Univerza v *Ljubljani*
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BIM WORKFLOW FOR PRE-CONSTRUCTION CONSTRUCTABILITY EVALUATION USING 4D TASKS

DELOTOK BIM ZA PRED-IZVEDBENO PRESOJO IZVEDLJIVOSTI Z UPORABO AKTIVNOSTI 4D

European Master in Building Information Modelling

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Izvleček:

Planiranje in izdelava terminskih planov gradbenih projektov so odvisni od tehnoloških in časovnih omejitev aktivnosti gradbenih del v določenem časovnem oknu, lokaciji in specifičnih zahtevah. Omejitve določajo proces izvedbe gradbenih del in medsebojne odvisnosti, ki se pojavljajo pri izvajalskih delih. Aktivnosti izvajalskih del določajo in zahtevajo ekskluzivni dostop do določenih področij na gradbišču.

Razpoložljivost prostora na gradbišču je odvisno od napredovanja gradbenih del. Ko se te omejitve, povezave in odvisnosti med aktivnosti ne upošteva, potreben prostor za izvedbo gradbenih del ni ustrezno upoštevan pri terminskem planiranju, lahko povzročijo neusklajeno izvedbo in nepredvidljive zastoje in dodatne stroške.

Običajno se uporablja terminsko planiranje z diskretno simulacijo elementov informacijskih modelov stavb. Dodatne podrobnosti, kot so organizacija gradbišča, uporabljena oprema, začasne konstrukcije in drugi viri, so komplementarni informacijam informacijskih modelov, in so nujno potrebni za bolj natančno terminsko planiranje. Ta raziskava se osredotoča na razjasnitev omejitev in na določitev

Za učinkovito simulacijo izvedbe potrebujemo ustrezne podatke, ki jih pridobimo iz informacijskih virov kot so modeli zgradb, deležniki, vodje gradbišč, standardnih tabel, in jih nadgradimo s dodatnimi informacijami o procesih. Priprava podatkov, njihova integracija in simulacija je izvedena s pomočjo interaktivnega pripomočka za simulacije, uvoza preglednic, in kasneje izvedemo presojo procesov za simulacijo, ki omogočajo nadgradnjo modela s potrebnim prostorom za aktivnosti. Model aktivnosti, ki je določen z aktivnostmi škatlami, ki določajo potreben prostor za aktivnosti. Simluacija kolizij med škatlami aktivnosti omogočajo projektnim vodjem, da identificirajo težave pri izvedbi, tudi z uporabo BIM na gradbišču.

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Abstract

The planning and scheduling of construction projects depends on technological and temporal constraints of construction activities within the frame of time, location, specific requirements, etc. The constraints determine the construction processes and their relationships that result in construction activities. Then, the construction activities define and require exclusive access to certain spaces at the construction site. Availability of these spaces often depends on the progress of construction. When these constraints, relationships and dependencies and their required spaces are not adequately considered for construction scheduling and during the process, they may cause conflicts at the construction site with the consequences of incalculable delays and extra costs. Nowadays, construction scheduling can be supported by discrete event simulation based on building information models (BIM). Yet further details from construction site plan and equipment and resources are required to compliment the information provided by building information models and required for construction scheduling. The focus of this research is on the clarification of constraints and suggest an efficient construction workflow in BIM. For an efficient construction simulation, data has to be extracted from underlying data resources like models, stakeholders, project managers, standard tables, etc. and enhanced with additional process information. Data preparation and its integration with the building model into simulation is done with the aid of an interactive mediator for construction simulation resulting in an activity loaded model. The activity model has task-boxes surrounding building elements representing the required space for the activities to construct each element in the building. Later, an evaluation process for the simulated construction activities to their optimization are held by assessing the in-task clashes among simulated activities (Marx and Markus König, 2011). This evaluation can alert project managers on the workflow and requirements of the construction site at pre-construction phase. In fact, constructability of the project is being organised by BIM-on-site.

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1 INTRODUCTION

1.1 Overview

The information is what differentiates BIM from being just a 3D model. Digitalization of data automates the coordination of tasks, people, facilities, movements, equipment, changes and any more involved in a construction project which enables those involved with the extraction of the information they need immediately after a change to the model or to anticipate in advance and determine based on it.

With BIM on site, it is possible to find and solve problems early (Vestermo *et al.*, 2016). BIM is a representation of collaboration and exchange of information in a proper time and through a reliable process. The current research will discuss each phase in the following chapters.

1.2 Problem Statement

Information is supposed to serve the team to ease up communication and therefore, the process. So, any fault or mishappening occur in the process, there has been a miscommunication that resulted from shortage of related information. In this study we are focusing on a method for collecting the existing information from the design phase and standards, then categorizing and channeling them to serve constructability issues that anticipation can address them in advance.

The information is inserted throughout the process into the model before it gets transmitted to the construction phase but not all the information inserted are needed at once and not all of the inserted information will necessarily be enough. So, categorizing them shows what information has been missing and how to bring to work every piece of them categorically.

The delay and consequently, the waste of money that are caused by lack of information are the missing points in evaluation of BIM process as the promising technology to improve efficiency of construction industry. One of the ways to address these delays are to put them under spotlight by categorizing the delaying issues and visualizing them in 3D; the way that BIM process initiates to conform information instead of treating them as data lines of 2D scheduling in project management.

1.3 Research Questions

- What is the current deficiency in the modelled data as a BIM model that affects the efficiency of the BIM process and its utilization in the construction site?
- What are the unseen obstacles affecting the progress of construction that can be addressed at previous phases namely: Design phase and pre-construction phase?
- Why do we need a reconsideration process applicable to the BIM model that can anticipate probable blockages in the construction process?

- Who will benefit from visualizing the task requirements in the construction site, prior to the construction process and during this phase?
- How to diagnose and visualize task requirements through BIM process and modelling to assist decision makers reaching a thorough work breakdown structure (WBS)?

1.4 Research Objectives and Scope

The modelled data should indicate the limitations on the site that can delay the next construction steps at every point of the job that we look at the model. The decisions should be based on the modelled data and not the initiatives.

The 3D representation of the BIM model at its best just shows the elements and their final status as they should be (As-Built and As-Designed models) but not how to reach to that level of accuracy and all activities needed around each element to lead us to the final phase.

Each element and phase of construction requires specific activities and considerations interconnected and engaged with other tasks around them. These activities and their requirements are missing visualization using BIM modelling potentials. Currently, the most common aspect of project scheduling that is being used and developed is through Microsoft Project Spreadsheet (MSP) scheduling and planning followed by matching and converting developed information to 4D and 5D phases of BIM process.

The requirements around each task in the construction process that are responsible for delays are unseen in advance; they cause shortcomings of the project management scheduling processes. To minimizes the probability of missing requirements of the construction tasks, we need to address them in advance through a 3D graphical representation.

All decision makers and actors namely: project manager, designer, stake holder, worker, foreman, etc. will benefit from this additional consideration because they can discuss over a visible matter and decide about visualized conflicts.

All the above mentioned will lead the process from To-Be phase to the To-Do phase with additional steps that were hidden or left unseen. These hidden requirements and necessities, if not the most determining factors of the whole construction process but can be known and categorized as the highly effective ones. In the next chapters, we will mention, categorize and consider these requirements to their level and radius of effectivity.

The current study will cover limited number of adjacent elements of one 3D BIM model as the selected case study to result in a prototype that can deliver both aspects of the development; the concept and its practicality. A 3D Revit model case study is selected as agreed by supervisor. The case study just serves as a real-world platform to implement the prototype otherwise, any other case-study can be used.

The software used in this study are the most current worldly known and used software package of Autodesk; Autodesk Revit, Dynamo and Navisworks with the same compatibility.

2 LITERATURE REVIEW

Collaboration is a necessity at every step of the construction process. A hidden step in the process of simulation of the construction work is Pre-construction phase. Pre-construction is the most critical step because it is a transitioning step from design phase to the construction phase which equals to the change of working environment and the methodology.

As defined by CDM (Construction (Design and Management) Regulations) this phase is known as the period of time that preparatory work or design is carried out for a project and often continue during the construction phase. It requires from construction clients to provide pre-construction information as soon as possible to have practicability for every designer and contractor appointed to the project. The principal designer is responsible on providing advice and help compiling the pre-construction information where there are multiple contractors appointed and provide it to the teams of designers and contractors.

Table 1 specifies the requirements at the scoped phases of the construction process forward and the related functions that can be included and reflected in the BIM model.

Table 1 – Model uses in function and specific requirements (Cerovšek, 2021)

Model Breakdown Structure: Functional Analysis		
Pre-construction	**Construction**	**Post-construction**
As-designed	As-built	As-managed
Architectural program	Change orders	Seating plans
Planning scenarios and site information	Supporting docs for litigation	Organizational occupants
Floor plans	Invoices	Personnel lists
Schedules	Purchase requests	Handicap designation
Costs of M/E/L	Cost estimates	Operating manuals
Space function	Network diagrams	Maintenance records
Classified areas, vaults	Procurement docs	Simulations of events
Material characteristics	Progress photographs	Continuation of operations plans
Area calculations	Inspection records	Disaster recovery plans
Volume calculations	Construction dates	Contingency plans
Engineering calculations	Hazardous materials	Furniture inventory
Specifications	Actual material used	Warranty data
Contract documents	EAN/RFID codes	Alarm diagrams
Legal description	Quality control data	Fire-escape plan
Shop drawings	Labour/Equipment	Data from meters

Information flow is the logical path or trace of information processing. The information flow is represented by conceptual and/or physical content or data. The flow exists if the information is being exchanged; Information routine to workflow, from creation to expose. In construction, good information exchange, efficient information flow and routine can improve collaboration.

We have to consider information from the point of view of decision making and the follow up processing of the information and the value that is being added by this processing. Information changes identity through the process.

- Information asymmetry has been established in economics. In the process model, architect and engineer can exchange information routinely or we will face asymmetry in information management.
- Information entity is anything that has a value and is independent of its storage location format (Cerovšek, 2021)
- Information determines the organization of the stakeholders and vice versa, determination of organizations and related information shows where we can gain missing information

Collaboration and information or resources in general are 2 out of 5 main steps of a development process – BIM in the context of our study – defined by Br and Moland as follows:

There are five elements that can distinguish between successful and less successful development and change processes (Br and Moland, 2015), namely:

- Clearly defined need and purpose
- Clear goals
- Anchoring
- Involvement and collaboration
- Resources

It is therefore important that the management and R&D units take responsibility for motivating the development work, so that a clear idea is created about what a real need is.

The purpose of a development project is something other than its goals. The purpose describes effective goals that goal achievement is expected to lead to. Formulation of intent challenges the actors on the benefits that the project is expected to achieve. Good formulations of intent will therefore help the actors to work goal-oriented and at the same time make the anchoring work easier. It is important to take a closer look at how the purpose is designed and what challenges are sought to be solved in the project.

With the BIM model created for a construction project, the first 2 elements are met by default. The latter 3 elements will be the issues we face by having the model but not utilizing it to its full potential. This study will evolve around these 3 elements by considering the BIM model(s) as the anchor that project planning evolves around it and is not only the final goal that we want to reach to it. We want to involve the model throughout the project (more than what it possesses currently and provides)

As addressed under problem statement in the previous chapter, collaboration arrangements can improve to its best status by proper insertion of data throughout the project design phase which eases up accessing to information at the right time afterwards. If the information and parameters of each modelled element in the BIM model preparation process happen at its expected level, then additional parameters to serve the next phases will increase the flexibility and practicality of the model without further complications.

Table 2 and the classified collaboration factors following that can sort out the relative actors, the timing of information exchange, the information and their relative effectual locations.

