



## **Enhancing the Functionality on the Interior Space within the Buildings through Using Building Information Modeling (BIM)**

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### **ABSTRACT**

Partition walls are one of the most crucial elements in the interior space of buildings and due to their significant impact on sustainability; they should be designed and constructed properly. Of many issues involved in sustainability of partition walls, functionality is of a great importance for meeting the particular requirements of buildings' residents. A relatively great deal of research has been conducted concerning the sustainability of partition walls; however, there hasn't been any take functionality aspect of these critical elements into consideration using BIM as a beneficial tool to do so. Therefore, this paper presents a new type of partition wall and examines its effectiveness in terms of materials and time needed to install the wall, and its functionality on the interior space using BIM. The scope of this research is the connections between internal wall to external wall, internal wall to internal wall, and internal wall to column. In order to calculate the materials and time required for installing the proposed partition wall, a building was chosen as the case study. The obtained results showed that installing the proposed partition wall would have noteworthy benefits for both contractors and residents of the buildings such as shortening the time duration of the construction process, decreasing the quantity of materials and components consumed during the construction process, no wastage of materials, and minimizing the optimal life cycle cost significantly through enhancing the functionality of the interior space of buildings.

**KEYWORDS:** Partition wall, functionality, and BIM

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### **1. INTRODUCTION**

One of the important elements in building construction, which affects significantly a building's overall life-cycle, is partition wall that is a thin element used for partitioning the indoor space into rooms and compartments. Partition walls play an important role in efficient space organization and the improvement of safety and comfort [1]. In general, they are not load-bearing walls to which the strength against vertical loads is of a great importance (since it affects the building's overall structural behavior). Instead, partition walls should be strong enough to support a surface for decoration as well as the accidental impacts exerted due to the occupation of building [2].

According to Addis and Schouten [3], partitions are sub-systems of buildings, and their appearance was due to number of factors, for instance, the development of frame construction in which internal walls do not need to have load-bearing function. Because of emergent aspects, the design of the current internal partition walls is based on new requirements [3], including the increased complexity and number of services that should be accommodated, the speed of technological and organizational change, the aesthetic and quality requirements to be satisfied, the flexibility in changing the organization and area of internal spaces, the need of compartments for acoustic separation, thinner elements for the maximization of net areas, optimal costs of life-cycle, and more enhanced performance of environmental life-cycle.

The international standards refer to BIM as "shared digital representation of physical and functional characteristics of any built object which forms a reliable basis for decisions" [17]. The origination of BIM is the product models [18, 19] extensively used in the automotive, petrochemical, and shipbuilding industries [16, 20]. BIM represents real buildings virtually over the whole LC as semantically enriched, consistent, digital building models [16, 21, and 22]. In recent years, new opportunities have been created for the improvement of scheduling processes due to the technological advancement of 3-D modeling in the architectural, engineering, and construction (AEC) industries and the development of building information modeling (BIM). The automation of schedules can be

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further improved through the combination of built-in intelligence of BIM with the previously-made research efforts. Exploiting the information that is stored in BIM for generation of schedules can obtain a significant time reduction in scheduling process in comparison with the conventional manual scheduling methods. The literature shows that construction schedules can be practically generated for the construction process by means of new technologies like BIM; however, to date, this topic has not been adequately and directly addressed [4].

Another practical task that can be automated using BIM is quantity takeoff (QTO). BIM-based models are assembly of objects defined by particular features, e.g., the element's geometric attributes. Most of the BIM tools consist of routines used for performing computations by means of the element's geometric properties, and these tools make available spatial quantities such as area and volume in text form. As reported in literature, the BIM-based QTO provides simpler and, simultaneously, more accurate and detailed cost estimations of the project, which decreases expenses and time consumption [5]; however, this is also so tricky feature that only experts can use it appropriately [6].

