Cost Comparison of a Building Project by Manual and BIM

Usman Haider [a*], Usama Khan [b], Asif Nazir [b], Muhammad Humayon [c]

[a] Department of Mechanics, Faculty of Civil Engineering, Czech Technical University in Prague, Czech Republic.

[b] Department of Technology, Branch of Civil Engineering Technology, The University of Lahore, Pakistan.

[c] Parsons Transportation Group,3577 Parkway lane, Peachtree Corners, GA, USA.

Abstract

This article focuses on comparison between Manual/Traditional and Building Information Modelling (BIM) software based approaches for cost comparison. Centre line method for manual and Revit software for BIM based approaches are used in this research. The principal objectives of this research are to calculate quantities by Manual Centre line method, then to make the cost estimation fast, accurate, efficient, and errorless by using BIM software Rivet, and finally the comparison study of manual based and BIM / Software based estimation. For manual approach, quantities are calculated by multiplying the measurements of length, breadth, and height. Then to get the total quantities the deduction is subtracted from the quantities and final BOQ is prepared for which estimated cost of building is calculated. For BIM based approach, 3D model from 2D floor plan of building is prepared in Revit software, then to estimate the cost of building structure elements, sheets of quantities are generated in the schedule option of the view tab in the software. The Percentage difference between Manual and BIM / Revit Software estimation in brick work, RCC Slab, Plaster Work, PCC for Flooring, Floor Tile Work, Skirting, Paint Work, False Ceiling, Doors and Aluminum Work is 4.57, 2.61, 7.58, 3.27, 1.87, 6.73, 8.03, 1.87, and 0.00% respectively. The total cost difference between manual and BIM based estimation approach comes out to be 4.8%. It is thus concluded that the BIM-assisted estimates have better performance over traditional/manual estimating methods.

Keywords: Cost; Manual; Building; Revit Software; Estimate; BIM.

1. Introduction

Cost estimation is initial stage for any construction project; it helps to evaluate project feasibility, cost controls, and tendering process [1, 2]. There are two types of cost estimation rough cost estimation and detailed cost estimation. Rough cost estimate can be an approximate estimate to find an approximate cost of a task based on plinth area rates very quickly and therefore it permits the competent authority worried to consider the financial aspects of the scheme for administrative authorization to the design [3]. Whereas, detailed cost estimation includes the specific particulars of the quantities, rates, and costs of all items for according technical sanction, tendering, and for satisfactory completion of a project [4]. There are two types of cost estimation method according to their generation, Manual and Building Information Modelling (BIM) [5]. In Manual detailed estimation approach, center line method is used for estimation in buildings where cross wall are not provided. In this method first we have to find the total length of the wall and then multiply it with the width and its height to get the volume [6]. In order to prepare a detailed manual estimate, the estimator must have the drawings of the work such as plans and sections for taking measurements, identification of the nature of materials specifications to be used, and their rates at which the different items of work are carried out as per the Market Rate System (MRS) of the Finance Department, Government of the Punjab [7] to obtain the Bill of Quantities (BOQ). In order to prepare a

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detailed Building Information Modelling (BIM) / Software based estimate the estimator must have prepared 3D model of the building structure and must obtain its quantities for different class of materials taken from the software [8, 9]. After this, rates taken from MRS system of the Finance Department, Government of the Punjab are inserted in the software to obtain the Bill of Quantities (BOQ).

With BIM Software, the software produces suitable specific and correct cost estimation for every single examined project. This technique generates estimation of construction jobs with more accuracy and reliability [10]. Building Information Modelling (BIM) technology improves the incorrectness in cost estimation and helps to reduce the cost of the project [5]. Building Information Modeling (BIM) generates accurate information and allows project collaborators to easily access information of various types, greatly promoting information transparency during the lifecycle of a facility. The quick adoption of BIM services and products is because of the benefits it offers to adopting companies. Moreover, BIM adoption may result in a positive return on the BIM investment for project collaborators through savings from reduced project costs. Literature is full of evidence which supports to demonstrate that BIM adoption supports the reduction of design and construction cost, increase in productivity, and improved risk management processes. BIM models richly describe buildings through classes of objects that contain their 3D geometry and other characteristics. Quantity can be measured automatically from BIM models by extracting geometric data and semantic properties of each building element [11-15].

There are two phases of cost estimation, one at the time of design of the project and second is at the time of construction. Estimation at the time of design helps for the project feasibility, project budget etc. Estimation at the time of construction should be done when additional construction is required with the use of information technology in cost estimation. At the time of design information technology helps us to provide support in making the cost estimate, maintaining of cost database and to save the record easily. Information technology helps construction estimation by maintaining the project data and items of work on project. Building cost estimation is very important for tendering process as it helps contractors and clients in comparing for the volume and price from different bidders [16, 17].

Cost estimation for building projects traditionally starts with tendering process. The process of manual cost estimation is prone to human error and tends to propagate inaccuracies. While the use of BIM software is to increase the accuracies of the cost estimation. Computer based estimating (Revit/BIM software) systems have gained a wide acceptance in the construction industry. It is widely used in construction management in the developed countries. In the developing countries using computers software for cost estimation is still at the early stages. Therefore, there is a dire need in countries such as Pakistan to do cost estimation by BIM software. The principal objectives of this research are to calculate quantities by manual centre line method, to make the cost estimation fast, accurate, efficient, and errorless by using BIM software Rivet, and finally the comparison study of manual based and BIM / Software based estimation.

2. Methodology

The adopted methodology to accomplish this study includes comparison of cost estimation by manual approach and by BIM software based approach as shown in Figure 1.
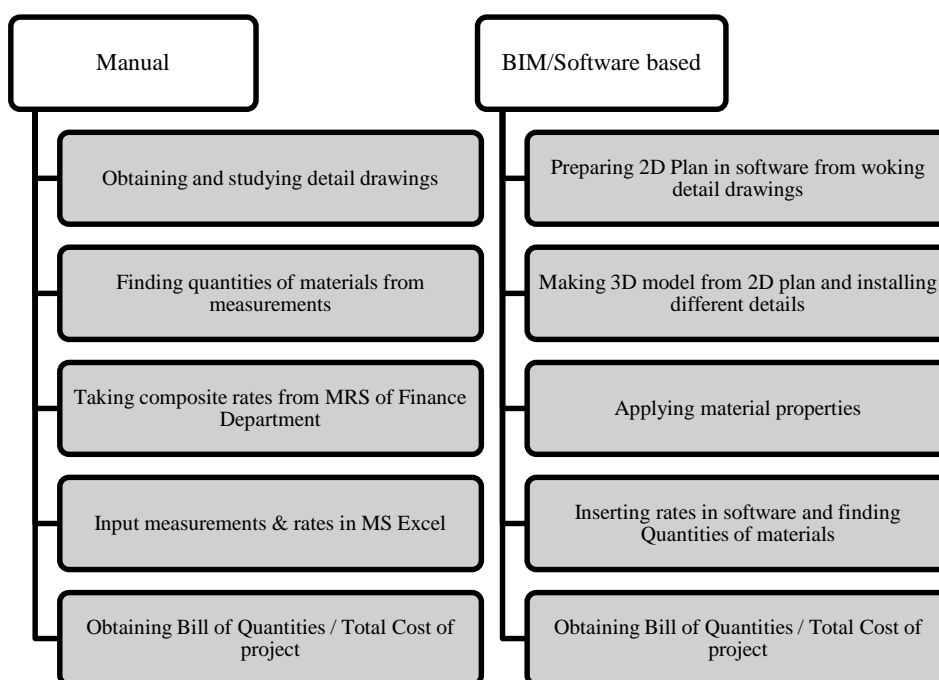

**Figure 1. Comparison of Manual and BIM Software based estimation**

Basic requirements for both Manual and BIM methods is the selection of site and collection of data. The site of college located in Bahria town near Multan road Lahore is selected for cost estimation in this research. Moreover, working drawings, layout plans, elevation, structural slab drawings were collected for this research on cost estimation. The step by step procedure to carry out cost estimation by manual and BIM approaches are as follows:

2.1. For Manual Cost Estimation

1. To carry out manual estimation the drawing of the project such as plans and sections are taken in hand.

2. Exact nature and class of materials to be used are to found.

3. Different Formulas which are used for cost estimation in manual approach are as shown in Table 1

4. In the manual approach, center line method is used for cost estimation as shown in Figure 2.

5. In this method first the total length of the wall is found and then it is multiplied with the width and its height to get the volume [6].

