Rischmoller L., Dong N., Fischer M., and Khanzode A. (2017). "Automation of the Building Information Model Breakdown Structure" In: *LC3 2017 Volume II – Proceedings of the 25th Annual Conference of the International Group for Lean Construction (IGLC),* Walsh, K., Sacks, R., Brilakis, I. (eds.), Heraklion, Greece, pp. 389–396. DOI: https://doi.org/10.24928/2017/0216

AUTOMATION OF THE BUILDING INFORMATION MODEL BREAKDOWN STRUCTURE

Leonardo Rischmoller[1], Ning (Tony) Dong[2], Martin Fischer[3] and Atul Khanzode[4]

Abstract: Breaking down project information via different breakdown structures has been a successful way of managing and controlling construction projects with levels of efficiency and effectiveness otherwise unimaginable to achieve over the past decades. However, the current practice of grouping and organizing building information models from multiple project participants does not reflect such breakdown structures well. This gap renders it a challenge to introducing Building Information Modelling (BIM) to on-site meetings in the construction phase, such as daily subcontractor huddle and pull planning meetings, in which on-the-spot-requests to query federated models are prevalent. This paper introduces the underlying concepts of a method that allows automatic grouping of models so that the model breakdown structure (MBS) matches a certain breakdown structure within a project. An automation tool has been developed accordingly and tested in two case studies, which prove that the proposed method enables project participants without extensive trainings of BIM the rapid identification of the desired model contents.

Keywords: Building Information Modelling (BIM), breakdown structure, model breakdown structure (MBS)

1 INTRODUCTION

It is an intuitive idea to breaking a project description into a series of small parts that could facilitate (1) the preparation of bill of materials, budgets, and schedules; (2) the allocation of resources and responsibilities; and (3) the execution and control of the project. The formalization of this idea dates back to the 1950's and 60's when the United States Department of Defense (DOD) and NASA adopted PERT/COST, the system that first described the work breakdown structure (WBS) as "a family tree subdivision of a program, beginning with the end objectives and then subdividing these objectives into successively smaller end item subdivisions" (DOD and NASA 1962).

By 1983 the WBS had been emphasized and successfully implemented as a program planning tool for more than a decade, and the DOD had been utilizing the WBS as a primary mechanism for the definition of contract work and the foundation for a management planning and control system (Lanford and McCann 1983). Currently it is generally recognized by project management professionals that the WBS is the foundation of planning, estimating, scheduling, and monitoring activities (Rad 1999). In the last 30 years a number research has been conducted on the WBS rationale, rules, as well as related methods (Hameri and Nitter, 2002, Mansuy 1991; Mueller 2000; Gloany and Shtub 2011; Kunz and Fischer 2012; PMI 2013).

1 DPR BIM Manager, DPR Construction LeonardoR@dpr.com
2 DPR R&D Manager TonyD@dpr.com
3 Center for Integrated Facility Engineer, Stanford University, Director fischer@stanford.edu
4 DPR Technology Group Director AtulK@dpr.com

Variations of the original WBS concept have led to the development of different types of breakdown structures subject to certain breakdown criteria, e.g. product breakdown structure (PBS), organizational breakdown structure (OBS), resource breakdown structure, cost breakdown structure, value breakdown structure, etc. Common to these breakdown structures is the same family tree subdivision originally conceived as part of the WBS concept.

Breakdown structures are very effective in managing a large amount of data and structuring the information to aid comprehension (Hameri and Nitter, 2001; Langford 1983; Globerson 1994; Deckro et al 1992). OBS indicates the organizational relationships and are used as the framework for assigning work responsibilities. PBS breaks up a project into a series of small "physical" parts. WBS breaks up a process into a series of small tasks. Together they provide a framework for a detailed cost estimating and control, along with guidance for schedule development and control. Every type of breakdown structure provides a legitimate way to view a project. Depending on circumstances, one approach may be preferred over the others.

Since different breakdown structures call for different structures or management practices during the implementation of the project, some degree of controversy exists as to which breakdown structure is better (Mansuy 1991). On the other hand, efforts in identifying the points of intersection and integration of different breakdown structures (e.g., using the PM software's capability to report with multiple breakdown structures) have been carried out in the last decades (Lanford 1983; Rad 1999; Cam 2005; Kunz and Fischer 2012).

