# SEMI-AUTOMATIC DEVELOPMENT OF THE WORK BREAKDOWN STRUCTURE (WBS) FOR CONSTRUCTION PROJECTS

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**Abstract:**
A fundamental requirement for effective project control is that the whole project is systematically decomposed into smaller, manageable units, creating a hierarchical structure generally referred to as the work breakdown structure (WBS). The development of the WBS has been noted to be one of the most difficult and challenging tasks facing project mangers especially on large complex projects. In spite of its enormous importance, little has been done to alleviate the difficulties associated with this task. The thrust of this research is geared towards addressing these difficulties.

With increasing interest in object-oriented modelling, more and more building information is provided and stored in computer interpretable format. This research effort takes advantage of the advancement in building modelling and proposes a framework for the semi-automatic development of the WBS. First, it examines the WBS generation process and the general requirements for developing the WBS. It then reports preliminary results of a survey aimed at identifying the various criteria used to decompose construction projects. A theoretical framework for facilitating the automatic development of WBS from a building model is then proposed.

**Keywords:**
Automation, Project Control, Work Breakdown Structure

## 1. Introduction

Delivering projects on time, within budget and to the required quality standard is probably the most difficult and challenging task facing project managers. As construction projects become more complex, the need for effective project control becomes equally pressing. One of the tools available to aid the project manager in effective project control is the work breakdown structure (WBS). The importance of the WBS in project management can not be overemphasised. Rad (1999) and Colenso (2000) noted that the WBS is generally recognised by project management professionals as the foundation for planning estimating, scheduling, and monitoring of activities. It paves the way for effective management of all facets of a project and its correct use contributes significantly to the probability of success (Globerson, 1994). According to Garcia-Fornieles *et al.* (2003), the WBS is probably the most valuable tool for project management because it defines the scope and structure of the project and establishes the foundation for planning, budgeting, responsibility assignment, project control and information management. Charoenngam and Sriprasert (2001) summed up the importance of the WBS as a tool that is simply indispensable for effective project control. Although an important tool, the WBS has difficulties associated with its development. Wideman (1989) writes:

*"Establishing the overall scope of the project, and then defining it in sufficient detail appropriate to each phase of the project, is possibly the most difficult part of project management. It is also probably the most overlooked."*

The need for a tool to aid the development of the WBS is not only hinged on its clear importance but also on the need to alleviate the difficulties associated with the process.

Taking advantage of recent advancement in technology, a plethora of studies have focused on designing tools that aid the construction project manager in effective and efficient project delivery. These research efforts focus on developing systems that enhance the performance of various pressing issues within the construction industry. The issues addressed in those efforts range from automating the data collection process (for example, Abdmajid *et al.* (2004), Trucco and Kaka (2004), Memon *et al.* (2005) ) to project planning and control (e.g Kahkonen (1994), Abeid and Arditi (2002), Abeid *et al.* (2003), Abeid and Arditi (2003), Poku and Arditi (2006), Vries and Harink (2007)). However, none of these systems focused specifically on the WBS despite its unquestionable importance and the difficulties associated with the current practice of its development. Given that the WBS is the corner-stone of effective project control, there is the need to explore alternative ways of alleviating the problems associated with its development. Moselhi *et al.* (2004) affirmed that the design, development and implementation of a robust project control system requires an improvement in the area of project definition, including WBS and work package formation.

To address part of the difficulties highlighted in the previous paragraphs, this research effort takes advantage of the growing interest in the object-oriented approach to modelling building information and proposes a framework for the semi-automation of the WBS. First, it discusses the WBS development and the key issues that need to be addressed in the development process. Then it proposes a framework for the semi-automation of the WBS.

