

# DEVELOPMENT OF A BIM AND BARCODE BASED MATERIAL MANAGEMENT SYSTEM FOR CURTAIN WALL INDUSTRY

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**Abstract:** The construction industry is slower to adopt new technologies than other industries. Traditional construction industry material management system involves tedious paperwork, frequent phone calls and challenging coordination, posing many difficulties for the project management. Recent development in the use of information and communication technologies in the Architecture, Engineering and Construction (AEC), namely the building information modeling (BIM), promises to introduce major changes in visualization, coordination and planning processes of the engineering projects.

The impact of the building's curtain wall has become increasingly more important when determining the operational and economic performance of construction projects. And as a recognized discipline of the construction industry, curtain wall design, and fabrication and installation process involves numerous stakeholders including designers, contractors, purchasing staff, suppliers, distributors, and on-site installers.

It is believed that the material tracking system, when integrated with BIM, can successfully address the major problems of the curtain wall industry. In this paper, the authors analyzed the current practice of material management in the curtain wall industry and proposed a BIM and barcode integrated material management system, which aims to provide a BIM based material management framework from the design phase to the construction phase, streamlining material management process and promoting collaborative working processes in the curtain wall industry.

**Keywords:** Curtain wall, BIM, Material Management, Barcode, China.

## 1. INTRODUCTION

Construction is the process of physically erecting the project and putting construction equipment, materials, supplies, supervision, and management necessary to accomplish the work (Clough and Sears 2000). Due to the complex and dynamic nature of the construction industry, construction material management faces many challenges from material planning, ordering, receiving and storing, handling and distribution, site usage and monitoring (Johnston and Brennan 1996).

Construction materials contribute 50-60% of the total project costs and material's tracking and locating is important to ensure that materials are available at the right time, in the right place and at the quantity required (Song and Haas and Caldas 2006). Because large amounts of materials and components are involved in the construction projects, tracking of materials and components in a construction project is not an easy task (Kasim et al. 2012).

Traditional construction material management processes in the construction industry still rely on manual data and paper lists to control large amounts of engineered components which not

only negatively affects construction performance but also has an additional negative effect on worker's efficiency and contributes to schedule and project delays (Kasim et al. 2012).

Issues regarding the tracking of construction materials on-site have received a great concern in the construction industry (Kasim et al. 2012). With the ability to automating and integrating some of the predefined tasks common to most projects, information technologies have the potential to significantly simplify the effort of responding to the complexity and demands that the construction industry are facing. Industry practitioners have also identified that current material tracking field practices could be improved if aided by new information technology devices(Liwan and Kasim and Zainal 2013).

A Building Information Model (BIM) is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analysed to generate information that can be used to make decisions and to improve the process of delivering the facility (AGC, 2005). The main characteristics of BIM include 3D CAD-based presentations and easy updating and transfer of information in the BIM environment(Ho, Tserng and Jan, 2017). BIM has a positive impact of material deliveries,which helps project stakeholders understand the project, reduce uncertainty and improve predictability of the project(Ocheoha and Moselhi 2013).

Although one assumes these advantages, how BIM can be used from the design phase to the construction phase in an integrated manner to improve material management has not been fully understood.

The objective of this research is to fill this gap by analysing the practices of material management and proposing a BIM based material management framework for a recognized construction industry discipline:curtainwall industry, aiming to improve low efficiency in the traditional material information extraction and facilitate the information sharing and communication among dispersed projected related parties. The proposed framework consists of three parts :

- 1.Web based project management system for process management.
2. BIM software plug-in for quantity take-off and BOM generation.
- 3.A mobile app for on site material management.

## **2. RESEARCH METHOD**

In order to identify the current practices of material management in the curtain wall industry and the ways of improving them, questionnaire survey and literature reviews were the methodologies conducted to achieve more valid and reliable findings. Questionnaire survey and interviews were carried out among three curtain wall companies in China. A BIM and barcode based material management system is presented based on the survey conclusions.