Creating a breakdown structure forces the project designers to choose one approach and adhere to it throughout the project life cycle (Golany and Shtub 2001). This leads to improved efficiencies gained by the specialization, but also to increased efforts in managing information integration, which is often rendered difficult when complex tasks from multiple disciplines (or functions) are created using different breakdown criteria. Building Information Models practices and tools, widely considered as the means to facilitate data integration for construction projects (Gao and Fischer 2008; Hartmann et al 2008) do not offer, however, Model Breakdown Structures that matches breakdown structures within a project with the level of flexibility for BIM coordinators and, more importantly, on-site personnel to navigate and query model contents in a timely fashion.

2 MBS CURRENT PROBLEMS

2.1 Limitations of current BIM practices regarding MBS

The existing BIM tools emphasize more on the information (e.g., properties, attributes, parameters, etc.) attached to each piece (e.g., the part, element, component) of the model and on the level of detail or level of development (LOD) of the BIM pieces. They are less concerned with how the pieces are arranged into a MBS. Some BIM tools offer limited functions of grouping different model pieces by location, elevation, discipline, or other criteria. These attempts however provide a number of "fixed" ways to organize a federated model (also known as integrated model), which either has no relationship with a project's WBS, PBS, or OBS; or makes it too difficult to obtain a MBS that matches any project breakdown structure.

From a general contractor's perspective, a federated model of a project can consist of digital model files from different sources (i.e., different project stakeholders using a variety of model authoring tools) and different project phases (i.e., design models, fabrication models, as-built models, etc.). Sometimes a BIM coordinator needs to combine several hundreds or even thousands of digital model files using some of the available BIM tools (e.g., Autodesk Navisworks®, Solibri®, Bentley Navigator®, Intergraph SmartPlant Review®, etc.). The MBS becomes, in this situation, a long list of digital model files, which do not provide an expedited way (i.e., a few seconds) to identify a certain piece or group of pieces within the federated model. Even if certain BIM tools can help group individual models files into one federated model with a certain MBS (e.g., area → level → discipline → system, etc.) it is very difficult and time consuming, if not impossible, to convert to another model with a different MBS.

2.2 MBS and on-site meetings

It has become a common practice for a general contractor to provide standardized model naming conventions, which facilitate the use of filter features that allow isolating and visualizing pieces or groups of pieces of the federated model. BIM coordinators normally save these visualization scenes as viewpoints (or snapshots) so they can be retrieved rapidly during a coordination meeting. There have been attempts of expanding the use of the federated model to on-site meetings, such as the daily subcontractor huddle, pull planning meetings, and owner-architect-contractor (OAC) meetings. Since on this type of meetings on-the-spot-requests to query the federated model are very common, without the saved viewpoints it could take a model operator minutes to find the right model contents relevant to a topic. In this process it is observed that meeting participants lose interest in models quickly, thus making the introduction of BIM unsuccessful. Without the model visualization, issues that could have been addressed and decisions that could be made within a meeting can be delayed significantly. In other words, the benefits of BIM are not realized in these meetings. This applies in particular to projects with meetings of over 20 participants. Dealing with topics or issues for which the model is not prepared in advance exposes the limitations of the current approaches of applying MBS to the federated model. In most of the on-site meetings the participants may have different ideas and understanding of how they want to breakdown a project. Accordingly, if a federated model matches these different breakdown structures the desired model contents can be rapidly retrieved.

3 THE CIFE MBS AUTOMATION TOOL

The Center for Integrated Facility Engineering (CIFE) at Stanford University has developed a method that allows to group digital model files reflecting different breakdown structures. The CIFE MBS automation tool was developed accordingly. The tool can convert model files created using almost all of the most commonly used BIM authoring tools (including Autodesk Revit®, Tekla®, Microstation®, AutoCAD, etc.) into Autodesk Navisworks® NWD-format files. These NWD files are then automatically nested into a family tree of NWD files using some project breakdown structure (e.g., area, sector, level, discipline, system, etc.). The project breakdown structure categories and the hierarchical order in which these categories will be displayed in every MBS created using the CIFE MBS automation tool, are arranged in a table within a Microsoft Excel® file. From this file the CIFE MBS automation tool pulls the relevant information to create a single Autodesk Navisworks® NWD model, which shows on the 'Selection Tree' window the MBSs corresponding to each arrangement of the breakdown categories. The CIFE MBS automation tool can create as many different NWD files with different MBS just by varying the hierarchical categories grouping criteria included in the Excel file.