## 2. The Work Breakdown Structure

The Project Management Institute PMI (2001) define the WBS as "a hierarchical structure that defines and organises the total project scope based on deliverables, with each descending level in the hierarchy representing an increasingly detailed definition of the project work". The aim is to ensure complete and proper definition of the entire work. The highest level of the structure represents the entire project. This is then subdivided into smaller elements that represent the next level in the hierarchy. The process continues until such a level when the entire project is deemed to have been sufficiently decomposed to allow for effective and efficient project control. The last level entries in the structure are referred to as work packages and represent the level where responsibility for the performance of the work in each work package is assigned to an individual or organisation (Haugan, 2002). Clearly therefore, two issues that must be addressed in developing the WBS are the decomposition criteria and the level of detail. These are discussed in the following paragraphs.

### *2.1 Decomposition criteria*

Identifying the criteria to apply in the decomposition of different WBS entries at various levels of the structure is obviously the first challenge. Several attempts have been made to develop standardised frameworks for the classification of construction information. The International Organisation for Standardisation for example, identified eight facets of classification for construction information (ISO, 1994). These include facility (e.g. hospital, school), space (e.g. recreational, office spaces), element (e.g. stairs, floors), work section (e.g. concrete work, masonry), construction product (e.g. paint, cement), construction aid (e.g. formwork, scaffolding) attributes (e.g. shape, size) and management (e.g. drawing, procurement). Kang and Paulson (1997) suggest a construction information classification system based on five facets – facility, space, element, operation and resource. Chang and Tsai (2003) proposed an engineering information classification system that consists of construction type, life cycle, product or service, function, tasks and man-hour facets. Other classification schemes include, for example, the masterformat, the samarbetskommitten for byggnadsfragor (sfB) and the Construction index/sfB (CI/sfB).

It is desirable to have one standard classification system whose facets are comprehensive enough to be employed as decomposition criteria since this will facilitate communication. However, these classification systems have their weaknesses. According to Kang and Paulson (1997), the masterformat gives more priority to construction components than functional components, the sfB system does not have facility classification and the coding system of the CI/sfB system is a complicated one. Jung and Woo (2004) noted that some of the facets in the ISO system (e.g. work section, construction products and construction aid) are less project specific and should follow the standard, while others (e.g. facility, space and element) are more project specific and should be independently defined by organisations. In addition, Globerson (1994) has shown how the choice of criteria and their sequencing in developing the WBS reflects different management styles and organisational structures. These issues raise the question as to what facets of information would be effective as decomposition criteria in the development of a WBS for construction projects. To answer this, it is perhaps reasonable to first identify the different criteria used by practitioners, and then assess their effectiveness in delivering an effective WBS.

The authors are not aware of any study that reports on the decomposition criteria used by construction project planners in developing the WBS. Hence, as part of the current study, a survey of UK contractors on the general practice of WBS development, including the decomposition criteria is already underway. The authors hope to uncover any trends in WBS structuring, including the various decomposition criteria applied by contractors. The following paragraphs give a summary of the preliminary results of the survey.

The survey was conducted by means of a structured questionnaire. The questionnaires were sent by post to the top 100 hundred contractors and 80 randomly selected contractors in the UK. Table 1 shows an overview of the respondents. So far, a total of 32 responses have been received. As shown on the table, respondents come from various kinds of contracting organisations with more than half being building contractors. Respondents also include 13 project managers and 7 planners. Table 2 shows respondents' level of experience. 27 of the 32 respondents have more than 10 years experience working with, and developing WBS. 15 of these have more than 20 years experience. Although the total number of responses is somewhat low (18%), the respondents' level of experience ensures high quality responses.

Table 1: Survey respondents

| Kind of Organisation | Job Description of Respondent | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Planner | Bidder | Estimator | Project Manager | Director | Marketing Manager | Technical Manager | Quantity Surveyor | **Total** |
| Building Contracting | 4 | 2 | 1 | 7 | 3 | 0 | 0 | 1 | **18** |
| Civil Engineering Contracting | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | **3** |
| General Contracting | 2 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | **7** |
| House Builder | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | **3** |
| Specialist Construction | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | **1** |
| **Total** | **7** | **2** | **2** | **13** | **4** | **2** | **1** | **1** | **32** |