### **3. LITERATURE REVIEW**

#### **3.1 Material Management**

Construction material management is critical for project success in the construction industry (Carlos et al.2015).Each construction project is the development of a single one-of-a-kind product which requires the joint efforts of different parties (Yeo and Ning 2002) .Owners, contractors, subcontractors, and suppliers collaborate for a definite period of time to deliver the project to the client (Carlos et al. 2015).

Another characteristics of construction material management is that construction materials are less homogeneous, less standardized, and more numerous than those of manufacturing industry and the characteristics of demand are different (Ibn-Homaid 2002).

Moreover, due to the dynamic nature of construction material management, many problems are created due to the lack of an integrated material management approach among different material management phases(Ren and Anumba and Tah 2010).Many contractors suffer losses in productivity resulting from insufficient material management which eventually affect a contractor's profit margin(Thomas and Sanvido 1989).

Problems identified from the literature regarding material management systems used by contractors include:

1. Material shortage and wastage due to inefficient management techniques;
2. Lack of material procurement collaboration system among different parties;
3. Lack of effective on-site material control techniques.

#### **3.2 BIM and material management**

BIM is a powerful tool to support life cycle integration and the information contained in the BIM-based design model can be shared directly among different parties which can reduce the heavy human workload and manual errors in traditional work(Aguiar and Grilo 2015).

The benefits of BIM based material management are the accurate and automatic quantity take-off and BOM generation, improvements in quality and waste reduction, visualization and productivity improvements, as well as improved communication and collaboration, and field co-ordination problems during deliveries(Ocheoha and Moselhi 2013).

An accurate quantity take-off is the start of a precise material management process.Traditional quantity take-offs generated from 2D drawings are based on the experience and assumptions of the engineers. The results can be overestimated and underestimated and may contain errors and omissions. BIM can increase the accuracy in the quantity take-off and allow precise future prediction of the construction costs(Choi, H. Kim & I. Kim, 2014).

Radio Frequency Identification(RFID)tags can help support the tracking of component delivery and installation onsite and BIM components that included references to RFID tags can automatically update with links to field scanning devices and provided the contactors with instant feedback of material status (Eastman et al., 2008).

## 4. SURVEY OF CURRENT MATERIAL MANAGEMENT PRACTICES IN THE CURTAIN WALL INDUSTRY IN CHINA

### 4.1 Curtain Wall Introduction

By definition, “curtain wall “is a light secondary rigid framing system filled or covered with a lightweight cladding(Karol 2008).Key requirements of the curtain wall are to provide air integrity in the cladding system, adequate wind, thermal and seismic response in addition to provide light transmittance to the interior space(Dudley 2017).Curtain walls are classified by their method of fabrication and installation in two categories: stick built system and unitized system (Dudley 2017).Unitized curtain wall systems are comprised of large units that are assembled and glazed in the factory. They are then shipped to the job site and erected on the building façade. Stick systems consist of the curtain wall frames and panels that are installed and connected piece by piece. Curtain wall material lists include panels, framing, connections, accessories and preembedded pieces(see Table 1).Table 1lists most common curtain wall materials.

*Table 1: Curtain wall material list*

Material classification	Panels	Frames	Connections	Accessories	Preembedded pieces
Material list	glass	steel	steel	weathering glue	steel
	clay board	aluminum	aluminum angle code	structural adhesive	cast iron
	aluminum veneer	stainless steel cable	stainless steel screws	foam rods	
	stone	stainless steel rod	bolt	tape	
	aluminum-plastic			rubber gasket	

### 4.2 Survey of the current material management practice in the curtain wall industry

The questionnaire and interview methods were used in the survey and four curtain wall firms were selected from 2016 China’s top 50 curtain wall companies list. After the analysis of the response from the survey, one company was interviewed to achieve the detailed workflow of the current curtain wall material management practice.

The questionnaire was divided into the following sections:

#### 1. Organization background

In this section ,factual information such as the value of the projects and the types of the contracts was requested.

#### 2. Current material management practice

This section was designed to enable the author to identify the current material management practice adopted by the companies and the inherent problems of traditional method.

#### 3. Application of BIM

The purpose of this section was to collect information on BIM maturity levels in different companies.

#### 4. Opinion of the BIM based material management system

This section asked for the companies suggestions to the BIM based material management system.

