
Challenging the Role of Location in Industry Foundation Classes

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Abstract

Location is a critical component of construction projects and yet it has received relatively little attention in mainstream digital systems. Efficient management of construction requires a more comprehensive and flexible breakdown of projects than is generally provided. Indeed, it is desirable to separate location as an expressed component of a work breakdown structure (WBS). This idea is not new, but previous definitions of the WBS have not paid any attention to the role of a location breakdown structure (LBS). Focusing on location enables flexibility in the WBS which also reduces data repetition, thereby supporting production efficiency in the management of construction projects. Achieving this requires a re-evaluation of the way location is handled in methods such as industry foundation classes (IFC). The IFC failure to build a comprehensive location definition model currently represents a significant opportunity cost to construction management globally.

Keywords: Construction management, Industry Foundation Classes, location, Work Breakdown Structure

1 Introduction

The 21st century attempt to manage construction more effectively has been through the development of digital environments capable of modelling built environment structures. These models, however, are based on computer generated logic rather than building logic. While development of Industry Foundation Classes (IFC) has enabled progress for design, the same level of progress is not evident for contractors (Mäki & Kerosuo 2015).

Construction management is usually considered to be a process of enablement, that is, a way of enacting elements of design to produce a built environment structure. A traditional method of undertaking this task is to create a work breakdown structure (WBS) representing an hierarchy of work to be done (Björnfot & Jongeling 2007). The concept of decomposition is the organising principle that enables the process of sub-dividing the total project into smaller parts. This smaller-world view is necessary for the contractor to progress the project. Thus, the project schedule represents the work to be done at the lowest level of the WBS, and as such, is the principle working 'model' for the contractor (Weaver 2006).

The project schedule, based on methods of decomposition, provides the units of management for construction projects in order to control resources (Perdicoulis 2013). Without a method of control, the progress of a construction project cannot be managed (Staub-French et al 2008).

Decomposition for construction is dependent on location, both the physical location on the construction site and the location of resources (human and materials). Thus all types of work decomposition, explicitly or implicitly, identifies location (Kenley & Harfield 2014b). Location information in the project schedule (as a model of the entire project) is traditionally constructed in a work breakdown-structure at the conception of a construction project. The result is an implicit location definition model for the project. And, because the model of

location is only constructed for the purpose of the WBS, it may be incomplete. The flexibility of a WBS framework is one of the reasons that the data repetition in a schedule related to works in specific locations can be re-defined through location-definition models (Kenley & Harfield 2014b).

According to Kim et al (2013), at present, rigid BIM models based on Industry Foundation Classes are unable to provide sufficiently detailed location information required to complete the work necessary for project completion. Indeed, much research is taking place to overcome identified IFC constructability issues (Cirbini et al 2016; Wang et al 2014; Khalili & Chau 2013). However, the flawed premise of a significant amount of research, is that the problem to be solved is not the IFC limitations, but troublesome traditional construction processes such as project decomposition and compatibility with the IFC location-definition model.

This paper provides an alternative problem definition: when different definitions of location are used for modelling construction projects, it is because the modellers have different world-views (Gu & London 2010). Ultimately, the differing meanings of location become locked into construction project modelling applications, to the detriment of the entire industry. The balance of the paper aims to outline the role of location in construction management and how it differs from the role of location in Industry Foundation Classes.

Sections 2 provides a short history of the importance of WBS in defining the work to be done for construction projects. It also identifies location as the defining characteristic of construction projects. Section 3 outlines the theory of the location-based structure (LBS) in the Location-Based Management System. Section 4 expands on location in relation to project work decomposition. It claims that the flexibility of WBS to deal with repetition could be more effectively handled by a LBS/WBS matrix. Section 5 outlines the lack of location flexibility in Industry Foundation Classes, as well as the issue of multiple meanings for the location model view within a BIM environment. The discussion of force-fixing the BIM constructability issues also sets the context for section 6. That section proposes that current research seems to offer new construction management models centred on forcing location detail into IFC solutions. Two examples of the research attempts to force-fix the multiple location meanings, design and construct, are outlined. The conclusion restates the argument and suggests options for future research by posing two questions.

