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Building information modeling & sustainability in railway

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Abstract—

We have seen that the advantages of BIM are today numerous, whether in the literature or in the feedback of projects. Controlling costs is an undeniable advantage, but it is not the only one.

In recent years, humanity has become aware of ecological problems and their consequences for the very future of ecosystems. Commitments are made at a high level by policymakers around the world to limit the impact of ecological disruption and to ensure sustainability.

In the field of construction and public works, the demands of the preservation of the environment are increasing. In this chapter, we will try to see what BIM can bring to sustainability.

Keywords - Building Information Modeling, BIM, sustainability, railway

I. INTRODUCTION

Sustainability is a common goal for all actors. The use of BIM obviously contributes to reducing the risk of error on a site with the benefits that this implies afterwards. The BIM approach in a project optimizes design inclusively with respect to energy and environmental criteria. Finally, BIM management of the entire life cycle of an installation optimizes the reuse of materials.

BIM allows, from an environmental point of view, a better management of natural resources thanks to databases of BIM objects that can integrate information relating in particular to their nature, their origin and the means provided to produce them. BIM makes it possible to integrate from the design phases thanks to the tools that it puts at our disposal all the data relating in particular to the reuse of building materials. BIM is also and widely used for the energy optimization of buildings and installations through energy re-engineering from the design phase. Finally, the BIM provides a relatively large database that through a controlled process to manage the flow of materials throughout their life cycle [6].

In this chapter, we will limit the study of BIM and sustainability in the following 3 main fields:

Optimizing the use of materials for durability

Energy efficiency.

Sustainability in the management of the life cycle.

In our analysis of the 3 fields, we will combine the results of the review of the state of the art and feedback from projects. A fall will be made at the end to explore these fields in our study, ie the BIM in the railway.

II. OPTIMIZING THE USE OF MATERIALS FOR DURABILITY SELECTING A TEMPLATE

United States Environmental Protection Agency (USEPA) estimated that there were 10.98 million tons of construction wastes generated in the US in 1996, and 15.1 million tons in 2003. USEPA gathered data from 95 residential projects and 12 commercial projects and found the average waste generation rate was 4.39 lb/ft² for residential projects, and 4.34 lb/ft² for commercial projects. Based on $353,652 million residential construction value and $256,501 million commercial construction value reported by Department of Commerce for 2003, and average construction cost of $76.80 per ft² for the residential project and $111 per ft² for the commercial project, reported from Census data, EPA estimated that 15.1 million tons of construction wastes were generated in 2003 (10.1 million tons residential, 5 million tons commercial, not including demolition) and 10.98 million tons were generated in 1996 (6.56 million tons residential, 4.42 million tons commercial, not including demolition). A survey of 809

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architects, engineers and contractors showed that prefabrication not only reduced waste, but also the project schedule and budget. Case studies of South Korean projects with BIM models that were used for post-design prefabrication: Comparing the BIM model from design and installation shows that BIM coordination solved design errors, avoiding thus potential retouching. Other researchers have also emphasized the BIM - prefabrication relationship and called it "BIM-driven prefabrication"; they surveyed 305 architects, engineers (civil and structural only) and contractors; 31% reported on-site labor reductions greater than or equal to 25% due to off-site manufacturing, and 27%, an increase in labor productivity on site greater than 25% due to the modeling process. As stated in the International Standards Organization's (ISO) environmental management systems, a well-executed environmental practice can also generate financial and operational benefits. In the case of waste reduction through BIM and prefabrication, time and cost savings can also be used [16].

Pre-fabrication is an important asset for projects. BIM allows, through the 3D model, to exit directly from manufacturing plans with almost no adaptations. The prefabrication of the metal frame, concrete products, mechanically welded parts, ... not only saves time but also optimizes the use of materials as it is done in factories and industrial sites with tools and specific machines, unlike the site where the elements are delivered in so-called standard dimensions of the market, which implies large amounts of waste [2][3].