Of many issues involved in sustainability of partition walls, functionality is of a great importance in order to meet the particular requirements of the residents' needs. Although relatively great amount of research has been conducted concerning the sustainability of partition walls, take functionality aspect of these critical elements into consideration exploiting BIM as a beneficial tool to do so. Therefore, this paper is mainly aimed to present a new type of partition wall and examine its effectiveness in terms of materials and time needed to install and its functionality on the interior space using BIM.

The scope of this research is the connections between internal wall to external wall, internal wall to internal wall, and internal wall to column. In order to calculate the materials and time required for installation of the proposed partition wall, a building was selected as case study for this research.

The previous research conducted on partition walls are explained in Section 2. Section 3 presents the framework and methodology taken into consideration for achieving the goal of this paper. In Section 4, the installation steps of the proposed partition wall are modeled. In Section 5, the case (building) selected in this study is modeled in order to calculate materials and time needed regarding the proposed partition wall's installation. The results demonstrate that the proposed partition wall would certainly shorten the process of construction besides decreasing the amount of materials to be used or wasted. More importantly, the functionality on the interior space within the buildings would be enhanced considerably. Section 6 presents a discussion on the obtained results and Section 7 concludes the whole paper.

## 2. LITERATURE REVIEW

### 2.1 Partition walls in terms of sustainability issues

Broun and Gillian [1] analyzed the embodied energy and the environmental effects of the partition wall systems that are most commonly-used in the UK, namely timber stud framing, clay Brick, and hollow concrete block. The timber stud wall was reported to have the least environmental effect compared to the others in terms of acidification potentials and global warming. The clay brick partition walls showed the highest environmental effects; however, they were reported potentially the best for recycling.

Flexibility is a feature that most of building designs lack; thus, these buildings can be hardly adjusted to the continuous updating of life style. Generally, the housing sector consumes big quantities of materials and, consequently, results in big quantities of waste [7]. As a result, to have a proficient construction system, pre-fabricated elements, which were underestimated in the past, should be used, which make easy both assembling and disassembling [8]. If housing spaces are flexible, the building lifetime is increased and the materials' life-cycle is extended. Flexibility of housing spaces could be fulfilled through different ways such as neutral and polyvalent spaces, passive flexibility, mobile elements that allow the transformation of the housing unit and active flexibility [9].

### 2.2 Types of partition walls

The most commonly- installed types of partition walls are heavy light block masonry, clay brick, and drywall.

#### 2.2.1 Block Masonry Wall

HCM is a single ceramic hollow brick (0.30 \_ 0.20 \_ 0.11 m) wall. In these walls, Portland cement mortar is used to fix the units. Both sides of the HCM wall is coated with a 0.02 m thick Portland cement plaster, resulting in a total thickness of 0.15 m and a total specific weight of roughly 150 kg/m<sup>2</sup>. Alkyd paint is applied to both surfaces of these walls. Some horizontal holes exist in the ceramic hollow brick units, and these units present a regular geometry with four striated sides, leading to a proper adhesion of any kind of finishing. The required installations are done subsequent to assembling the wall and prior to plaster through the grooves execution that accommodate the

installations; then, the grooves will be filled in with mortar. This procedure leads to producing a significant amount of material waste [2].

### **2.2.2 Brick Wall:**

Brick wall is made up of clay bricks with the size of 215mm (length) by 102.5mm (height) by 65mm (depth), with six voids in two rows [8]. One steel bar is applied to reinforcement of all third horizontal courses and intersection points of two interior walls. To hold together the bricks, cement lime mortar (1 part lime, 1 part cement, and 6 parts sand) is used. Compared to pure cement mortars, the lime mortars enjoy higher elasticity, which allows the take up of moisture movement in bricks. Both sides of the wall are coated with a 25 mm thick Portland cement plaster. Then, as the final coating, latex or water based paint layer are applied to both surfaces of the wall for finishing them [10]. Overall, the thickness of wall would be a total of 150 mm.

