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A Preliminary Case Study on Circular Economy in Taiwan's Construction

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Abstract. After realizing the serious environmental problems caused by current linear economic model, designers, researchers and policy makers around the world started to look into the possibilities of a more sustainable model- circular economy. And the construction industry is no exception to this change. In recent years, not only in Europe, circular economy in the built environment has also become a key focus for public and private sectors in Taiwan. Several projects aiming at constructing circular buildings have been initiated. However, the understanding of circular buildings in Taiwan is very little. Furthermore, how Building Information Modeling (BIM), known as a powerful tool for circular buildings, contributes to these projects for building circularity is beyond exploration. Through one in-depth interview and case study, this paper aims at disclosing the current development, barriers and future potentials of circular economy in building sectors and related BIM applications in Taiwan. The current awareness of stakeholders, key challenges and enablers for circular economy in construction have been identified. How BIM is utilized for circular building design, and its benefits, limitations and potentials are also recognized.

Keywords: Circular Economy in Construction, Building Information Modeling, Case Study

1. Introduction

Modern construction industry is wasteful and unsustainable. It consumes a major portion of materials and resources on this planet yet little of them are reused, recycled or regenerated at the moment (Cheshire, 2016). Therefore, precious materials and resources are getting fewer yet more waste are produced every day. There is an urgent need for construction industry to shift from a linear economic model into a circular one. For Taiwan, a small island with very limited resources yet large population, this transition is even more critical.

After realizing this urgent need, in recent years, many public and private sectors in the world have made circular economy (CE) a main focus for their construction industry. For example, a cross-national European research project named "Building As Material Banks (BAMB)" has been established for enabling a systemic shift in the building sector by investigating and creating circular solutions (Debacker



& Manshoven, 2016). Meanwhile in Taiwan, several public and private housing projects have been initiated aiming at constructing circular buildings. However, compared to studies on European cases, how CE has been adapted in Taiwan's construction industry is little known. Furthermore, how Building Information Modeling (BIM), known as a powerful tool for circular buildings, has contributed to these building projects for building circularity is also beyond exploration.

In order to have a better understanding of the current development, barriers and future potentials of CE in Taiwan's building sectors and its related BIM applications, this research has conducted a series of interviews and case studies. The research findings are discussed and compared with the present literature in order to provide more insights on the present progress of CE in construction globally.

2. Literature Review

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2.1. Circular Economy in Construction

The concept of CE was formed in 1960s by environmental economists, who pointed out the problems of present open-ended economic system and the needs to "close the loop" for the sustainability of human life on earth (Ghisellini, et al., 2016). Various definitions of CE have been developed in recent years by a number of interlinked schools, with the common elements including eliminating the concept of waste and maximizing the value of materials (MacArthur, et al., 2015). Compared to earlier implementation of CE in other industries, this model of thinking only gains more attention in construction industry not too long ago (Pomponi & Moncaster, 2016). Several ideas corresponding to CE have emerged in construction with keywords such as reuse and recycle of building materials, design for flexible, adaptable, modular, standardized buildings, etc. (Durmisevic, 2015). However, how CE principles apply in the built environment with a system context is still a question to be answered (Adams, et al., 2017). In response to this, Adams, et al. (2017) have conducted an online survey and a follow-up workshop to investigate the awareness, challenges and enablers of CE in construction in UK with an industrywide perspective. They analyzed their research results by different stakeholders in construction and three dimensions of issues- technical, financial and organizational (see Fig. 1). This has provided a good framework for gaining a holistic and systematic picture of CE adoption in construction.

2.2. Building Information Modeling and Circular Economy in Construction

Besides this changeover wave of sustainability and circularity, construction industry is also undergoing a "smart" transition ushered by the fast-developing information and communication technology (ICT) in this digital age. Moreover, many believe that with the powerful capacity of these ICT for data storage and sharing, CE in built environment can be achieved more easily (Zimmann, et al., 2016). Among all these ICT, Building Information Modeling (BIM) is the most discussed one in recent times. Some have looked into the synergy between BIM and circular buildings. For example, Durmisevic, et al. (2017) utilized BIM to visualize and simulate the transformation capacity of reversible buildings during initial design phase. Moreover, Swift, et al. (2017) employed BIM and automated Radio Frequency Identification (RFID) to create an ongoing dynamic data repository for managing adaptable and reusable building elements in operational stage. However, how BIM helps in delivering circular buildings throughout building life cycle is still a field to be explored (see Figure 2). To gain more knowledge on this matter, van den Berg & Durmisevic (2017) have identified and classified eight BIM uses for reversible building design through an in-depth case study of a Dutch system builder (see Fig. 2). This is a good approach to measure the benefits of BIM in projects (Kreider, et al., 2010).