Table 2 – Information Lifecycle Management (Cerovšek, 2021)

Information Logistics	Information Lifecycle
Move the right product	Development time (time to create, organize, integrate, model)
In the right quantity	Distribution time (time required to distribute the model)
Of the right quality	Activation time (time required to retrieve, access and use)
In the right place	Update time (time required to change a model)
At the right time	Detention time (time required to archive the model)
At the right cost	
For the right customer/contractor/etc.	

The table above steps towards the intentions of this study by prioritizing the information in the collaboration assembly. If we consider information as 3D goods instead of 2D data - the protocol that BIM is based on - information exchange is what is represented in the table under information logistics column and the factors of the right place, the right time, for the right customer with the right cost are the steps that needs further development in the BIM process.

The following quantitative division of collaboration system simplifies the inputs, outputs, controls and benefits of this system implementation process. In fact, the divisions clarify the main element among involved participants in a project at the time of collaboration.

Collaboration: Quantitative division (Cerovšek, 2021)

Participants (Who):

- Number of stakeholders involved and their groupings
- Direction of communication throughout supply chain (uni or bi-directional);

Information (What):

- Number of information exchanges and amount of information
- The extent of changes in information exchange

Time (When):

- Time required for preparation and interpretation of information
- Frequencies and intervals of communication sessions
- Overall time span of several communication sessions
- Duration of individual communication sessions
- IDLE time: the time information is available, but has no effect

Location (Where): Spatial (geographic)/organizational (business):

- Single or multiple physical locations of senders and receivers
- Internal and external communication to an organization/project

The increasing pressure of deadlines and shorter delivery schedules created a critical resource at construction sites namely space. Project managers need the help of a formalized approach or tool to analyse spatial conflicts between activities before stepping into the construction site which the current industry practice lacks. Consequently, time-space misreading and conflicts occur frequently and make a significant impact on the construction processes.

Per Akinci et. al., there are three characteristics that differentiate time-space conflicts from design conflicts:

1. They have temporal aspects that means, they occur only during certain periods of time;
2. They exist in different forms; and
3. They create different types of problems on site.

One of the approaches towards this issue has been introduced by (Kumar and Cheng, 2015), The Construction Site Layout Planning (CSLP) step which consists of optimizing the locations for temporary facilities that will define them with a close approximation as one or more rectangles, on the free spaces of a construction site.

In most of CSLP tools, the user specifies the dimensions of each facility prior to the layout optimization conformation. Yet, this approach has a significant disadvantage that directs to an insufficient use of site space. We use site facilities to store materials and equipment, or to define the working area for humans. Therefore, the specified area of the facility for the specific task needs to meet the essential requirements. Here is an example of CSLP tool that has helped in the formation and development of current research. As an example, the layout planner defines a 25 square meter of floor area for a site office (caravan) that can place 12 engineers. Still, the decision on the exact dimensions will be made after acknowledging the available space in the construction site which it is to be set up on. So, the planner defines the form of the facility as a variety of rectangles with different parameters and values of length and width. The only but imposing constraint is that the facility, in this case the caravan, should be of reasonable dimensions that also provides the necessary floor area. Therefore, allocating fixed dimension for a facility before locating it on the site limits the layout planning possible solutions severely. At the same time, it limits the possibility of vendors or facility providers that can help in optimised arrangement of site layout.

The objective of construction site layout planning (CSLP) is to determine the optimal layout of temporary facilities (such as storage areas, fabrication shops, machines, residence facilities and equipment) within the boundaries of a construction site in order to enable the safe and efficient movement of materials, equipment and labour (Zouein, Harmanani and Hajar, 2002).

Whereas this study will subdivide the construction site as parts that each have various needs and requirements namely: dimensions, safety measures, movement directions, usability turns, temporal usage, etc. and this is where CSLP have not been successful in practice because it looked at the construction site optimization instead of considering each task independently with its requirements, restrictions and considerations. Also, it is necessary to mention that these demands are not a repetitive work to be done for every project every time but the information regarding the specifications and requirements of each task can be collected, adjusted and defined with a variation range to be adjusted in case of special situations. Then, they will be applied to the BIM model as a data attachment reviewed by the project manager.

The CSLP problem can be subdivided into three parts (Kumar and Cheng, 2015)

1. Determining the required size of facilities,
2. Identifying at which stage of construction each facility is required, and
3. Allocating facilities to different site locations

Besides all the above-mentioned aspects of this method, this is an extra step that needs to be taken in between design phase and pre-construction which may even extend itself to the construction phase; it will take extra man hours consisting of time, skills & individual people dedicated to an optimized layout planning. Therefore, the BIM oriented approach of this study introducing “TaskBox” will absorb this step in since it is actually being originated and developed while the “BIM model” and the “project Work Breakdown Structure” is being generated. Yet, the purposeful study of Kumar and Cheng can give directions to the current study.

2.1 An illustration

An information system is a computer-based system which makes it possible to store and retrieve information of relevance to the information needs of a user. (A Ekholm, 2001)

The following section of this research discusses the theoretical framework for modelling task-related activities and space needs, and the information of interest in building design.

Modelling of activities and processes is following a strong development in the construction area but has so far not been developed to suit the needs of building construction and facility management. The aim of this project has been to develop a prototype add-in or introduce a workflow that can model user activities in the context of a BIM program for construction sector.

Process is a sequence of events in a system. An activity is a sequence of goal-directed actions with intention to transform the state of a thing. Our development study is a goal-directed process. The terms ‘process’ or ‘activity’ may also be used to designate the system itself since it is a characteristic feature (A Ekholm, 2001).

A human activity system is composed of persons and equipment, i.e., the latter are things that are used during the performance of the activity. Work is a specific kind of activity; it is a useful activity (Bunge, 1977). A sociosystem engaged in some work activity is in management science called an” organization” (Child, 1984), ”human activity system” (Checkland and Haynes, 1994), or ”enterprise” (Bubenko, 1993).

Information derived from user activity is needed throughout the construction and facility management processes because there is a need for an accommodation of user needs by new formation of an organization. To create and acquire a suitable building, we must start with a description of its organization that also covers its activities. The activity description is a foundation for developing a space functioning program that explains necessities of the building’s spaces.

The building program together with the activity description and the space program are used as a background for building design but can also be used for building performance analysis during the facility management stage (Ekholm and Fridqvist, 2000).

A list of activity information needed for space function programming is mentioned below. The list is based on (Hales, 1984), and (Hus, 2000).

2.1.1 General activity description

Design is an activity with the aim of achieving an outcome with specific required properties. Design may be considered as a problem-solving process. Lack of knowledge about the properties of a thing can be defined as a problem. Problem solving therefore is a knowledge acquisition process (Bunge, 1983).

A general description with the focus on factors that determine spaces and installations is necessary.

2.1.2 Activity relationship information

- Sequences of a process

- Exchange of materials between activities
- In-person communication or through media
- Spatial relations, visibility, audibility, supervisory, safety and security, shared resources and other relationships;

2.1.3 Activity properties

- Type of activity
- Activity area
- Dimensioning measurements
- Duration
- Disturbances (Noise, Heat production, etc.)

2.1.4 Person information

- Personnel data; skills, working hours

2.1.5 Equipment information

- Furniture, machinery and equipment
- Quantities
- measurements
- EPC (Products and materials), their delivery schedule and procedure from the producer to the installation location

2.1.6 Building information

- Building (and process) support; HVAC-requirements, fire rating, sound proofing, electricity
- Lighting; daylight/black-out
- Atmospheric pressure

Anders Ekholm utilized the following parameters for the necessary and effective factors in the development of its introduced ArchiCAD Add-in:

Activities may have Name, Description, Duration, and Relations. A Person has Name and Description, it can only exist within an Activity. Equipment may be composed of other Equipment. It may have Name and Description. An Equipment element can exist independently during the time period between the Activities in which it appears. Between Activities it has the same state as in the last Activity.

The entities and their connections as implemented in the Ekholm prototype are shown in the figure below.

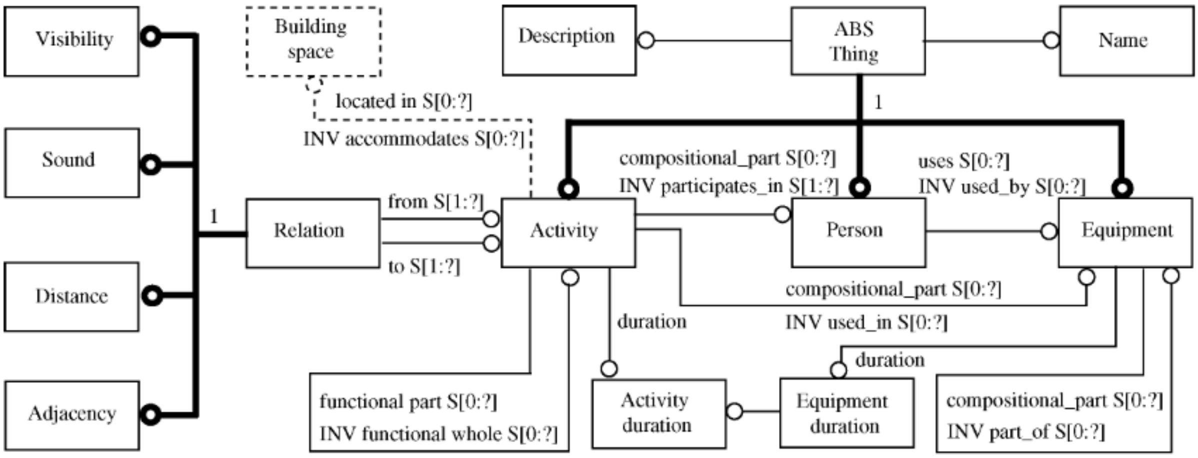

Figure 1- conceptual schema of the activity add-in (A Ekholm, 2001)

Below is listed the information needed in building design for an organization user in spatial layout planning according to (Hales, 1984), see also (Ekholm and Fridqvist, 1996); all the following information does not necessarily engage with activity modelling of building tasks but can complement the BIM model and come into use for operation and maintenance phase.

1. Personnel data: numbers, skills, attitudes, working hours, physical needs etc.
2. Product and material data: quantities, activity cycles, size, weight, composition, etc.
3. Routings or manufacturing sequence data: data for products and material in a production process; procedures for the work process in administrative or institutional facilities.
4. Furniture, machinery and equipment data: quantities, activity cycles, size, weight, required installations etc.
5. Building (and process) support: mechanical and electrical systems, HVAC-systems, plumbing, lighting, maintenance, waste disposal, pollution control, fire control, etc.
6. Personnel support: food services, break and recreational facilities, parking, first aid, etc.
7. Activity areas: “Activity areas” are organizational units based on functional or product/process-based grouping of activities. All project data on flow, communications, space, equipment, personnel, etc. are collected and reported by “activity area”.
8. Material flow: Data on material flow between activity areas; by estimates; by work sampling or other formal survey; by extraction from production control reports; etc.
9. Communications: Data on personnel communication based on surveys which display both the overall communication pattern and the aggregate relationships between workers.
10. Activity relationships: Communications and flow are the chief bases of relationships between people and departments; other issues are shared supervision, shared equipment, shared records, shared utilities, etc. This item is what this study has under investigation because all the factors mentioned here by Ekholm and Hales are involved

to the decision-making process throughout construction at the same time and each factor can get priority over the others at some point. All of these factors can affect the visualization process of activities around each task.

From the next section, the study will move towards introducing foundation of its proposed workflow inspired from the previously introduced Add-in to reach to the prototype.

2.2 Functions of the Activity Add-in

Buildings are constructed to enable different kind of activities. It is necessary to be able to define user activities in 2D and 3D during design phase or facility management and how they are accommodated in the building.

There was a need to link elements with their fabricating process and tasks. An element is part of an Autodesk Revit library that can represent different things, e.g., people, furniture, building parts, movements, logistics, materials, etc. like kitchen fit-outs, building services parts, etc. The link between elements and related activities can only be active by a visibility parameter.