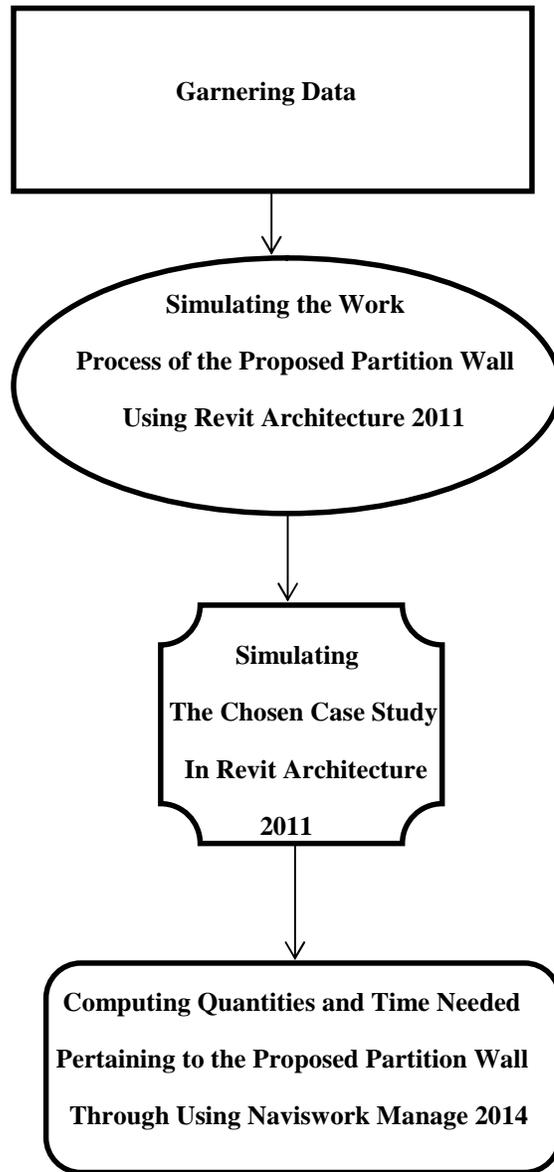
### **2.2.3 Drywall:**

As a part of gypsum drywall system, gypsum wallboard is known as the most commonly-used wall finish in modern constructions. Gypsum wallboard is generally applied to covering timber and steel stud framing. Wallboard is the panel of wall finish system, which consists of gypsum slurry that is solidified into large panels. Normally, mechanical fasteners such as screws or nails as well as adhesive are utilized to connect the wallboard to the supported framing. After the attachment, operations such as taping and compounding of joints, texturing (if desired), and painting remain to be done [11].

## **3. Methodology and Framework**

The framework used in this paper to achieve the aforementioned goal has been illustrated in Fig 1. The first step is to collect and analyze data through reading articles and papers, site investigation, and discussing with experts. In the next step, work process regarding the installation of the proposed partition wall has been modeled with the aim of enhancing the accuracy for taking off materials and time needed through using Revit Architecture 2011. In the next step, the chosen case study was modeled in details employing Revit Architecture including all plan, elevation and section views, and components such as exterior and interior walls, floors, ceilings, columns, roofs, windows, doors, and so on. Revit software has the ability to categorize different components of the buildings into sub-categories based on their identifications. Therefore, it divides all the interior partition walls into smaller parts with regard to their lengths, widths, and thickness. Then, in order to compute quantities and time needed, the modeled case study was exported to Naviswork Manage 2014.

According to the above-explanations, take-off from the modeled partition walls on the interior space of the mentioned case study has been done automatically through identifying different specifications for each type with respect to their sub-divisions' characteristics in Naviswork Manage 2014. Subsequently, time needed to install each type of partition wall was computed regarding the created work process and installation stages in step 2. Finally, the functionality of the proposed partition wall has been assessed with the respect to the work process simulated in step 2.



