Management of deconstruction of construction objects

O Bukunova¹, A Bukunov²
¹Department of information technology, Saint Petersburg State University of Architecture and Civil Engineering, 4, 2-a Krasnoarmeyskaya st., Saint Petersburg 190005, Russia
²Higher school of cyberphysical systems and management, St. Petersburg Polytechnic University of Peter the Great, 29, Polytechnicheskay st., Saint Petersburg 194064, Russia

E-mail: bukunovaolga@yandex.ru

Abstract. A change in any design variable can affect the environment during all relevant stages of the building life cycle. Because of competition, design and construction companies have become very interested in developing sustainable construction due to the modernization of resource potential optimization and management. The production chain has been built as part of an assessment of the life cycle of a construction project to address the challenges of sustainable construction. The possibilities of using information modeling for the planning and design of building deconstruction are analyzed. A deconstruction control method using information modeling has been developed, which implements control based on a simple and advanced feedback loop.

1. Introduction
In recent years, building information modeling (BIM) has been actively implemented at different stages of design, construction, and even operation [1, 2]. BIM makes it possible to monitor system operation in a virtual reality environment, thus simplifying construction, including renovation, overhaul, oversight, and supervision [3, 4]. Despite its benefits, BIM does not cover the final stage of the life cycle of a building, the useful life of which has ended [5]. Deconstruction is a comprehensive strategy to dismantle a building intended to save as many materials suitable for reuse as possible [6]. Deconstruction is “construction in reverse” or the careful dismantling of a structure [7]. Reuse means the use of materials without altering their form except for minimal processing, i.e. removing fasteners, cleaning, and reshaping [8].

2. Rationale
Modern buildings are complex structures that consist of multiple materials and components, with many of them having various design characteristics that were determined at the design stage but will be continuously modified up to the very disposal. Companies increasingly often embrace the principles of green and sustainable construction, which implies resource-saving [9]. This means activities intended to use resources efficiently and save them [10]. A distinctive feature of the logistics approach within the management theory is process management in space and time with minimum consumption of resources and maximum customer satisfaction [11]. For sustainable construction, a method of assessing the project life cycle is relevant when implementing resource management and
the possibility to change input and output flows of data at each stage of the construction project life cycle [12]. A developed information model of a construction project (starting from its design on paper and ending with building’s disposal) is variable. We can introduce any changes to such model and see instantaneously how they affect building construction, operation and deconstruction.

3. Aims
The study aims to analyze the capabilities that building information modeling offers for resource management during sustainable construction at the deconstruction stage for efficient teamwork when handling data in the decision-making process. In the course of the study, the following tasks were determined and solved:

- analysis of the construction project life cycle assessment as one of the management tools used to solve sustainable construction tasks;
- analysis of the possibility to use BIM for planning and designing building deconstruction;
- development of a method to manage deconstruction using BIM-based integration and interaction of data flows.

4. Assessment of the construction project life cycle
Let us analyze the product life cycle assessment as one of the management tools using the logistics methodology, intended to solve tasks of resource-saving and determine the environmental impact of production. The Life Cycle Assessment (LCA) method consists in a systemic approach to various resources used in the production of components, construction, and operation during the life cycle starting from the extraction and processing of raw materials and ending with the disposal of individual components of the construction project [13]. The entire production chain, from the production of construction products to the operation of facilities and disposal of production waste, is subject to the analysis and assessment of inputs/outputs and environmental impact. To successfully apply this method, ERP information systems are needed [14].

The method includes making a list of input (energy and material) and output (environmental emissions) components at each stage of the life cycle; assessing potential environmental implications related to the components identified; interpreting the results to make justified decisions [13].

The relations between the construction stages and the environment can be represented by means of the product life cycle concept as a production chain (Figure 1). In terms of environmental impact management, the life cycle is a set of sequential stages of the production chain [13].

To improve the efficiency of construction and optimize the environmental impact at each stage of the life cycle of a facility under construction, resource flows shall be considered. The analysis of resource flows makes it possible to determine the criteria and characteristics of the resources necessary for the system to function, identify components of the system and compare alternative options of construction materials, components and processes. The LCA method is relevant as it represents an analytical tool that helps to justify the choice we make selecting a technology that will ensure the reliability and adequacy of the results [13].

Construction project LCA includes the quantitative assessment of the environmental impact and it is used for the optimization of sustainable construction at different stages of the building life cycle. The analysis is expedient at planning, finding alternatives, designing construction processes, as well as during operation and even deconstruction. The LCA method is not always accurate due to unavoidable assumptions, large volumes of data on the analyzed processes and their adequacy (related to measurement errors, different dimensions, and averaging). The low prices of some resources (water and energy) and problems in production organization have led to the insufficient accounting of these resources. Electronic resource accounting has started to be used only lately due to the active implementation of building information modeling (BIM). However, even when data are collected on a regular basis, averaging is significant, and it is very difficult to determine the share of resources used for the production of a certain type of components, much less to evaluate their contribution to pollution.
5. BIM for building deconstruction

Let us consider the deconstruction process in more detail. Scheduled deconstruction means planned works performed when the useful life of a building comes to an end. These works make it possible to efficiently recover components of the building for reuse, recycling, or repair [8]. The purpose of building deconstruction is to avoid facility demolition as a method for the disposal of a building with the expired useful life. First of all, deconstruction eliminates pollution and waste generated during construction and demolition, which is typical for any type of demolition. Other advantages include lower harmful emissions, saving of used energy, fewer disturbances during operation, etc.

