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# Knowledge Management in Construction using a SocioBIM Platform: A Case Study of AYO Smart Home Project

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**Abstract**

Knowledge is one of an organization's most important assets, hence organizations should strive to capture and reuse the knowledge of their workers in order to have continuous improvements. The construction industry is often associated with low levels of productivity, one of the reasons for which is due to poor knowledge management since mistakes made in one project are often repeated again in future projects. Building Information Modelling (BIM) is a technology that has caused a paradigm shift in the Architecture, Engineering and Construction (AEC) industry. Social media platforms are another recent invention that have diverse applications in every field. The main objective of this paper is to assess the usefulness of a BIM-based social platform for knowledge management, in particular tacit knowledge, in the construction industry. A case study demonstrating the use of such a platform, called Green 2.0, has been presented in this paper. The case study, relating to the construction of high performance, low cost housing, provides a proof of concept and shows that such platforms can provide an informal and engaging method for project-related discussions, in addition to providing advantageous visualizations to project stakeholders.


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*Keywords:* Knowledge Management; BIM; Construction; Tacit Knowledge; Social Platform

## 1. Introduction

Knowledge management is the process of capturing, developing, sharing, and effectively using organizational

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knowledge. Knowledge in an organization can be broadly classified into two categories: explicit and tacit knowledge. Explicit knowledge is that which can be measured, captured, examined, and can easily be passed onto others in a codified format–a formal and systematic language. Tacit knowledge, on the other hand, is highly personal, context-specific and comes from one's experience. It is hard to measure, capture or examine.

Construction is a project-based industry where the project team comes together to work on a project and often disintegrates at its termination. The dynamic nature of the industry results in new learning every day related to issues and successes on the construction site but often these are not captured, resulting in a state of "reinventing the wheel" when a similar issue arises in the future. The common practice in the industry to capture lessons learnt is through project reviews that happen at the end of project (if at all). However, these reviews often happen very late after the end of the project when most of the team have moved on to other projects, and typically not enough importance is given to these reviews by team members. Hence, they end up being a mere formality and do not capture the tacit knowledge of individuals [1].

There are various techniques and tools available for knowledge management. Some common techniques include brainstorming, communities of practice, face-to-face interactions, post-project reviews, mentoring and apprenticeship. The tools which can facilitate knowledge management include, but are not limited to, groupware, intranets, knowledge bases, instant messaging, and data/text mining technologies [2].

Building Information Modeling (BIM) is a technology that has caused a paradigm shift in the Architecture, Engineering and Construction (AEC) industry, it has transformed the way buildings are designed, constructed and managed. BIM is moving the construction process from "lonely" to "social" data, in the sense that BIM is enabling professionals: designers, constructors and building managers to easily share information with each other. SocioBIM applications (introduced in [3] and [4]) are defined as a combination of BIM and social networking to produce socio-technical systems, particularly related to BIM applications that involve the public or end users (e.g., building occupants). In the introductory papers relating to SocioBIM applications, Grover et al. (2015) and Shoolestani et al. (2015) focus primarily on applications during the pre-construction and post-construction phases. However, another potential area for SocioBIM applications is the phase *during* construction, which deals two way interactions between building professionals relating to issues such as constructability, productivity, site safety, lessons learnt quality issues etc. This paper is based on the hypothesis that use of a BIM based social platform in the construction phase for knowledge management can result in effective capture and reuse of tacit knowledge.

This paper describes an implementation of a SocioBIM application called the Green 2.0 system (described in the later sections of the paper) during the construction phase of a smart home project being built on the campus of The University of British Columbia (UBC) called the AYO smart home. The first section of the paper provides a brief review of knowledge management in construction. This is followed by a use case of the SocioBIM application and a brief overview of the Green 2.0 system. The next section provides the background of the AYO Smart Homes Project, describes the implementation methodology, and gives a review of the system. The paper concludes by stating the main contributions of this paper and scope for future work.