### 4.3 Survey results

#### *Current contract type and material management practice*

In the survey, it is concluded that most curtain wall projects in China adopt the design build method which means the owner contracts with a single entity to provide both the design and construction of the building. All of the stakeholders have the same goal of developing a curtain wall system that meets the requirements and fulfilling the owner's and architect's vision for the building.

When adopting the design build method, curtain wall design and engineering is a collaborative effort among the curtain wall designer, project manager, procurement manager, processing plant worker and on-site material administrator. The process can be divided into the following phases(see Table2): Bidding and schematic design phase, project start-up phase, design development and construction document phase, construction preparation phase, engineering design and material preparation phase, material procurement phase, transportation phase, material receiving phase and construction phase.

In the traditional method, the curtain wall designer will calculate Bill of Materials (BOM) from 2D CAD drawings. The correctness of BOM relies on both the accuracy and level of detail of drawings and it is difficult to check if there are omissions or miscalculations from 2D drawings with the increasing complexity of the project. The BOM is then exchanged by each agent for printing and recreating, which frequently results in critical errors that could affect project cost and schedule. Besides that, some information ends up being unavailable to parties who need access to them for the decision making process and the data is difficult to be traced and accessed in the future. The current practice of material management is basic and depended on paperwork and subjective decisions which contributed to late ordering and delivery of key materials and high wastage.

*Table 2: Material management process in curtain wall industry*

	Designer	Project Manager	Procurement Manager	Processing Plant	Material Administrator
A. Bidding and Conceptual Design Phase	Conceptual design	Construction organization planning			
Project Start-up Phase	Contract management design task issued and construction tasks issued				
C. Design Development, Construction Documents Phase					
D. Construction Preparation Phase		Prepare project plans, refine material preparation plan and send it to the designer. Review the designer's BOM list and send it to the procurement manager			

Engineering Design and Material Preparation Phase	Refine the design based on material preparation plan and send BOM list for project manager to review		Receive BOM list		
Material Procurement and Preparation Phase			Purchase material	Material processing	
G.Material Transportation Phase					
H.Material Receiving and Construction Phase		Curtain wall construction			Receive material

### ***Suggestions to the BIM based material management system***

The following summarizes the suggestions to the system by the respondents:

1. A systematic approach for project related parties to understand when and where the materials are need and instant material information sharing scheme.
2. A systematic classification system of the curtain wall materials.
3. Improvement of BIM software functions for automatic generation of BOM lists.
4. Automatic onsite material inventory management using IOT technology.
5. A historical database as reference for future projects.

## **5. THE PROPOSED BIM AND BARCODE BASED MATERIAL MANAGEMENT SYSTEM**

### **5.1 BIM and Barcode Based Material Management System Framework**

Information technologies can benefit the industry by automating and integrating some of its predefined task functions common to most projects. The American Institute of Architects has defined BIM as "a model-based technology linked with a database of project information". Considering this issues, the author proposes an innovative approach that uses BIM and barcode to support material management process in the curtain wall industry which integrates and streamlines material management processes throughout the project process. The shifts from traditional paper based to the information based environment could strengthen the automation of material management tasks and supports more accurate decisions and strategic approaches.

The proposed system is comprised of three parts: web based project management system for process management (see Fig1), BIM software plug-in for BOM generation (see Fig2)and a mobile app(see Fig3) for onsite material management. The proposed system allows the designer to initiate an automatic BOM takeoff (see Fig4)process using a BIM software plug in and strengthen instant information sharing among project related parties. The automating material tracking approach could have eventually provided a permanent and updated record of the received materials as they arrive onto the site, releasing material manager from inventorying activities. Fig5 shows the BIM based material management process.