The efficient strategy for the closed loop of recovery and reuse of construction materials implies a number of basic requirements: the building shall be sectional and demountable; the construction materials shall be suitable for recycling; the production and use of materials shall be harmless; the materials obtained after the recycling shall be harmless as well [6]. However, even during scheduled deconstruction, at the final stage of the building life cycle, many unexpected circumstances may happen that will require immediate solution depending on the tasks of the workers as well as the analysis and assessment of the situation. The deconstruction process, like the majority of processes, requires managerial decisions.

Due to BIM capabilities, it is possible to design an optimal building in terms of deconstruction criteria based on the use of mechanisms and tools to create a common data environment for multiple-user access to data, efficient teamwork when handling such data and extracting information from the Knowledge Base to make decisions [15]. Buildings that were initially designed for deconstruction will allow us to recover a lot more materials for reuse. This will provide significant economic and environmental advantages. The active use of information modeling for the development of various scenarios of building operation and disposal has a great future. Through the software application programming interface (API), BIM improves the cooperation between different stakeholders, makes it possible to visualize the deconstruction process and develop the deconstruction plan, analyze its efficiency, and make a quantitative evaluation of the materials recovered [16]. Using BIM, we can
model alternative options for buildings with the expired useful life and perform more efficient management of the building life cycle on the basis of an LCA model. In search of an optimal solution, BIM capabilities allow us to perform recalculations for various options of project implementation at all stages of the building life cycle [17]. It is obvious that BIM shall be actively used in the management of building deconstruction. Proper design solutions based on BIM can have a impact on waste minimization and performance characteristics of buildings at the end of their useful life.

6. Method of building deconstruction management based on BIM

Let us apply the process approach to the management of various construction stages. According to the ISO 9000 standards, any process represents an activity or a set of interrelated activities that have inputs and outputs [10]. Inputs are objects intended for transformation and value addition when the process is conducted, while outputs are the results of such transformation and value addition. Components and their elements, information, resources, or documents can be inputs and outputs. Resources include personnel, infrastructure, and production environment, as well as financial resources, environmental resources, etc. Input and output flows can include the use of resources, environmental releases, discharges to water and soil. Stakeholders can significantly influence process management. This especially goes for consumers as well as suppliers, developers, competitors, expert evaluation and regulatory authorities, and the entire environment of interrelated processes.

Deconstruction management will ensure efficient decision-making mechanisms with regard to the optimization of deconstruction. Let us distinguish a system of management objects and a management entity when modeling the deconstruction process. The system of management objects includes the deconstruction process and its managed parameters based on BIM. It also includes processes supplying inputs and management resources, processes of interaction with consumers of outputs (developers of a new building, buyers of components and materials) and other stakeholders, as well as processes of the internal and external environment that affect deconstruction. The management entity is the management system and its resources. A deconstruction process management diagram with the suppliers of inputs, consumers of outputs, management system, and environment is given in Figure 2.

![Deconstruction process management diagram with BIM-based planning.](image)

Two-way material and information flows are indicated with the solid lines, while other information flows are indicated with the dashed lines.

In the majority of models, planning of the management of dynamic processes when solving construction and deconstruction improvement and development tasks is not considered. BIM-based design and planning make it possible to ensure efficient decision-making processes for optimal deconstruction. Let us take into account the following provisions when building a deconstruction
management model. We will consider deconstruction as a part of a system of interrelated processes in a specific environment, take into account the dynamics of deconstruction being managed and the environment with related processes, and classify management and planning schemes and resources depending on the purposes and conditions of process manageability. We assume that the feedback principle, as well as planning, organization, and coordination of performance, motivation of contractors, analysis of objectives, control, and managerial decision-making underlie deconstruction management.

In the deconstruction management model suggested, interrelated cycles are formed from elements of the management object (deconstruction process with its manageable parameters based on an information model) and the corresponding management system. Management on the basis of a simple and extended cycle including feedback depends on changes in the planning and management objectives. The planning and management cycles can operate in the regulation mode and the mode of changes in the parameters of the management object depending on the condition of interrelated processes and the environment affecting the objectives of the deconstruction process.

In the conditions of the permissible impact that the managed parameters of the deconstruction process have on the decisions made, the regulation mode applies. It ensures stable operation at the last stage of the construction project life cycle. If the deconstruction parameters significantly deviate from the planned and expected ones (in terms of the condition of materials and components, use of toxic paints in old buildings, etc.), the management objectives are replaced. The use of information modeling which allows us to adjust the objectives efficiently enough will contribute to this [18]. The management system regulates all the components of the management object: suppliers’ work, deconstruction operations that include the recovery of parts, components, and materials and their reuse, requests from consumers and other stakeholders, environmental state, and the very management system. The methodology of the approach requires the continuous coordination of the deconstruction management objectives, parameters, and resources. Thanks to the powerful visualization capabilities of BIM, teams of developers can demonstrate the advantages of various options of sustainable deconstruction with ease. A common data environment is implemented by means of BIM for multiple-user access to data, efficient teamwork when handling such data and extracting information from the Knowledge Base to make decisions [19].