## 2. Social Media Platforms for Knowledge Management in Construction

The building blocks of a social media platform, as defined in the framework proposed by Kietzmann et al. [5], include: identity, presence, relationships, reputation, groups, conversations, and sharing. It is not necessary that all social media platforms have all these elements; there may be cases where the focus is just on a few of these blocks. Web 2.0 technologies such as wikis, blogs, web-based forums, and social networks have been implemented by many organizations to capture and share knowledge. Some of the benefits of Web 2.0 over traditional knowledge-management technologies include its ease of use, search capabilities, open-source availability and, most importantly, its potential to re-create a virtual social environment by promoting discussions [6]. Such social platforms have the potential of capturing both the tacit and explicit knowledge that is generated every day in projects and sharing them among different stakeholders, ultimately resulting in cross-project learning. Past research suggests that a community model or a personalization strategy is better than a database approach [7,8,9, 10]. Panahi et al. [11] argue that the use of social web tools can be regarded as complementary to facilitate tacit knowledge capture and sharing. Wahlroos [12] identified some of the main factors that impact employee's knowledge sharing behavior on social media platforms, which include personal (benefits, experience with social media), organizational (managers' &

colleagues' activity, guidelines, collaboration features) and technological (user-friendliness and skills required). Vuori and Okkonen [13] found that the main motivators for employees are desire to reach the organizational goals, help colleagues, and receive knowledge in return, all intrinsic benefits. Extrinsic factors, such as financial rewards or promotion opportunities, were the least motivating factors. The main barriers impeding knowledge sharing through the social platform were found to be fear of the additional time and effort required, the concern that it may be just another un-used information system, and the expectation of not receiving significant knowledge in return. According to Panahi et al. [14], some important requirements in a social platform that can facilitate tacit knowledge include: social interaction, experience sharing, observation, informal relationships/networking, and mutual trust.

The use of social collaboration platforms such as SharePoint, IBM Connections, Confluence etc. for knowledge capture and sharing has become quite prevalent in other industries such as automotive, manufacturing, IT, and oil and gas. However, the temporary nature of construction projects, resistance to change, and heavy fragmentation makes it a challenging industry to apply such platforms. Furthermore, historically the construction industry has been slow in adopting ICT developments. The industry does a good job in capturing the explicit knowledge generated on the projects, but has not developed systems to capture tacit knowledge. Newell et al. [1] critique the current way of knowledge sharing in the construction industry and use a case study approach to conclude that placing efforts on developing personal networks can be more effective than using databases to capture knowledge. Dave and Koskela [15] used a case study approach to test a social platform, based on Internet forums, in a construction company. The platform was able to enable an active exchange of knowledge, had high user participation, and the knowledge generated as directly applied in the workplace. Their work also highlights some of the challenges associated with implementing a platform for tacit knowledge capture such as ease of use, trust amongst employees, importance of knowledge sharing in organization, and involvement of top management. In their paper, Tan et al. [16] highlight the requirements for the live capture and reuse of project knowledge: accuracy of knowledge captured, facilitation of knowledge capture and reuse, and avoidance of legal issues, additional cost or workload for workers. They propose a methodology for live capture and reuse of knowledge comprising of a web-based knowledge base, a project knowledge manager and an integrated work-flow system. Kivrak et al.[17] built on their framework to propose a Knowledge Platform for Contractors (KPfC). Some potential benefits of this system have been proposed (without any empirical evidence): reduction in rework, sharing and retaining of tacit knowledge, innovation encouragement, continuous improvement, client satisfaction, and organizational learning. Ferrada et al. [18] proposed a mobile lesson-learned system application which allows creating, allowing, evaluating, and searching lessons learnt inside the database. The users also have an option of posting a microblogs, similar to twitter, and directing it to a particular person or a group of people. The lessons learnt are collected in a structured format where user were asked to enter fields such as title of lesson, description, creation date, classification, and name of lessons approver.

Most of these aforementioned papers point out that there is a lack of empirical evidence to support the benefits of social media platforms for knowledge capture in construction. This paper adds another case study illustrating the use of a BIM-based social platform for knowledge management in construction. The next sections describes the use case for the SocioBIM application and the Green 2.0 platform.

## 3. SocioBIM Application for Knowledge Management

### *3.1. Use Case*

In the context of SocioBIM applications, a platform to facilitate collaboration amongst different project stakeholders is envisioned as "a single shared interface between two or more interested individuals, enabling them to participate in a creative process undertaken by two or more interested individuals, sharing their collective skills, expertise, understanding and knowledge (information) in an atmosphere of openness, honesty, trust, and mutual respect, to jointly deliver the best solution that meets their common goal(s), while simultaneously creating an auditable electronic record of people, processes, and information employed in the delivery of the solution(s)" [19]. The main requirement of design is to provide a rich social experience where knowledge exchange happens in an open and informal way.