2.2.1 Activity Menu

The Activity Add-in manages an Activity System by its user corresponding with the Activity factors:

The Task Add-in will enable the user to determine and edit activities around a task. The main functions to configure the Activity System of each task follows the script prepared in the Dynamo add-in of Autodesk Revit which is applicable to each project that has elements defined and modelled in it. The task is defined as an element itself; a visualized 3D box that represents the occupied space around each task and is modifiable by the operator based on the requirements of each task which are actually “Activity Properties”.

The Activity Add-in of ArchiCAD defines “Activity System” and “Activity Links” as well besides the activity properties which each has their definitions and place in the process, but we believe that dividing the activity as a whole to separate issues to consider will complicate the process. The aim is to simplify understanding and examining the task around each building element that leads the decision-makers to an easy platform that reveals task conflicts. This diagnosis should even be understandable by BIM-illiterate team-players like foremen and handy-men since they can even participate in diagnosing these clashes while being involved in the actual site and implementing the Work Breakdown Structure.

Following by the Activity Add-in that considered Activities in each level as a composition of Persons and Equipment, we will subdivide them to a combination of Persons, Goods, Time, Clearance;

- Goods will cover materials, machinery, equipment,

- Persons can be the number of people, their movement around the specified task area.
- Time which goes back to the temporal property of construction tasks
- Clearance shows the distance needed to be kept from the activity space within a period of time and consists of noise production, heat production, movement, quality preservation, safety, security, etc.

Data regarding the considerations above are mostly repeatable by the concept and can be saved as a spreadsheet and with a general review and customization can be applicable to various projects.

The task properties can be defined by their effectivity. Visibility, Connection, Adjacency, and Distance. The properties can be set at direction and certain grades of importance. The Activity Properties includes name, description and duration, the clearance dimensions and comments, the number of people involved and their responsibility. The operator or user can control the appearance of element related activities in time. Activities around a task can be set to be either periodical or temporary placement or happen once.

This prototype enables us to manage activities as objects. It allows people and equipment to be kept together as systems instead of being separate entities. Modelling of activities and processes is an area in strong development, but has so far not been developed to suit the needs of building design and facility management (Ekholm, 2000). The aim of this project has been to develop a prototype workflow that can model task-related activities in the context of a BIM-based program for building design.

In the methodology chapter we will discuss the properties of tasks in particular and how each can be visualized or affect the appearance of the proposed Task-Box as the activity representative element in our model.

2.2.2 Task-Activity space

An activity space is the spatial extension of any task that concludes activities in and are of different scale. For instance, the smallest can be defined by the human body and the used tools. For example, for an individual’s job, the body, accessibility, movement, safety and reach characteristics belong to the key determining factors.

A work unit occupied space composed of persons with their equipment and materials will depend on the material used in the process and the resulting products. Persons, equipment and material activity-spaces are time-dependent because they change position and dimension over time.

Similar categories are listed in so called “space function programs” commonly used to document user activities and space requirements in a construction project. A space function program contains information about the activity and its requirements on the building spaces. A typical example from university facility planning contains the following activity information, building requirements excluded (Hus, 2000):

- Activity description, focusing on factors determining spaces and installations
- Number and kind of workspaces
- Estimated site area
- Dimensioning measures
- Placement/Connections to other activities
- Clearance to including possible Chemicals and flammable liquids/gases, Sound conditions, noise generating/silence requiring, Security demands, Climate conditions, Hazardous/safety clearance
- Personnel permanent/temporary: hours daily
- Equipment

1.1.1.1. Task space definition

The Task-Box visualizer is defined as a translucent bounded area/box developed as an Autodesk Revit family. Then, when the operator or user demands, it is possible to define the Task-Box as an Activity Space using the Task-Box transformation tool.

2.3 The Process

A process is a sequence of events in a system; an activity is a goal-directed process. The terms ‘process’ or ‘activity’ may also be used to designate the system itself since it is a characteristic feature. The process of acquiring a suitable building starts with a description of the organization and its activities.

In Navisworks, we have set of elements selected in groups following the sequence and schedule of their construction.

There is Work Breakdown Structure (WBS) prepared for construction sequences in Microsoft Project or CSV format.

The WBS will append to the elements from Autodesk Revit. Elements form objects, groups, sets, etc. in Navisworks. The working schedule with be attached to each related element either manually or rule-based auto-attachment using the Revit-created & assigned share parameter that is diagnosable by NW (A common parameter between objects and tasks).

Dynamo can help to create elements that are diagnosable by Navisworks rooting from the 3D objects that are modelled in Autodesk Revit representing our goal structure. We name the elements created by Dynamo after the family that is designed and defined for this procedure in RFA format with its necessary characteristics and parameters, Task-Box.

1. Dynamo can extract the location parameters or properties of the elements from Revit and assign a Task-Box (TB) to each GIS.
2. Dynamo can diagnose each object as an element and create a bounding box around them and translate that bounding box into a Task-box.

We tried both scripts and the selected procedure is the second one since it is easier to be understood and used by users and is more flexible for future developments.

2.4 Time and Space

As stated by Akinci et. al., the challenges in time-space conflict analysis involve the detection of spatial conflicts in x, y, z, and time dimensions, the categorization of the conflicts detected, and the prioritization of the conflicts categorized

Several aspects should be investigated. For example:

- Illustration of user activities
- Spatial lay-out design
- Temporal space use analysis
- Versatility analysis
- Space function programs
- Activity libraries
- Process modelling

The properties that this research considered for the Task-box at this stage of development are as follows:

1. The dimensions of each Task-Box (TB) are adjustable to cover the required space for various affecting factors in the working space that has been studied before this; the activity, safety clearance, Material loading and/or unloading space, delivery and moving path. The dimensions will be instance properties to be adjustable by the user or operator.
2. Naming category to give the user the possibility of filtering based on the categories of each activity. This factor will help the project manager or the planning team to arrange timing for multiple activities that are related in an aspect like delivery method, the working crew, requiring special treatment, etc.
3. Comment property for specific requirements of each task to notify the related actor. This aspect can be developed in the future researches to activate a task-specific alert to notify the crew for that demand in a proposed time or when the construction process is reaching to its adjacency.
4. Visibility option for the Task-box to turn it on or off. It will add a flexibility for the user when presenting the conflicted tasks and elements.
5. A color-coding visibility can also be activated in the Revit family to categorize the activities based on their priority of effectivity in the construction process so the planner can rearrange the conflicted activities following their priorities as a clue. This color-coding system can be affected or merged with the filtering option of Autodesk Revit to make an informed decision for activity rearrangement by the activity priority and category.

“ANYTHING THAT ALERTS A MANAGER”

2.4.1 Task-box Sizing Example

To give an example on TB sizing, we can consider storage facilities dimensioning. They should be sized so as to facilitate (1) best practices for material storage, (2) safe work conditions for labourers, and (3) efficient functioning of the facility.

The facilities for storing materials should ensure that there is enough space for storage throughout the construction duration. Facilities with daily use such as fabrication shops, carpentry yards and site caravans or offices should provide an unhindered working accessibility. Production capacities of facilities such as batching plants will be the affecting factor to size those production facilities. The temporary facilities sizing depends upon variables such as the estimation on quantity of work, rate of consumption of resources, number of field workers and site area.

An example of a process of facility sizing by adopting the following steps, as shown in Figure 2:

Step 1: The option of quantity take-off in BIM model can give us detailed information about the total amount of resources needed in an activity. This total amount will come in use when we need to know the peak of usage in the duration of that activity in construction process. For instance, the total volume of rebar and concrete needed for an activity named as “Level 1 Columns” will be derived directly from the QTO of BIM model.

Step 2: The durations of the activity should be calculated which is needed to understand how long the facility will occupy the land. This information could be read from the planned construction schedule. For example, the duration of activity “Level 1 Columns” would refer to the number of days assigned to this activity in the project schedule.

Step 3: at this step we can determine the peak rate of consumption. For each activity, the rate of consumption is the result of dividing the consumed amount of resources by the duration of the activity. The peak consumption rate could then be obtained as the maximum rate of consumption among all activities.

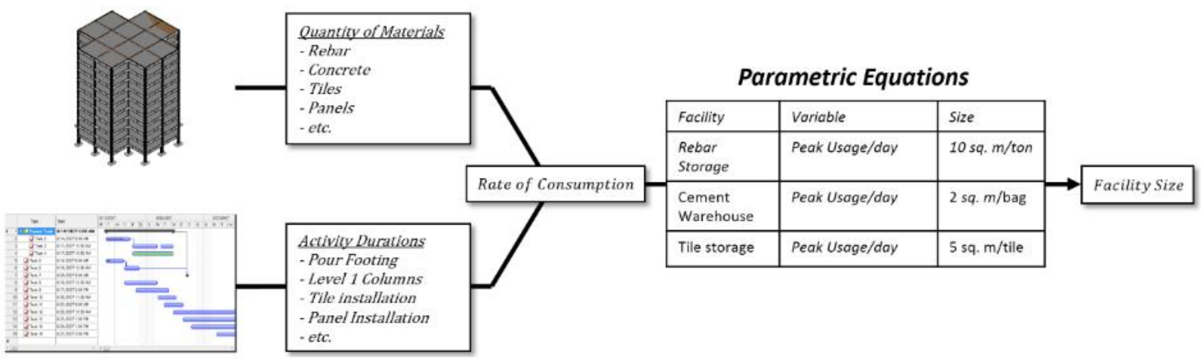

Figure 2 – Facilities in-use classification and sizing (Kumar and Cheng, 2015)

Or as another example, the size of the engineer's caravan could be computed assuming six engineers.

In this work, the BIM tool used was Autodesk Revit and scheduling were done by Microsoft Project. The data of planned construction schedule as well as the information of resources from the BIM model were exported into Excel spreadsheets. After performing the necessary calculations and hence obtaining the required facility sizes (see Figure 2), they will affect the sizes of Task-boxes in our As-constructed model. The Excel spreadsheets will be updated following changes in the design or schedules, enabling them to be reflected in the final calculations. This framework allows a quick and easy to follow method for facility sizing and will not need manual input of project specific information by users. This framework also results in significant reduction in effort when applying changes to design and construction plans.

2.4.2 Dynamic Layout

Some facilities are just required temporarily throughout the whole project duration. So many of the facilities will be placed in the site for a limited duration and will be dismantled afterwards. Then, their occupied space becomes available to set up other facilities. For sites with smaller area and therefore, available space, multiple facilities might need to be positioned at the same location on the site during different stages of construction.

For example, determining the time during construction that a rebar storage yard might be needed has some pre-requisites to follow; firstly, we need to identify the activities that need access to a rebar storage yard, and secondly, their start and end dates. By considering the logic that a facility should be present on site only as long as it is required by an activity, the requirement for the rebar storage yard to the durations of related activities can be correlated to each other.

Another example for considering dimensions in the construction sites is the logistics. The width of the path required for personnel and equipment transportation. Light materials may be carried by workers which they still need properly sized routes to not clash each other's directions. Whereas heavier materials require heavy machinery for transportation like wheelbarrows or forklifts. The width of the path is related to the size of the equipment which is different in each case. A layout which provide safe and navigable paths is essential in order to ensure that different locations are accessible by both labor and equipment.

The contractor in these cases can realize the spatial conflicts only when they occur at the site with no time to explore options which results in delays from the original project duration. If the time-space conflicts have been identified and analysed prior to construction, different options to manage these conflicts could be explored by the consultancy and/or contractor team since a certain set of construction methods and sequencing decisions has not been made yet. For example, the construction methods for conflicting tasks can change in many cases which can suggest an alternative schedule incorporating this change in the construction method and result in less to zero conflicts in tasks or activities.