6. Rates are found at which the different items of work are carried out as per the MRS system from the website of the Finance Department, Government of the Punjab, Pakistan.

7. Detailed estimation sheet of each item is prepared.

8. After this, following things are calculated:

   - Quantities of items.
   - Composite rates from MRS
   - Abstract of total cost.
   - Preparation of bill of quantities.

Table 1. Formula sheet for manual cost estimation

Sr. No	Item Name	Unit	Formula
1	Brick Work	Cft	L×B×H
2	RCC Slab	Cft	L×B
3	Plaster Work	Sft	B×H
4	PCC for Flooring	Cft	L×B×H
5	Floor Tile Work	Sft	L×B
6	Skirting	Rft	Running foot
7	Paint Work	Sft	L× B
8	False Ceiling	Sft	L× B
9	Doors	Sft	L× B
10	Aluminium Work	Sft	L× B
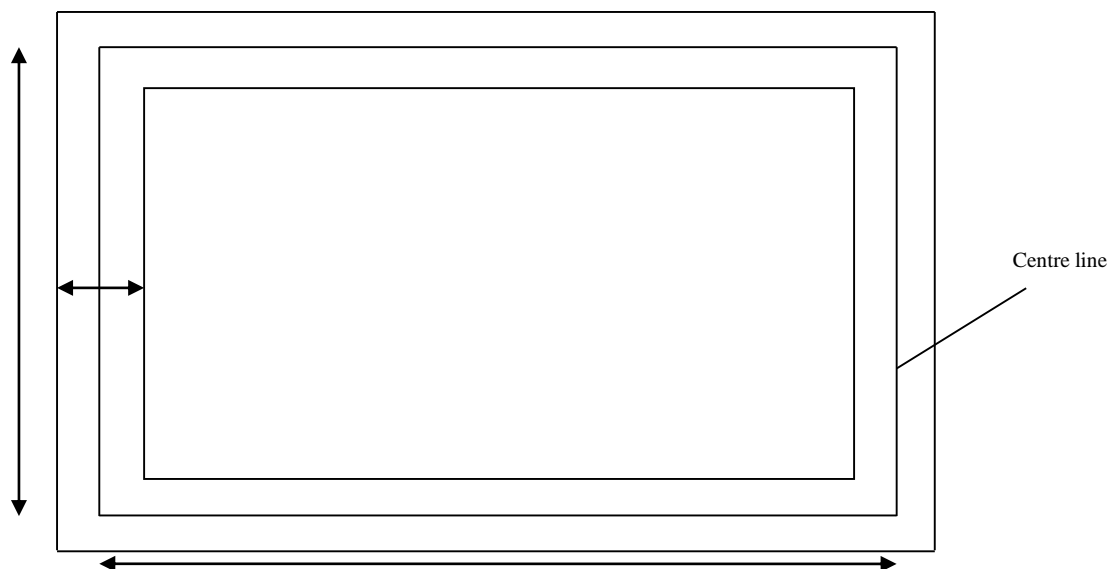
Figure 2. Centre Line method

2.2. For BIM / Software Approach

1. For BIM based approach, Revit software as shown is to be used in this research.

2. 2D floor plan of the project was drawn in Revit software.

3. 2D floor plan is converted into 3D model of the structure.

4. The building elements and material are identified.

5. After this the quantities for each component are obtained [5,9].

6. Rates of each item as shown in Table 2 are taken from the MRS system of the first Bi-Annual 2019 of the Finance Department, Government of the Punjab, Pakistan and are inserted in the software.

7. Detailed estimation of quantities of each item is obtained from software

8. Abstract of total cost and bill of quantities is calculated from software.

9. After this, aabstract of total cost and bill of quantities are taken from software [19].

Table 2. Rates of items taken from MRS first Bi-Annual 2019 [19]

Sr. No	Item Name	Unit	Composite rates (Rupees)
1	Brick Work in Super Structure	Cft	222
2	RCC Slab	Cft	360
3	Plaster Work	Sft	180
4	PCC for Flooring	Cft	135
5	Floor Tile Work	Sft	300
6	Skirting	Rft	100
7	Paint Work	Sft	45
8	False Ceiling	Sft	65
9	Doors	Sft	700
10	Aluminium Work	Sft	550

3. Results and Discussions

Detailed calculation of quantities in manual cost estimation along with model based calculation for BIM software [20] based method are carried out.

3.1. Manual Cost Estimation

In manual cost estimation, quantities of different items are calculated step by step as explained below by using the architectural plan as shown in Figure 3. In this figure, five colours red, blue, magenta, green, and black are used to distinguish different wall sections from each other.
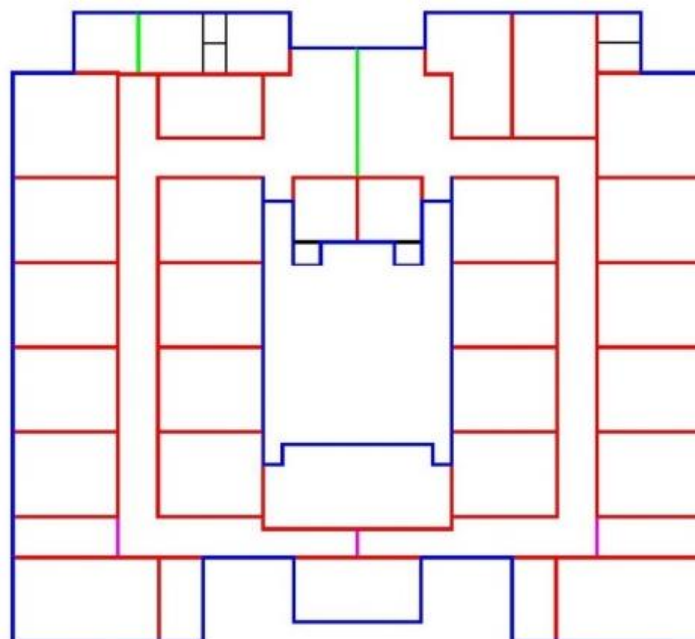
Figure 3. 2D Architectural plan for manual cost estimation

For manual cost estimation Table 3 to 7 have been prepared. Table 3 presents the quantities calculation of brickwork and of reinforced concrete slab. Table 3 has ten columns altogether, in description column name of item to be calculated is presented, in the column of No, the number of items of this description from the floor plan is presented, then under the measurements, the length, breadth, and the height of a particular item is presented, deduction are made for an item which is within another item, for e.g. quantities of windows are deducted from the wall sections as they lie within the wall section. Quantities are calculated by multiplying the measurements of length, breadth, and height. Then to get the total quantities the deduction are subtracted from the quantities. Net calculated quantities of brick work and reinforced concrete slab are 19475 and 10947 cft shown in Table 3.