III. Energy efficiency

The construction sector contributes greatly to socio-economic development, due to its strong participation in employment and its contribution to the enrichment of a country's architectural heritage. However, this sector also contributes substantially to energy consumption, greenhouse gas emissions, resource consumption, but also to the production of waste or pollutants causing significant environmental damage. To act on the reduction of greenhouse gases, the energy efficiency of buildings is today identified as a relevant and profitable means. In addition, digital transformation, through BIM, has led to changes in practice and is beginning to break through in regulations and scientific research. This creates potential for better digital management of the energy efficiency of buildings and at the same time a very important need for new skills for all construction professionals.

Buildings account for 50% of global energy consumption and produce about 35% of Greenhouse Gases. This is why legislations around the world are particularly addressing this sector aimed at reducing energy consumption, for new construction, but also in renovation projects. In this context, BIM can stimulate and facilitate energy-efficient construction on the basis of improved data exchange and communication flow. In practice, it can enable, for example, accelerating the realization of energy simulations for the search for beneficial solutions for the building and future users, in particular by establishing specific commissioning requirements, and by offering an opportunity for systematic management of maintenance.

Recent research describe the “green BIM” as a model-based method of generating and managing coordinated and consistent building data throughout its project life cycle that enhance building energy-efficiency performance, and facilitate the accomplishment of established goals of achieving sustainability goals. The finding of this Research shows that Building Information Modelling (BIM) based sustainability analysis helps to improve project performance by optimizing resource consumption. Data interoperability and information management through BIM platform solves the problem of building data integration. Interoperability between BIM based design and sustainability analysis tools can improve the workflow between analysis, applications and design deliverables. It reduces the time required for delivering a project; also, help in achieving design intent during the operation of constructed facility [10].

This being said, the current technological development does not always make it easy to trade between the BIM and the BEM Building Energy Modeling. Indeed, a 2015 Brazilian study concluded that BIM and BEM software are not currently interoperable, in contrast to what it is wrongly stated by several software development companies. The transfer of the building geometry, which is the basic input parameter for BEM, is still deficient. The views of analytical models of a building in BEM are not updated automatically with changes in the BIM model. Therefore, several iterations of changing, importing, and exporting the BIM model have to be done in order to ensure that the geometry is correctly transferred. As well as geometry (basic input parameter BEM) is not correctly read by the BEM software, families of objects cannot be translated properly in some other variables analyzed by the BEM software [13]. The same conclusion was made by another British study[7]: Industry practitioners managing the design development of building require an understanding of how that design progresses, and the means of sharing information in an efficient and accurate manner. Use of a framework such as that suggested here could assist designers to include information in their models that can then be used to understand a buildings operational performance, and provide a definitive source of information that can be referenced by all members of the design team. Pezeshki [12] concluded in a recent article that the lack of interoperability between BIM and BEM poses challenges for the development and execution of projects seeking sustainable, efficient and satisfactory energy performance throughout its life cycle, for example incomplete or incorrect HVAC system modeling and missing information about controls.

However, other research [8] has concluded that BIM technology can reduce errors at the design stage and effectively improve the overall efficiency of design. Choosing appropriate methods based on BIM analysis can facilitate successful design and provide different design alternatives, ultimately identifying the most cost-effective and energy-efficient solutions. BIM technology was proven capable of developing a highly accurate simulation platform for the energy consumption of buildings. BIM technology has many features such as visual analysis, collision checking, and construction schedule simulation. Through the established BIM model, the solar radiation, sunshine, ventilation, lighting and lighting of buildings can be simulated to discuss the most appropriate orientation, layout, and floor spacing of buildings, as well as to formulate reasonable construction design schemes and select scientific lighting methods, which effectively reduce building energy consumption. “For the energy-saving renovation of residential houses in towns and villages, the application of BIM technology mainly includes the following aspects: Make up for the lack of building information; determine a Reasonable House Pattern, strengthen professional coordination and reduce the cost of renovation”[9].