2 WBS Decomposition and the Role of Location

The work breakdown structure (WBS), as a tool to ensure scope management, emerged from the earliest days of formalising processes for the management of projects. The WBS creates a framework for network planning and a critical path management method (CPM), and thus was a method for driving task allocation in projects in the 1950s and 60s.

WBS is an essential component of project management according to almost all scholars and practitioners. The commonly accepted definition for work breakdown structure is: "...a product-oriented family tree subdivision of the hardware, services and data required to produce the end product which is structured in accordance with the way the work will be performed and reflects the way in which project costs and data will be summarised and eventually reported." (Kerzner, 2013).

The WBS has subsequently been accepted as fundamental for project management with very little challenge (Weaver 2006). According to Archibold and Villoria (1967), project definition equates to a WBS, with eight substructures: Project Organisation, Network Plan, Calendar Time, Estimating, Chart of Accounts, Funding, Authorisation Control and Report. These sub-structures have become the basis of construction project management processes.

A work breakdown structure is an hierarchical decomposition framework for presenting the entire work that needs to be completed in order to achieve the project objectives (Kerzner 2013). It links the work to be done to successively lower levels of project management. Each descending level of the WBS describes project work at an increasingly detailed level. WBS is also context dependent, and can be structured according to project phases, major deliverables, disciplines or locations. This means that the detail of work

provided by WBS is necessary to ensure the strategic outcomes for project management are enacted: Initiating, planning, implementing, and controlling (Weaver 2006).

The principle characteristic of construction projects is 'location', which becomes a key breakdown component of the traditional WBS. Ibrahim et al (2009) found that the most frequently used decomposition criteria in the formulation of a WBS for building projects are elements, work sections, physical location and construction aids. This indicates that in construction projects, location is embedded within the WBS hierarchy. Indeed, the authors proposed an hierarchical decomposition of a building project based on these criteria.

However, when Ibrahim et al (2009) were doing their research, little had been published on Location Breakdown Structures (LBS). The authors noted that they were not aware of a standardised classification for the 'location' criterion. They therefore, simply adopted a classification based on floor level since this was identified as the definition commonly adopted by planners. To-date, there is no standard based on location classifications. However, the location-centric nature of a construction project, can be captured in a project schedule.

The term location-based scheduling was coined by Kenley (2004) as both more appropriate and descriptive of the basic character of a construction project. This provides a methodology for managing both activities and locations in that specific type of project. A project may be modelled by including individual packages of works (activities – at the lowest level of the WBS) into a connected whole entity called a task, which represents the aggregation of all same-work activities across multiple locations.

However, location in traditional WBS decomposition, necessitates substantial repetition in data and processes (Stal-Le Cardinal & Marle 2006). For example, the repetition of process to achieve deliverables in different locations, such as floors (Lucko et al 2014). To capture this feature of construction projects, Harris and Ioannou (1998) suggested the generic term repetitive scheduling method (RSM).

The concept of the RSM does capture a finer level of location detail in the WBS. However, the consequence is a consider important the greater effort to replicate work packages. In the end, this acts to constrain minimisation of resources allocation through a work breakdown structure (Dawood et al 2002). There is a need, therefore, to improve the sophistication of location-definition models for management purposes.

Unfortunately, the perceived improvement has been to developed structures, such as Industry Foundation Classes, from a design perspective rather than a construction perspective. This means that consideration of the link between location and data repetition within project schedules is absent. The IFC model has been driven predominantly through a desire for common parameters for design. In other words, by the need for visualisation view of the design (Russell et al 2009) which does not equate to the construction model (Lopez et al 2016).

3 LBMS & Location Breakdown Structure (LBS)

There is a body of research in the planning and control of construction projects which provides a richer view of the location breakdown structures: Location-Based Management System (LBMS) for construction (Kenley & Seppänen 2010). The location-based terminology for referencing an approach to planning and controlling construction was coined by Kenley (2004) and has subsequently received acceptance amongst the majority of construction theorists (eg. Russell, Sacks, Seppänen, etc.). This body of theory holds that location is a critical component for managing construction projects.