Table 3. Calculation of brick work and RCC slab

Sr. No	Description	No	Measurement			Deduction	Quantity	Unit	Total
			L	B	H				
1	BW in super structure								
	Red wall Section	1	1381.5	0.75	12		12433.5	cft	
	Windows	35	5	0.75	5	656.25		cft	
	Windows	6	8	0.75	5	180		cft	
	Windows	2	5	0.75	3	22.5		cft	
	Windows	4	6	0.75	5	90		cft	
	Windows	2	5	0.75	7.5	56.25		cft	
	Windows	3	3	0.75	3	20.25		cft	
	Windows	6	9	0.75	9	364.5		cft	
	Windows	4	6	0.375	2	18		cft	
	Windows	4	2	0.75	2	12		cft	
	Windows	2	15.75	0.75	12	283.5		cft	
	Windows	2	10	0.75	5	75		cft	
	Windows	2	12.5	0.75	5	93.75		cft	
	Door	2	5	0.75	8	60		cft	
	Door	2	3.5	0.75	5	26.25		cft	
	Blue wall Section	1	1009.33	0.75	12		9083.97	cft	
	Door	25	5	0.75	8	750		cft	
	Door	8	3.5	0.75	8	168		cft	
	Door	2	2.5	0.75	8	30		cft	
	Magenta wall Section	1	20	0.75	12		180	cft	
	Door	2	3.5	0.75	8	42		cft	
	Green wall Section	1	62.18	0.75	12		559.57	cft	
	Door	1	5	0.75	8	30		cft	
	Black wall Section	1	47	0.375	12		211.50	cft	
	Door	2	2.5	0.375	8	15		cft	
	Net					2993.25	22468.55		19475.30
	Total brickwork							cft	19475.30
2	Reinforced Concrete Slab	1	21895		0.5		10947.5	cft	
							Total	cft	10947.5

Similarly, Table 4 presents the quantities calculation of plaster work and paint work. Table 4 has ten columns altogether, in description column, name of item to be calculated is presented in this case windows, doors, plaster work, and paint work. In the column of No, the number of items of this description from the floor plan is presented, then under the measurements, the length, breadth, and the height of a particular item is presented, deduction are made for an item which is within another item, for e.g. quantities of windows are deducted from the plaster and paint work on the wall sections as they lie within the wall section. Quantities of plaster and paint work has been made twice because the plaster and paint are applied on both sides of the wall sections. Similarly, quantities are calculated by multiplying the measurements of length, breadth, and height. Then to get the total quantities the deduction is subtracted from the quantities. Net calculated quantities of Plaster and white wash is 52702 sft shown in Table 4.

Table 4 Calculation of Plaster work and Paint work

Sr. No	Description	No	Measurement			Deduction	Quantity	Unit	Total
			L	B	H				
1	Windows for deduction								
	Windows	35	5	2	4.5	1575		Sft	
	Windows	6	8	2	4.5	432		Sft	
	Windows	2	5	2	3	60		Sft	
	Windows	4	6	2	4.5	216		Sft	
	Windows	2	5	2	7.5	150		Sft	
	Windows	3	3	2	3	54		Sft	
	Windows	6	9	2	9	972		Sft	
	Windows	4	6	2	2	96		Sft	
	Windows	4	2	2	2	32		Sft	
	Windows	2	15.75	2	12	756		Sft	
	Windows	2	10	2	4.5	180		Sft	
	Windows	2	12.5	2	4.5	225		Sft	
			Total			4748		Sft	
2	Doors for deduction								
	Door	2	5	2	8	160		Sft	
	Door	2	3.5	2	5	70		Sft	
	Door	25	5	2	8	2000		Sft	
	Door	8	3.5	2	8	448		Sft	
	Door	2	2.5	2	8	80		Sft	
	Door	2	3.5	2	8	112		Sft	
	Door	1	5	2	8	80		Sft	
	Door	2	2.5	2	8	80		Sft	
			Total						3030
	Grand Total								7778
3	Plaster work and paint work								
	Red wall Section	2	1381.5	-	12		33156		
	Blue wall Section	2	1009.33	-	12		24223.92		
	Magenta wall Section	2	20	-	12		480		
	Green wall Section	2	62.17	-	12		1492.2		
	Black wall Section	2	47	-	12		1128		
	Total								60480
	Deduction								7778
	Net plaster								2702
	Net paint work								2702

On similar grounds Table 5 has been prepared. In this table calculations for Plain Cement Concrete (PCC) for flooring, floor tile work, and false ceiling are presented. Wall sections have been deducted to get the total net area of the room to calculate the net required quantities of PCC flooring, tile work, and false ceiling. Net calculated quantities for PCC Flooring, Floor Tile Work and False Ceiling is 5001, 20005, and 20005 sft as shown in Table 5.

Table 5. Calculation of PCC for Flooring, Floor Tile Work and False Ceiling

Sr. No	Description	No	Measurement			Deduction	Quantity	Unit	Total
			L	B	H				
1	Walls for deduction								
	Blue wall Section	1	1009.33	0.75	-		757	Sft	
	Magenta wall Section	1	20	0.75	-		15	Sft	
	Green wall Section	1	62.175	0.75	-		46.63	Sft	
	Black wall Section	1	47	0.75	-		35.25	Sft	
	Total						853.88	Sft	
	Total building area						20859	Sft	
	Net area of rooms					853.88	20859	Sft	20005
2	PCC for Flooring		20859 Sft	0.25				cft	5001
3	Floor Tile Work						20005	Sft	
4	False Ceiling						20005	Sft	

Calculation of windows and doors are presented in Table 6. In this table quantities of windows and doors have been calculated by multiplying their length, breadth, and height. No deduction is made in these quantities. Net calculated quantities of windows and doors 2374 sft and 1515 sft as shown in Table 6.

Table 6. Calculation of windows and doors

Sr. No	Description	No	Measurement			Deduction	Quantity	Unit	Total
			L	B	H				
1	Window Calculations								
	Windows	35	5	0.75	4.5		787.5	Sft	
	Windows	6	8	0.75	4.5		216	Sft	
	Windows	2	5	0.75	3		30	Sft	
	Windows	4	6	0.75	4.5		108	Sft	
	Windows	2	5	0.75	7.5		75	Sft	
	Windows	3	3	0.75	3		27	Sft	
	Windows	6	9	0.75	9		486	Sft	
	Windows	4	6	0.375	2		48	Sft	
	Windows	4	2	0.75	2		16	Sft	
	Windows	2	15.75	0.75	12		378	Sft	
	Windows	2	10	0.75	4.5		90	Sft	
	Windows	2	12.5	0.75	4.5		112.5	Sft	
							Total	Sft	2374
2	Doors Calculation								
	Door	2	5	0.75	8		80	Sft	
	Door	2	3.5	0.75	5		35	Sft	
	Door	25	5	0.75	8		1000	Sft	
	Door	8	3.5	0.75	8		224	Sft	
	Door	2	2.5	0.75	8		40	Sft	
	Door	2	3.5	0.75	8		56	Sft	
	Door	1	5	0.75	8		40	Sft	
	Door	2	2.5	0.375	8		40	Sft	
							Total	Sft	1515.000

Calculation of skirting is presented in Table 7. In this table quantities of wall sections have been taken in Rft on both sides of the wall skirting would be provided that is why lengths of wall sections have been taken twice. Lengths of doors have to be deducted from the skirting as skirting is not provided on doors. Net calculation of skirting is 3838 Rft as shown in Table 7.

Table 7. Calculation of Skirting

Sr. No	Description	No	L	B	H	Deduction	Quantity	Unit
1	Doors for deduction							
	Door	2	5		-	10		Rft
	Door	2	3.5		-	7		Rft
	Door	25	5		-	125		Rft
	Door	8	3.5		-	28		Rft
	Door	2	2.5		-	5		Rft
	Door	2	3.5		-	7		Rft
	Door	1	5		-	5		Rft
	Door	2	2.5		-	5		Rft
					Total	192		Rft
2	Total walls length							
	Red wall Section	2	1381.5	-	-	-	2763	Rft
	Blue wall Section	1	1009.33	-	-	-	1009.33	Rft
	Magenta wall Section	2	20	-	-	-	40	Rft
	Green wall Section	2	62.175	-	-	-	124.35	Rft
	Black wall Section	2	47	-	-	-	94	Rft
	Total						4030.68	Rft
						Deduction	192	Rft
	Total skirting						3838.68	Rft

3.1.1. Bill of Quantities for Manual Cost Estimation

BOQ sheet is prepared during the step of calculation of material and it shows the quantities of items, unit cost of items, and total cost of project by manual cost estimation. Total estimated cost of the project is Rs 30967389 by manual cost estimation ($1000\ Rs$ (Pakistani Rupee) $= 6.42\ \$\ (US\ Dollar)$). This BOQ sheet includes the total quantities and cost of materials to be used in the construction of project. The BOQ sheet is shown in Table 8.

