



Improving AEC Project Performance in Syria Through the Integration of Earned Value Management System and Building Information Modelling: A Case Study

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Abstract

The Construction sector in Syria is adversely far beyond other industries in terms of economic growth rate and technological advancements, in what makes AEC projects less committed to schedule, cost, and quality. Yet, there aren't binding criteria that stakeholders, such as contractors, and design and implementation firms might adhere to. This study explores the performance of implementing construction projects to establish a methodology to enhance schedule and cost performance through the use of Earned Value Management System (EVMS) and Building Information Modelling (BIM). This research will be key in determining key mechanisms and approaches in regards to AEC project management to improve project performance and achieve optimal efficiency regarding cost, schedule, and scope of the projects. A case study will be conducted through stages, starting with redoing the project using BIM; then using EVMS to track the schedule of the project; and finally ending with a comparison between the traditional methodology. The study suggests new methodology to the AEC projects in Syria to enhance cost and schedule performance, in addition to quantity surveying, using the EVMS and BIM. This study will constitute a cornerstone for researchers to enhance construction project management practices by using EVMS and BIM, for it is a new field of research in Syria that will help decision makers in the AEC industry to adopt a new methodology that improves upon the construction sector situation. Finally, this study will pave the way to contribute in the establishment of BIM standards and EVMS guidelines.

Keywords: Earned Value Management System (EVMS); Building Information Modelling (BIM); Cost performance; Schedule performance; Project Controls; Primavera P6; Autodesk Revit

1. Introduction

The majority of AEC projects are in danger of schedule and cost overruns due to many problems, including contractual agreements, design procedures, and other difficulties during the implementation of the project [1, 2]. A project, to be successful, depends on different characteristics related to the project manager's experience; the project team harmony; and the level of planning, monitoring, and control, where the availability of resources isn't the only key factor for the project to succeed, but rather a suitable management system is of the most important factors for a project to succeed, and that's through setting aims, standards, and procedures, in addition to assigning clear and defined responsibilities for each individual [3]. There are different criteria, according to some studies, to measure the performance of projects, of which the most important are schedule and cost performance [4, 5]. Yet, knowing success factors isn't enough, it rather more important to study the adversely

affecting factors on project performance, which are classified into different categories according to literature; such as physical or human-related factors [6, 7, 8], environmental or natural factors [9], design-related factors [9, 10], logistics-related factors [6, 8], financial factors [6, 8, 10, 11], legal, political and administrative factors [9], project direct implementation related factors, such as the difference between actual and contractual quantities, design changes, problems with subcontractors, and not documenting change orders [6, 7, 8], of which (change orders) one of the major leading factors is inaccurate contracts [12]. Also, work site is an important factor to study, where it is key that the work site is well-prepared to achieve tasks within the best possible work environment depending on the surrounding environment [14]. Effects of weather, whether direct or indirect, should be considered, too [15], alongside the quality of used materials to achieve the desired work quality [16], because achieving contracted-upon quality is key to the customer satisfaction, where Industrial Building System (IBS) might be used in this case [17], and for the long-term investments [18]. Finally, insufficiently-detailed requirements can be of an adverse effect on the project performance, mainly for the complicated direct and indirect relationship with all the factors that might lead to a less-satisfying project performance [19]. This research will help AEC project managers to enhance project schedule and cost performance, where AEC projects in Syria need such improvement due to the poor performance, especially during the economic crisis the country is going through. The case study in this paper will be a guide to help AEC professionals consider different factors in the phases of design and implementation to help the project planner save time and cost.

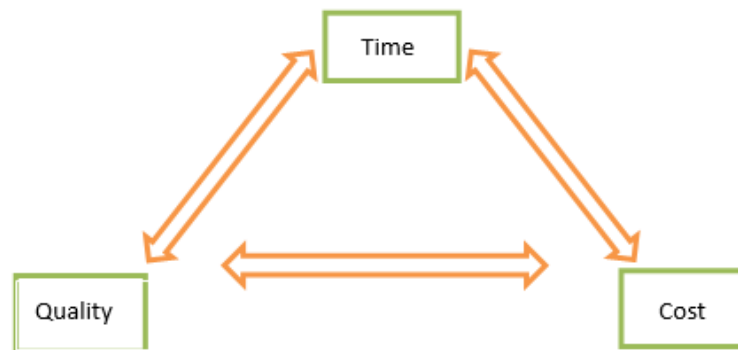


Figure 1: Triangle of project goals [5]

2. Related Work

With the mentioned problems and issues within the AEC Industry, especially the cost and schedule overruns [20], specifically in mega-projects [21]; an urgent need arose for a new methodology to address the aforementioned problems. Building Information Modelling (BIM), a system that contains all possible information about a building, such as engineering dimensions, quantities, and properties [22]. [21] defined BIM as an effective environment that all stakeholders participate in to deliver a more innovative project. The adoption of BIM has dramatically increased in the last couple of decades [23], for it proved efficiency and effectiveness in the AEC industry, where it enhanced the performance of projects [24], which led to more demand for implementing projects with BIM, and provoked Academic researchers to integrate BIM in the educational curriculum and courses [25]. Countries that use BIM are in different phases of BIM implementation and adoption [26]. For example, developing countries are in the early phases of BIM implementation, mainly due to lack of awareness of BIM [27], and the absence of engineering training and qualification [25]. [28] indicated that BIM is rarely adopted on the governmental level, especially in the unindustrialized countries. For example, in Syria, the majority of public administration employees do not know what BIM is [18]. Moreover, most AEC project work is performed using traditional methods [29]. Therefore, [25] proposed setting standards for engineering education and training, and [30] demonstrated that during the training process, the surrounding environment is key to make education and training more effective. However, training is not everything about BIM application and adoption, but there must be clear and detailed procedures based on solid methodology and standards [31]. After BIM adoption is

done, BIM maturity should be assessed [32], where [33] suggested that governments should support the adoption and implementation of BIM by enacting mandatory regulations mandating the use of BIM, and [34] emphasised this requirement from the perspective of educational institutions through creating educational programmes that support the process of adopting BIM.

