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Building Lifecycle Modeling

Svitlana Tsiutsiura[1], Yevhenii Borodavka[2]

Abstract: ***This paper describes building lifecycle modeling process in general.The basic stages of building lifecycle and its connections are pointed and building representation models at each lifecycle stages are described. Correspondingly, we suggest distinguishing the information types of the representation models. Furthermore, the list of common problems to solve during the building lifecycle modeling is presented. In addition, we have provided the analysis of current state-of-the-art solutions for the building lifecycle modeling for the sake of extraction typical information types are used by different tools. As a result we suggest a hierarchical decomposition of computer aided tools which are used forthe building lifecycle modeling.***

Keywords: building lifecycle, PLM, BIM, CAx, AEC CAD, information types

1. Introduction

The problem of the building lifecycle modeling automation is still an actual. Nowadays there are lots of different solutions in this field, but all of them do not provide exhaustive solution of the problem.

Today, the generation and management of digital representation of buildings called Building Information Modeling (BIM). In fact BIM is the subtype of the Project Lifecycle Management (PLM) in construction. The BIM term includes processes which arise during planning, designing, constructing, operating and maintaining diverse physical infrastructures [3]. In addition, the BIM term includes software solutions used for building lifecycle automation (Fig.1).

Figure 1: Building Information Modeling (BIM)

The common problem in BIM today is integration between different stages of the building lifecycle. To handle this problem we need to create digital representation model of the building at each stages of the lifecycle and to develop standards for data transferring between different software solutions. Meanwhile, the market giants such as Autodesk and Nemetschek are making their own environments which include automation tools for each stages of the building lifecycle. Which way is better currently is unknown. But in this work we want focused at the building lifecycle stages and their digital models.

First of all, we need to prepare the list of common problems, after that we will distinguish basic building lifecycle stages, then we will describe digital representation models of the building at these stages and after that we will suggest decomposition of information types for each of the digital models.

2. Previous Work

There are several works related to building lifecycle modeling in general.

The works [1, 2] are related to Computer Aided Design (CAD) and are considered as predecessors of the BIM term.

The paper [5] presents a building model conception which describes basic stages of the building lifecycle and their common parts.

The paper [6] considers possible data structure architecture for storing the digital information about the building representation model at each stage of its lifecycle.

The article [9] is dedicated to problem of PLM in construction and describes main stages of the building lifecycle, corresponding tools and executors for each stage.

3. The Problem List

Before we start describing the building lifecycle and it stages we need to prepare the problem list we have to solve. The common problems to solve are the following:

- Building lifecycle stages researching;
- Researching digital model representation of the building at each stage;
- Analysis and classification of the contemporary tools of the building lifecycle modeling automation;
- Creation of a conceptual model for a data structure at each stage of the building lifecycle;
- Researching of common methods for a data structure optimization for the sake of effective data usage during the building modeling.

The main problem list is created, thus we can start main research.

4. Building Lifecycle

We suggest stepping away from classical BIM decomposition and aggregate it stages to six: concept, sketch, design, construction, maintenance and demolition (Fig. 2).

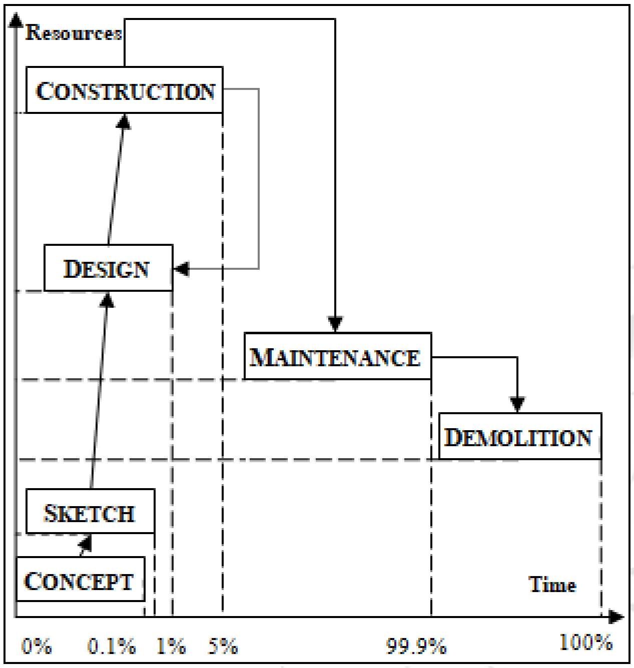

Figure 2: Building Lifecycle

As you can see the most problems arise between design and construction stages. It is very often situation when during construction stage the design documentation is changing. That is why we need to have tools for total automation of the building lifecycle. But for the creation of such kind tools we need to understand which types of the building digital representation models are used at every lifecycle stage. We need to analyze current state-of-the-art computer aided tools for the sake of extraction information types and representation models were used for the building modeling. We will use the CAx term for marking the computer aided tools are used for the building modeling.

Firstly, we suggest using decomposition of CAx tools according to its place in building lifecycle modeling (Fig. 3).

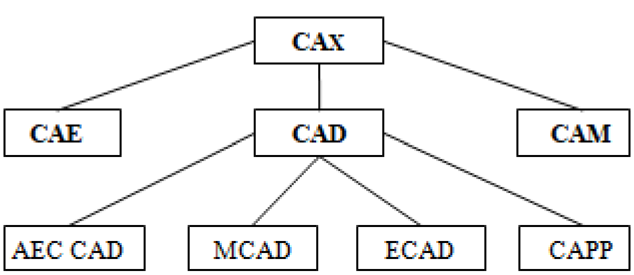

Figure 3: CAx tools classification

Here CAE is Computer Aided Engineering, CAD – Computer Aided Design, CAM – Computer Aided Manufacturing, AEC CAD – Architecture Engineering and Construction CAD, MCAD – Mechanical CAD, ECAD – Electronic CAD and CAPP – Computer Aided Process Planning.