Table 8. BOQ for manual cost estimation results

Sr.no	Item Description	Unit	Quantity	Unit Cost	Total Cost
1	Brick Work in Super Structure	Cft	19475	222	4323450
2	RCC Slab	Cft	10947	360	3940920
3	Plaster Work	Sft	52702	180	9486360
4	PCC for Flooring	Cft	5001.25	135	675168.75
5	Floor Tile Work	Sft	20005	300	6001500
6	Skirting	Rft	3838	100	383800
7	Paint Work	Sft	52447	45	2360115
8	False Ceiling	Sft	20005	65	1300325
9	Doors	Sft	2375	700	1662500
10	Aluminium Work	Sft	1515	550	833250
	Total				Rs 30967389

3.2. Revit Software/ BIM based Estimation Process:

Cost estimation by using Revit software is carried out by the following steps:

1. 2D drawing/plan of the structure is drawn as shown in Figure 4.

2. After this from the view tab in software, 3D model was generated without roof as shown in Figure 5(a) and with roof as shown in Figure 5(b) [21]. Cross sections and elevations are shown in Figure 6(a), (b), and (c).

3. To estimate the cost of structure elements, sheets of quantities is generated in the schedule option of the view tab of Revit software as shown in Figure 7(a) and Table 9(a) for room areas, Figure 7(b) and Table 9 (b) for quantities of brickwork material.
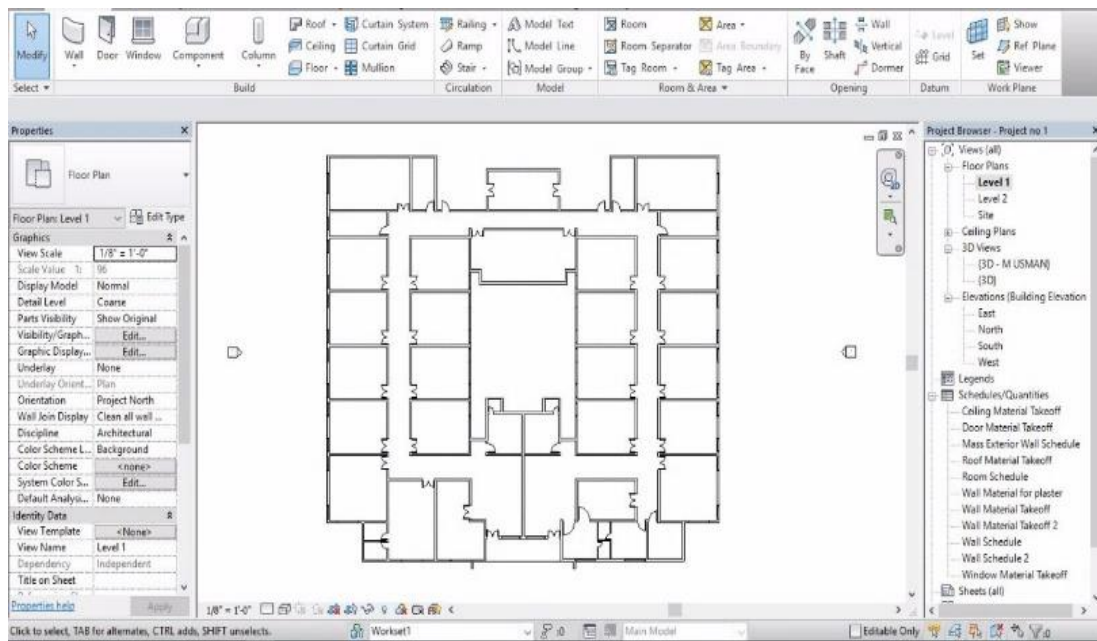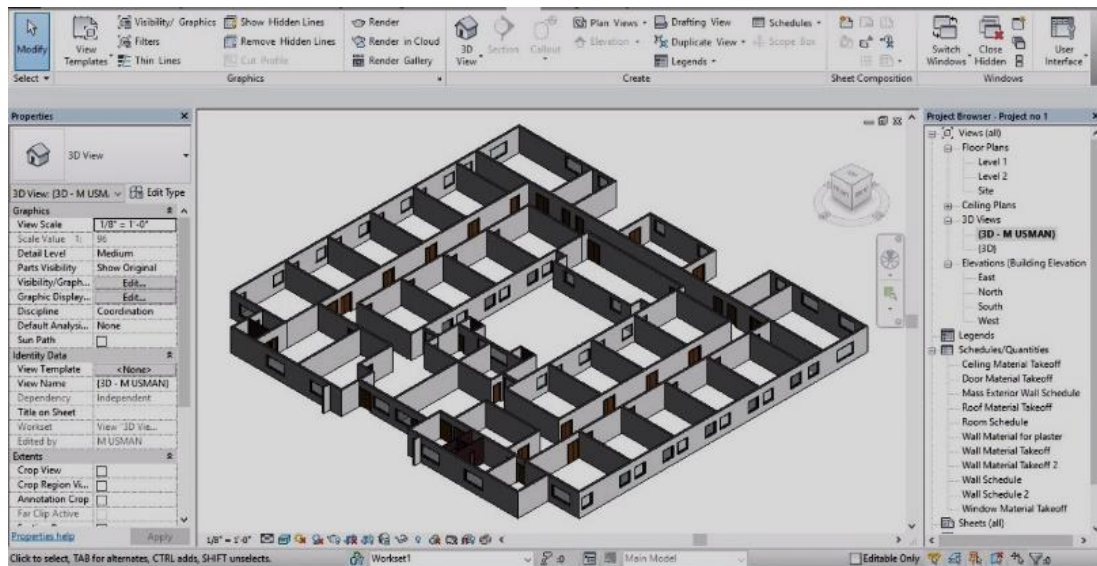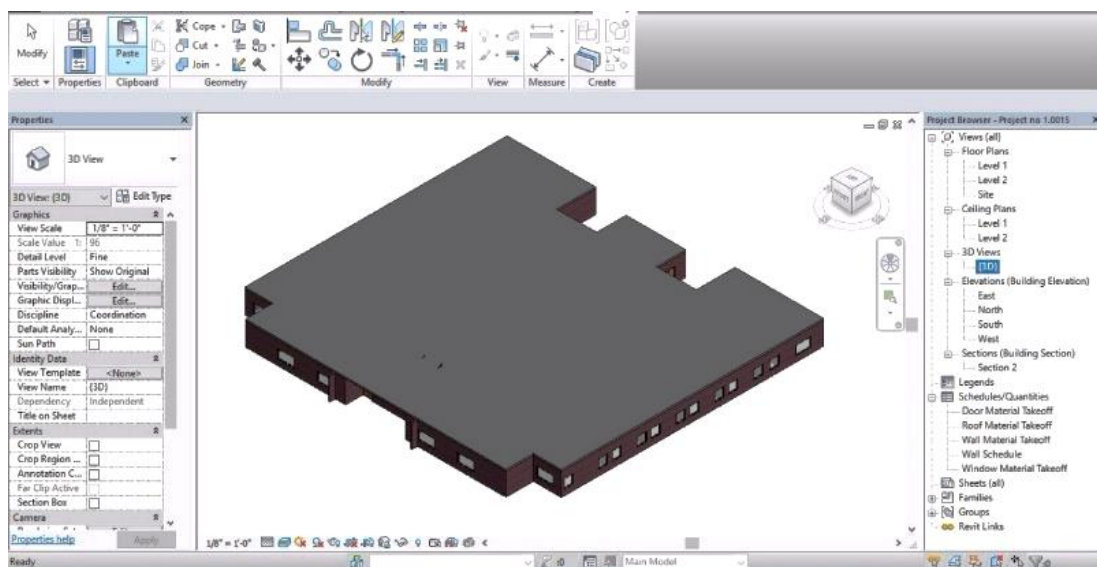
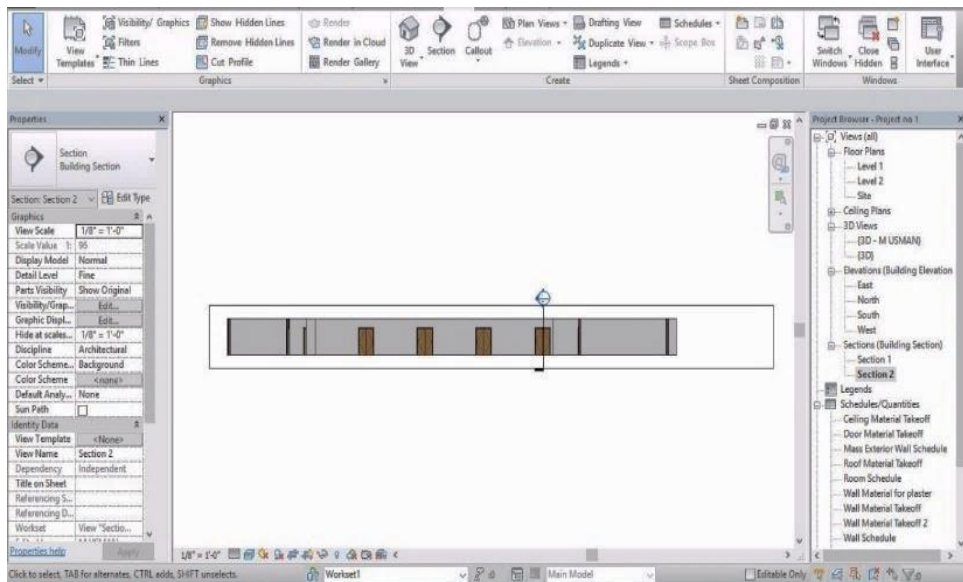**Figure 4. 2D Drawing for cost estimation in Revit software**
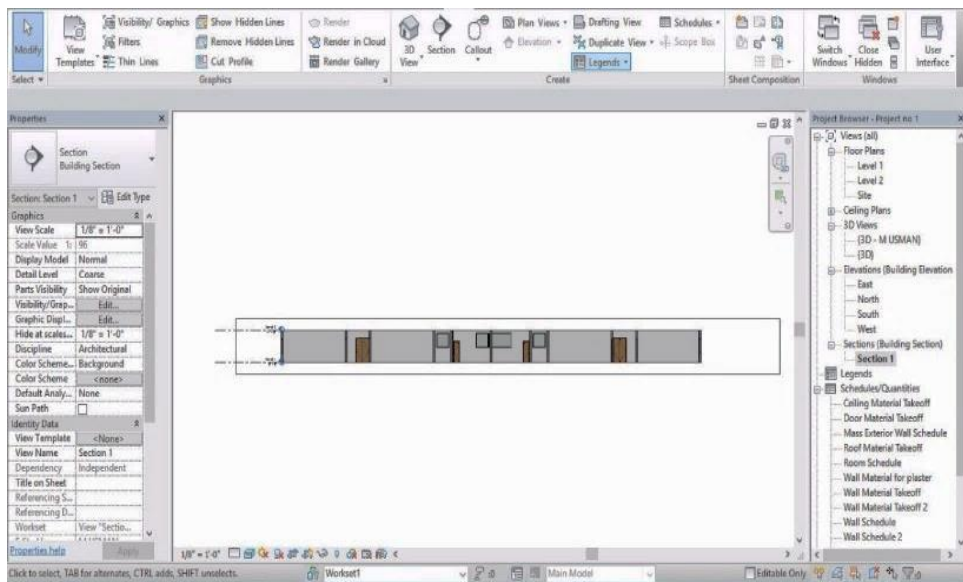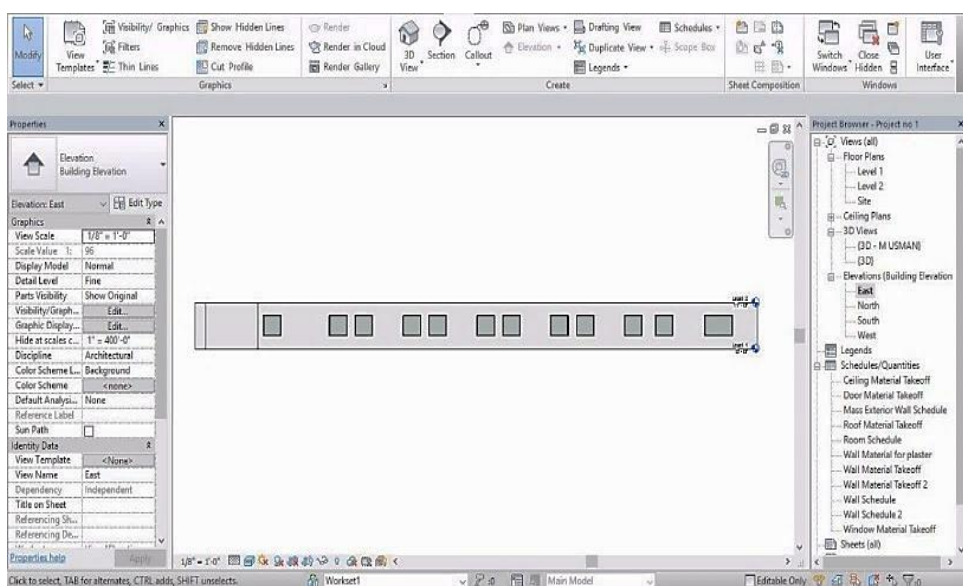

(a)

(b)

Figure 5. 3D Drawing for cost estimation in Revit software: without roof (a), with roof (b)

(a)

(b)

(c)