2.4.3 Characteristics of Task Clashes

Computer systems come in handy for project managers to identify, analyse and manage clashes among tasks since due to the variety of characteristics of these conflicts, it will be difficult to consider all aspects of them without any human-error. The characteristics are:

Temporal or time-limited aspect

Since activity space requirements change over time (Tommelein and Zouein, 1993a; Akinci, Fischen and Levitt, 2002), task clashes only occur for certain periods of time which suggests that not only 3D geometric clashes should be detected but also the analysis should include reasoning behind the conflicts.

Multiple types of time-space conflicts

Multiple types of clashes result from the types of task boxes for different activities, equipment, crew, etc. and the ratio of the volumes of the interfering space boxes to the volumes of the required space boxes. They can be categorized following by types of clashes defined in clash detection standards as hard clashes and soft clashes which each can be subcategorized and exemplified by safety/hazardous, Logistics/transportation, Material, equipment, etc. Project team need to understand all possible task clashes and the ones happening within their proposed project existing in a schedule to develop customized solutions or alternatives for each case and prioritize the clashes detected for management optimization.

2.4.4 Tasks Clashes Analysis Workflow

To formulate clash analysis among tasks, Clancey's classification model can be applied which includes abstracting detailed problem data to a class of typical problems, matching the abstracted problem class to its generic class of solutions, and refining the generic class of solutions by using the detailed data about the problem (Clancey, 1985).

Likewise, our initiated workflow of clashes analysis will excavate clashes from a Task-loaded model in two levels of abstraction and refine them in the next two levels. The initial data for the analysis workflow is the task-loaded production model in which the required space for multiple activities around a building element is represented as an intelligent object and shows the data included in the task-loaded production model. The steps of workflow formulation are as below:

1. Detection of task clashes in given task-loaded model;
2. Aggregation of clashes detected;
3. Categorization of aggregated clashes;
4. Prioritization of the categorized clashes; and

5. Managing prioritized categories.

The research presented in this paper focuses on formalizing the generation of a proper task-loaded model. Then aggregating these tasks and inserting them into the clash detecting software. When the clashes are detected, categorization and prioritisation of tasks can be done using the implemented parameters into the Task-Box. Automation of the management of the conflicts prioritized—the fifth step—will be user-defined by specific strategies for managing the time-space conflicts.

Previous research studies on construction space scheduling (Tommelein and Zouein, 1993b; Zouein and Tommelein, 2001; Zouein, Harmanani and Hajar, 2002) focused on formalizing and automating the strategies necessary to automate the management of time-space conflicts. In those researches studies directly address the first step to the fifth step by formalising the space scheduling without categorizing the conflicts detected in a formal manner. Still, the implemented strategies in the space-scheduling systems are mostly temporarily and adhoc and do not address the time-space conflicts each particularly and separately.

Moreover, the implemented strategies in those systems do not cover managing time-space conflicts in every possible manner. For instance, alternative construction methods to install the same component is not among the suggested time- space conflict management strategy where changing the construction method can eliminate time-space conflicts between activities effectively.

Our research is aiming to provide a reliable platform to the previous researches by visualizing the spaces required for construction activities which is the pre-requisite of space-scheduling by developing a taxonomy of time-space conflicts and by formalizing time-space conflict analysis as a classification task. Hence, our research can be utilized as the missing link for space-scheduling strategies development to improve the time- space conflicts management. The next sections are a general description of previous studies regarding time-space conflict analysis and management which are helpful to clarify the goals for our study and generate guidelines and principles to a better outcome.

Tasks Clashes Analysis Workflow (An example)

Temporal property of conflicts among activities and their occupied spaces in a construction site is a considerable factor at the beginning of clash analysis. This means that they occur only during a certain period of time. Therefore, the clashes detection needs identification of 3D geometric space in addition to time conflicts.

The time-space conflict detection algorithm is a combination of basic 3D geometric clash detection algorithms (Lin and Gottschalk, 1998) with discrete event-simulation mechanisms (Law and Kelton, 1991).

In Task-Box visualization procedure, spaces are represented as rectangular boxes in parallel to the orthogonal planes of the related element that the box is surrounding it, The task-loaded model will be used to simulate the construction process according to the schedule developed by the user.

A list of spatial conflicts among different spaces can be generated after detection of clashes between visualised construction activities. It shows spaces required by concurrent activities and clashes between the different spaces required by activities and the work-in-place. This list will show that clashes can be common among activities since activities are happening concurrently on site and a space needs to be used by different people and activities.

The geometric conflicts or Task-Box clashes will become manageable by the project managers after aggregation since they reveal all common clashes between different activities. The next section describes the process on this matter.

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3 TASK-BOX WORKFLOW

3.1 The Overall Idea

The idea is to visually highlight conflicted tasks in the selected site area. This is to alert managers to prevent any waste of time, money, materials, etc. and help them o visually find a solution to occuring conflicts during construction and arranging tasks in 3D rather than through numbers and data.

Project managers can run what-if analyses and they can implement strategies to manage different task clashes proactively by managing time and space conflicts. Exploration of possible alternatives for spatial conflict management prior to construction could increase productivity, constructability, safety, and quality and can reduce project delays and enhance safety performance on sites, consequently.

Our defined Task-Box is a translucent box that will be smart linked to managing schedules in Navisworks through a shared parameter defined within the Revit family of the box. The box is an element recognizable by Navisworks to highlight tasks that will clash in time and/or space.

So, this info box is a container of direct and indirect affecting factors to that specific task in that specific location in that specific timespan. Collaboration and Awareness are the information or data that Task-boxes share provided by the current actors of the project or from the knowledge managed (Life-Cycle Management) throughout the project survey/planning and imported from previous people or lessons learned from previous or current projects.

So, there is a flow of resourceful information that are authorized, verified, validated and can be tracked prior insertion into the properties of the smart parametrical Task-box (parametrical to give dimensions to the task-occupied area).

Table 3 - Data Characteristics and Categorization

Dynamism ⇨ <u>Time-related</u> <u>Behavioral</u> Dependencies.

Time-related	Behavioral
Data	Spatial.RV
Experience	
Organizational	
Contractual	
Cooperation	

3.2 Prototype Development

A prototype system to automate the analysis process has been developed. Autodesk Revit, Dynamo and Navisworks are the primary software engaged in this development. A script from dynamo detects modelled components of the building within Revit selection box and converts them into Task-Boxes that is a predefined parametric Revit family through this research. This will generate a Task-Box loaded model since the initial production model - an integrated product and process model of a project - is expanded to include the space requirements of construction activities which is actually a model that represents all required activities around each element of a system resulting in the full building.

Within the task loaded production model, each Task-Box represented in three dimensions and across time, represents tasks as intelligent objects. The space requirements of activities show the location of the element and its involving activities and how much volume they occupy all together.

There are different types of spaces required by construction activities. The development and representation of these activities could be either by different colours of boxes or by implied non-graphical constraints included in an independent box surrounding each element.

Different boxes can be useful if filters can separate them to prevent confusion. So, for example, when the usual transportation route of materials or equipment disables some activities to proceed at an area of the site, filtering logistic boxes enables decision makers to find out an alternative path or method of transportation.

Alternatively, if we consider 1 Task-Box for each element and input related non-graphical data as constraints to the related task box, the constraints can be alarming to the manager or planners to look for a replacement to rectify or limit the task clashes.

Following by previously defined spaces for a construction task by Akinci et al., in this research, our defined Task-Box can represent six types of volumes usually occupied during construction activities. These are:

1. Building elements: physical space occupied by building component to be installed;
2. Labour crew space: space used by labour crew installing components;
3. Equipment space: space used by equipment supporting labour crew or component during installation;
4. Hazard space: space generated when activity creates hazardous situation;
5. Protected space: space required to protect component from possible damage for certain period of time; and

6. Temporary structure space: physical space occupied by temporary structures, such as scaffolding and shoring. Temporary structures are modelled like permanent building components.

In this research, instead of dedicating an independent parameter to each of the above-mentioned categories, they will be covered by the 3-dimensional offsets that each Task-Box can get manually or through excel sheet import to a dynamo script; the method that is being used in this research. The data in the excel sheet should be inserted with the supervision of the project manager corresponding to the requirements of activities including in a task.

The Task-Box can/should get activated with a run of Dynamo script resulting in surrounding each element selected. It can adopt various visual styles responding to the visibility demands. We can also define and filter specific scope of work that we are looking into its process.

The Task-box will have a smart-shared-parameter attached to it that will be picked in Navisworks automatically on-demand, so time-schedule can be rearranged as well based on diagnosed clashes of boxes in Navisworks.

Logistics and material unloading decks also can have a graphical box visualizing their clashes during the project with other ongoing tasks or activities.

(Parametric Task-Box can take properties of tasks in project management software, Navisworks, separately; aside from the objective task. So, if the Task-Box maintains independent from the object, it can correlate with other tasks at the same location or close surroundings.)

The task box will cover all the volume of activities for a specific task. For example, considering scaffolding as the task on the construction site, the following activities with corresponding space should be available:

- Lorry path or transfer route of materials to the location on site
- Unloading materials
- Space needed for work-around to set up or erection of the scaffolds
- Accessibility steps or ladder to levels of scaffolds
- Workers walk-around the scaffold
- Safety clearance for accidental falling of tools or materials, or construction processes like welding, painting, concrete pouring, etc.

All above-mentioned will occupy an area together in addition to the duration that scaffold will stay in place as a temporary facility.

The Task-Box loaded production model in conjunction with six different above-mentioned occupying volumes will be fed to the Navisworks as inputs. It will firstly detect spatial conflicts between activities by simulating the construction process while checking for possible 3D geometric clashes between the different types of spaces required by activities. The detected task clashes can be categorized and grouped differentiating the clash cases where multiple types of task conflicts exist between the same pair of conflicting activities. As well, prioritizing the conflicts according to the severity of the problems can help through decision making process.

For the alternative approach to consider all different types of clashes within the body of 1 clash box or as we call it, “Task-Box”, another process of differentiating and prioritising clashes can happen by grouping Task-Boxes by their ticked instance of previously implied shared parameter. (6 different shared parameters can be assigned to the Task Box family based on 6 types of possible clashes that discussed before and the operator will select which types of clashes include in the conflict existed among 2 or more elements). Conflict types each have a priority over the next one. A schedule of all the Task-Boxes showing their ticked parameters can give a score to tasks and then their priorities will be revealed following their criticality.

Project managers can modify their initial production model or BIM model based on the information to prevent and/or solve all various types of task clashes by changing construction sequences, methods, and so forth to minimize problems resulting from time-space conflicts and any kind of wastage following that (time, money, material, etc.) prior to construction.

3.2.1 Case-Study

Regarding putting the introduced prototype into practice, we chose a simple case-study for our research. We just needed a variety of modelled elements in 3D in the chosen software, Autodesk Revit, to run the dynamo script on them. The case-study was a project delivered by the author of this research (Figure 3). Four elements on the west of this project are chosen for Task-Box process application. These four elements are adjacent to each other but not overlapped as tagged on the figure below.