Within LBMS, location provides the container for all project data that allows data to be collected at different levels within the hierarchy. The location contains the following types of data:

- Building objects or components such as elements and sub-systems
- Planned and actual building component quantities
- Building system production assemblies
- Planned and actual material costs
- Building system costs

But, it could be argued that the key to changing the way we think about the management of construction projects, is to change the way we decompose their structure (Kenley & Harfield 2014a). Utilisation of an LBS for construction projects, along with suitable project models and management strategies, has been shown to systematically improve project production efficiency (Seppänen et al 2014).

As with the WBS, a location break-down structure (LBS) is hierarchical. The higher level location logically includes all the lower level locations. Each of the location hierarchies has a different purpose. The highest level is used to optimise construction sequence, because the structures of such sections are independent of each other, therefore, it is possible to start them in any sequence or to build them simultaneously. The middle levels are used to plan production flow of structure (and often reflect physical constraints). The lowest levels are used for planning detail and finishes. LBS, in some ways this is just another view of a product decomposition: decomposition of the physical product into its constituent parts.

The LBS higher level location logically includes and is the sum of all the lower level locations. The location hierarchy goes from larger components (eg buildings) to smaller components (eg rooms). In addition, each level of the LBS hierarchy can have different purposes.

In LBMS there may be multiple LBSes required, based on the important flexibility characteristic of a WBS. This is possible because it is not a fixed hierarchy. The WBS is a flexible representation of a project that enables progressive decomposition of the project as it evolves through continuing construction planning, management, monitoring and control phases of a project (Kerzner 2013).

4 LBS-WBS Matrix Solution for Repetition

While the WBS is designed to be a comprehensive project breakdown, it is highly repetitive for the construction part of the WBS. The repetition results from the need to decompose the physical project into manageable parts which are typically location-based. As mentioned above, the key to changing the way we think about the management of projects, is to change the way we decompose their structure. The problem with current practice is that the WBS is a single hierarchy structure which must meet conflicting demands.

It is easy to observe location components, such as site, building, wing, floor, zone and room, appearing in the WBS. The problem is that further levels of the project breakdown, such as elements or packages, are frequently made subservient to the locations, forcing repetition of child components within different parent location branches.

A simple example is outlined in Table 1. The compounding of the data repetition increases as the size or height of a building increases. The two types work in Table 1 do represent the work that needs to be done at each level of an 80 storey building, but the repetition of processes across multiple locations impedes productivity (Björnfot & Jongeling 2007).

Table 1 A table demonstrating location repetition for building construction management

Location number	Disciplines	Types of repetitive work
Location n	Concrete work	Slabs
		Columns
	Services rough-in	Fire services
		Mechanical services
Location n+1	Concrete work	Slabs
		Columns
	Services rough-in	Fire services
		Mechanical services

To gain more effective productivity through scheduling construction projects, there is a need to identify opportunities and supporting methodologies for an improved method of work breakdown that integrates location as an explicit element of construction projects. Repetition in the WBS does reflect the real repetition of work in the physical project. However,

alternative construction management models can more efficiently handle this repetition (Kenley & Harfield 2014a).

A simple way is to separate location from the WBS model as its own LBS. The next step would be to re-introduce these two structures in a new matrix model for project decomposition: a 2D matrix of the LBS and the WBS as illustrated in Figure1. The WBS, once freed of location-repetition, can more efficiently describe the work to be done.

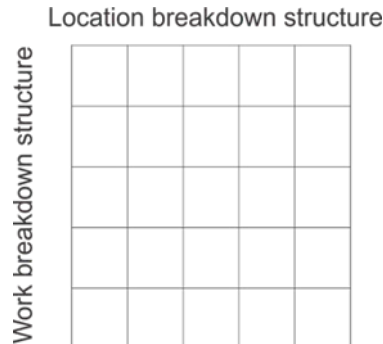


Figure 1 Matrix view of project/product decomposition

Considering the intersection of two differently focused breakdown structures has received little attention by project management researchers. Yet potentially the concept of the 2D model reveals a significantly different view of the WBS from the conventional definition of a hierarchical tree (Kenley & Harfield 2014b). When looked at this way, the resulting LBS has a great deal of flexibility within projects and variation in structure between projects. The concept of flexibility is important because reducing repetition for a more effective construction management process, requires flexibility. Thus the difficulty of an IFC rigid location-definition model.