V. SUSTAINABILITY IN THE MANAGEMENT OF THE LIFE CYCLE

Although the design of the models via the BIM, and their use during construction are becoming commonplace to increase the efficiency of the building sites, in reality, it is the building management phase that represents the bulk of the expenses. Because of maintenance, but also because it is at the time of operation that must be paid for all errors made at the time of design and construction. Gradually, the world of BIM is focusing more and more on the maintenance of buildings and how this can be implemented in existing software. That's why there should be opportunities in the future to connect the two worlds. According to Marzouk, to create a sustainable building, you have to choose building materials, which are inexpensive throughout their life cycle. Since construction cost estimates for construction projects involve inherent or uncertain risks, life-cycle costing models have been developed to determine the cost-effectiveness of the optimal scenario for building materials. The assessment system was used to determine the degree of environmental sustainability of buildings based on the use of traditional and environmentally friendly materials in construction. The evaluation was conducted by proposing a framework integrating the Building Information Modeling (BIM) [11].

Several logistics optimization studies [5][14] integrating quality, safety and the environment have expressed the need to move into a new way of designing the life cycle of buildings in a more relevant way. BIM can bring a lot in this scheme. As seen before, these are BIM benefits:

Fig. 1. benefits of BIM during all phases [2].

Phase	BIM benefits	Cost impact of using BIM	Results and comments
Idea	Concept, Feasibility, and Design Benefits		
	Increased Building Performance and Quality		
	Improved Collaboration Using Integrated Project Delivery		
Design	Earlier and More Accurate Visualizations of a Design		
	Automatic Low-Level Corrections When Changes Are Made to Design		
	Generation of Accurate and Consistent 2D Drawings at Any Stage of the Design		
	Earlier Collaboration of Multiple Design Disciplines	reducing 15% change orders	Change orders estimated to 10% of project costs. This corresponds to 1.5% reduction of the cost of construction
	Easy Verifi cation of Consistency to the Design Intent		
	Extraction of Cost Estimates during the Design Stage		
	Improvement of Energy Effi ciency and Sustainability		
Construction and Fabrication	Use of Design Model as Basis for Fabricated Components		
	Quick Reaction to Design Changes		
	Discovery of Design Errors and Omissions before Construction		
	Synchronization of Design and Construction Planning	reducingg 5-15% schedule	10% reduction of time corresponds to 5% reduction of the cost of construction of the project (50% of the cost of the projects are relative to manpower, management and machinery)
	Better Implementation of Lean Construction Techniques		
	Synchronization of Procurement with Design and Construction - reduction of wast & reworks	saving 9% of materials	This corresponds to a 4.5% reduction in the cost of construction
Post Construction Benefits	Improved maintenance process	Saving 10% of cost	
	Improved Commissioning and Handover of Facility Information		
	Better Management and Operation of Facilities		
	Integration with Facility Operation and Management Systems		

In this sense, here are the main contributions of BIM in post construction:

- Operation phase: Improve maintenance processes; integrate changes into the life cycle.
- Better management and operation of facilities.
- Integration with facility operation and management system.

VI. SUSTAINABILITY BIM AND RAILWAY?

Before going into the subject of sustainability, BIM and rail, let's look at a concrete example. In France, SNCF has launched a vast 3D BIM acquisition program for its infrastructure. BIM is in the era of time and promises great opportunities for a company like SNCF. Although BIM was initially intended to help professionals during the construction phase of buildings, the tools have evolved. For SNCF, the goal is mainly to look at the existing. This reverse engineering is possible today: all data is a mine of information to support infrastructure management. We must be able to improve the predictive maintenance of our network and the stakes are of size: the regularity of the traffic is to optimize while preserving our requirement with the level of the safety of the users. A first pilot project was launched at the end of 2015. The idea is to take advantage of the collaborative power of BIM as part of a program to implement European safety beacons. BIM is used for track and signaling trades. On this pilot, SNCF works with Dassault Systèmes and the regions of Metz and Strasbourg. Two other pilot projects follow: one in connection with the catenaries in the framework of the Charles de Gaulle Express project for which the power supply must be modeled. SNCF uses the Bentley tools. The other with the station of Saint Cloud, whose modernization is planned, with Revit edited by Autodesk. Although SNCF is only in the early stages of implementation, it is already reaping the support of management who believes in the performance of BIM. And they are not alone: many tenders call for the use of BIM. It is up to us to go even further in this direction. SNCF is also involved in the workshops conducted as part of the MINDD project. The rail must not be left out and our voice is heard. The exchanges are constructive.