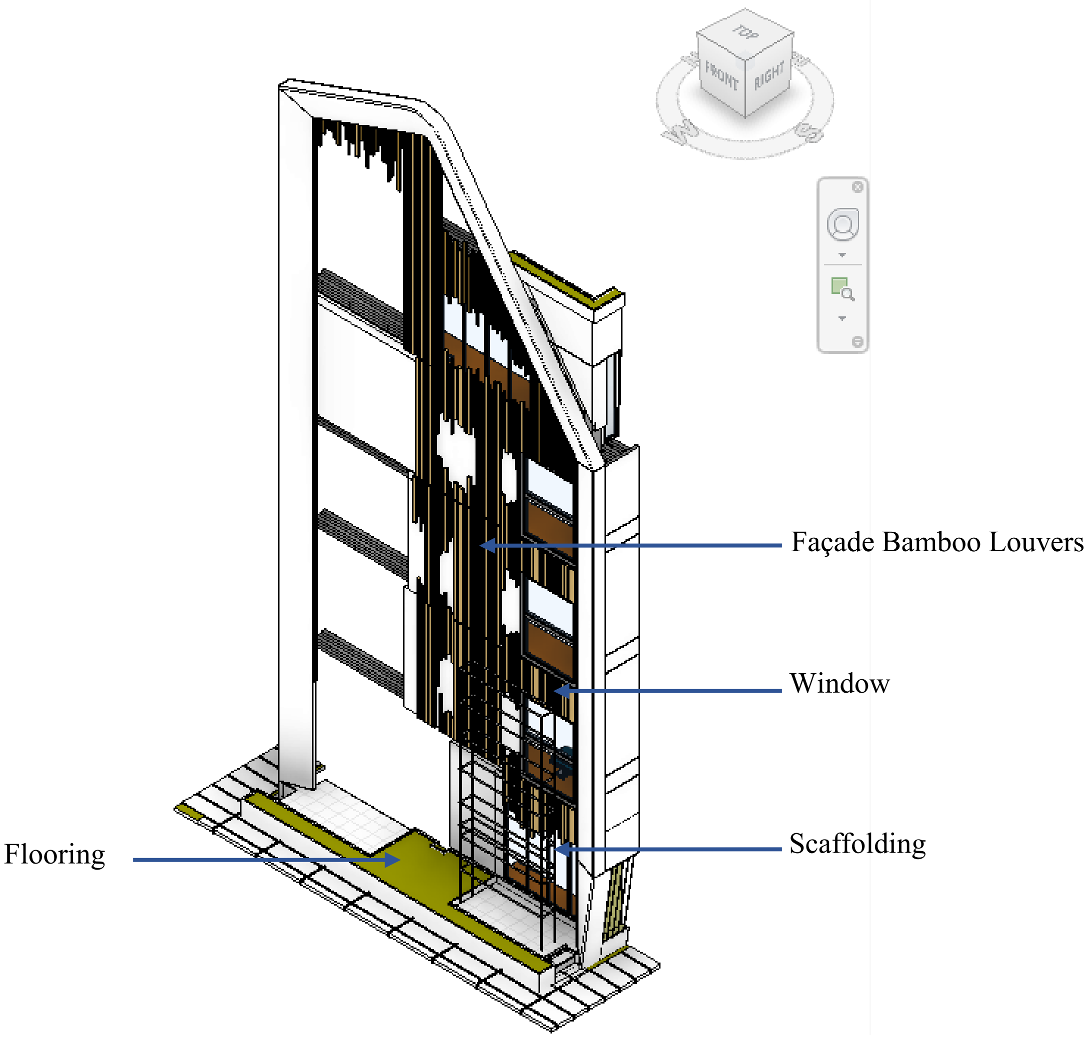


Figure 3 - Selected Case-study Project

The chosen building elements are isolated in Revit as the scope of our work to apply the Task-Boxes to them. The same practice can be applied in real-world construction.

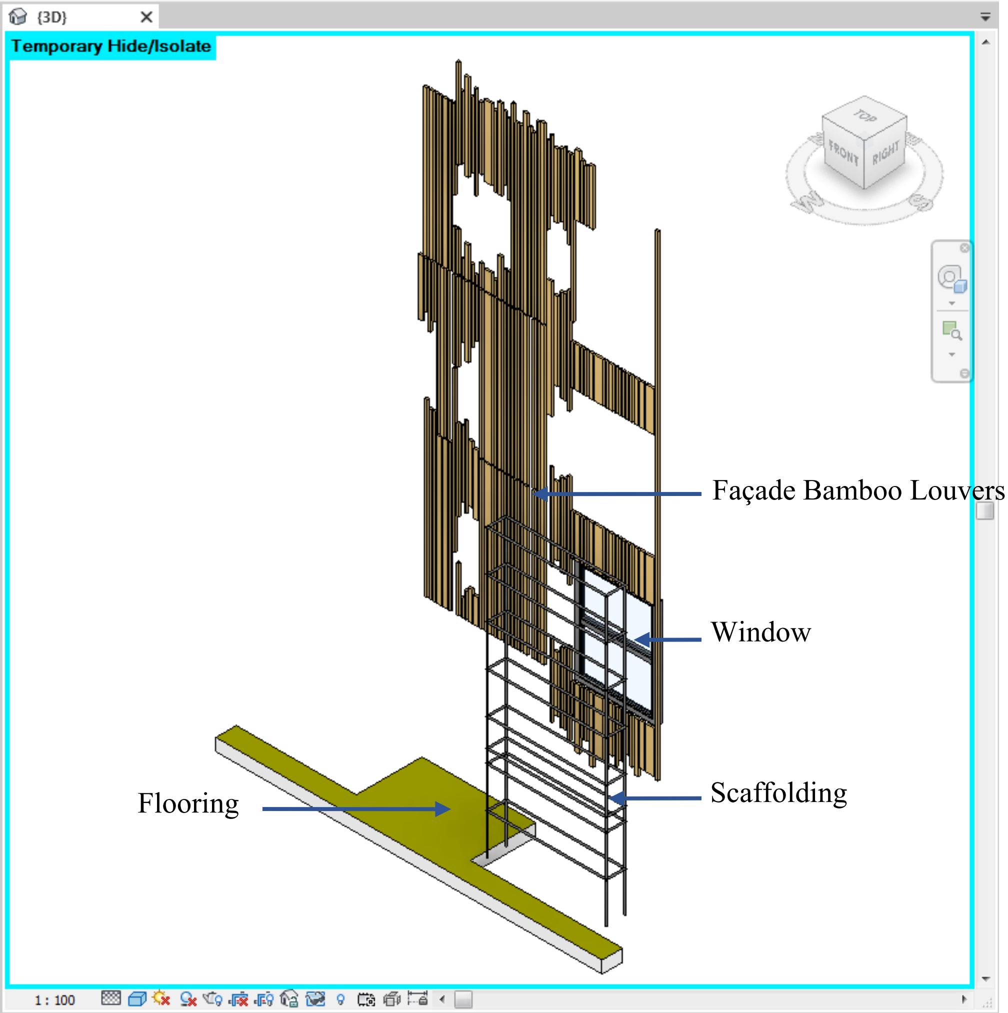


Figure 4 - Selected elements for the Task-Box application process isolated

3.2.2 Task-Box Application Process

At this point, designed dynamo script comes in practice to ease up the rest of the process and its repetition at each stage of the construction and as many times as needed for different activities and tasks defined in WBS of project management scheduling. Figure 5 shows the nodes that will be used to select the building elements of the construction scope.

There are 2 nodes to be used. One allows to pick the element by selecting them and another one allows to select the element using selection box which is suitable for a range of elements in a construction site. We are choosing the selection box for our case of study.

Figure 6 shows the selected elements as geometries in dynamo. The next node will create bounding boxes around the elements which are boxes surrounding the elements by their borders.

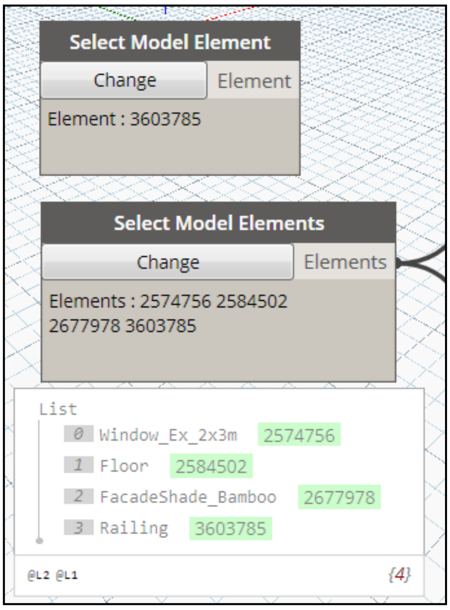


Figure 5 - Dynamo selection nodes

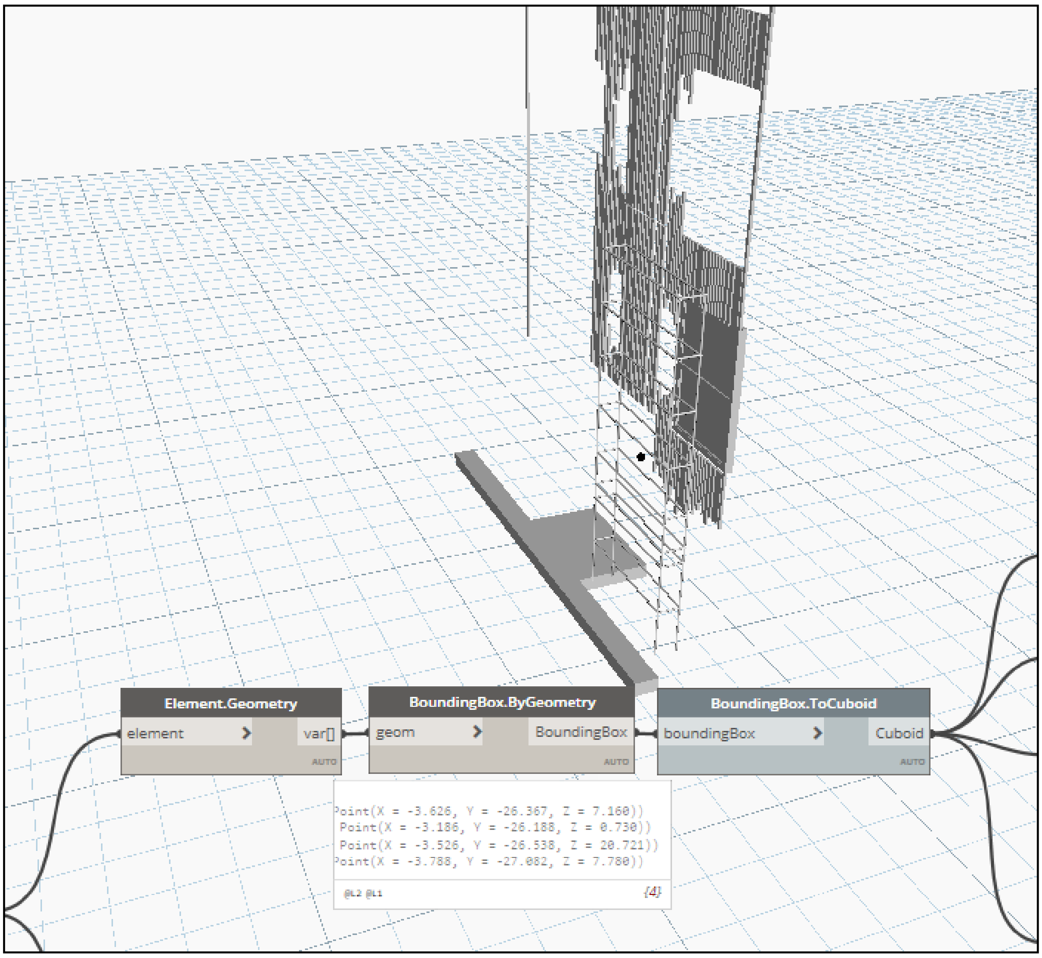


Figure 6 - Selected geometries in dynamo

The next node translates the bounding boxes into cuboids (figure 7). Cuboids are 3D cubic shape of the bounding box. The cuboids are the ones that will be replaced by the Task-Box family.

Figure 8 shows the nodes that bring out the dimensions of the cuboids. We need these properties to be added as parameters to the Task-Box. Height, Width and Length are the parameters. The Task-Box family as previously described is a specific family defined for the purpose of activity-space clash detection. The Task-Box family can be redesigned with additional parameters to suit the needs of each project. The centroid point is being used to draw out the elements' locations and their parameters.