7. Results
In the course of the study:
- We have proposed a production chain within the framework of the construction project life cycle assessment as one of the management tools to solve sustainable construction tasks.
- The possibility to use BIM for planning and designing building deconstruction was analyzed.
- The method to manage deconstruction using BIM-based integration and interaction of data flows was developed that makes it possible to perform management on the basis of a simple and extended cycle including feedback.

8. Conclusion
Information modeling makes it possible to improve the efficiency of the decisions made, but it requires the transfer of information in digital form, its repeated use at stages of the facility life cycle and information processing for the purposes of decision-making [20]. BIM-based design for deconstruction is relevant not only for the recovery of building components at the end of the useful life but also for processes that facilitate building assembly and disassembly. Despite the efforts made to reduce deconstruction waste, it is still a long way to the minimization of waste based on the development of disassembly tools using BIM.

Proper design solutions based on BIM can have a significant impact on waste minimization and performance characteristics of buildings at the end of their useful life. The study focuses on revealing the capabilities of BIM that will ensure efficient decision-making mechanisms with regard to
deconstruction at the design stage. It will also be possible to optimize management resources at the final stage of the life cycle using BIM tools.

References
[1] Eastman C Teicholz P, Sacks R and Liston K 2011 *BIM Handbook Second edition* (NJ: Wiley) p 626
[2] Azhar S et al 2011 Building Information Modeling for Sustainable Design and Leed (R) Rating Analysis. *Automation in Construction* 20(2) 217–224
[3] Succar B 2009 Building Information Modelling Framework: A Research and Delivery Foundation for Industry. *Automation in Construction* 18(3) 357–375
[4] Tardif M and Smith K D 2009 *Building Information Modeling: A Strategic Implementation Guide* (Hoboken: John Wiley & Sons.) p 216
[5] Azhar S et al 2012 Building information modeling (BIM): now and beyond *Australasian Journal of Construction Economics and Building* 12(4) 15–28
[6] Akinade O O et al 2015 Waste minimisation through deconstruction: a BIM based Deconstructability Assessment Score (BIM-DAS) Resources, *Conserv. and Recycling* p 105
[7] Giglio F 2002 Controlling environmental impacts in the dismantling phase. Design for deconstruction and materials reuse *Proc. of the CIB task group 39. Deconstruction Meeting* (Karlsruhe) p 272
[8] Kibert C J 2002 Deconstruction’s role in an ecology of construction. Design for deconstruction and materials reuse *Proc. of the CIB task group 39. Deconstruction Meeting* (Karlsruhe) p 272
[9] Tetior A N 2003 Architectural and construction ecology. Sustainable construction *Legal issues of environmental protection. Express information* (Moscow: VINITI) 11 39–40
[10] GOST R 52107-2003 Resource Saving. Classification and definition of indicators (Moscow: Gosstandart of Russia) p 7
[11] Anikin B A 2013 *Logistics* (Moscow: Prospectus) p 406
[12] Repin V V and Eliferov V G 2005 The process approach to management. *Business Process Modeling* (Moscow: RIA "Standards and Quality") p 408
[13] Ulanova O V and Starostina V U 2012 A brief overview of the method of assessing the product life cycle and waste management systems *Modern problems of science and education* 4
[14] Starostova E N 2010 *ERP-systems for general contractors* (Head of a construction organization) 4 34–39
[15] Bukunov A S 2018 Lifecycle management of a construction object based on information modeling technology *System analysis in design and management: sb. scientific tr. XXII Intern. scientific -practical conf.* Part 1(SPb.: Polytechnic Publishing House. University) pp 324–330
[16] Bukunov A S and Bukunova O V 2019 Tools of data transmission at building information modeling *International Science and Technology Conference "EastConf" Vladivostok Russia* (IEEE Xplore Digital Library)
[17] Bukunov A S and Bukunova O V 2019 Information exchange in the common system when creating BIM *BIM in construction and architecture: Proceedings of the II International conference BIM* (SPb: SPSUACE) pp 59–64
[18] Bukunov A S and Bukunova O V 2018 Integration of blockchain technology and information modeling of real estate objects *BIM – modeling in construction and architecture problems: materials of the All-Russian Scientific and Practical Conference* (SPb: SPSUACE) pp 45–51
[19] Jiao Y et al 2013 A Cloud Approach to Unified Lifecycle Data Management in Architecture, Construction & Facilities Management: Integrating Bims and Sns. *Advanced Engineering Informatics*. 27(2) 173–188
[20] Gudgel J 2014 *Building Information Modeling: Transforming Design and Construction to Achieve Greater Industry* (McGraw-Hill SmartMarket Report) p 42