Table 2: Respondent's Experience

| Respondent's Level of Experience | Job Description of Respondent | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Planner | Bidder | Estimator | Project Manager | Director | Marketing Manager | Technical Manager | Quantity Surveyor | Total |
| Less than 5 Years | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 3 |
| Between 5 and 10 Years | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Between 11 and 15 Years | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 4 |
| Between 16 and 20 Years | 1 | 0 | 1 | 4 | 0 | 1 | 1 | 0 | 8 |
| Over 20 Years | 3 | 2 | 1 | 4 | 4 | 1 | 0 | 0 | 15 |
| Total | 7 | 2 | 2 | 13 | 4 | 2 | 1 | 1 | 32 |

Respondents were asked to indicate the criteria they use for decomposition of construction work from the construction information classification facets identified from literature. The aim is to identify the most widely used criteria. Figure 1 shows the result. The facet most used as decomposition criteria is 'elements', and building contractors are the most frequent users of this criterion. Next most highly used facet is 'work section', again building contractors being the most users. This is followed by 'construction aids' and 'location' respectively. The least used facet is 'spaces' followed by 'attributes', 'function', 'construction product', 'facility', 'management', and 'lifecycle phases' respectively. Although preliminary, the results seem to highlight the range of criteria used by different contracting organisations. Only three kinds of contracting organisations (Building, Civil, and General contracting) use 'attributes', 'construction product', 'function', and 'management' as decomposition criteria. House builders use only 'elements' and 'lifecycle phases' while civil engineering contractors, as expected, do not use 'spaces'.

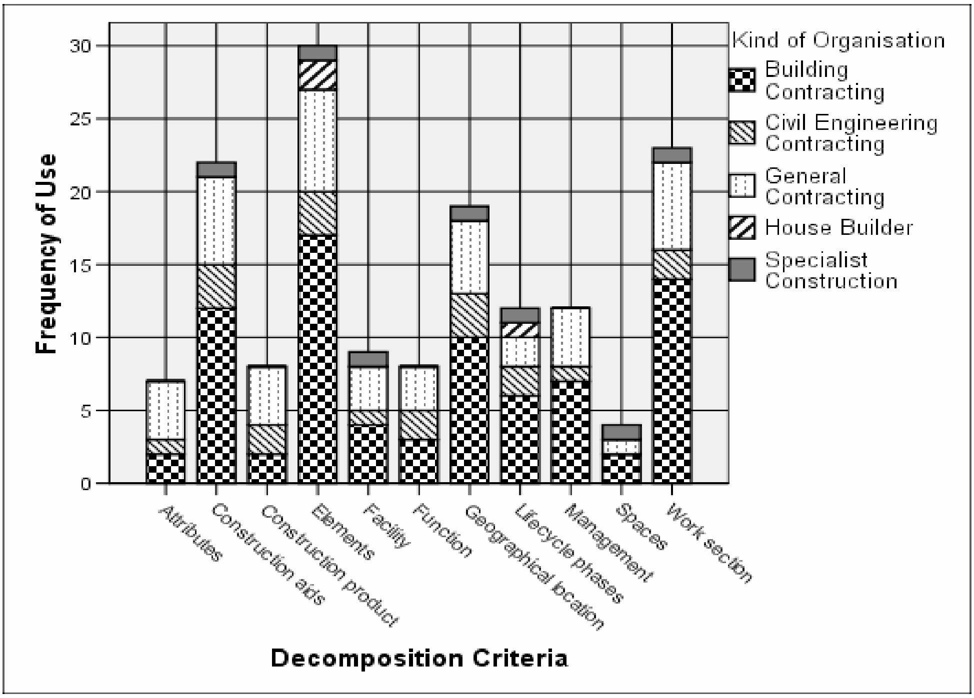


Figure 1: Decomposition Criteria

### *2.2 Level of detail*

The level of detail reflects the extent of decomposition and the sizing of work packages. For effective project control, the WBS must reflect an appropriate level of detail. As noted by Jung and Woo (2004), the number of work packages rapidly increases as one work package is decomposed further. This however, comes with it, additional administrative costs for managing the resulting work packages. While it is clear that a higher level of detail provides more detailed information for project control, the additional management effort required to collect and manipulate this information is obviously a concern. Therefore a balance must be sought between the level of detail and the associated costs.