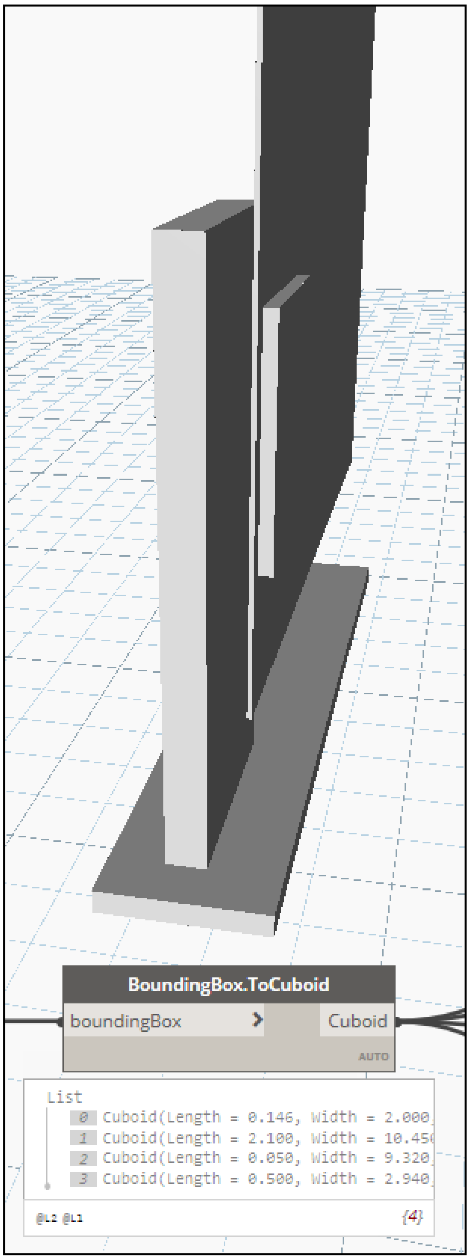


Figure 7 - Translation of bounding boxes to cuboids geometries

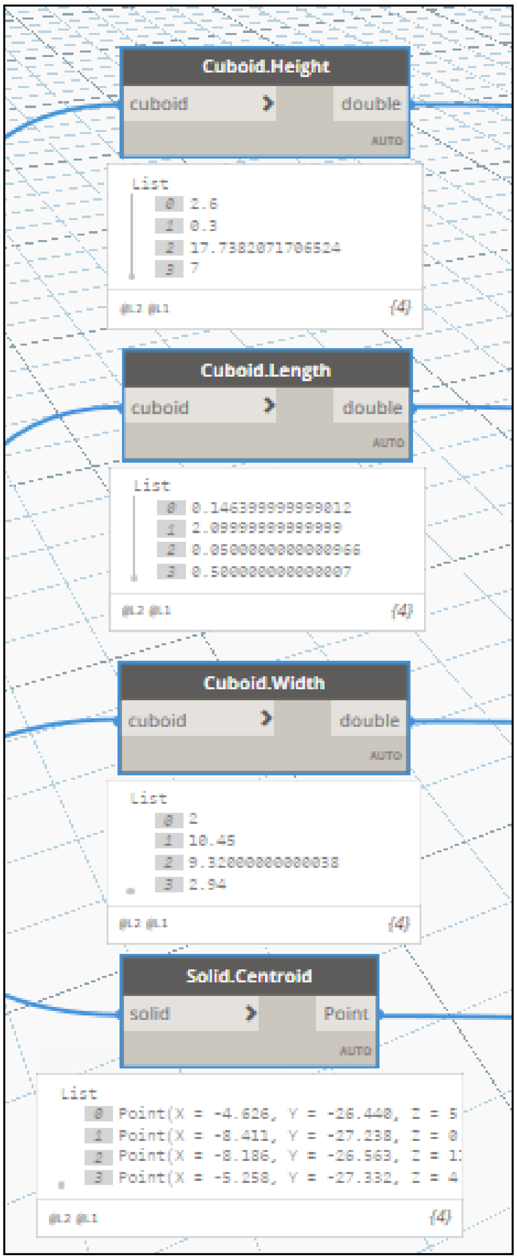


Figure 8 - Cuboid dimensions

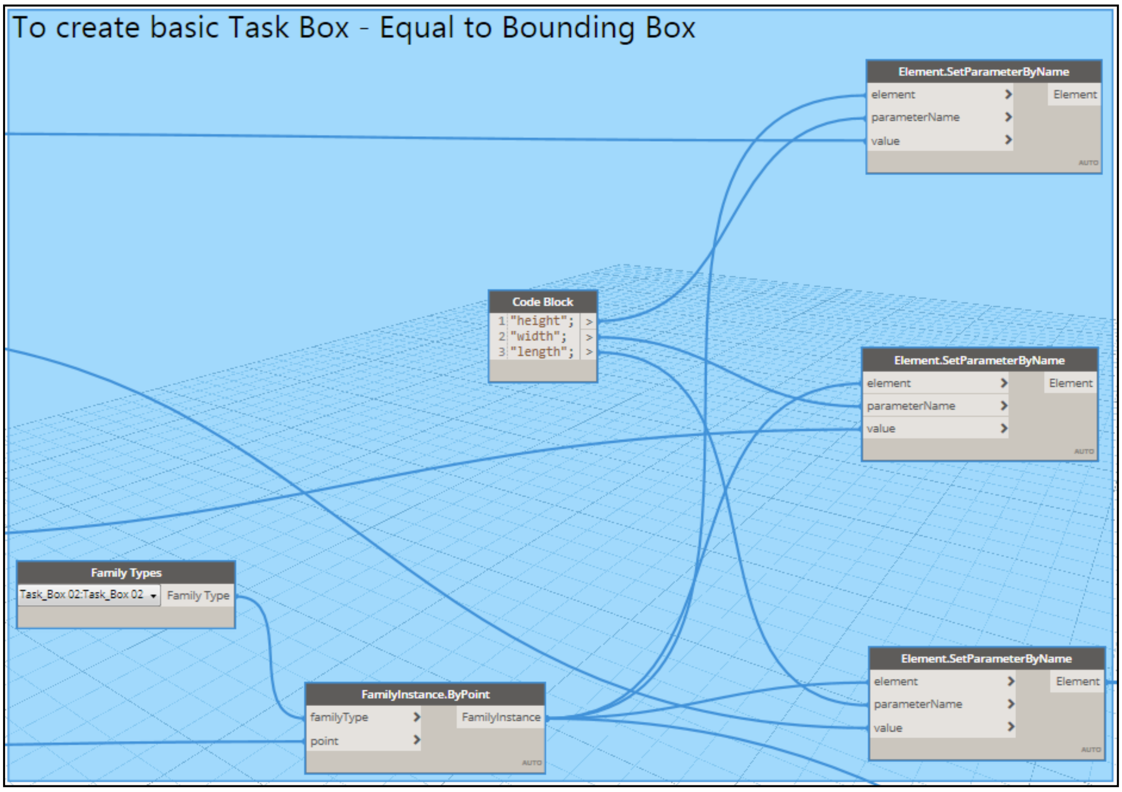


Figure 9 - Nodes to replace bounding box with Task-Box

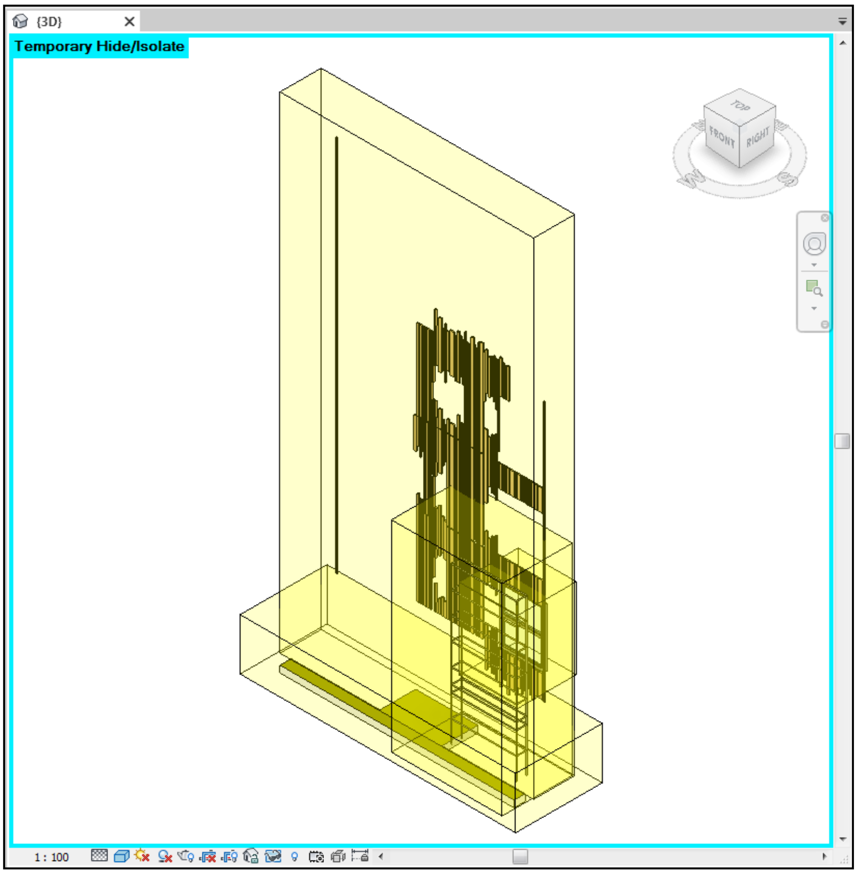


Figure 10 - Replacing the cuboids with Task-Box family

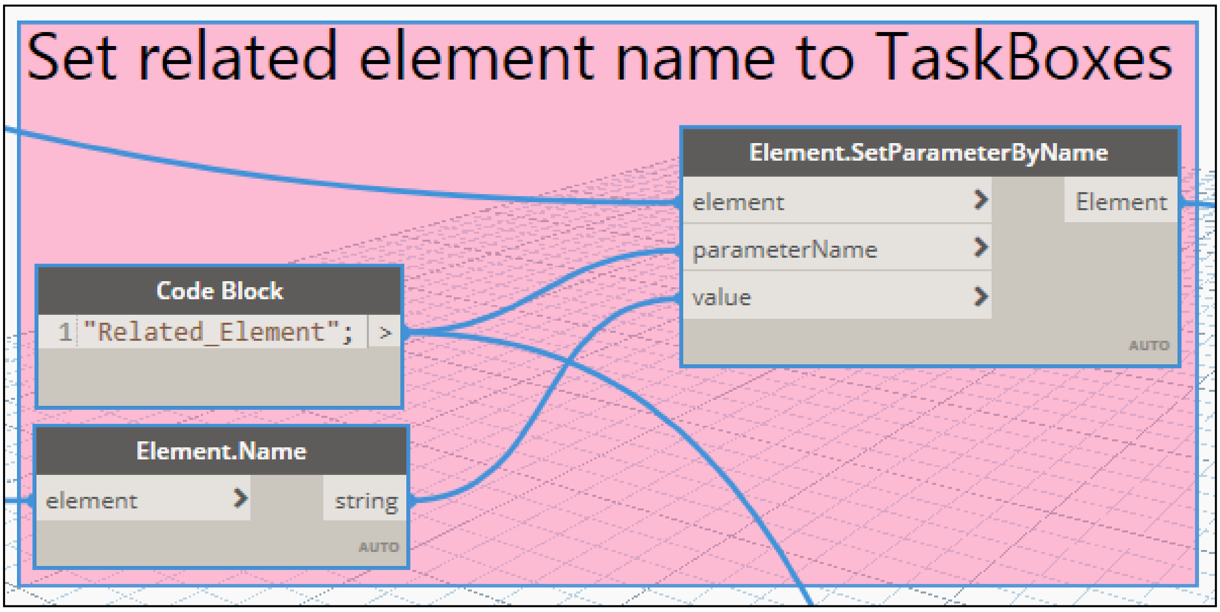


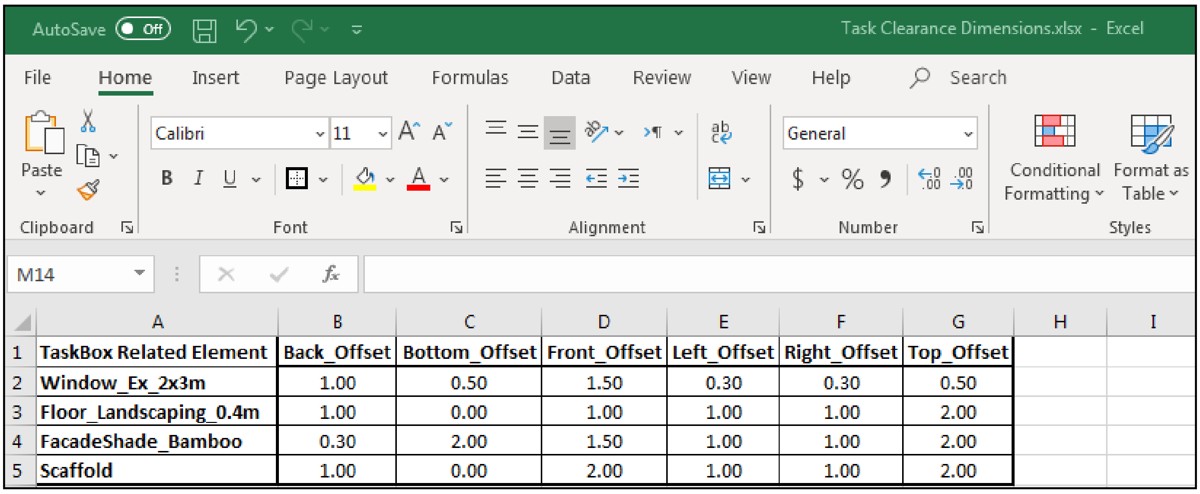
Figure 11- Parameter application to the family

Figure 11 shows the nodes that insert a parameter to the created Task-box families. This node will draw out the name of the element and apply it to its related Task-box. So, we will have Task-boxes named after their encircled element to be able to recognise them and categorize or filter them as needed.

Now that our selected elements are loaded with Task-boxes, we can control their dimensions either manually within the Revit family instance to suit the needs of the project planner or the construction activity or the method that we are applying in this research using excel spreadsheets. The instance parameters are also useful to make a quick check in task adjustments. For instance, at a time that project manager is checking for any possible activity clashes for the next 2 weeks in construction schedule, possible clashes can be checked and adjusted by quick changes in Task-box instance parameters and later be reflected back in the project schedule for confirmation and collaboration.

The method used in this research includes an excel sheet that contains dimensions for the Task-boxes. These dimensions will be provided by the project manager or foremen or other decision makers who are involved in the construction process. These people are experienced and well-informed about all activities around each task and the space being occupied by each activity and then the clearance offset required for that activity. They will input data in the excel sheet to suit the needs of the proposed activities in the construction site (Figure 12). They do not need to have the knowledge of BIM as expected except designation of the sides of Task-boxes with their related clearance offset parameter namely, Back_offset, Left_offset, etc. This method results in a firm documented calculable adjustments for task-boxes which also adds up to the collaboration among team members in different phases of construction process; design, preconstruction, construction, etc.

