A Comparative Study on Various Stages of Level of Details in Advanced 3D Building Construction Using BIM Tools

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Abstract. Building Information Modelling is one of the most emerging technologies that provide productivity, efficiency and compliance in the construction industry. There are various platforms on which the 3D buildings can be created with large viewing capabilities. The current paper concentrates not only on the construction of 3D buildings with extrusions but also compares the various levels of details in two different BIM based 3D softwares namely ESRI City Engine and Revit Architecture. A 3D building object can be represented basically with four LOD levels at each stage of the building construction. The focal point of the current study also reflects the creation of building interiors and their corresponding attribute information to each element of the building. In City Engine software developed by ESRI, CGA codes are modified and customized to enhance the advancement in the building construction such as generation of building mass, segments, Roofs, Facade Creation, and other Architectural elements. These basic blocks of the building are produced by using Rule based pseudo codes in City Engine. The study illustrates a sample building and incorporates these codes to generate the 3D Building and the interiors are designed with more detailed components in Revit software. Hence, BIM is a path that provides effective monitoring, coordination and collaboration in construction field.

1. Introduction
Building Information modelling (BIM) is a boon to the construction industry. There are many milestones involved while planning and constructing a building from base level to the roof level. “Plan before construct” is achieved more easily with the BIM technology. There are various stages of construction in a building development since beginning. The floor plan design, development and construction stages of the building domain are specified using the BIM models. Numerous softwares providing great access to build such models efficiently. Virtual building models are the scope for the future construction industry. It performs the task of a civil engineer, Architect, Electrical engineer, planning industry and provides an important contribution to the builders in order to make the analysis, estimate the cost and other decision making time frame. BIM is a cloud computing which is accompanied with integration and management of the Building life cycle.
related project planning, geometrical distribution, design, construction and maintenance [1]. When it comes to the real existence of the building model, the BIM Tools help to attain the original planning scenario and develops a technology revolution in the construction field. Hence, BIM technology can be simply understood as a source and sink of large amount of information regarding the building models.

2. Objectives
The objectives of the current study include comparison of level of details involved in the building lifecycle that enables reliable construction and to generate building architecture using rule based pseudo code and obtains a scenic view of the topology by taking two sample buildings as inputs.

3. Methodology
The methodology and procedure involves the identification and flow of work by considering two sample buildings in two softwares ESRI City Engine and Autodesk Revit Architecture. Each stage of the building construction are analysed at different level of details from LOD - 0 to LOD - 4 as shown in the below methodology flowchart.

![Methodology flow diagram of the current project](image)

**Figure 1:** Methodology flow diagram of the current project

4. Building Creation in CITY ENGINE Software

4.1. Building block from foot print
In order to construct a building the basic block is the generation of the foot print. There are various sources from which a foot print can be delineated. These sources may include open source base maps, Toposheets, High Resolutions Satellite Images, Cadastral Maps (Aerial Survey). The current
study incorporates the footprint from the ESRI base map. In city Engine software, CGA Pseudo code has already been inbuilt which enables the user to modify the codes according to the design of the construction.

4.2. Building attributes
Each CGA Code in the City Engine software should begin with the defining of building attributes. If they are initiated in the middle of the rule, user understanding may be an issue. Once, these attributes are defined in the rule set, based on the call out functions, they are automatically appeared in the inspector tab so that CGA Grammar editor is enabled for the customization of the geometry and other asset management.

4.3. Asset creation and management
The assets required for the creation of the current model are well defined in the CGA Code itself. As soon as they are defined, the corresponding assets are called out from the asset management folder of the City Engine. The created assets in this building are shown in the below code. The advantage of this kind of CGA pseudo coding is that one need not write the code from beginning instead the software itself generates it at the background section [2]. But user should need to customize the code as per the requirements of the building model.

![Figure 2: CGA Code in City Engine defining the asset creation](image)

4.4. Declaration of the texture and colouring
It is observed that the assets are defined in the early stages of the CGA Code flow. Similarly, textures of the walls, windows, roof etc. are also declared. After the declaration, the software itself performs the tasks of loading the texture from the corresponding in built folder.