Table 1 shows an example of a CIFE MBS automation tool input table containing:

- Four project/model breakdown categories
- Two hierarchical order in which these categories will be displayed (i.e., MBSs)
- A list of eighteen model files that can be in any format readable by Autodesk Navisworks®.

Table 1 Example of a CIFE MBS automation tool input table

MBS-1	**1st**	**2nd**	**3rd**	**4th**
MBS-2	**1th**	**3th**	**2th**	**4th**
MODEL NAME	**PROJECT/MODEL BREAKDOWN CATEGORIES**			
	AREA	**LEVEL**	**DISCIPLINE**	**SYSTEM**
Model A	Area A	Level 1	Concrete	Columns
Model B	Area A	Level 1	Concrete	Columns
Model C	Area A	Level 1	Concrete	Columns
Model D	Area A	Level 2	Concrete	Columns
Model E	Area A	Level 2	Concrete	Columns
Model F	Area A	Level 2	Concrete	Columns
Model G	Area A	Level 1	Concrete	Slab
Model H	Area A	Level 1	Concrete	Slab
Model I	Area A	Level 1	Concrete	Slab
Model J	Area A	Level 2	Concrete	Slab
Model K	Area A	Level 2	Concrete	Slab
Model H	Area A	Level 2	Concrete	Slab
Model L	Area A	Level 1	Drywall	Wall Type 1
Model M	Area A	Level 1	Drywall	Wall Type 1
Model N	Area A	Level 1	Drywall	Wall Type 2
Model O	Area A	Level 2	Drywall	Wall Type 1
Model P	Area A	Level 2	Drywall	Wall Type 1
Model Q	Area A	Level 2	Drywall	Wall Type 2

Figure 1 show the MBS 1 generated by the CIFE MBS automation tool which, for example, could be of great value for a model operator (who does not need to be a BIM coordinator) to rapid retrieve model contents to facilitate discussions in a pull planning meeting, in which the flow of discussion generally follows locations, disciplines, and crews.

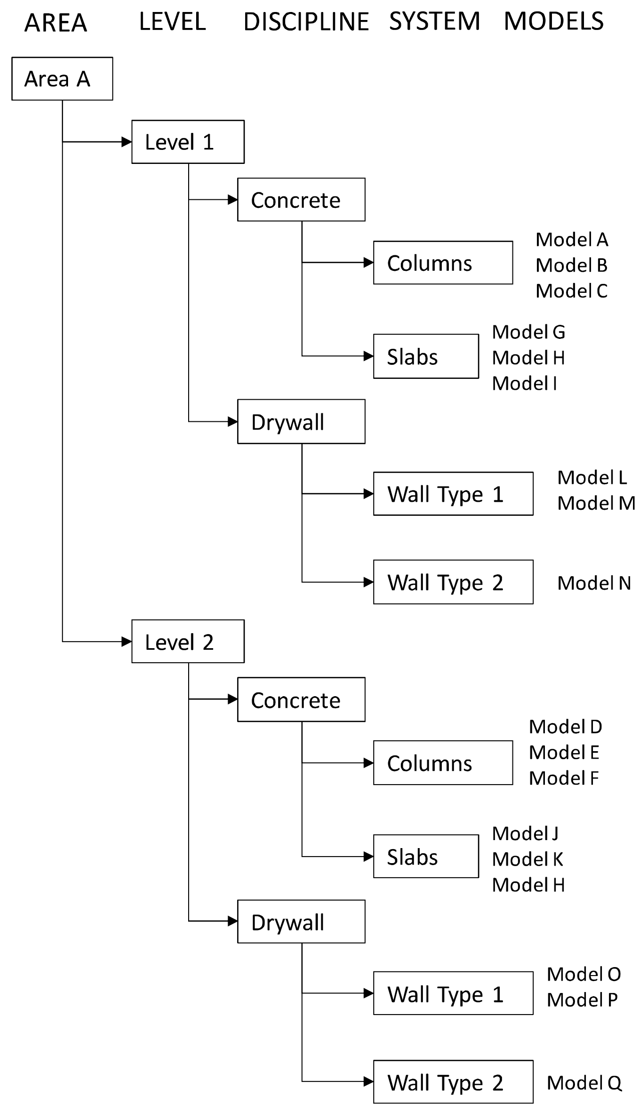

Figure 1 MBS-1

Figure 2 shows the MBS 2 generated by the CIFE MBS automation tool in which the order of the breakdown categories could, for example, be useful in a subcontractors' daily huddle meeting, in which individual trades sequentially report their work progress and plan for the day.