**Fig 1. Framework for computing quantity and time required of the proposed partition wall through using BIM**

#### **4. Work process of the proposed partition wall**

In this research, the work process comprises different steps of installation regarding the proposed partition wall with the aim of enhancing the accuracy for taking off materials and computing the time duration needed for installation. Furthermore, visualization of the installation steps in this research proves the fact of improving functionality on the interior space with the usage of proposed partition wall.

In the industrialized building system, a factory manufactures the components of a building, on or off site, then assembles them into structures with a minimum additional site work [12]. IBS is an example of construction systems built by means of pre-fabricated components. The components are manufactured systematically by means of formworks, machine, and other mechanical equipment. The manufacture procedures are performed offsite, then the manufactured components are delivered to the construction sites to be assembled and erected [13]. In this research, a new type of IBS partition wall is proposed, whose installation benefits every construction practitioners. These types of wall partitions are well-suited to be used in the projects constructed with the technology of Industrialized

Building System (IBS). In order to join the interior wall to any components of IBS tightly, an embedded hole inside the exterior walls or columns is required to be designed while prefabricating them (see Figure2a). This proposed partition wall consists of a precast concrete panel that has a protruded surface in order to be connected to exterior wall or column as illustrated in Figure2b. In order to reduce the weight of the precast concrete panel, it is suggested to use textile wastes as a core fiber with textile meshes embedded in the central part of lightweight panel [15]. It is recommended to connect two panels to each other where the length of an internal wall is more than 10 meters. The different installation steps of IBS partition wall have been explained hereinafter.

**Step 1:** Locating face of the walls on the surface using chalk line with considering the places of the embedded holes inside the exterior wall or column.

**Step 2:** Lifting precast concrete panel and placing it on the located face of wall by means of crane as illustrated in Figure2c. The protruded surface must go through the embedded hole inside the exterior wall. Figure3 shows the corner connection between two IBS partition walls, followed by illustrating how two panels are connected where the length of internal wall is more than 10 meters (see Figure 4). Figure 5 shows the connections between an IBS partition wall and precast concrete column.

**Step 3:** Using a spirit level for checking the balance of the installed panels.

**Step 4:** Painting all the surface of the installed panels, including undercoating and finishes.

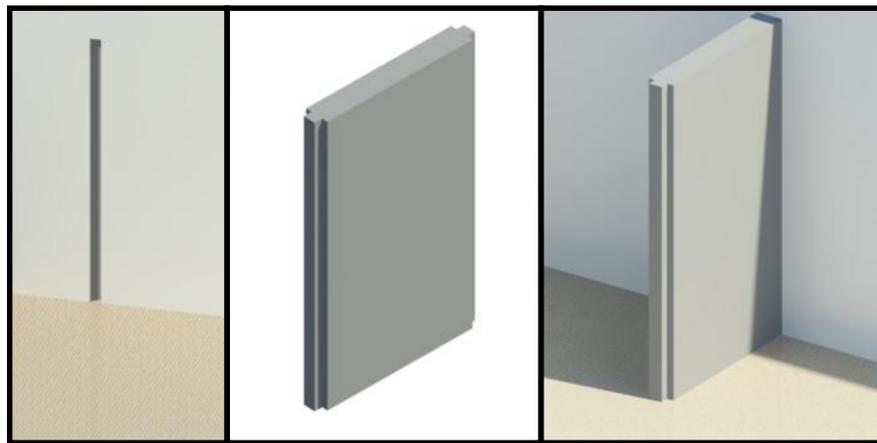


Fig 2. Exterior wall (a) IBS partition wall (b) and Installing IBS partition wall to the exterior wall (c)