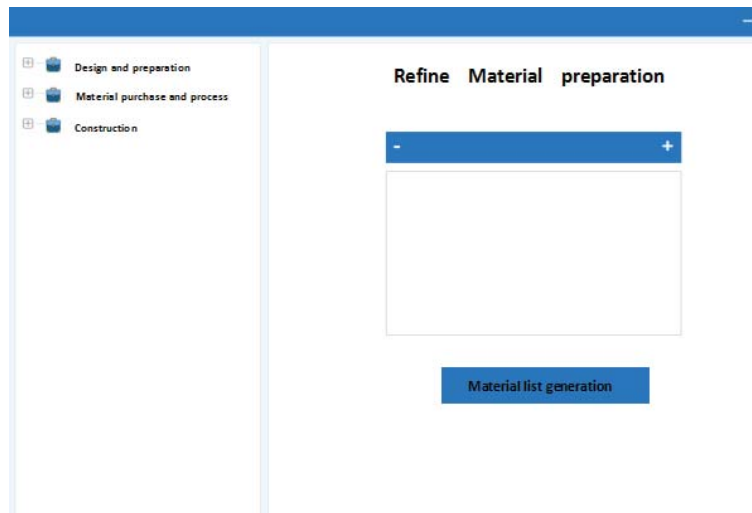


Figure 1: Web based project management system



Figure2: BIM software Revit Plug in

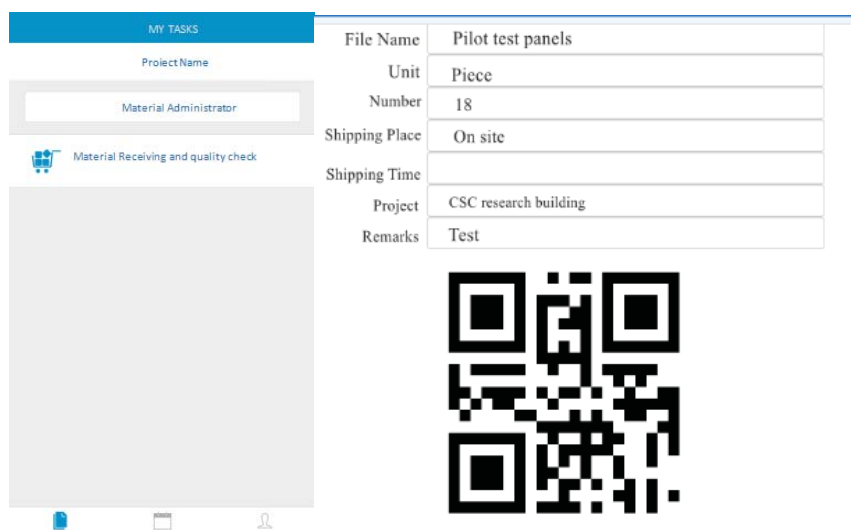


Figure 3:Material management app





Table 3: Level of development and model requirements of AIA Document E202-2008

LOD	MODEL CONTENT REQUIREMENT
100	height, volume, location, and orientation may be modeled in three dimensions or represented by other data.
200	Model Elements are modeled as generalized systems or assemblies with approximate quantities, size, shape, location, and orientation.
300	Model Elements are modeled as specific assemblies accurate in terms of quantity, size, shape, location and orientation. Non-geometric information may also be attached to Model Elements.
400	Model Elements are modeled as specific assemblies that are accurate in terms of size, shape, location, quantity and orientation with complete fabrication, assembly and detailing information
500	Model Elements are modeled as constructed assemblies actual and accurate in terms of size, shape, location, quantity, and orientation.