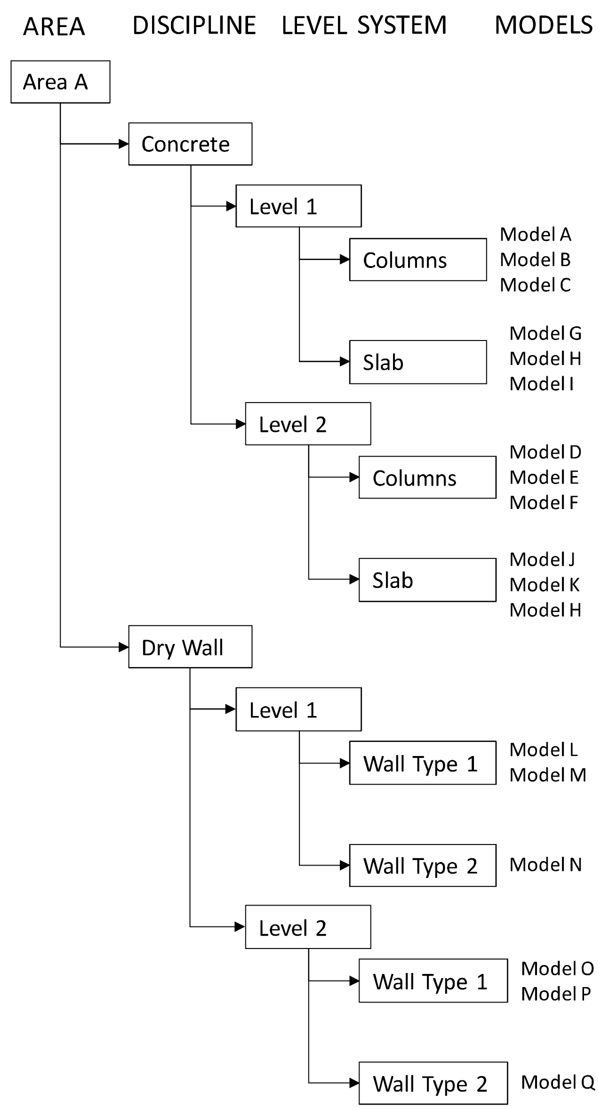

Figure 2 MBS-2

4 Testing the CIFE MBS Automation Tool

4.1 Case Studies

The CIFE MBS automation tool was tested in two case study projects in two different years. The first case study is a multi-billion-dollar power plant megaproject. The second case study is a multi-million-dollar data center project. When testing the model, both projects had just started the construction stage, in which BIM models had been created by designers and some fabricators, to be used for coordination. The power plant had several thousands of models available, while the data center had several dozens of models available. In each case the construction management was carried out by a main general contractor who managed a group of design-build subcontractors to execute the work. Approximately 35 subcontractors were involved in the power plant project, and around 15 subcontractors were involved in the data center project.

Using different combinations of the project breakdown structures (e.g., area, level, discipline, contractor, system, etc.) the CIFE MBS automation tool was used to create Integrated (or Federated) Project Models (IPMs) that combined the existing design and fabrication models of different formats into Autodesk Navisworks® NWD format models. Each IPM contains a different MBS displayed on the Navisworks® 'Selection Tree' window.

4.2 Results

In the first test case finding the right model contents on-the-spot in a meeting was almost impossible due to the many models included in the federated model. After introducing the CIFE MBS tool a BIM coordinator was able to identify the model contents relevant to the topic of discussion in 15 seconds or less. After one-hour training sessions 18 project members (project engineers, project managers, planners and schedulers) eventually became the main model navigator leading their respective meetings. Before introducing the CIFE MBS tool these project members had little to no experience with the models. In the second test case, project engineers hosting different types of meetings were able to navigate and query the model to find the right contents in 15 seconds or less when used the MBSs created with the CIFE tool. Finding the right content had taken several minutes when the MBS were not available. The latencies in resolving issues during the on-site meetings were reported to be significantly reduced (Rischmoller et al, 2017).

Within two weeks of the introduction of models with MBS created using the CIFE MBS tool other meeting participants (e.g., subcontractor's superintendents and managers, owner representatives, planners, safety and quality managers, etc.) started to realize the "presence" of the IPMs and how the models "followed" the ongoing discussions. The participants started shifting their focus of attention from the screen displaying 2D documents to the screen displaying the IPM. After another two weeks, the meeting participants realized that they could not only expect the model to "follow" the discussions but that they could actually "require" the right model contents to lead the ongoing discussions with the confidence that they were going to get an answer, not in the next meeting several days or weeks later, but in the same meeting in most cases.