Moreover, the BIM method would also be an important source of savings for project management of SNCF projects. Philippe Druesne makes the accounts: the BIM model would significantly reduce the cost related to the correction of defects of a building - currently, this cost is at least 35 € / m² of additional expenses during the construction period, and of € 2.3 / m² / year when the building is put into operation.

In Norway, several major governmental clients, like the national road and railroad authorities, increasingly demand BIM. BIM will become mandatory in large public Norwegian infrastructure projects in 2016. This makes the Norwegian infrastructure sector a global pioneer in this area of BIM use. The initiative is driven by sustainability, cost, time, environmental, and quality considerations [1].

From this point of view, the rail sector takes the same consideration of the building and construction sector in the adoption of BIM in a sustainability process. BIM in the railway will in this sense: optimization of the use of equipment, energy efficiency (by combining the tools of energy management) and life cycle management (including the reuse of materials during the infrastructure deconstruction).

VII. Discussion of the Results

Awareness of the impact of human activities and the importance of sustainable development that has been embedded in different sectors in recent years has evolved. BIM allows a major change in project management. It allows a global consideration thanks to a database that, organized and structured, can be exploited and used both for 3D visualization (plans, sections, etc.), as well as for sustainable development issues. The integration of BIM allows [4]:

- A more accurate estimate of the quantities needed to get the right materials at the right time on the job site, thereby reducing imprecise orders and thus waste.
- Minimization of documentation and records.
- The calculation of the energy consumption of the structure.
- Training of the thermal balance of a work.
- Better analysis of the impact of the project on the environment through the measurement of key performance indicators (KPIs) including long-term impact factors that are transferable throughout the project life cycle.
- Increased productivity through improved interoperability and documentation.
- Coordinated planning and consideration of energy and environmental considerations.
- Simplification of internal and external energy audits.

The cost of non-quality is often estimated at more than 10% of the amount of work, sometimes 20 to 30%. Data modeling is a tool for improving the consistency and accuracy of study files, both upstream and in execution studies. This improvement has consequences [15]:

- Better anticipation of the problems to be solved, be they geometry, implementation or supply.
- Detection and resolution of problems throughout the project life cycle for less improvisation on site.
- More clarity between the actors vis-à-vis the delivery to achieve.
- A grouping of information on a single digital model. The project participants are based on a single source of information. BIM builds the model as new data or information arises.
- Facilitate maintenance and after sales service.

BIM will certainly improve quality, reduce time and lower costs. But will it also have a positive effect on risk prevention? BIM is an essential risk management and control tool: not only to identify them at the earliest, but also to trace the actions to be implemented and memorize the processes, it allows:

- Avoid expensive improvisations on the site by anticipating conflicts in the planning phase.
- Facilitate using 4D in connection with the digital mockup, simultaneous task detection or access and ergonomics issues between successive tasks and adaptation of security based, or, if necessary, postpone a task which would not be compatible with the execution of another. Sensitive points and risk situations can therefore be identified earlier and better managed on site to ensure safety of human and technical resources.

- Share useful information between design and structure actors because security data on the construction site is rarely shared with all relevant stakeholders, which may lead to voluntary acts that may be detrimental to the realization project in the best conditions.
- To be more efficient at the moment of the realization.
- Improve the implementation of architectural and technical programming that allows project owners to express the objectives and constraints of the project in order to proceed with its modeling and implementation.

VIII. Conclusions – Perspectives

Human consciousness is increasingly taking into consideration the issues of sustainable development. In construction in general, the issue of sustainability has become increasingly important. In this chapter, we have seen how BIM can contribute to sustainability, especially in terms of material use optimization, energy management and life cycle. Literature and experience feedback shows us that there is still a long way to go to make BIM optimal on this sustainability approach, but that the trend is good.

BIM in the railway is part of the same process. It would allow more integration of the sustainability approach into the projects and the life cycles of the facilities.

In the previous researches, we reviewed the literature regarding BIM to rail, its usefulness in terms of cost optimization. We will now move on to a practical case study.

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