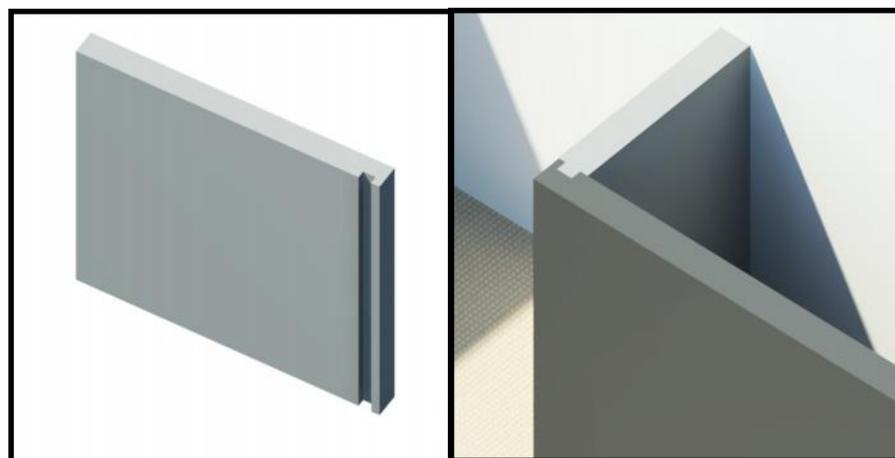
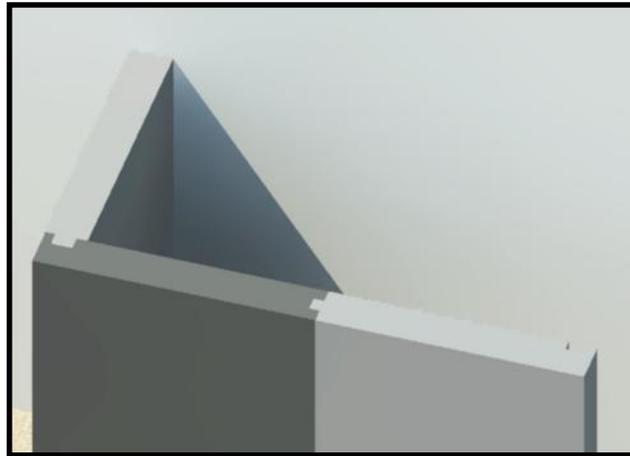
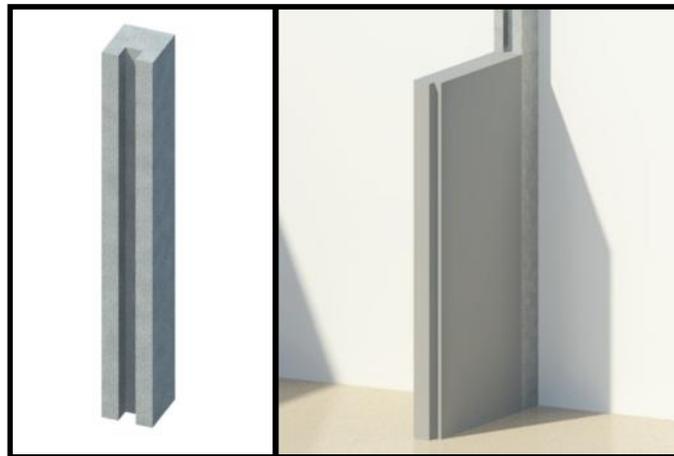


Fig 3. IBS partition wall's Installation for corner



**Fig 4. Installing two IBS panels to one another**



**Fig 5. IBS Column (a) and Installing IBS partition wall to IBS column (b)**

### 5. Case study implementation

In order to calculate the materials and time needed for installing IBS partition wall, a case study, located at Universiti Teknologi Malaysia (UTM), was chosen. The function of the chosen case study is office building for faculty of civil engineering. This building had 7 different levels as shown in Table 1. Figure 6 shows the perspective view of the chosen building as a case study for this research.