The simplicity to navigate and query the IPMs led several meetings' participants to believe that this was the "normal" way of working using BIM, which they had not been aware of previously. Furthermore, it was not difficult to find in each case study a tech-savvy field engineer ready to take charge of navigating the model during meetings rather than relying on the "model operator".

5 Conclusions

This paper introduces the underlying concepts of a method that allows flexible MBS configuration reflecting different project breakdown structures. Based on this method the CIFE MBS automation tool is developed which enables quick query in an IPM without saved viewpoints. Without the introduction of this tool the advantages and benefits of BIM could have stayed in the world of modellers and BIM coordinators in the construction phase. According to the case projects team members, the tool allowed on-site personnel to easily overcome their fear of technology and take the lead in using BIM to improve the efficiency of their meetings. Detailed discussions of the results as well as surveys to case studies meeting participants are provided in the paper titled "Improving on-site meeting efficiency by using an automated model breakdown tool" for the same conference.

6 REFERENCES

Chachere, J., Kunz, J., and Levitt, R., Integrated Concurrent Engineering: Grounded Theoretical Factors that Enable Radical Project Acceleration, CIFE Working Paper #WP087, Aug, 2004.

Chachere, J., Kunz, J., and Levitt, R., The Role of Reduced Latency in Integrated Concurrent Engineering, CIFE Working Paper #WP087, Aug, 2004.

Coffe, T., The Future of Integrated Concurrent Engineering in Spacecraft Design, The Lean Aerospace Initiative Working Paper Series, MIT, 2006

Deckro, RF; Herbert, JE; and Verdini, WA, Project Scheduling with Work Packages, OMEGA International Journal of Management Science, Vol. 20, No 2, pp. 169-182, 1992

DOD and NASA Guide, PERT/COST System Design, June 1962

Gao, J.; and Fischer, M. (2008). Framework & Case Studies Comparing Implementations & Impacts of 3D/4D Modeling Across Projects. CIFE Technical Report 172.

Gloany and Shtub 2011????

Globerson, S. Impact of various work-breakdown structures on project conceptualization. International Journal of Project Management 1994 12 (3) 165-171

Hameri, A., and Nitter, P. Engineering data management through different breakdown structures in large-scale project. International Journal of Project Management 20 (2002) 375-384

Hartmann, T.; Gao, J.; and Fischer, M. (2008). Areas of Application for 3D and 4D Models on Construction Projects. Journal of Construction Engineering and Management, 134(10), pp. 776-785, doi: 10.1061/(ASCE)0733-9364(2008)134:10(776)

Kam, C. Dynamic Decision Breakdown Structure: Ontology, Methodology, and Framework for Information Management in Support of Decision-Enabling Tasks in the Building Industry. Doctor of Philosophy Thesis. Department of Civil and Environmental Engineering, Stanford University, 2005.

Kunz, J. and Fischer, M., Virtual Design and Construction; Themes, Case Studies and Implementation Suggestions, CIFE Working Paper #097, Version 14, Jan, 2012

Lanford, H.; and McCann, T. (1983). Effective planning and control of large projects using work breakdown structure. Long Range Planning, 16(2) pp. 38-50, doi:10.1016/0024-6301(83)90054-7.

Mansuy, J. Work Breakdown Structure: A Simple Tool for Complex Jobs. Cost Engineering Magazine, American Association of Cost Engineers, Vol 33, No 12, December 1991

Mueller, S. Resolving Work Breakdown Structure Problems. AACE International Transactions, 2000

Park, B., and Meier, R., Reality-Based Construction Project Management: A Constraint-Based 4D Simulation Environment. Journal of Industrial Technology, Vol. 23, Number 1, pp. 1-11. 2007

PERT Coordinating Group (1962) DOD and NASA Guide, PERT Cost Systems Design.

Rad, P.F. "Deliverable-Oriented Work Breakdown Structure," 1999 AACF International Transactions, CSC 02. Worker Cost (1999).

Yassine, A., and Braha, D., Concurrent Engineering: Research and Applications, Four Complex concurrent engineering and the design structure matrix method. Sage Publications, Vol. 11, No. 3, pp. 165-176. 2003