As long as the required area for task activities are considered based on the real needs of the activity, all groups involved in the construction can benefit from that with the least changes by the time of scheduled activity. Seemingly, the process is following the main path of BIM regarding collaboration among different disciplines and actors. This time, collaboration between phases of construction are becoming possible.



TaskBox Related Element	Back_Offset	Bottom_Offset	Front_Offset	Left_Offset	Right_Offset	Top_Offset
Window_Ex_2x3m	1.00	0.50	1.50	0.30	0.30	0.50
Floor_Landscaping_0.4m	1.00	0.00	1.00	1.00	1.00	2.00
FacadeShade_Bamboo	0.30	2.00	1.50	1.00	1.00	2.00
Scaffold	1.00	0.00	2.00	1.00	1.00	2.00

Figure 12 -Task clearance offsets excel sheet

Figure 13 shows the nodes used to link excel sheet to the dynamo script.

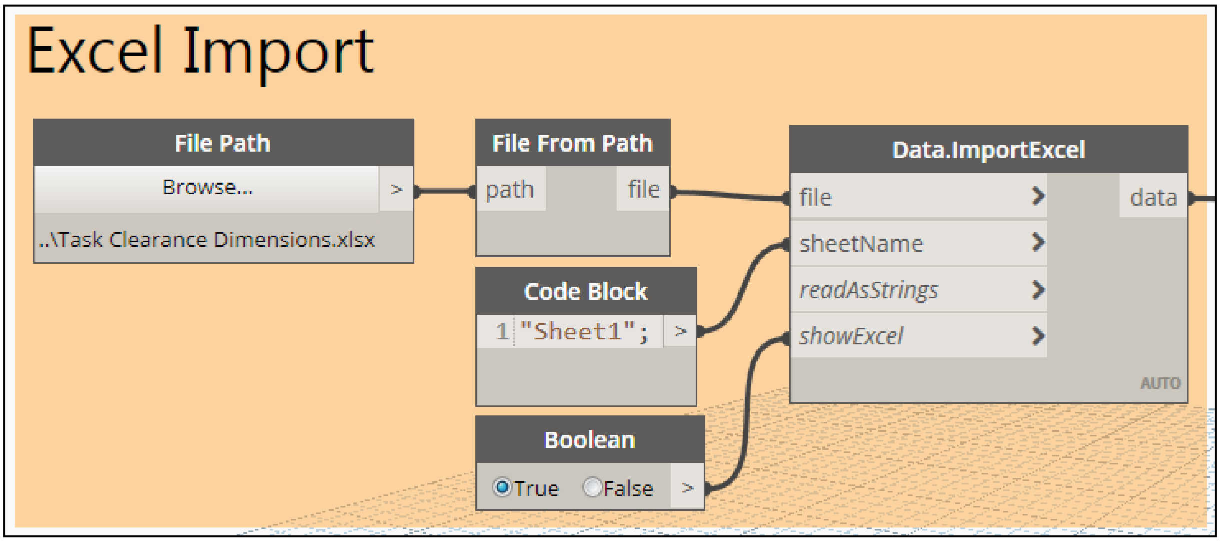


Figure 13 - Task clearance offsets excel sheet import process

After selecting the excel file to be imported into the dynamo script, we need to extract the data included in the sheet/s and feed them to our defined parameters for task boxes. Figure 14 shows the nodes for this process. As it shows, the data are extracted as a list from excel file. Then the list is flattened to be fed to the elements as an index.

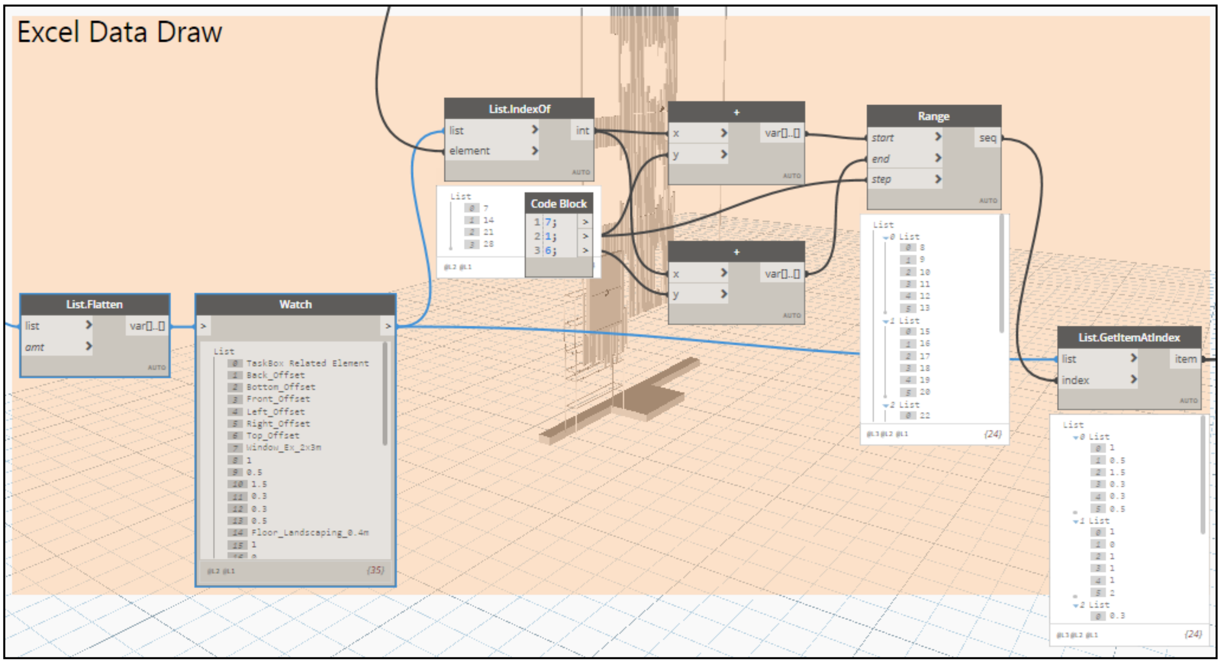


Figure 14 - Excel data extraction

Figure 15 shows the process of alignment between the six parameters of the Task-box and data extracted from excel sheet. At this point as many times as the data change in the excel sheet by the construction team, they can be updated easily in the model and task-boxes will update as well by dimensions.

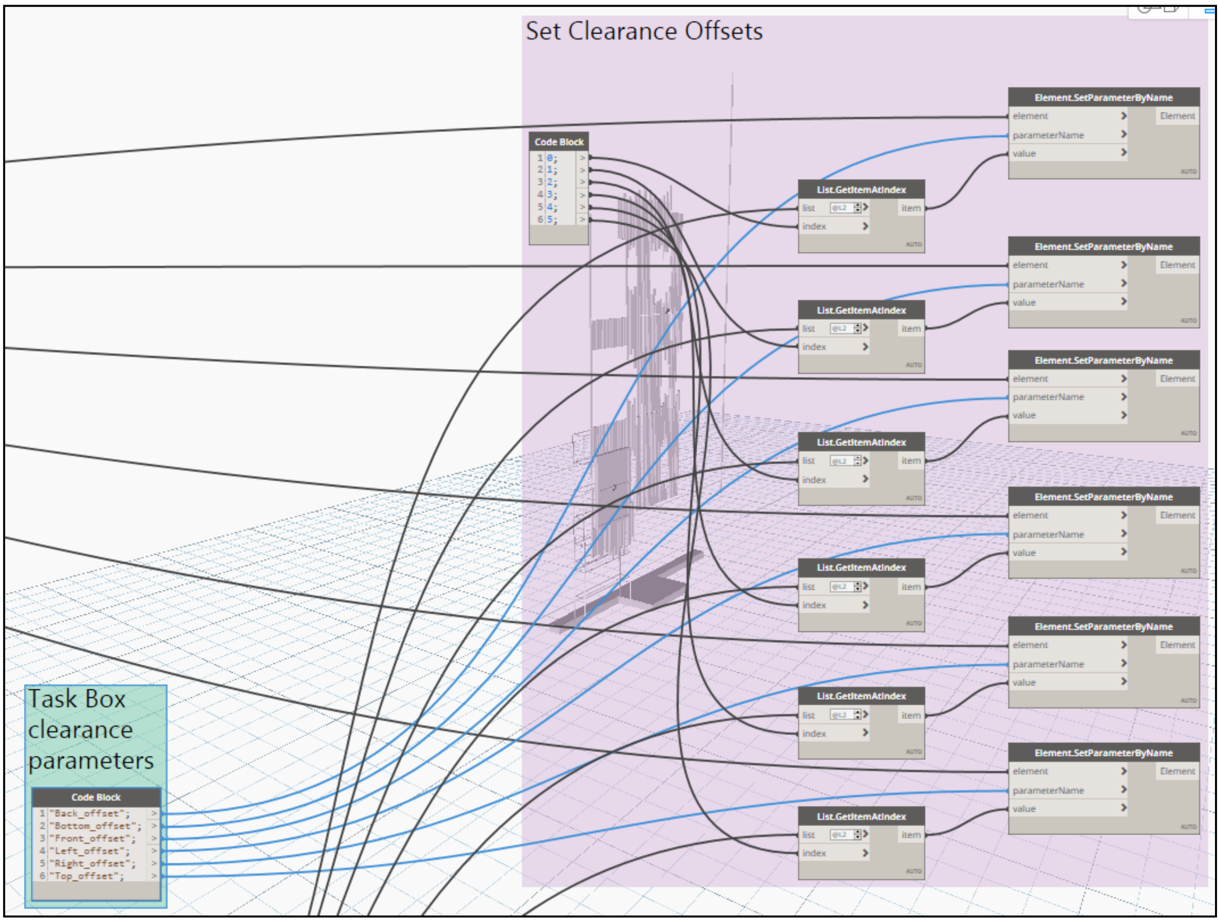


Figure 15 - Applying clearance offset to Task-boxes through excel data

At this point, after a completed run of dynamo script on the model and creation of task-boxes (Figure 16) - the model should be imported to Navisworks for clash detection among task-boxes.