The decision to further decompose a work package is obviously dependent on some factors. Some of these factors are project specific and include, for example, extent of technical complexity, project size, cost, and duration. Some other factors relate to the work package in question and include the extent of technical complexity in the work package, the value of the WP, duration, and the need for close monitoring of the WP.

Raz and Globerson (1998) give a comprehensive analysis of the factors and how they may affect the decision to further decompose. Of immediate significance to the present study is the identification of an optimum level of detail in the development of a WBS for construction projects.

Globerson (1994) submits that the size of a work package can be measured in units (e.g. budget, man-hours) and for each work package, there is an optimum size. With reference to construction projects, Charoenngam and Sriprasert (2001) are of the opinion that an adequate level of detail is achieved when the decomposition goes beyond three levels in the hierarchy and the value of each element has a value of less than or equal to twenty-five thousand US dollars ($25,000). The basis for this opinion is not clear. It is clear however, that for each work package, there is an optimum size that reflects the best trade-off between the benefits of keeping to that size (level of detail) and the costs of managing the WP at that level of detail. Again, the authors are not aware of any study that focused specifically on identifying the optimum size of a WP for construction projects. In a separate effort, the authors are investigating this issue with a view to building a framework for identifying the optimum size of a WP. For the present study, however, we assume that the user knows the appropriate level of detail to work with.

### *2.3 Steps in creating a WBS*

Colenso (2000) detailed the necessary steps to follow in creating a WBS. For a deliverable-oriented WBS, he identified the following steps:

1. Identify main deliverables from project statement of work or other project concept documentation. For a construction project, at the tactical phase, these documentations can be in the form of detailed drawings, specifications and bills of quantities.

2. Logically decompose each main deliverable into lower level entries. The process continues for all subsequent lower level entries until an appropriate level of detail is reached. Decomposition should be based on the 100% rule which Haugan (2002) puts as follows:

   *"The next level decomposition of a wbs element (child level) is 100 percent of the work applicable to the next higher (parent level)"*

3. Examine, adjust and validate the WBS. This entails checking for completeness, making adjustments where necessary and ensuring that the developed structure addresses the main objectives of the project.

## 3. Proposed framework for automating the WBS

There has been a significant improvement in the area of building product models (See Liebich and Wix (2002) for detailed analysis of building models). This development has made it possible to represent more and more building information in a computer interpretable format. In this way, it is possible to represent information relating to the various decomposition criteria in a building model. Each design component can be defined based on the identified criteria. For example, each component can be defined by element type, its physical location, work section it belongs to and so on. Figure 2 shows a typical representation of an instance of a building model.

An instance of a building model may represent one or more facility types at its highest level. Each facility is in turn represented by a collection of design objects. It is possible to define, for each instance of a design object, attributes that define various decomposition criteria. Once each object is sufficiently defined in terms of all decomposition criteria, it is then possible to export and store the entire information for all design objects in a depository. Figure 3 shows an overview of the proposed framework.