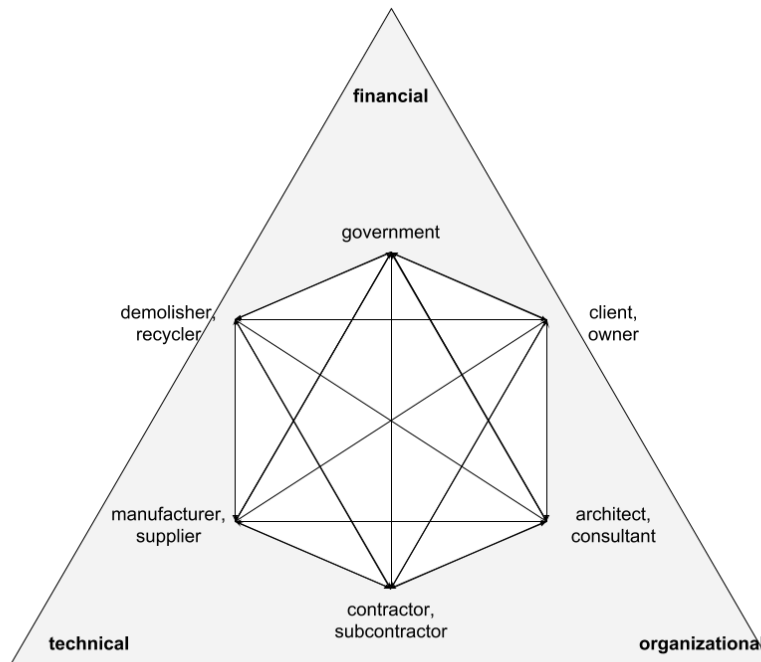


Figure 1. Main stakeholders and three dimensions for circular economy in construction (after Adams, et al., 2017).

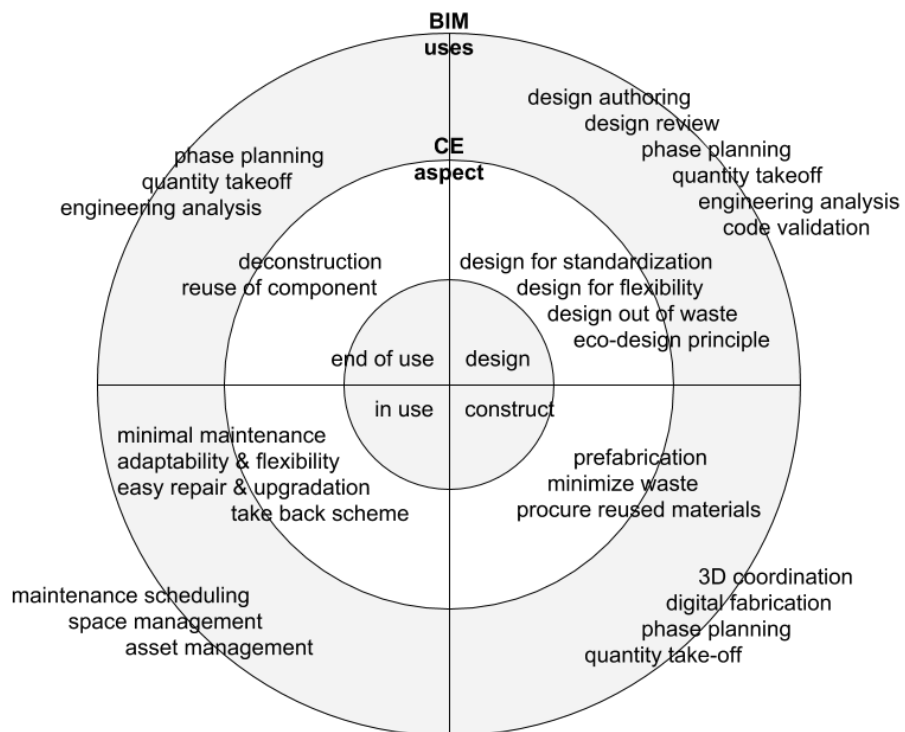


Figure 2. Key circular economy aspects and BIM uses in different building project stage (after van den Berg & Durmisevic, 2017 and Kreider, et al., 2010).