Figure 6. (a) Cross section 1-1, (b) Cross section 2-2, (c) East side elevation
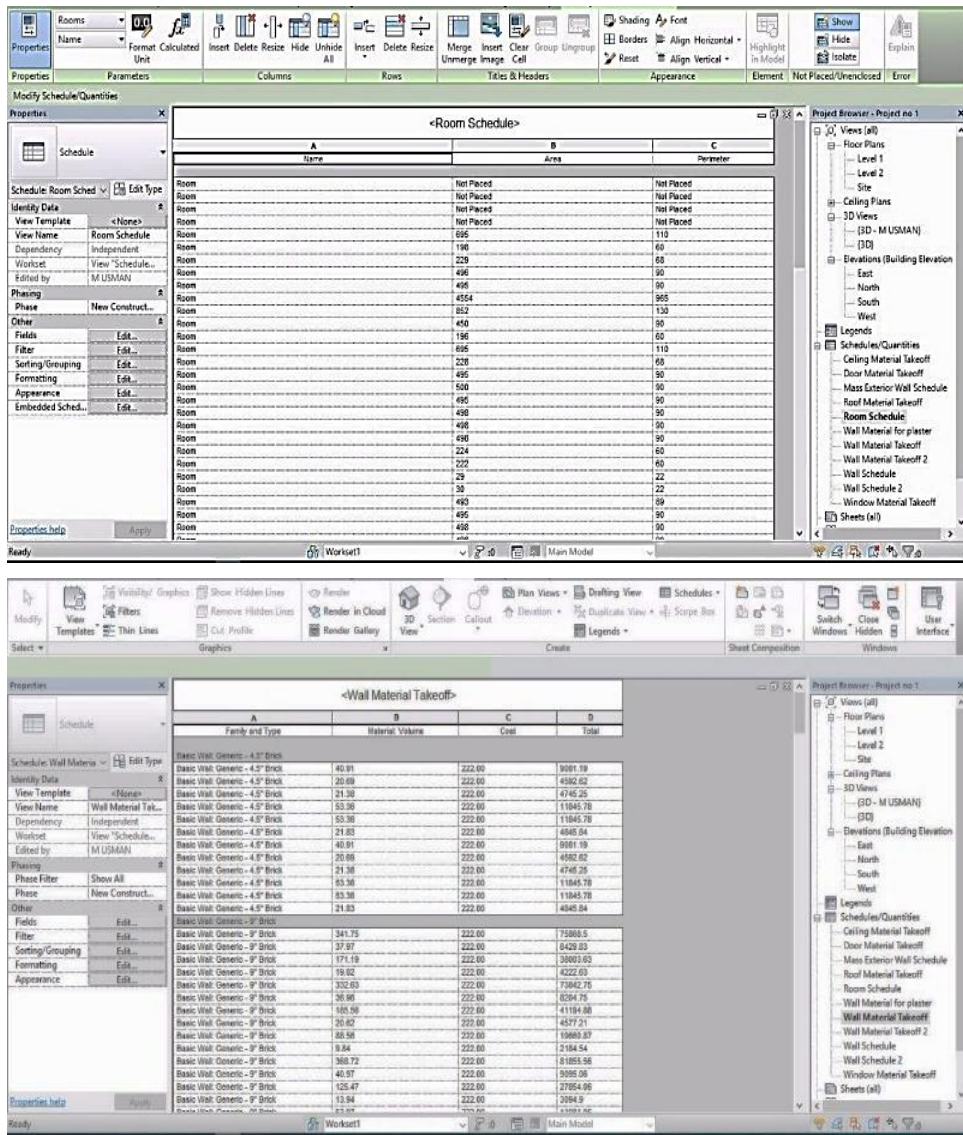
(a)

(b)

Figure 7. (a) Room Schedule, (b) Wall Material / brickwork

Table 9. (a) Room Schedule

Name	Area	Perimeter	Name	Area	Perimeter	Name	Area	Perimeter
Room	Not Placed	Not Placed	Room	500	90' - 0"	Room	66	33' - 2"
Room	Not Placed	Not Placed	Room	495	89' - 6"	Room	68	33' - 7"
Room	Not Placed	Not Placed	Room	498	89' - 10"	Room	367	79' - 3"
Room	Not Placed	Not Placed	Room	498	89' - 10"	Room	212	58' - 3"
Room	695	109' - 8"	Room	498	89' - 10"	Room	37	24' - 5"
Room	198	59' - 8"	Room	224	59' - 10"	Room	37	24' - 5"
Room	229	68' - 4"	Room	222	59' - 7"	Room	215	58' - 9"
Room	496	89' - 8"	Room	29	21' - 8"	Room	209	57' - 6"
Room	495	89' - 6"	Room	30	22' - 0"	Room	617	99' - 4"
Room	4554	965' - 1"	Room	493	89' - 4"	Room	495	89' - 6"
Room	852	130' - 1"	Room	495	89' - 6"	Room	495	89' - 6"
Room	450	90' - 2"	Room	498	89' - 10"	Room	500	90' - 0"
Room	196	59' - 6"	Room	498	89' - 10"	Room	495	89' - 6"
Room	695	109' - 8"	Room	623	99' - 10"	Room	279	81' - 8"
Room	228	68' - 0"	Room	596	99' - 9"			
Room	495	89' - 6"	Room	514	101' - 1"		**20386**	