For different building lifecycle stages are used different types of the CAx tools and each tool has specified a digital representation model of a building.

After analyzing different CAx tools we have distinguished the next types of the digital representation models (Fig. 4).

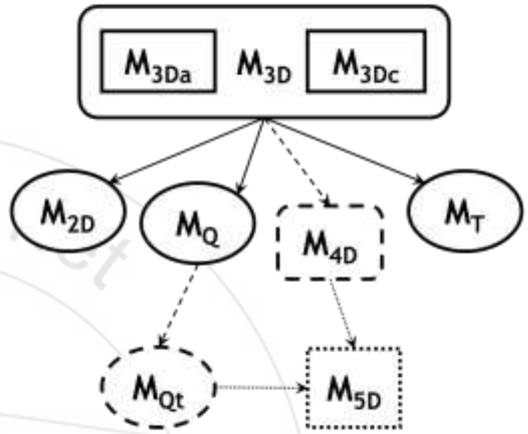

Figure 4: Types of the building digital representation models

Here $\mathbf{M_{3D}}$ is the common 3D model, $\mathbf{M_{3Da}}$ – architectural 3D model, $\mathbf{M_{3Dc}}$ – structural 3D model, $\mathbf{M_{2D}}$ – common2D model, $\mathbf{M_{Q}}$ – quantity and financial model, $\mathbf{M_{T}}$ – topological model, $\mathbf{M_{4D}}$ – 3D model with time parameter, $\mathbf{M_{Qt}}$ – quantity and financial model with time parameter, $\mathbf{M_{5D}}$ – 3D model with time, quantity and the financial information.

The general building digital representation model is a union of the specified models:

$$M_B = M_{2D} \cup M_{4D} \cup M_T \cup M_{Qt} .$$

Now we can specify types of information are used by the general building digital representation model.

The $\mathbf{M_{3D}}$ model firstly consists of geometric information (I_G). It is information about spatial location of the building elements, its shape and dimensions:

$$I_G = \left\{ \sum_k \left[O_k(X,Y,Z,W), S_k\left(\sum_n G_{k,n} \left[\sum_i (x_i, y_i, z_i, w_i) \right] \right) \right] \right\},$$

here O_k – base point of the building element in homogeneous ($W \neq 1$) or Euclidian ($W=1$) coordinates;
S_k – geometric shape of kth element of 3D model;
$G_{k,n}$ – set of geometric primitives for geometric shape of kth element of 3D model.

The next type of information is used by 3D model is topological information (I_T). This type of information describes different interconnections between building elements:

$$I_T = \left\{ \bigcup_i \bigcup_j \left[e_i (\cup | \cap) e_j \right]; e_i, e_j \in E, i \neq j \right\},$$

here$E$ – set of all 3D model elements.
And at last, for complete 3D model we should consider another one type of information – attributive (I_A). Any information can be an attribute: number, text or graphics. The important attributes for a building element are: element type, material or others specified attributes like, for instance, computation formulas:

$$I_A = \left\{ \sum_i \left[T_i, M_i, \sum_j P_{i,j} \right] \right\},$$

hereT_i – type of i^{th} element of building 3D model;

M_i – material of i^{th} element of building 3D model;
$P_{i,j}$– j^{th} specified parameter of i^{th} element of building 3D model.

All others the digital representation models of the building used different unions of described information types. And for the sake of possible extension of the building representation model we suggest add one more information type – meta-information.

Developers of the CAx tools should take into consideration described digital representation models and its information types for creating effective software for the building lifecycle modeling.

5. Conclusions

This work describes the basics of the building lifecycle modeling. We have considered stages of the building lifecycle and its interconnections. The most valuable stages are design and construction.

Furthermore, we have suggested the building digital representation models for each stage of the building lifecycle and have described information types are used by these models.

Our future work is to create conceptual model for the data structure at each stage of the building lifecycle and to research the common methods for the data structure optimization for the sake of effective data usage during the building modeling.

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Author Profile

Prof. SvitlanaTsiutsiura is Head of Department of information technology in Kyiv National University of Construction and Architecture (KNUCA), Ukraine. SvitlanaTsiutsiurahas studied at the Kyiv Institute of Technology of Food Industry, Department of automation of technological processes (1988), Ph.D. (1995), D.Sc. (2007), Professor (2008), Academic Secretary of the Academic Council for the theses defense D 26.056.01 (since 1995), deputy dean of Faculty of automation and information technology KNUCA (2000-2010), Member of the Academy of Construction of Ukraine (2014). Prof. Tsiutsiura published over 200 works including 6 manuals, 1 monograph.Since 2008, Prof. Tsiutsiurahas prepared 2 Ph.D. and 1 D.Sc.

Dr. YevheniiBorodavka received B.Sc. and M.Sc. degrees in computer science, Ph.D. degree in computer aided design and D.Sc. degree in information technologies from Kyiv National University of Construction and Architecture, Ukraine, in 2002, 2003, 2009 and 2017, respectively. Since 2005 assistant professor, since 2009 associate professor of the Information Technologies of Design and Applied Mathematics department in Kyiv National University of Construction and Architecture, Ukraine. From 2004 to 2009 – lead engineer and from 2009 to 2012 –senior scientific staff in State Enterprise "State Research and Development Institute of Computer Aided Design in Construction". From 2013 to 2017– lead engineer and since 2017 is senior engineer in Samsung Research and Development Institute Ukraine (SRK).