In the use case shown in Figure 1, the building industry provider, which include architects, contractors, site foremen, superintendents, workers, project managers etc., are able to walk through the BIM model of the facility. They can post comments regarding any issues related to constructability, quality, safety, clashes, or any other lessons learned related to a particular building element. They have the option of attaching pictures, writing microblogs, and tagging their colleagues or sharing their posts with a specific group of industry providers. The other users are then able to view these issues and engage in a social discussion on them resulting in collaborative decision making. The users are also given an option to provide a numerical rating to the postings by other users, which can establish a reputation of various users and get expert opinions on feasibility of solutions to issues.

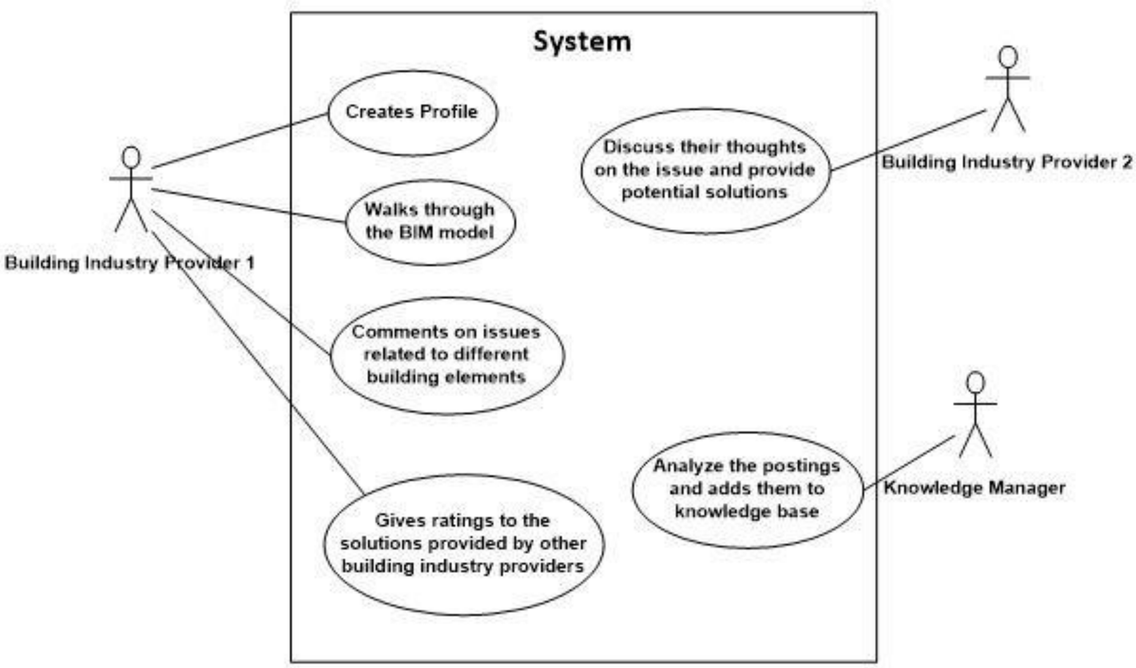



Fig. 1 Use Case for SocioBIM application for Knowledge Management

This process has the potential of enabling a continuous capture of knowledge coming from different stakeholders, especially the tacit knowledge being generated on-site every day.

### 3.2. Green 2.0 Platform

The Green 2.0 project [20], which undertook to develop a middleware platform for enabling socio-technical analytics of green buildings, was a collaborative research project led by the University of Toronto. The project aimed at developing a web-based middleware platform to empower professionals from diverse background to create analysis applications while engaging public users' ideas. The platform brings together several core enabling technologies: open BIM for modeling buildings and related project information; social networks and social network analytics for supporting user interactions and investigating the results of this social interaction; energy analysis to model and provide feedback about the impact of various design alternatives; and business process modelling to model public users' activities. The Green 2.0 platform is open source and free to use for both building professionals and public users. The original intent of the platform is "to make homes and buildings more energy efficient by allowing designers to educate themselves on the preferences of the people who will live and use their buildings, and by allowing the same people to be engaged in the decision-making process that will directly impact their lives" [20].

In this project, another potential application of this platform focused on Knowledge Management in the construction phase is being explored.

The Green 2.0 platform does not meet all the functionality requirements for the SocioBIM knowledge management application described in section 3.1, but it has the potential to act as a useful tool to demonstrate the proof-of-concept of the use case shown in Fig. 1. It is a cloud based platform, allows users to walk through a BIM model, comment on particular elements, categorize their comments, and reply to comments by others. Commercially available software's like AutoDesk BIM 360 [21] exist which provide better functionalities in comparison to Green 2.0 platform but the objective of this paper is not to propose a new software. We are interested in analyzing the impact on knowledge management in the construction phase of the project by using a SocioBIM platform. Hence, Green 2.0 platform was selected as an appropriate platform to implement and test on a live construction project.