Table 9. (b) Wall Material / Brickwork

Family and Type	Material: Volume	Family and Type	Material: Volume	Family and Type	Material: Volume
Basic Wall: Generic - 9" Brick	341.06	Basic Wall: Generic - 9" Brick	101.55	Basic Wall: Generic - 9" Brick	206.25
Basic Wall: Generic - 9" Brick	37.9	Basic Wall: Generic - 9" Brick	178	Basic Wall: Generic - 9" Brick	22.92
Basic Wall: Generic - 9" Brick	170.5	Basic Wall: Generic - 9" Brick	19.78	Basic Wall: Generic - 9" Brick	206.25
Basic Wall: Generic - 9" Brick	18.94	Basic Wall: Generic - 9" Brick	801.12	Basic Wall: Generic - 9" Brick	22.92
Basic Wall: Generic - 9" Brick	331.94	Basic Wall: Generic - 9" Brick	89.01	Basic Wall: Generic - 9" Brick	204.88
Basic Wall: Generic - 9" Brick	36.88	Basic Wall: Generic - 9" Brick	219.31	Basic Wall: Generic - 9" Brick	22.76
Basic Wall: Generic - 9" Brick	185.56	Basic Wall: Generic - 9" Brick	24.37	Basic Wall: Generic - 9" Brick	206.25
Basic Wall: Generic - 9" Brick	20.62	Basic Wall: Generic - 9" Brick	24.75	Basic Wall: Generic - 9" Brick	22.92
Basic Wall: Generic - 9" Brick	88.56	Basic Wall: Generic - 9" Brick	2.75	Basic Wall: Generic - 9" Brick	247.5
Basic Wall: Generic - 9" Brick	9.84	Basic Wall: Generic - 9" Brick	319.5	Basic Wall: Generic - 9" Brick	27.5
Basic Wall: Generic - 9" Brick	368.72	Basic Wall: Generic - 9" Brick	35.5	Basic Wall: Generic - 9" Brick	204.88
Basic Wall: Generic - 9" Brick	40.97	Basic Wall: Generic - 9" Brick	597	Basic Wall: Generic - 9" Brick	22.76
Basic Wall: Generic - 9" Brick	125.47	Basic Wall: Generic - 9" Brick	66.33	Basic Wall: Generic - 9" Brick	204.88
Basic Wall: Generic - 9" Brick	13.94	Basic Wall: Generic - 9" Brick	213.13	Basic Wall: Generic - 9" Brick	22.76
Basic Wall: Generic - 9" Brick	53.97	Basic Wall: Generic - 9" Brick	23.68	Basic Wall: Generic - 9" Brick	163.63
Basic Wall: Generic - 9" Brick	6	Basic Wall: Generic - 9" Brick	558.56	Basic Wall: Generic - 9" Brick	18.18
Basic Wall: Generic - 9" Brick	98.91	Basic Wall: Generic - 9" Brick	62.06	Basic Wall: Generic - 9" Brick	38.16
Basic Wall: Generic - 9" Brick	10.99	Basic Wall: Generic - 9" Brick	213.13	Basic Wall: Generic - 9" Brick	4.24
Basic Wall: Generic - 9" Brick	262.88	Basic Wall: Generic - 9" Brick	23.68	Basic Wall: Generic - 9" Brick	40.56
Basic Wall: Generic - 9" Brick	29.21	Basic Wall: Generic - 9" Brick	206.25	Basic Wall: Generic - 9" Brick	4.51
Basic Wall: Generic - 9" Brick	669.81	Basic Wall: Generic - 9" Brick	22.92	Basic Wall: Generic - 9" Brick	267.06
Basic Wall: Generic - 9" Brick	74.42	Basic Wall: Generic - 9" Brick	206.25	Basic Wall: Generic - 9" Brick	29.67
Basic Wall: Generic - 9" Brick	213.13	Basic Wall: Generic - 9" Brick	22.92	Basic Wall: Generic - 9" Brick	37.47
Basic Wall: Generic - 9" Brick	23.68	Basic Wall: Generic - 9" Brick	206.25	Basic Wall: Generic - 9" Brick	4.16
Basic Wall: Generic - 9" Brick	133.63	Basic Wall: Generic - 9" Brick	22.92	Basic Wall: Generic - 9" Brick	33.69
Basic Wall: Generic - 9" Brick	14.85	Basic Wall: Generic - 9" Brick	204.88	Basic Wall: Generic - 9" Brick	3.74
Basic Wall: Generic - 9" Brick	114.94	Basic Wall: Generic - 9" Brick	22.76	Basic Wall: Generic - 9" Brick	42.09
Basic Wall: Generic - 9" Brick	12.77	Basic Wall: Generic - 9" Brick	204.88	Basic Wall: Generic - 9" Brick	4.68
Basic Wall: Generic - 9" Brick	125.81	Basic Wall: Generic - 9" Brick	22.76	Basic Wall: Generic - 9" Brick	126.84
Basic Wall: Generic - 9" Brick	13.98	Basic Wall: Generic - 9" Brick	204.88	Basic Wall: Generic - 9" Brick	14.09
Basic Wall: Generic - 9" Brick	907.31	Basic Wall: Generic - 9" Brick	22.76	Basic Wall: Generic - 9" Brick	26.44
Basic Wall: Generic - 9" Brick	100.81	Basic Wall: Generic - 9" Brick	204.88	Basic Wall: Generic - 9" Brick	2.94
Basic Wall: Generic - 9" Brick	99.94	Basic Wall: Generic - 9" Brick	22.76	Basic Wall: Generic - 9" Brick	260.56
Basic Wall: Generic - 9" Brick	11.1	Basic Wall: Generic - 9" Brick	164.31	Basic Wall: Generic - 9" Brick	28.95
Basic Wall: Generic - 9" Brick	218.25	Basic Wall: Generic - 9" Brick	18.26	Basic Wall: Generic - 9" Brick	153.28
Basic Wall: Generic - 9" Brick	24.25	Basic Wall: Generic - 9" Brick	571.56	Basic Wall: Generic - 9" Brick	17.03
Basic Wall: Generic - 9" Brick	93.06	Basic Wall: Generic - 9" Brick	63.51	Basic Wall: Generic - 9" Brick	179.5
Basic Wall: Generic - 9" Brick	10.34	Basic Wall: Generic - 9" Brick	211.75	Basic Wall: Generic - 9" Brick	19.94
Basic Wall: Generic - 9" Brick	171.19	Basic Wall: Generic - 9" Brick	23.53	Basic Wall: Generic - 9" Brick	378.12
Basic Wall: Generic - 9" Brick	19.02	Basic Wall: Generic - 9" Brick	557.19	Basic Wall: Generic - 9" Brick	42.01
Basic Wall: Generic - 9" Brick	304.19	Basic Wall: Generic - 9" Brick	61.91	Basic Wall: Generic - 9" Brick	44.34
Basic Wall: Generic - 9" Brick	33.8	Basic Wall: Generic - 9" Brick	206.25	Basic Wall: Generic - 9" Brick	4.93
Basic Wall: Generic - 9" Brick	913.94	Basic Wall: Generic - 9" Brick	22.92	Basic Wall: Generic - 9" Brick	44.34
Basic Wall: Generic - 9" Brick	4.93	Basic Wall: Generic - 9" Brick	145.38	Basic Wall: Generic - 9" Brick	57.56
Basic Wall: Generic - 9" Brick	121.69	Basic Wall: Generic - 9" Brick	117.22	Basic Wall: Generic - 9" Brick	6.4
Basic Wall: Generic - 9" Brick	13.52	Basic Wall: Generic - 9" Brick	13.02	Basic Wall: Generic - 4.5" Brick	20.69
Basic Wall: Generic - 9" Brick	367.34	Basic Wall: Generic - 9" Brick	218.63	Basic Wall: Generic - 4.5" Brick	21.38

Basic Wall: Generic - 9" Brick	40.82	Basic Wall: Generic - 9" Brick	24.29	Basic Wall: Generic - 4.5" Brick	53.36
Basic Wall: Generic - 9" Brick	124.09	Basic Wall: Generic - 9" Brick	122.03	Basic Wall: Generic - 4.5" Brick	53.36
Basic Wall: Generic - 9" Brick	13.79	Basic Wall: Generic - 9" Brick	13.56	Basic Wall: Generic - 9" Brick	24.75
Basic Wall: Generic - 9" Brick	237.63	Basic Wall: Generic - 9" Brick	92.03	Basic Wall: Generic - 9" Brick	2.75
Basic Wall: Generic - 9" Brick	26.4	Basic Wall: Generic - 9" Brick	10.23	Basic Wall: Generic - 9" Brick	24.06
Basic Wall: Generic - 9" Brick	22.76	Basic Wall: Generic - 9" Brick	204.88	Basic Wall: Generic - 9" Brick	2.67
Basic Wall: Generic - 9" Brick	33.84	Basic Wall: Generic - 9" Brick	16.15	Basic Wall: Generic - 4.5" Brick	21.83
Basic Wall: Generic - 9" Brick	3.76	Basic Wall: Generic - 9" Brick	702.81		**Total: 20408.74**
Basic Wall: Generic-4.5" Brick	40.91	Basic Wall: Generic - 9" Brick	78.09		

3.2.1. Bill of Quantities for BIM / Revit Software Based Cost Estimation

BOQ sheet is prepared like Manual BOQ sheet but the difference here is that the quantities of the items are calculated by BIM / Revit Software. Quantities calculated by BIM / Revit Software [22] are more accurate than manual estimation. Total estimated cost of the project is Rs 32453745 by BIM / Revit Software cost estimation. The BOQ sheet is shown in Table 10.

Table 10 BIM / Revit Software Cost Estimation Results

Sr.no	Item Description	Unit	Quantity	UNIT COST	Total Cost
1	Brick Work in Super Structure	Cft	20408	222	4530576
2	RCC Slab	Cft	11240	360	4046400
3	Plaster Work	Sft	57025	180	10264500
4	PCC for Flooring	Cft	5170	135	698004
5	Floor Tile Work	Sft	20386	300	6115800
6	Skirting	Rft	4115	100	411500
7	Paint Work	Sft	57025	45	2566125
8	False Ceiling	Sft	20386	65	1325090
9	Doors	Sft	2375	700	1662500
10	Aluminum Work	Sft	1515	550	833250
				Total	RS-32453745

3.2.2. Levels of design based on CAD and BIM

As per the literature there are four Levels of design based on CAD and BIM which can be distinguished from each other as shown in Table 11[23]. The present research as per the literature falls in Level 1 and 2.

Table 11. Levels of BIM

Level	Description
0	Contains any kind of paper documentation, created by hand or with the aid of CAD programs.
1	Concerns documentation 2D and 3D in the form of digital files without use of a detailed database
2	Starting level of building information modelling
3	Intelligent BIM (iBIM), which makes construction management possible throughout life cycle of the design.