5 Industry Foundation Classes (IFC) and Location

The hard work of buildingSmart researchers around the world has led the development of the industry foundation classes (IFC) which has enabled open BIM to be used as the platform for growth in digital technology (Lopez et al 2016). For the most part, within the construction and project management literatures, IFC-based models are concerned with reporting on the application of building information modelling (BIM). The acronym has become the short-hand for a variety of digital systems and software that aims to modernize traditional construction activity globally (Halfawy & Froese 2005).

The focus on digital technology that easily provides a model view for information exchange is the basis of much research and continuing development (Lopez et al. 2016; Kim et al. 2013). The technology has allowed the abstract to appear tangible with 3D digital modelling capabilities. Placing the emphasis only on visualization has resulted in an elegant, but simple, location-definition model in IFC: Site, Building, Floor and Room – with aggregation to zones or functional areas for such needs as services design.

However, construction project management requires a different model view. The introduction indicated the importance of work breakdown structure (WBS) decomposition for managing construction projects. As noted above, the WBS is a guiding principle of management models that support the completion of projects, such as project schedules. It has also been argued that for construction, location is the guiding principle and the IFC location-definition model is inadequate for construction project management needs.

Does this mean that IFC (in the current iteration) presents a barrier to integration of IFC and current construction management processes, such as scheduling?

One conclusion from reading through the IFC related construction management literatures for the last 20 years, is the flawed premise of a significant amount of research. The premise seems to be that the identified problem to be solved is not IFC limitations, but rather, the 'troublesome' traditional construction management processes such as project

decomposition resulting in a flexible WBS framework. It may be that in the research more designers are represented than builders or construction managers (Mäki & Kerosuo 2015).

Even if that is the case, it does not negate the discrepancy of location detail in the IFC that contributes to the continuing difficulty with information flow interoperability. The point has been made that the granularity or level of location detail is absent from the BIM models based on Industry Foundation Classes. Indeed, the lack of constructability has been the beginning point for a significant amount of research (eg. Cirbini et al 2016; Mäki & Kerosuo 2015; Wang et al 2014; Khalili & Chau 2013, etc.).

The consequence is that researchers attempt to force-fit the management problem (such as constructability) into IFC-based models. Put another way, researchers have been constrained to the IFC location-definition model when addressing the needs of construction management.

6 Forcing Location to Accommodate IFC Models

The relationship between resources and location is critical for construction projects. Therefore, greater levels of location detail are paramount if efficiencies are to be gained through effective use of resources (Khalili & Chua 2013; Kim et al 2013; Björnfort & Jongeling 2007; Halfawy & Froese 2005; Kenley 2004). While this might be the obvious aim of some BIM research, most attempts do not even consider the WBS, let alone the LBS in their discussions of BIM applications for construction.

For the purposes of this paper, the focus is based on IFC, the underlying standards on which the BIM environment is currently being built. This perspective suggests two important questions. Do constructability problems using a BIM environment relate to the IFC model view? Is the need for such research being driven by the inflexibility of the IFC location-definition? This report has not carried out research to answer these questions directly. Speculation on answers lies in critically reviewing the literatures.

The lack of direct discussion within the BIM research reports to frame their questions from the perspective of the contractor means that only two examples are presented to indicate the persistence of the flawed premise that the problem to be solved is not the IFC limitations, but troublesome traditional construction processes such as project decomposition and compatibility with the IFC location definition model.

The following sections present examples that illustrate what could be considered as forced-fitting a constructability solution into current IFC-based models.

6.1 Links between CAD objects and scheduled activities

Staub-French et al (2008) report on a project to link 'CAD and linear planning'. They argue that there is a two-way flow of information. However, for the information flow to work, they acknowledge that grouping CAD components 'level of detail and location' is necessary to interact with the 'aggregation' found in the schedule model. The schedule for the six-story condominium project under discussion is problematic because the IFC project view is not a decomposition of the project. IFC objects are easy to consider at 'floor level', but buildings have rooms, floors and construction zones for purposes of scheduling allocation of resources (Sacks 2016; Kenley 2004).