3. Methodology

3.1. Interviewee selection

As mentioned above, in recent years there are several public and private housing projects in Taiwan aiming at constructing circular buildings. All of them are at the design stage and yet to be constructed. Therefore, the design teams are the targeted interviewees for this preliminary study. One architectural design firm is selected for their rich experiences in both sustainability and BIM (more than 10 years).

3.2. Interview questions

As mentioned above, this study aims at exploring the current development, barriers and future potentials of CE in construction in Taiwan and the related BIM applications. Therefore, the interview questions are comprised of two parts: one is to disclose the industrywide situation from the architects' perspective, and the other is to investigate the empirical practices through case study. The questions covered in the interview are as follows:

Table 1. Interview questions covered in this study

Part 1. Awareness, challenges, enablers of CE in Taiwan's construction
(1) What is your understanding of CE in construction?
(2) What is the current awareness of construction industry towards CE? (Please share your view towards different stakeholders, e.g. clients, designers, contractors, manufacturers, government)
(3) What are the current challenges and future potentials for CE in Taiwan's construction? (Please share your view towards three aspects, i.e. technical, financial, organizational)
Part 2. Adoption, limitations and potentials of BIM application for CE in Taiwan's construction
(1) Which BIM uses have been adopted in your project? (e.g. design authoring, design review, cost estimation, phase planning, performance analysis, code validation, etc.)
(2) What are the benefits of BIM application for circular buildings in your project?
(3) What are the limitations and potentials of BIM application for circular buildings in your project?

4. Results & Discussions

4.1. Introduction of interviewee and study case

The interview in this study is the founding partner and principal architect of the selected architectural design firm. The study case is a housing project which includes 400 housing units and is located in Southern Taiwan. Currently it is in the end of design stage and aims to be completed in 2020 summer. Many concepts related to circular economy, smart control and healthy living systems are instilled in the project in line with the overall policy of local master plan (see Figure 3).



Figure 3. Design concepts and visionary picture of study case (after BAF, 2018).

4.2. Circular Economy in Taiwan's Construction

According to the responses of the interviewee to the first part of questions and information and collected from the study case, their understanding of CE in the built environment includes keywords such as buildings as material banks (including material passport and modular design), resource management (including energy, water, food and waste management), sharing economy (including cohousing), which has covered a board range of the topic. According to his point of view, currently the Taiwanese government has high awareness of this issue; However, meanwhile, the rest of the parties in the industry are still falling behind, especially the manufacturers, which for him should be the core players in the industry for CE. In his opinion, the lack of incentive given by governments is the key challenge for CE in Taiwan's construction. The establishment of financial incentives and platforms for building material exchange are the key enablers from his perspective.

Compared with the findings by Adams, et al. (2017) in the UK scenario, the perceived level of awareness of manufacturers by other sectors shows differently between two countries, as manufacturers were considered to be the most aware in their survey. According to them, this could be due to the existing network of various trade associations in material sector on sustainability, which might be a hint for further investigation on manufacturer sector in the Taiwan scenario. As for the key challenges for CE in construction, the lack of incentive to design construction products for circularity is also regarded as the most significant problem by all stakeholders in the study of Adams, et al. (2017). Furthermore, to have a clear business case for CE in construction is also seen as the most critical enabler. Regardless the strong emphasis on CE in the built environment by both governments, the related financial scheme is yet in place.

4.3. Building Information Modeling and Circular Economy in Taiwan's Construction

According to the responses of the interviewee to the second part of questions and information and drawings collected from the study case (shown as in Figure 4), BIM is used for design authoring, design review, quantity take-off, phase planning and energy analysis. According to the principal architect, the

major strength of BIM for circular building is its capacity to store and share meaningful properties of different building elements for future optimal operation and material harvesting. However, what relevant information to be stored and shared via the model is still unclear meanwhile. Thus, this major strength of BIM is yet to be fully realized. Furthermore, except analysis between operational and renewable energy on site, other kinds of analysis for resources management cannot be done by BIM at this point. Nevertheless, the architect does not see the necessity for BIM to do all the performance analysis for circular buildings (e.g. on food and waste management) since he regards different tools have their own strengths and weaknesses.