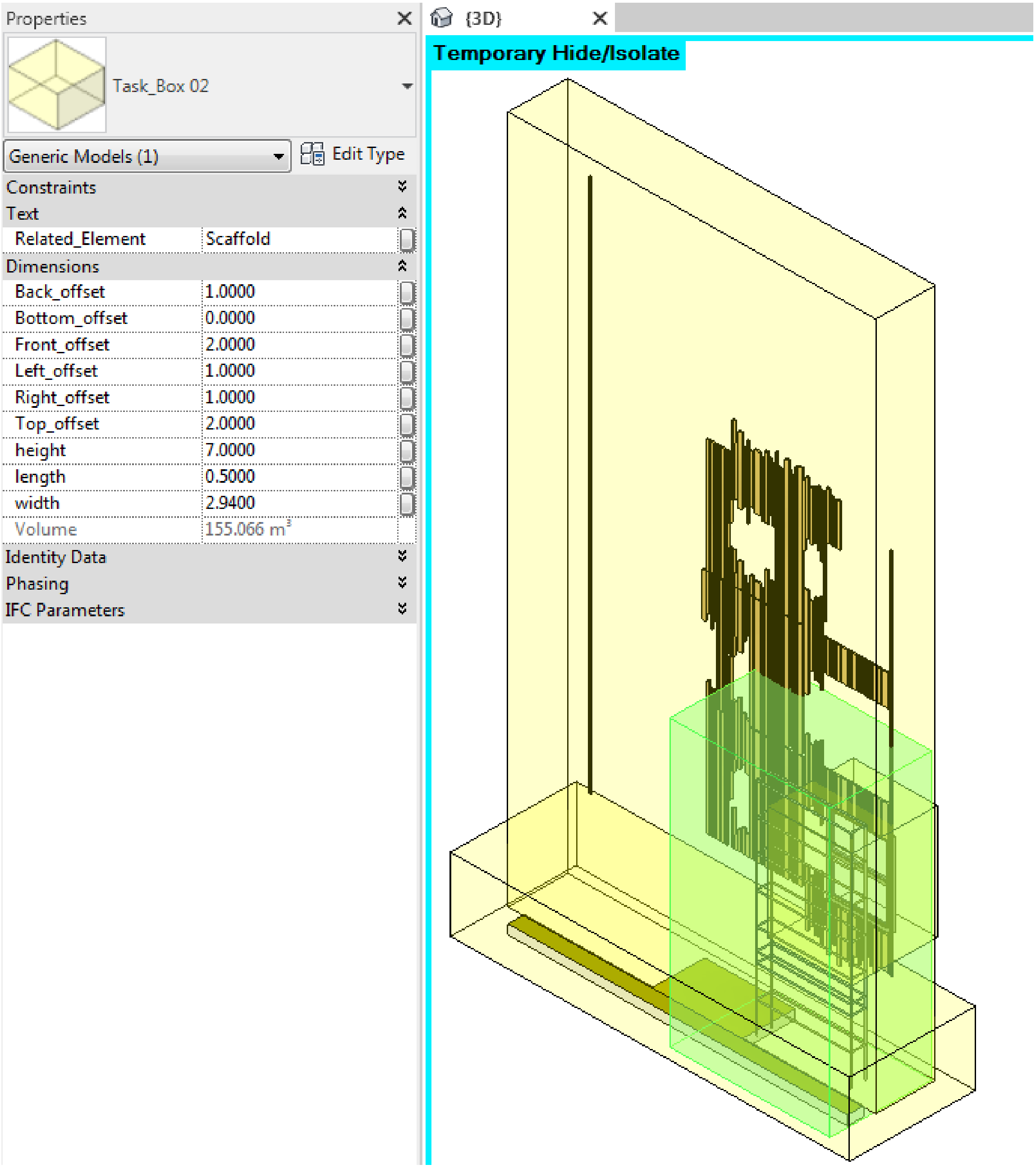


Figure 16 - An example of the Task-Box family with its parameters

In this prototype, due to the limited number of selected elements to simplify understanding the concept of the research, clashes are quite visible but for a higher number of elements and within the schedule and deadline of project management, a proper clash detection step is necessary.

As well, this step can be reported and documented for future references. Also, additional categorization is possible in both softwares by the elements and their related task-boxes, their priority, their effectivity in the working process and etc. Figure 17 shows 2 examples of clash detection run in Navisworks between 2 set of selected task-boxes each time. As stated before, this process will be helpful more when the number of activities and their related Task-boxes increases.

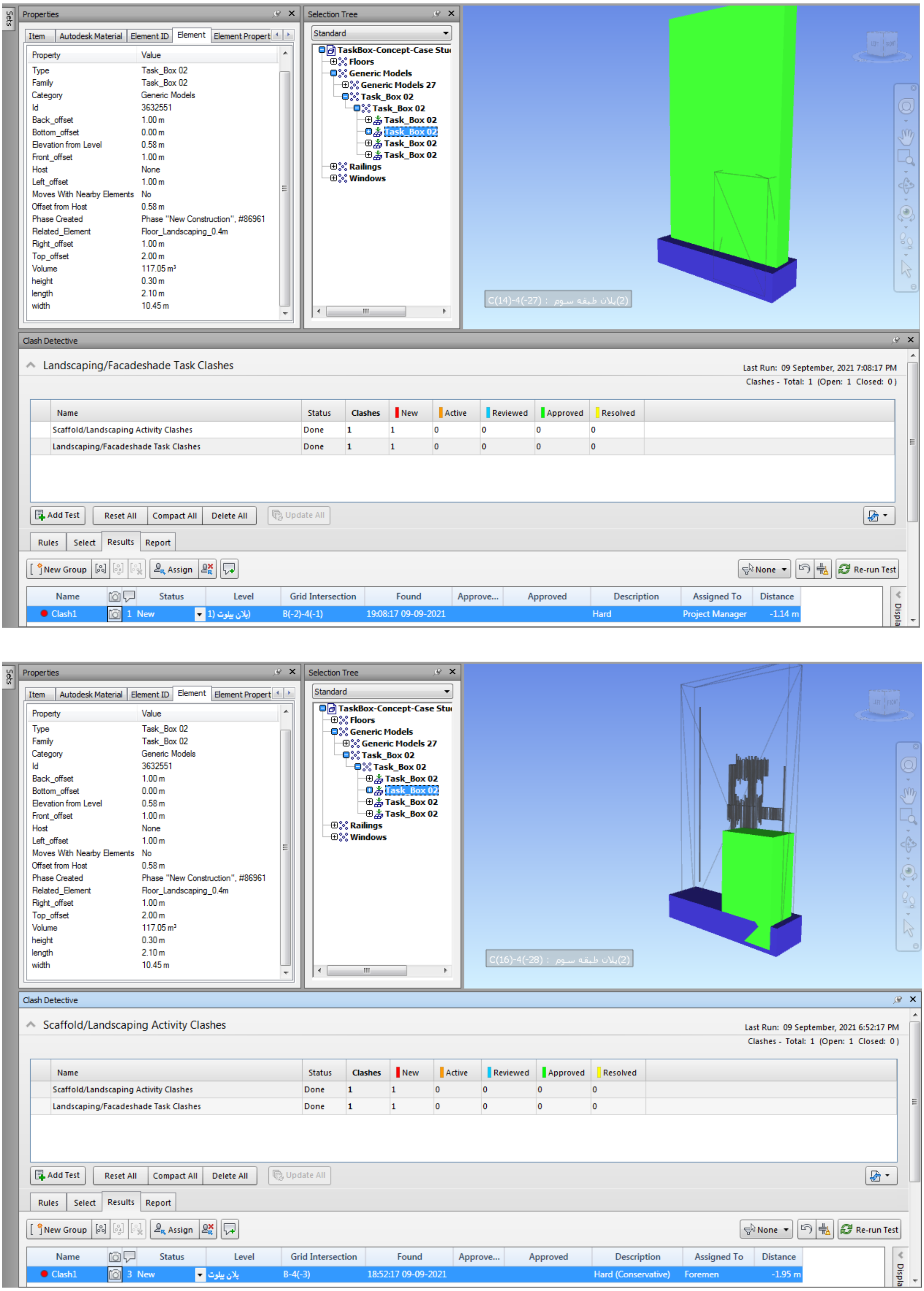


Figure 17 - Navisworks clash detection between task-boxes

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4 CONCLUSIONS

In the scope of this research, a successful customizable solution has been introduced and applied to a selected project with the prospect that this method makes a platform for further improvements in the AEC industry.

In this research we addressed several gaps in the preconstruction phase that can cause serious problems in the execution of the construction works. Availability of information in the pre-construction phase, and simulation of these information with the aim of detailed scheduling and controllability over the scheduled tasks are the gaps that we aimed at this research. This research was an attempt to cover these gaps in pre-construction phase through a BIM workflow.

Building Information Modelling has proved its usability and stability in response to the AEC industry needs via its collaborative characteristic. Yet, there is improvement potential in the management of pre-construction and construction phases to reduce or eliminate all types of wastages (Time, Cost, Material, etc.) as the main goal of BIM application. It has been foreseen in BIM application that advance collaboration among different disciplines engaged in the project will have a considerable impact on waste reduction in material, time, labour and costs at the end and improves the work flow of the project but there are still teams of players in the construction process that affect this process strongly and considerably but are missing from the loop of advance collaboration. The remaining clashes are wastages resulted of the mentioned gaps.

The introduced Task-box concept in this research and its practical workflow and its customizability is a solution to minimize the above-mentioned unresolved steps and give an extra controlling ability to the construction site workers, planners and managers.

This concept has potential of improvement in many aspects:

- It can be applied in a bigger project with multiple elements in more compressed space with a set of elements that are connected to each other as a system like MEP systems or across disciplines.
- The categorization of Task-box clashes or activity conflicts is another aspect of this practice that can be developed to help decision makers in more precise planning and schedule adjustments.
- Tasks and time have first-tier connection with each-other. Therefore, a huge improvement on this concept can be linking the task-box 3D representations to time-line of project schedule so as much as the task moves forward in time, the task-box that shows occupied space by that activity can be reduced and disappeared by the end of the task. So, the possible clashes among activity spaces will be in real-time and more precise.

- This process can be developed as an Add-in that can notify project managers when multiple activities are being planned in a common space during a specific time. So, they can attend to adjust the task breakdown structure in pre-construction phase while facilitating the site.
- Logistics in a construction site have a strong impact on facilitation of the site and safety and time management. 3D representation of occupied space by logistics, machineries and their travelling paths will be helpful in both pre-construction and construction phases.

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