| Levels    | Base Level's Height From Ground's Surface (mm) | Top Level's Height From Ground's Surface (mm) |
|-----------|--|---|
| Level 1   | -2500  | +2500   |
| Level 1-1 | Ground's Surface ( $\pm 00$ )                  | +5000   |
| Level 2   | +2500  | +7500   |
| Level 2-1 | +5000  | +1000   |
| Level 3   | +7500  | +12500  |
| Level 3-1 | +1000  | +15000  |
| Level 4   | +12500   | +17500  |

**Table 1. Different levels in the chosen case study**

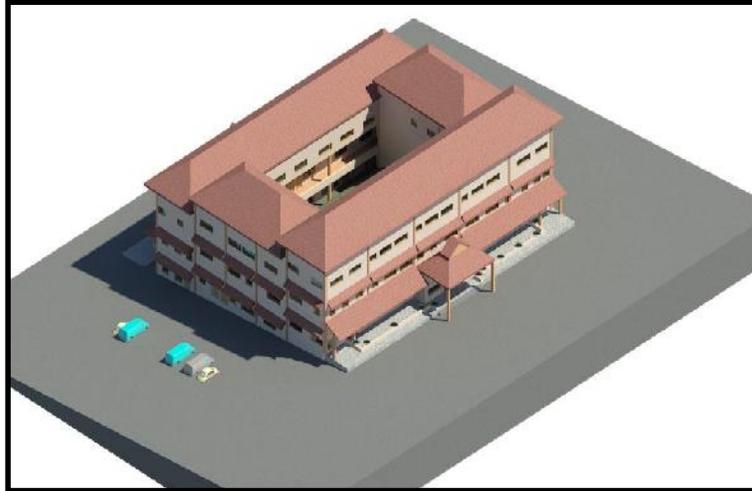


Fig 6.Perspective view of the chosen case study

**5.1 Data extraction from implementing IBS partition wall in the chosen case study**

In this section, the amount of materials and time duration needed to install IBS partition wall is extracted through its implementation on the interior space of a real case study.

**5.2 Material Takeoff:**

In regard to various drawn plans in Revit Architecture 2011, eight types of different interior walls for taking-off have been categorized based on factors such as thickness, height, length, and number to be exported to Naviswork Manage 2014 (see Table 2).

| Type of Wall | Length (mm) | Height (mm) | Thickness (mm) | Numbers |
|--------------|-------------|-------------|----------------|---------|
| A            | 1600        | 3500        | 150            | 40      |
| B            | 2750        | 3500        | 150            | 24      |
| C            | 3500        | 3500        | 150            | 146     |
| D            | 4500        | 3500        | 150            | 66      |
| E            | 5250        | 3500        | 150            | 55      |
| F            | 7000        | 3500        | 150            | 17      |
| G            | 10000       | 3500        | 150            | 9       |
| H            | 20000       | 3500        | 150            | 2       |

Table 2.Types of Interior Walls

After exporting the Revit file to Naviswork Manage, different materials used in the installation of the IBS partition wall were specified based on their lengths for each type of wall. For instance, the specification identified in Naviswork Manage for Type A is shown as follows:

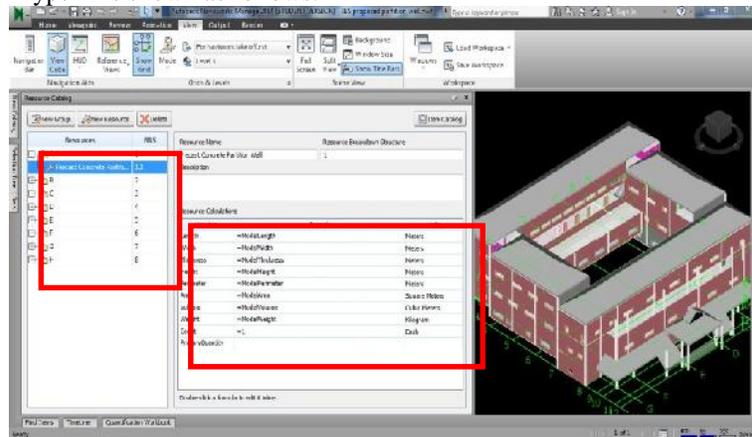


Fig 7. Identifying specifications in Naviswork Manage 2014

The total amount of materials used for installing IBS partition wall have been shown automatically in Naviswork Manage as follows:

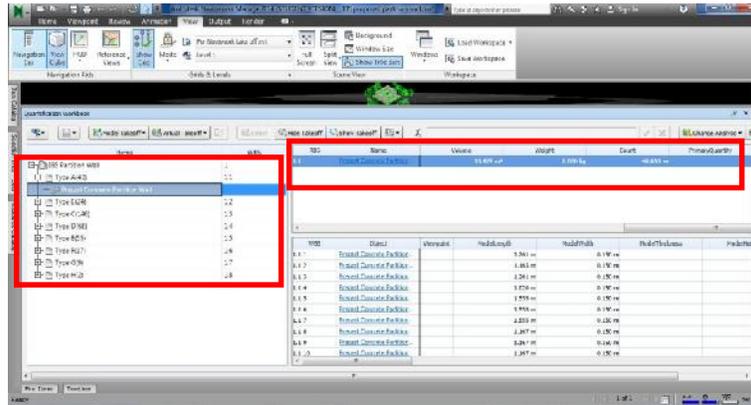


Fig 8. Showing the total quantity takeoff in Naviswork Manage 2014

Table 3 shows the total quantity takeoff from IBS partition wall calculated in Naviswork Manage as follows:

| Size of Panels (mm)            | Numbers                      |
|--------------------------------|------------------------------|
| 1600*3500*150                  | 40                           |
| 2750*3500*150                  | 24                           |
| 3500*3500*150                  | 146                          |
| 4500*3500*150                  | 66                           |
| 5250*3500*150                  | 17                           |
| 7000*3500*150                  | 40                           |
| 1000*3500*150                  | 13                           |
| <b>Total Area For Painting</b> | <b>9,781 (m<sup>2</sup>)</b> |

Table 3. Total Quantity Take-Off from IBS Partition Wall

**5.3 Time Calculation:**

In Revit Architecture, not only the various types of partition walls(from A to H) are determined, but also, in each level, the accurate number of any type has been identified. This identification is considered as the most suitable way to calculate the time required for the installation of IBS partition wall in a given project. Table 4 shows these categories.

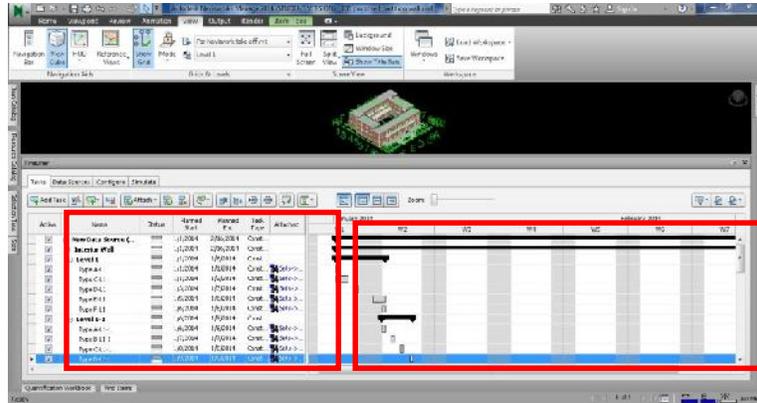
| TYPE | LEVEL 1 | LEVEL 1-1 | LEVEL 2 | LEVEL 2-1 | LEVEL 3 | LEVEL 3-1 | LEVEL 4 |
|------|---------|-----------|---------|-----------|---------|-----------|---------|
| A    | 14      | 3         | 9       | 2         | 10      | 2         | -       |
| B    | -       | 4         | 10      | 1         | 8       | -         | 1       |
| C    | 15      | 15        | 26      | 12        | 28      | 4         | 46      |
| D    | 9       | 4         | 20      | 5         | 11      | 10        | 7       |
| E    | 14      | 7         | 6       | 7         | 8       | 11        | 2       |
| F    | 1       | -         | 3       | 2         | 11      | -         | -       |
| G    | -       | 1         | 3       | -         | 5       | -         | -       |
| H    | -       | -         | 2       | -         | -       | -         | -       |