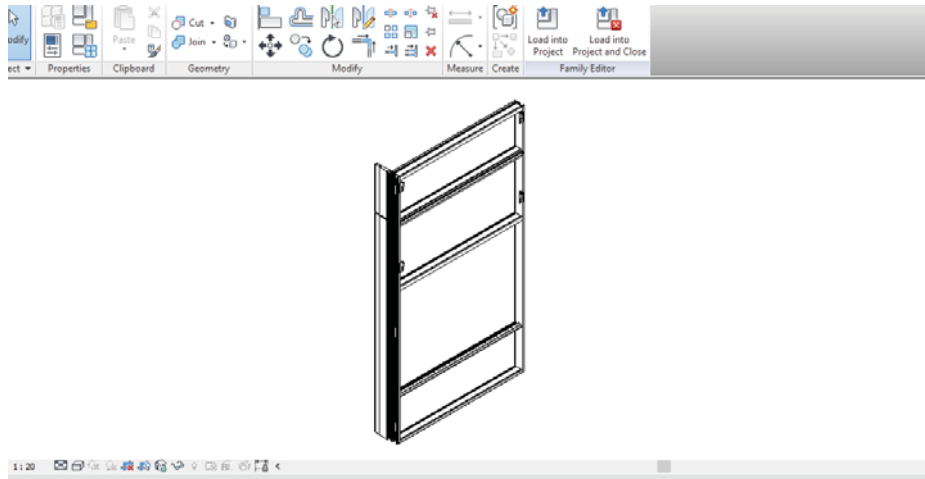


Figure 6: Unitized panel LOD 300 model

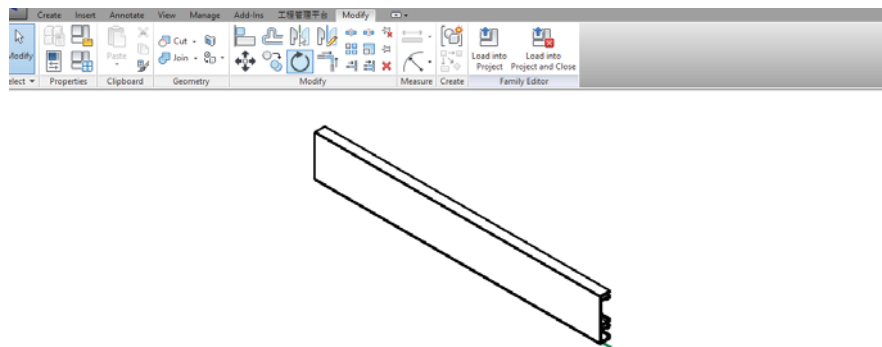


Figure 7: Aluminum frame LOD 300 model

### 5.3 Curtain Wall Material Classification System

To meet the need for exchanging the information of the BIM models with different partners, the organizing of the system in a systematic way is critical for data management (Howard, 2001). Despite the fact that there has been various classification

systems developed by several countries and institutions over fifty years such as Uniclass in the UK, and OmniClass in North America (Ekholm & Haggstrom, 2011), these systems are not specific enough for material management in curtain wall industry. For the information flow of the system, a classification system for curtain wall material management was developed which consists of four parts: company code, project code, delivery area code and material type code. The material type code is classified according to the typical unitized curtain wall materials: frames, panels, connections and accessories, preembedded pieces. Fig 8 shows an example of a type of aluminum frame described with the classification system.

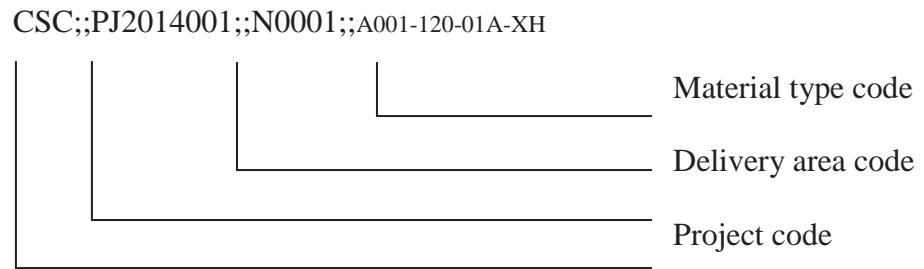


Figure 8: Example of the curtain wall material classification system

## 6. CONCLUSIONS

This study proposed an innovative approach of automating the material management process for curtain wall industry to improve information management and stimulate collaboration. For this purpose, the author first analyzed the current material management practice in the curtain wall industry and proposed a BIM and barcode based material management system prototype was proposed.

This BIM and barcode based material management system may reduce the time and effort variables related with material management activities as BIM model will serve as a unique repository of all this information used by various agents involved in the material management process, enhancing the integrity and reliability of information used and diminishing the errors due to information operation. This approach requires a deep understanding about how to create the curtain wall BIM models, set up modeling configurations, and how to classify the information included in the models using predefined properties. This is particularly important as information flow across different agents and the effort also requires standard business documents among various agents.

In the next stages of the research process, the author will apply the system in a pilot test and quantify the benefits of the system.

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