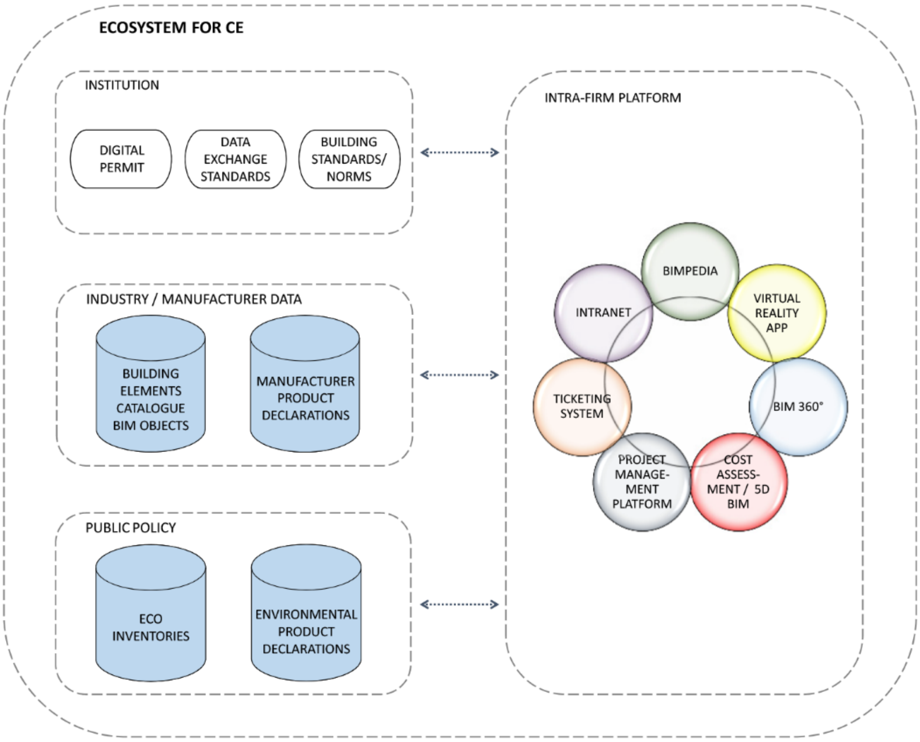

Figure 4: Proposal of Digital Ecosystem enabling life cycle inter- and intrafirm data exchange and integration of CE.

Therefore the proposed digital ecosystem (DEEP) in our research framework assumes a *hub-spoke network form* (Figure 5), where multitude of outside firms and institutions, (periphery) are connected to the central platform (core) via shared or open-source technologies, technical standards (Jacobides et al., 2018). They are modules loosely coupled to the central platform through standardized interfaces, based on graph networks.

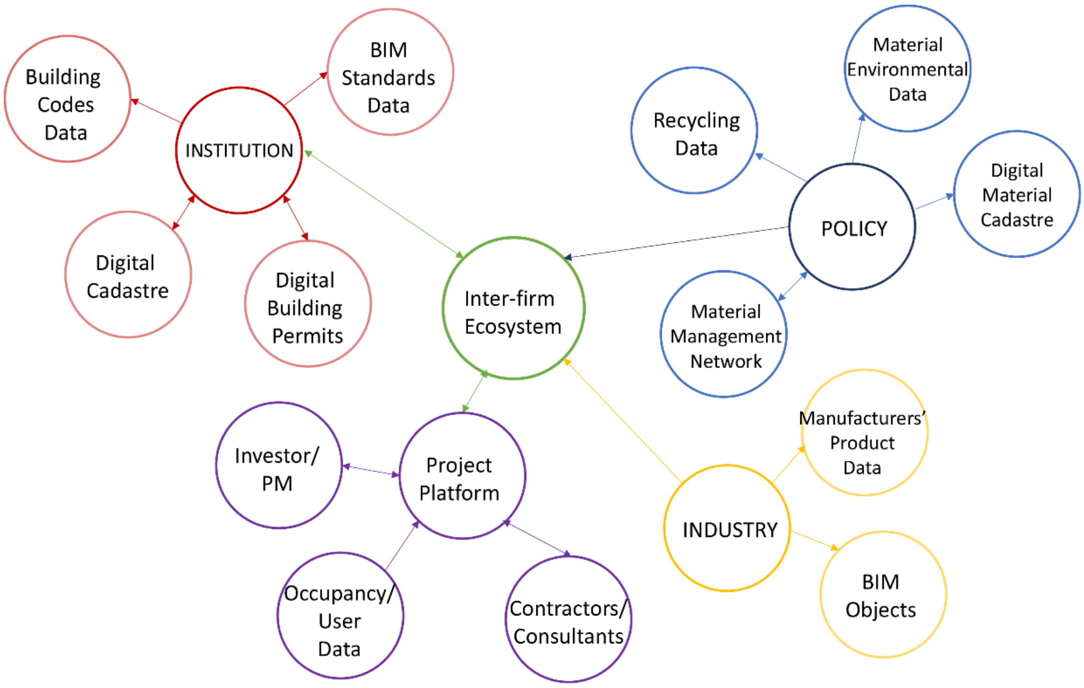

Figure 5: Digital Ecosystem for CE as Hub-spoke platform

CONCLUSION

Our DEEP framework assumes the form of a hub-spoke platform which has a corresponding architecture (core-periphery), design, interface, degree of openness, governance mode and boundary resources. In our proposal for digital ecosystem, the central platform is placed towards intra-firm network to access necessary information from the periphery (organizations/institutions) for the integration of eco-repository data, manufacturers' environmental product declaration data and manufacturers' BIM objects as well as digitised public policy regulations (rule sets) for each design project, under the premise of CE. The characteristic of the DEEP framework fits into the recent research on ecosystems (Jacobides et al., 2018) concerning:

1) coordination – the central platform of the intra-firm network (DCP) assumes the role of a coordinator of organisations/institutions who have their own business models and are autonomous in the way they design, operate, offer data; but when connected to the central platform add value respectively enable specific combinations of data/objects necessary for each project;

2) governance – the periphery (institutions/organisations) are encouraged to align with the central platform through rules of engagement, standards and codified interfaces, as the platform ecosystem offers access to data otherwise not accessible to them. This includes openness and system boundaries - with the DEEP framework the question also arises how to govern the openness of the system and how to encourage and incentivize membership and participation in the ecosystem.

The industry platform for the circular economy would offer structured and open data exchange formats for the enhancement of productive processes, including improved engineering, procurement and supply chain management; finally resulting in the creation of new business models and thus innovation in AEC industry. This platform for the AEC industry would increase productivity and optimize material usage in the circular economy – from cradle to grave, foster mutual learning and coordination, identify knowledge and intervention gaps.

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