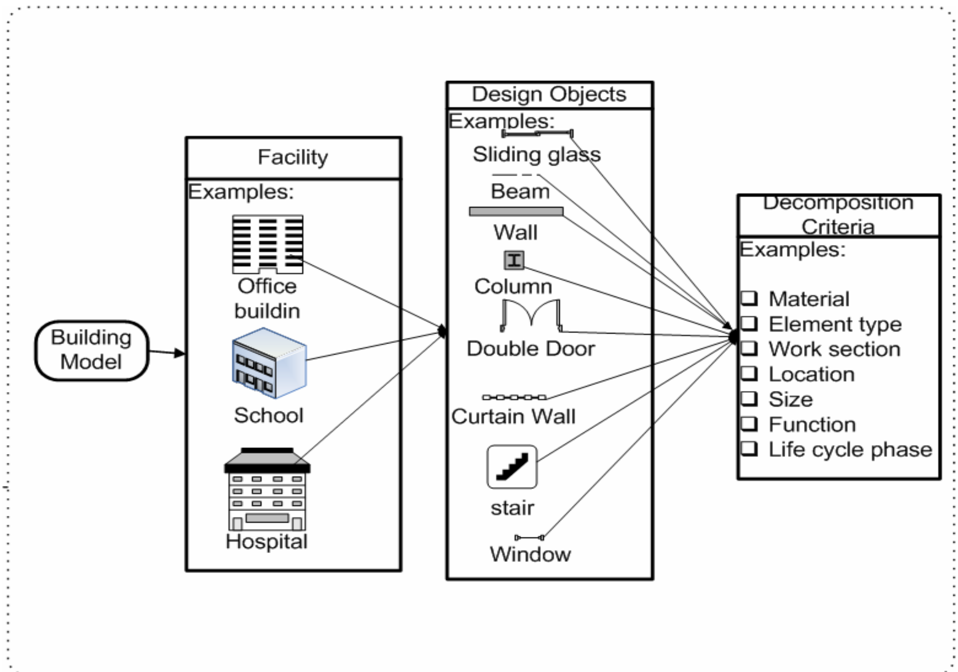


Figure 2: An instance of a building model

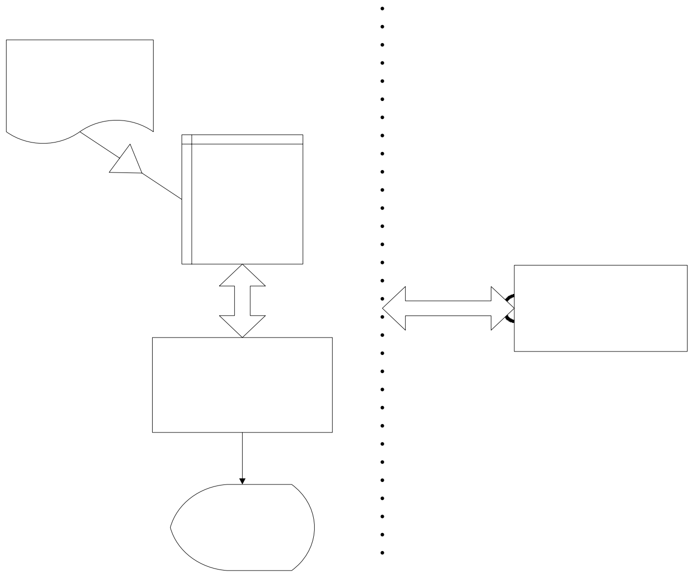


Figure 3: Framework overview

This section needs a bit more explaining: Once all information is captured in a database, it is then possible to classify and group the information by querying, for example the database based on the identified criteria. Figure 4 shows a conceptual process framework for generating the WBS from the database. The process begins by first, selecting the decomposition criterion to apply at the first level. Applying this criterion generates a number of WBS elements at the second level. Each WBS element at the second level is in turn decomposed into subsequent level WBS elements based on a selected criterion, and the process continues for all subsequent level elements until an appropriate level of detail is attained. The last WBS elements represent the work packages which represent management control points. It is essential therefore, that the resulting work packages are evaluated in terms of size and content to ensure their effectiveness for project control.

It is worth noting that not all work items that should form part of the WBS are well represented in a building model. For example, work items like temporary works (e.g. scaffolding, tools) may not be physically represented in a building model, yet they may be required to form part of the WBS. Such work items are less project specific and are therefore easier to standardise. Nevertheless, this work is still ongoing and possible ways of incorporating such work items into the proposed framework are being investigated.