The paper discusses scheduling and location as both physical and individual. Thus, the concept of multiple-definitions for location indicates some understanding from the builder's perspective. However, the limitations of location/levels are the embedded CAD constraints. The authors' do write about the necessity to take into account the differences in each of the levels concerning specific attributes such as location as well as inputs and outputs of the challenges of using their automated systems. But the purpose of the research appears to be to 'find ways to force-fit' a construction schedule into an object-based model. It could also be said that the Staub-French et al (2008) article is a very good historical description of the limitations of computing as well as the development of IFC software 10 years ago.

6.2 Granularity, IFC Objects and Scheduled Activities

One article, Ciribini et al (2016), reports on an Italian public sector client working through the continuing interoperability issues in 2016. The 10-year gap does not seem to have reduced that basic problem that IFC is still more compatible with design of buildings, than the location-orientation nature of construction projects. The needs of contractors remain unresolved between what is developed at the design stage of the process and the requirements for scheduling the work to be done. In this instance, intermediary software, Synchro PRO is an improvement, but only as a more effective method to 'force-fit' the object-based model with the resources allocation model. Clearly the levels of detail (or granularity) for location with a BIM model is limited.

The authors' explanation is that an extraction from the IFC models provides comparative modelling to deal with the difficulty of conflicting BIM objects and work packages generated using a WBS. While 4D models can incorporate resources allocations, the large amounts of extra object-based extraneous data remains 'a work in progress'.

The authors do attempt to discuss constructability issues from the contractor's view point, but the details of construction project scheduling based on a WBS or a LBS is absent.

The main positive outcome of using BIM for this construction project seems to have been the ability to visualize the construction sequences. However, the fuzzy quality of the actual schedules reproduced in the article, does not allow scrutiny of what exactly the 'macro errors in the logical link between activities' means. Macro implies that the identified errors were at the floor or section level, not the room or zone level of analysis.

While some progress with stakeholder cooperation is reported, the possibility of adding levels of efficiency to scheduling process, and thus the work-flow, seems to continue the long-term trend of absence.

7 Conclusion and Future Research

The report is only able to speculate on cause and effect from reviewing available research reports. However, this desktop study, combined with practical construction industry experience, did identify some issues to add to the current debates.

BIM interoperability issues continue to plague global industry implementation. At present, BIM models based on IFC, that are unable to provide sufficiently detailed location information required for effective construction project management. Much research is taking place to overcome IFC constructability issues. However, the flawed premise of a significant amount of that research, is that traditional construction process not the problems of IFC implementation are the problem.

The traditional work breakdown structure, that is the foundation model of work to be done for construction projects, provides a framework for the principle characteristic of construction projects, location. A location breakdown structure (LBS) provides the necessary level of detail to allocate resources: such as site, building, wing, floor, zone and room. The problem with the IFC location-definition is the need to aggregate to zones or functional areas.

This paper suggests that problems arise when construction management systems interface with IFC-based systems. These problems arise from the simplicity and inflexibility of the rigid location-definition model inherent in the design of IFC. In contrast, the typical model for construction work, the flexible WBS, usually reflects inconsistency and variation on the location-definition model. Construction management processes currently make use of location in unstructured and inconsistent ways.

Construction management research rather than design research, provides evidence of contrasting definitions of location-definitions used for modelling construction projects. The paper has argued that the different location-definitions become locked into construction project modelling applications. And it could be argued, that the consequences are detrimental to the entire construction industry because of the 'force fitting' of construction schedules into IFC based BIM environments.

It might be time to reconsider the location-definition model for IFC. It might be time to stop force-fitting management systems into a simple static model and rather, to explicitly,

model the flexible requirements for location-definition within the IFC model. This would require an IFC location-definition model that accommodates views beyond visualization. What is needed is the inclusion of: time, phase, trade, element, and function as determinators of the location-breakdown model at any stage of the process. Or at the very least there is a need to find answers for these two important questions. Do constructability problems using a BIM environment relate to the IFC model view? Is the need for such research being driven by the inflexibility of the IFC location-definition?

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