## 4. Case Study

### *4.1. Company Background*

AYO Smart Home is a company based in Vancouver, Canada founded in 2015. Their goal is to provide First Nation communities and other markets with affordable, durable, and culturally appropriate housing, while maintaining high levels of livability and energy efficiency. To help reach this goal, they have built a pilot home on the UBC campus to use as a research platform to optimize the construction of future homes. The design was finalized in August 2015 after several consultations with the members of the First Nations community. The construction started in Sept. 2015 and achieved substantial completion by January 2016. The two story, 1620 sq.ft demonstration home has a Magnesium Oxide (MgO) Structural Insulated Panel (SIP). In addition to the high-performance SIP panel envelope, the home makes use of innovative mechanical and lighting systems while adopting a passive design approach to maximize solar energy [22].

This project was appropriate for implementation of the SocioBIM platform since it adopted a new approach to constructing houses with ambitious goals of achieving low cost and high energy efficiency targets. It was anticipated that the pilot home would face several challenges during the construction that would result in knowledge creation, both explicit and tacit, on a daily basis. If this knowledge was captured, it could potentially be reused in future projects, improving the overall efficiency and creating a useful knowledge base for future project teams.

### *4.2. Implementation of Platform*

Installing the pre-fabricated SIP panels was selected as an appropriate activity for implementing the platform. The installation lasted for approximately 14 days. The challenges, issues or successes relating to productivity and site safety were documented on a daily basis through conducting semi-structured interviews with stakeholders, recording time lapse videos, and on-site observations. A total of five members from the project team were interviewed: the Project Manager, the Architect, the Site Superintendent, the Structural Engineer, and the Panel Installer.

An experiment was established to simulate the use of the prototype system on a daily basis by these central project participants (since it was not possible to impose the system on the actual participants in real time during construction). Once the panel installation was complete, five research participants (graduate students at UBC who were also involved in studying the construction phase of this project and were therefore very familiar with the details of the construction operation) were assigned one of the 5 aforementioned roles. They were introduced to the Green 2.0 platform and its various functionalities. Each participant was asked to register on the system. The architectural BIM model of the project was uploaded on the system (using IFC format) and shared with the participants. The participants were then directed by the platform administrators to walk through the BIM model and discuss the various issues related to specific elements on the platform. This exercise lasted for 14 days, the same duration as the installation of the panels. On each day of this exercise, the participants were shown the recorded time-lapse video of panel installation on the actual day of construction. They were also orally briefed on what

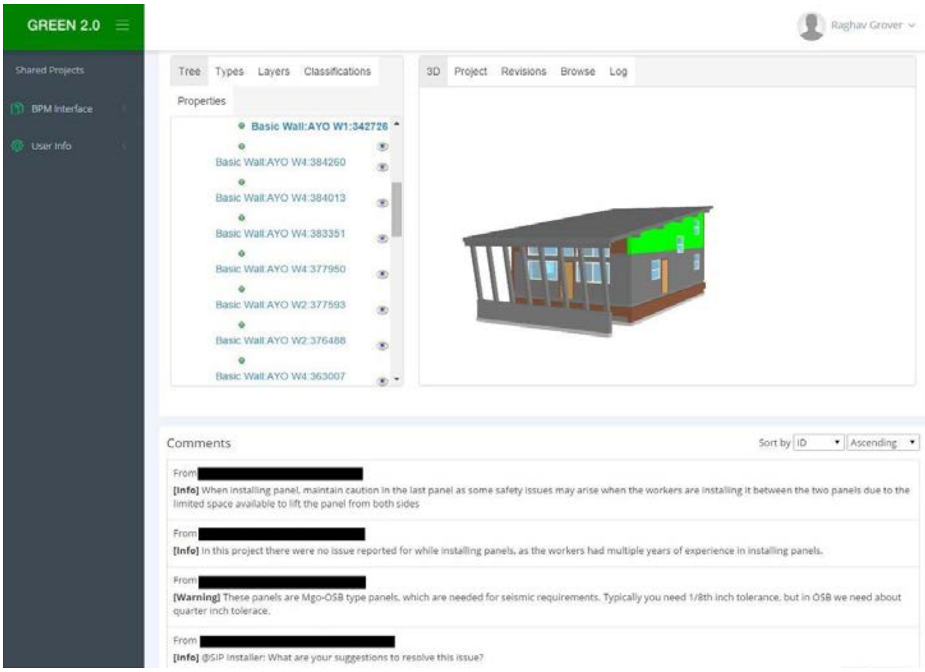
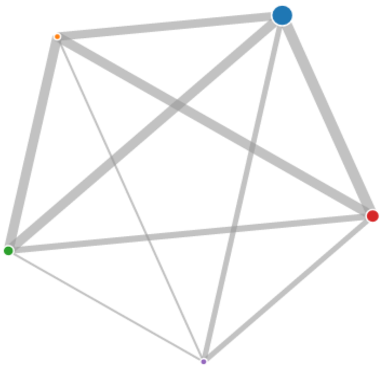
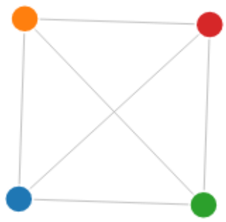