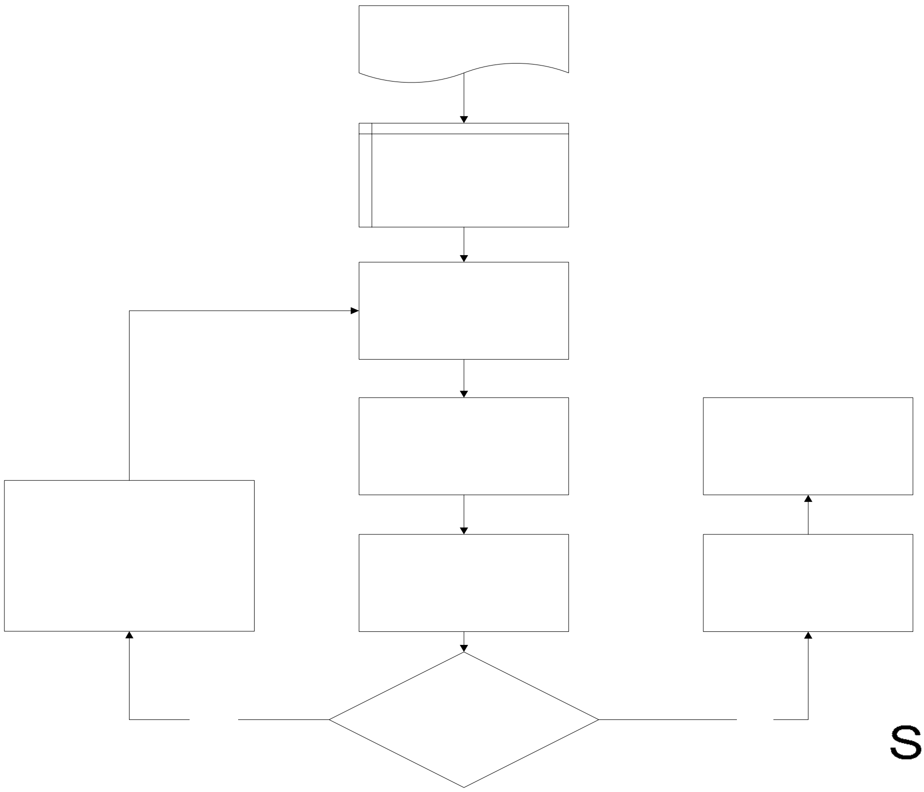


Figure 4: Proposed process framework

The proposed framework allows the user to generate the WBS to any desired level of detail. It therefore assumes that the user knows the appropriate level of detail required for effective project control. As discussed earlier, identifying the appropriate level of detail can be onerous, especially for the inexperienced manager. Developing a strategy for identifying an appropriate level of detail and incorporating it into the proposed framework will be of great benefit to the user. This will alleviate the workload for gathering and manipulating the excessive amount of data required for integrated cost and schedule control. It will also facilitate standardisation of work packages since work package formation can be monitored from project to project within the database (Jung and Kang (2007)).

## 4. Conclusion

The significance of the WBS as a tool for effective project control has been emphasised. In spite of its importance however, there are real difficulties associated with its formulation. Given the level of importance, there is the need to investigate ways of alleviating the difficulties associated with the development of the WBS for construction projects.

The WBS development process, including issues relating to various decomposition criteria and level of detail, were discussed and a theoretical framework for the semi-automatic generation of the WBS was then proposed. This required the identification of the various decomposition criteria to use in the framework. Hence, a questionnaire survey was conducted and the preliminary results were presented. Although incomplete, initial indications of the result suggest that elements, work section, geographical location and construction aids are the most used criteria in the formulation of the WBS. The results also showed that different kinds of contracting organisations used different criteria to varying degrees.

Based on the object-oriented approach to modelling building information, the proposed framework allows for the semi-automatic generation of the WBS directly from a building model. The authors believe that apart from easing the task, the framework can facilitate the standardisation of the WBS within an organisation since different WBS databases from different projects can be easily compared. The proposed framework is limited in its application only to components that can be represented on a building model. Work items such as excavation and earthworks that may not be easily represented on the model are not considered in developing the framework, although ways of incorporating these are being investigated.

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