3.3. Cost Comparison between Revit and Manual Methods

The main purpose of the cost estimation is to find the accurate value of the project before construction. Quantities calculated by BIM / Revit Software are more accurate than manual [24]. Total estimated cost of the project by manual cost estimation is Rs 30967389 and Rs 32453745 by BIM / Revit Software as shown in Table 10. The comparison of quantities of items is shown in Figure 8. The difference of the Project cost comes out to be 4.8%. It has been found that the quantities estimated by BIM / Revit Software are more accurate due to the accuracy of the BIM / Revit software estimation [25]. The Percentage difference between Manual and BIM / Revit Software estimation in brick work, RCC Slab, Plaster Work, PCC for Flooring, Floor Tile Work, Skirting, Paint Work, False Ceiling, Doors and Aluminium Work is 4.57%, 2.61%, 7.58%, 3.27%, 1.87%, 6.73%, 8.03%, 1.87%, 0.00% and 0.00% as shown in Figure 9. The study conducted by shen and Issa (2010) [26] also showed that the BIM-assisted estimate had better performance over traditional/manual estimating methods. Both the visualization and aggregation functions of the BIM-Assisted Detailed Estimating (BADE) tool had significant impact on the performance of the detailed estimate. Study by shen and Issa

(2010) [26] further found that the more complex the estimating tasks, the clearer the advantages were of using BADE tools instead of traditional/manual estimating methods.
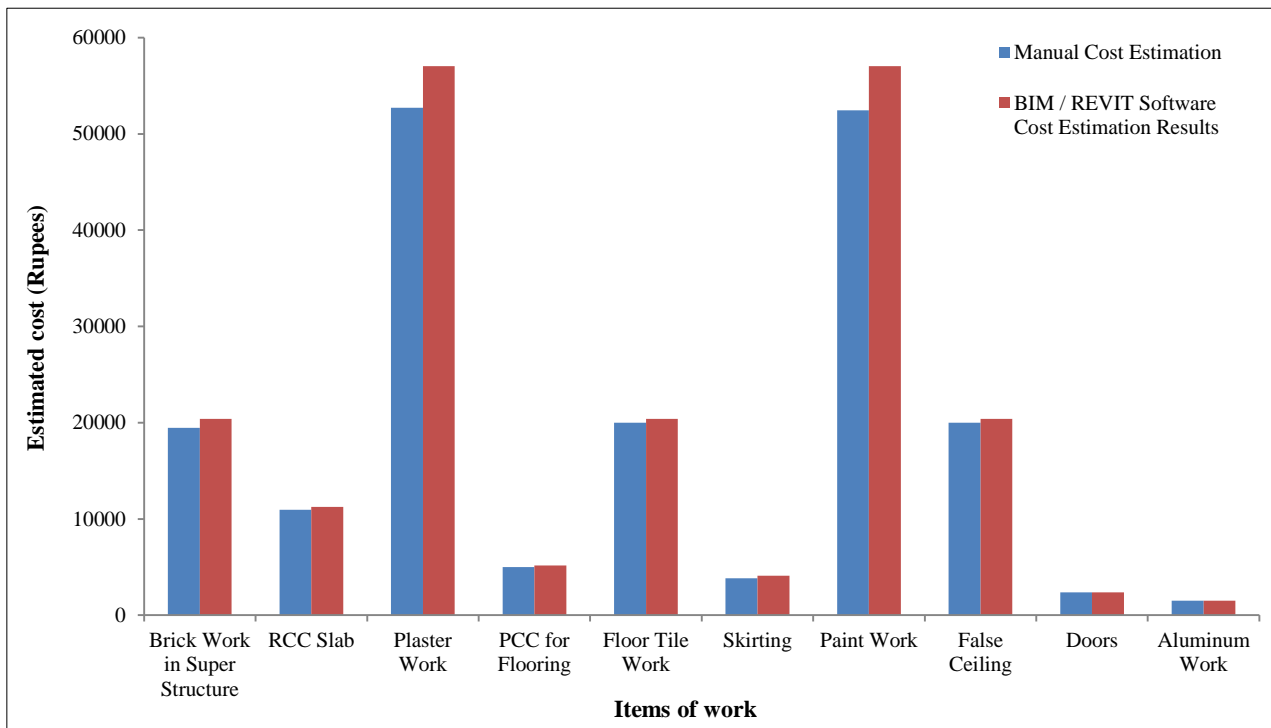

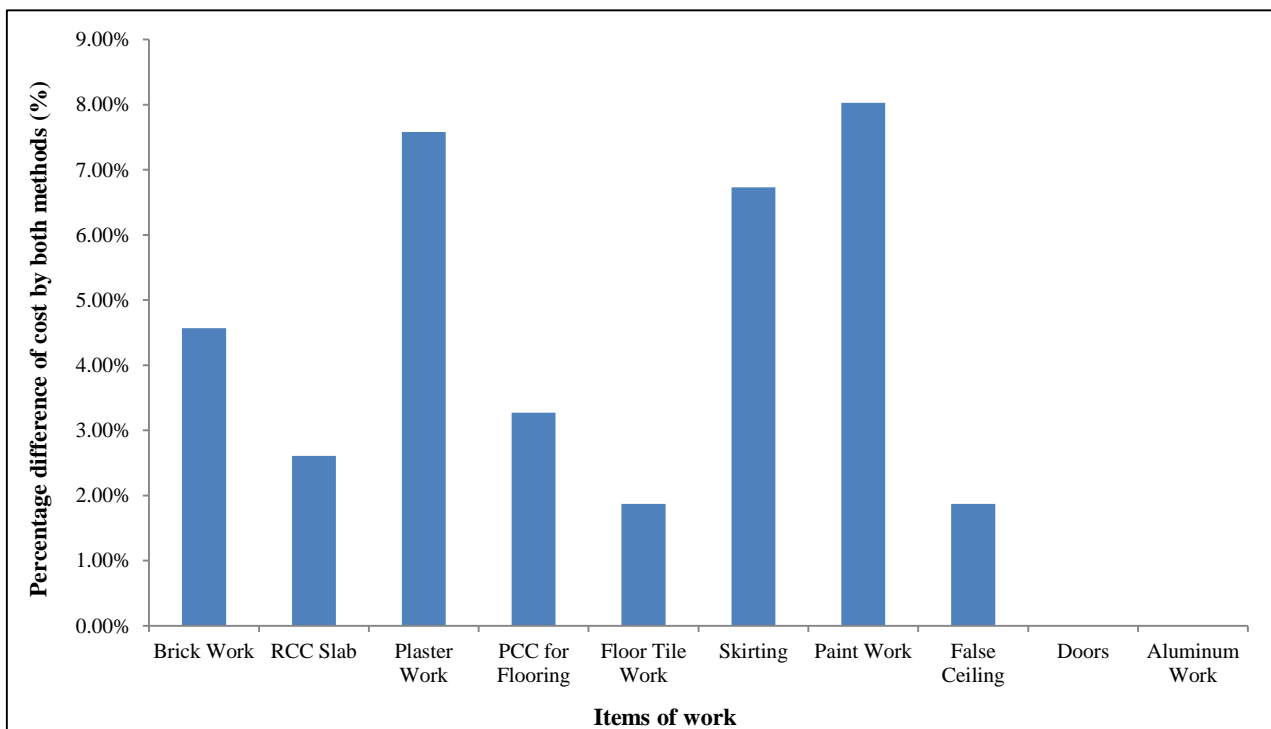**Figure 8. Comparison of cost by Manual and BIM software for each item**

Figure 9. Percentage difference of cost by both methods (%)

4. Conclusions

The following points are concluded from this research:

- Manual work is hectic, time taking and there are much chances of error, whereas estimation on Revit Software is fast, easy, efficient, automatic, and have less chances of error.

- The manual work includes manual calculation work and there are chances of error because some formulas are long and complex, while in Revit Software there is no need to calculate manually, just model can be drawn and measurements can be inserted to get material quantities.

- In manual work each task has to be considered e.g. quantities calculation, material calculation, abstract of cost etc. while in Revit software it is be automatic.

- It is difficult to rectify errors or to make changes in manual, while in Revit Software it is very easy.

- The usual practice in the field for doing manual cost estimation is that full room sizes are considered, whereas, for the BIM software cost estimation due to subtracting wall plasters, the room sizes are reduced. This causes the difference of cost for BIM based cost estimation approach.

- The other reasons for different costs of project calculated by BIM software based approach compared with manual is that finishing items such as plastering, flooring and skirting consist of quantities which are not considered in the manual cost estimate.

5. Conflicts of Interest

The authors declare no conflict of interest.

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