Table 4: Categories of Interior Walls in each Level for Time Calculation

According to Baker [14], for computation of activity duration, the quantity of work involved should be divided with the number of resources utilized and with the activity’s corresponding production rate. Hyunjo Kim et al. [4] believe that, before the calculation of each activity’s duration, the productivity rate of needed elements in one working day should be specified. For example, in a case where 16 doors are installed during one working day, each door takes 0.0625 day to be installed.

In this case research, the assumption is that three skilled labors have been involved 8 hours daily to install IBS partition wall (working is assumed to be started on the first of January 2014 and Saturdays have been considered as day-off). The Revit file has been exported to the Naviswork Manage 2014 to calculate the amount of time consumed

for the installation of IBS wall partition. This duration of time in each level has been determined separately in regard to different factors of installation, quantity of work, and productivity rate that have been already computed. Figure 13 illustrates the time computation of IBS partition wall's installation in Naviswork Manage 2014. Furthermore, Table 5 shows the time duration of installing the IBS partition wall in each level and in total.



**Fig 9. Time Calculation in Naviswork Manage 2014**

| Duration of IBS Partition Wall's Installation |                |
|---|----------------|
| Level 1                                       | 5 days         |
| Level 1-1                                     | 4 days         |
| Level 2                                       | 9 days         |
| Level 2-1                                     | 4 days         |
| Level 3                                       | 10 days        |
| Level 3-1                                     | 2 days         |
| Level 4                                       | 7 days         |
| <b>Total</b>                                  | <b>40 days</b> |

**Table 5. Duration of IBS Partition Walls' Installation**

## 6. DISCUSSION

In this research, the effectiveness of the proposed lightweight IBS partition wall has been examined in terms of quantity, time, and functionality of its installation on the interior space within the buildings. Kamran Aghaee and Mohammad Foroughi [15] recommended the use of light panels to decrease the dimensions of structural sections, and they believed that less transportation expenses could lead to a reduction in both performance and construction cost.

Regarding the work process and pertinent tables of quantity takeoff and time calculation in regard to the IBS partition wall's installation, it is quite convincing to state that this type of proposed partition wall would shorten the process of construction and decrease the amount of materials needed compared to the existing ones.

Regarding the sustainability of the partition walls, flexibility is pivotal to enhancement of the buildings' lifespan. According to Ricardo Mateus et al. [2], the qualitative parameter of flexibility is one of the key aspects in the sustainability of partition walls; it enables the users to move the wall on the indoor space of building. As illustrated in different steps of IBS partition wall's installation, there is no necessity to use any fasteners to connect partition wall to any other components. Therefore, it can be moved along any desired directions solely by detaching the protruded surface from the embedded holes inside the IBS components. This matter would fulfill the particular needs for next generations in terms of changing the role of interior space.

## 7. Conclusion

Partition walls have always been considered as one of the most crucial and critical elements in the interior space within the buildings, through which particular requirements of the residents can be met. Therefore, the authors took into consideration the studies conducted on this critical element and proposed a new type of partition wall using BIM tools. Summing up the results, it is concluded that the proposed type of partition wall could accelerate the pace of construction and diminish the amount of different materials or components used during a construction process.

Furthermore, flexibility of the interior space of buildings would be increased through installing this type of partition wall due to its simple movement along any desired directions.

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