Fig. 2 Green 2.0 Platform for Knowledge Management

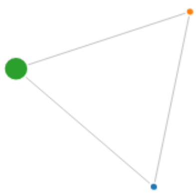


a) Project Level

1) Columns



2) SIP Panels



3) Front Footing

b) Element Level

Fig. 3 Social Networks of participants at project and element level activities took place on-site and what challenges and successes happened on the actual day of construction. An example of the user interface of the platform is shown in Figure 2.

### *4.1. Post Implementation Review*

A total of 44 comments were created by the participants, and 24 of these were replies to other comments. The system then mapped the social networks related to collaboration at two different levels–the project level and the building-element level. These are shown in Figure 3. Each node represents a unique user, the size of node represents the number of comments created by that user on a particular element or project. The edges represent, at the element level, co-commenting by different users on the same element and, at the project level, users who have co-commented on at least one element. The weight of an edge is proportional to the number of elements shared between two different users for commenting.

It is difficult to explicitly evaluate the success of a SocioBIM platform by using it in only one project. The sizeable benefits can only be realized when the platform is used for a longer time and across different projects to enable reuse of the knowledge being captured and better decision making. However, a few observations regarding the use of the platform can be made:

- The element graphs were useful in identifying the specific building components on which the most or least discussions happened. This can be useful in future designs, scheduling, fabricating etc. For example, in the case of the SIP panels, one of the discussions was focused on grouping the same panel shapes together by the use of numbers to reduce installation time, and there was a consensus amongst the four participants involved.
- The 3D BIM model in the platform made the discussions more holistic and engaging as the visualization made it easy to identify conflicts between different building elements and to anticipate future risks related to delays, safety, or other issues. For example, one discussion highlighted that the installation of the front posts and the roof could have been accelerated if certain modifications were made on the concrete footing in advance.
- The size of the nodes was useful in identifying the most active participants in the discussions and, since each participant has their own profile, different kinds of analytics on this information could provide insights about the social construct of the discussions
- The problem solving followed a collaborative approach and there was continuous feedback from different participants. This can ultimately result in creating a continuously evolving knowledge base of best practices that can be used in future projects

In addition to these observations, some of key recommendations were made by the participants to improve the platform functionality and to make it more engaging for users:

- Have the option of tagging different participants, quoting comments from others, and rating the solutions of others.
- Add an ability to select multiple building elements at once to assign group comments.
- Include an ability to search for keywords within the comments.
- Add multimedia content to the comments.
- Provide a structured format for comments.

## 5. Conclusion

This paper discussed the current issues with the construction industry related to the capture and reuse of knowledge, in particular the tacit knowledge. The various benefits and challenges have been highlighted through a review of past research done on using social platforms for knowledge management in construction. The demonstration of a social BIM platform, referred to as a SocioBIM application, for knowledge construction in construction was presented. The limitations and benefits of using such a platform have also been discussed based on post-implementation reviews and feedback from participants. The main objective of the paper was to assess the usefulness of using a BIM-based platform for capture and reuse of tacit knowledge. The platform serves as a proof-of-concept for the idea of using BIM-based social platforms for knowledge capture and adds another case in the limited pool of case studies related to innovative approaches for knowledge management in construction. The idea of the SocioBIM effectiveness can be further supported by future applications in subsequent projects. More research and case studies are needed to further assess the usability of such platforms. In conclusion, the authors believe that knowledge management is an area of construction that has often been neglected in the past. The construction industry needs to adopt some innovative ways to capture and reuse the knowledge of their workers and move away from the current trend of storing project review documents in company databases.

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