Compared with the findings by van den Berg & Durmisevic (2017) on BIM uses for reversible buildings, design authoring, design review and quantity take-off are recognized as strong features of BIM in both case studies. However, phase planning and engineering analysis are not relevant in their study. This might be due to the lack of skills and needs of the study case in their research. However, since construction and resources management are important aspects of CE in the built environment, these two BIM uses should not be overlooked. In addition, at the moment the capacity of BIM in code validation is not considered in both studies because there is a lack of related code for circular buildings. Nevertheless, the establishment of related guidance and tools for the assessment of building circularity is essential for circular building design and worthy for more studies (Durmisevic, et al., 2017).

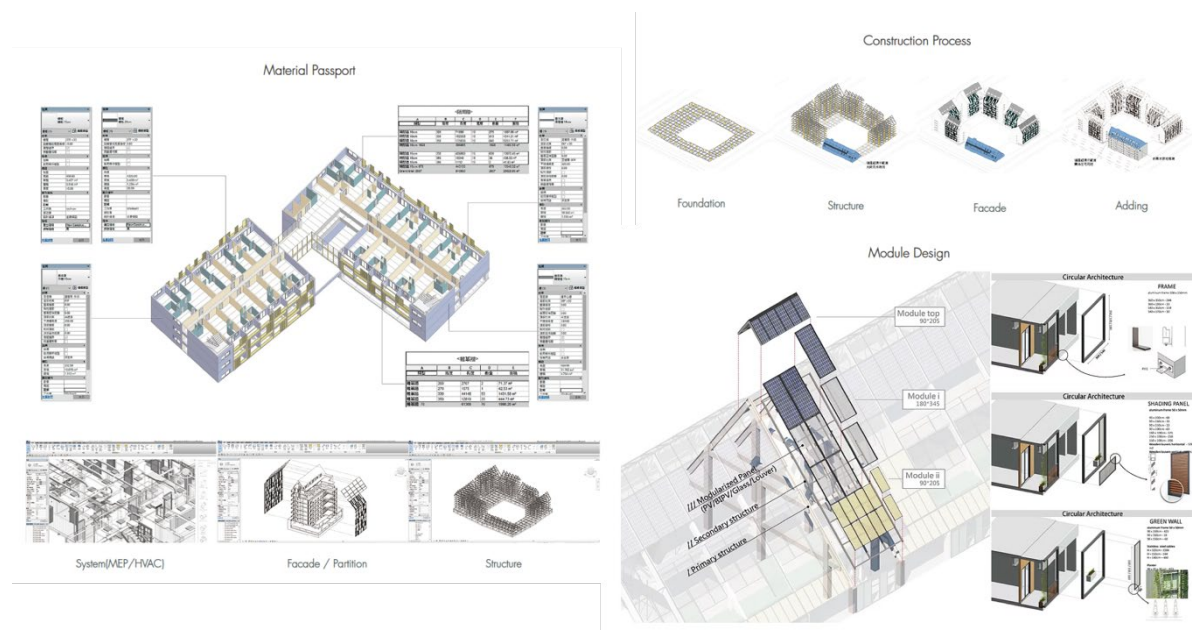


Figure 4. Drawings extracted from BIM model of the study case for different uses (after BAF, 2018)

5. Conclusions

This study aims at disclosing the current development, barriers and potentials of CE in construction and the related BIM applications in Taiwan. An in-depth interview and case study is carried out with professional who are working on a circular housing project and with rich experiences in sustainability and BIM practices. According to the interviewee, even though the present Taiwan government has made strong emphasis on CE in construction, the current awareness of the other stakeholders is still low. More engagement and networking among the key players (e.g. manufacturers) are critical and need to be investigated. Furthermore, the establishment of financial incentive and platforms for material circularity are the key enablers in Taiwanese scenario. Concerning BIM uses for circular building design in Taiwan, design authoring, review, quantity take-off, phase planning, and energy analysis are recognized as

powerful BIM applications. Nevertheless, what relevant information to be stored and shared via the model is still a crucial question to be answered for more realization of BIM capacity. Moreover, more guidance and tools for the assessment of building circularity should be developed to optimize building design. The feasibility of BIM on conducting other types of performance analysis for resource management (e.g. food and waste) also needs to be explored.

Through this preliminary study, current adoption of CE and the related BIM application in Taiwan are explored from designer perspective. More interviews and case studies will continue to be carried out with more design teams and other stakeholders (e.g. government, contractor and manufacturer sector) in the near future in order to have a complete picture of Taiwanese scenario.

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