![Figure 3: CGA Code in City Engine declaring the texture and colouring of Facades](image)
4.5. Creation of the building mass
The creation of the building mass starts with the LOT Rule and extrude command is used to elevate the building to a specific height. As a result of the command “LOT → Extrude (height) building”, the building block is created. The LOT Rule is followed by Façade modelling code. To this particular building model, there exist two types of façade models namely front façade and side façade. This is driven by using the component split command. The shape is split by the code of the building component split which is used to divide the mass models into faces providing front façade (Front shape of the building and several side shapes along with the roof shape [3]). The below commands explain the front and side façade shape of the actual building photograph and the building is constructed based on this CGA coding. The horizontal and vertical ledges are also clearly mentioned in the rule set defining the dimensions and the offset values.

![Figure 4: CGA Code for the Creation of current Building Mass](image)

4.6. Creation of Building Components (Windows, Walls, Door and Roof)
The architectural modelling of the building is achieved by making a few customized and modified City Engine CGA coding for roof, walls, doors, window assets and by dividing the floors using the pseudo code.

![Figure 5: Skeleton of Building block (LOD – 2) and a part of LOD -3 (City Engine)](image)
5. Creating LOD-4 with Revit Architecture

Autodesk Revit Architecture Software is used to develop Building Information Modelling (BIM) which retains data and consequently adapts to the related changes. Revit is helpful for extracting
various drawings from the each model that is possible for architecture, mechanical, plumbing, electrical, electronics and communications [4].

5.1. Floor plan preparation
Another sample building is constructed in the Revit Architecture with tentative measurements of the floor plan. The total length of the building is taken as 200 meters which contains two blocks and three floors (ground floor, first floor and second floor) for illustration purpose.

5.2. Wall extends
The settings of the wall in the Revit software can be directly drawn in the architectural template at different levels extending each wall element with respect to the base and top constrains.

5.3. Creation of floor and ceiling
Creating the floors and ceiling in Revit Architecture is as easy as digitization procedures. The levels to which floor/ceiling is planned need to be created and the walls are picked up for the rectangular stretch.

![Figure 8: Creation of Levels in Revit Architecture with elevation gaps (Section View)]
5.4. Staircase construction and revit families
It is essential to identify that level of detail 4 (interior construction) contains all the building elements including staircases and interior room partitions and other furniture components. These building elements such as furniture components are represented in the form of Revit families. The creation of staircase contains Runs, landings, supporters and railings which necessitate the individual creation. The stairs connecting the level 1 to level 2 and so are designed as below figure. An integrated management of the building information and life cycle is the key point in enhancing and improving the efficiency of BIM Models [5]. Analysis on BIM also explores the benefits of cross section of the construction industry [6].
Figure 11: Realistic view of stairs created in Revit cutting down the floor to reach next level

Figure 12: LOD – 4 building interiors Doors, Windows, Rooms and Furniture components
6. Conclusion

Building Construction involves stage by stage design and development. Virtual Building Models can also be constructed as realistic as possible by using the BIM Software tools. In the present analysis, the two sample building models are compared based on the level of details. It is observed that this kind of analysis provides a revolution in the building planning and the implementation of workflow because it involves detailed attribute domains and data sharing among the various stakeholders. Though 2D building plans are beneficial to some extent, 3 Dimensional virtual models provide more insight and effective visualization for the user understanding. The comparison of the four levels in the study states that LOD 0 is merely building footprint that can be generated by using toposheets, satellite data or Aerial Photographs etc. LOD 1, the next phase to LOD 0 includes the z factor that is building elevation. An extruded building along with the roof shape which comes under LOD 2 and an added building model such as Facade details, Structure and Architecture are obtained by using City Engine Pseudo code generation. LOD 4 is the complete finishing of the building along with the cumulative level of details (LOD 0, LOD 1, LOD 2, and LOD 3). Revit Architecture has provided efficient details and modelling in this study to bring out the interior structure of the building including attribute data. Computer Generated Architecture (CGA) rule based pseudo codes inbuilt in the software contributing more access to modify and customize the BIM Models based on its structure and Architecture whereas Revit Architecture is used to bring out level of detail 4 (interior construction) reflecting the actual façade models, walls, windows, doors and other components. The difficulty in assigning the non-spatial data information detailing the building at every phase of BIM Development. The analysis provides more scope for the construction and planning to demonstrate their 3D Building models with more accurate results and productive representation of the Building Information Models.

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