Earned Value Management (EVM) is defined as a methodology that combines schedule, resources, and scope to evaluate the performance and progress of the project [35]. Also, [36] considered EVM a method of Project Performance Measurement (PPM) into which the three key components of the project, namely, cost, schedule, and scope. But [37] suggests that scope isn't directly regarded with EVM, where to successfully define work scope one should have completed work packages adequate to the project requirements and specifications. EVM is an advantageous methodology to follow-up on project progress and performance when considering project schedule and cost, where it can also serve as a forecasting tool to expect how the project results will look like [37]. In addition, it is a tool that benefit in modifying the project strategy depending on the planned objectives to be suited to the work environment [38, 39].

To successfully conduct EMV monitoring, there are key parameters that need to be assessed [40]. Figure 2 shows key parameters to consider in EVM.

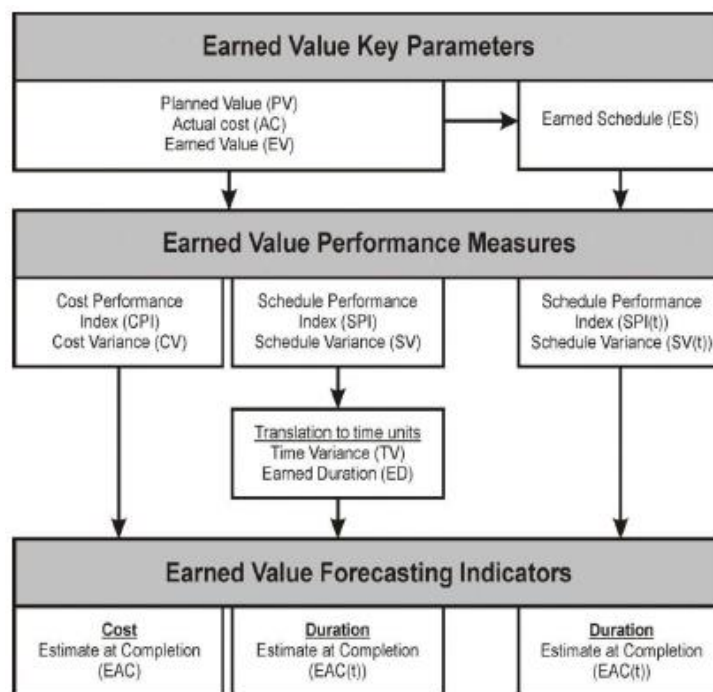


Figure 2: EVMS key parameters [39]

After obtaining BCWP, BCWS, and ACWP, Cost Variance (CV)/Cost Performance Index (CPI), Schedule Variance (SV)/Schedule Performance Index (SPI) are calculated [41]. The aforementioned parameters are defined by [37] as follows:

$$\text{Budgeted Cost of Work Scheduled (BCWS) / Planned Value (PV)}$$

The aggregate financial allocations of all work packages projected to be completed within a specific timeframe.

Budgeted Cost of Work
Performed (BCWP) /
Earned Value (EV)

The total value of the allocated budget for the completed work units and the work packages that are under ongoing work.

Actual Cost of Work
Performed / Actual Cost

The realized expenses related to the completion of tasks within a specified timeframe.

Performance Measurement
Baseline

The BCWS, represented by the sum of all work packages for each period, which is computed for the EV analysis for the entire project duration.). This serves as the time-phased budget plan that is utilized as a benchmark for evaluating project performance.

Schedule Variance (SV)

The measure of the deviation between the work performed BCWP and the work scheduled BCWS. It is calculated by subtracting BCWS from the BCWP for a given period as a dollar value, providing an indication of whether the project is with the schedule or behind it in terms of its budgeted cost.

Cost Variance (CV)

Refers to the variation between the projected cost of the completed work (BCWP) and the paid cost for the work (ACWP), indicating the actual monetary amount by which a project is exceeding or falling below its estimated cost.

Estimate at Completion
(EAC)

The expected total project expenses, which is determined by evaluating project progress and identifying potential risks. During the initial stages of the project, BAC and EAC are identical. However, changes in actual costs incurred (ACWP) versus planned costs (BCWP) will cause the EAC to deviate from the BAC.

Estimate to Complete (ETC)

Refers to the projected expenses required to finish the project at any given point and can be calculated by the difference between EAC and AC.

The variance at completion (VAC)

Indicates the monetary deviation from the project budget and is calculated by subtracting the earned value from the budget at completion. The VAC represents the projected amount that the project will be over or under budget.

Cost Performance Indicator (CPI) measures the effectiveness of the resource’s usage in the project. CPI is equal to either BCWP/ACWP or Earned Value (EV)/Actual Cost (AC). Also, Schedule Performance Indicator (SPI) measures the time-related project development. It equals to (EV/PV) [42]. [43] illustrated PV, EV, and AC curves, in addition to the variances of cost and schedule in Figure 3.

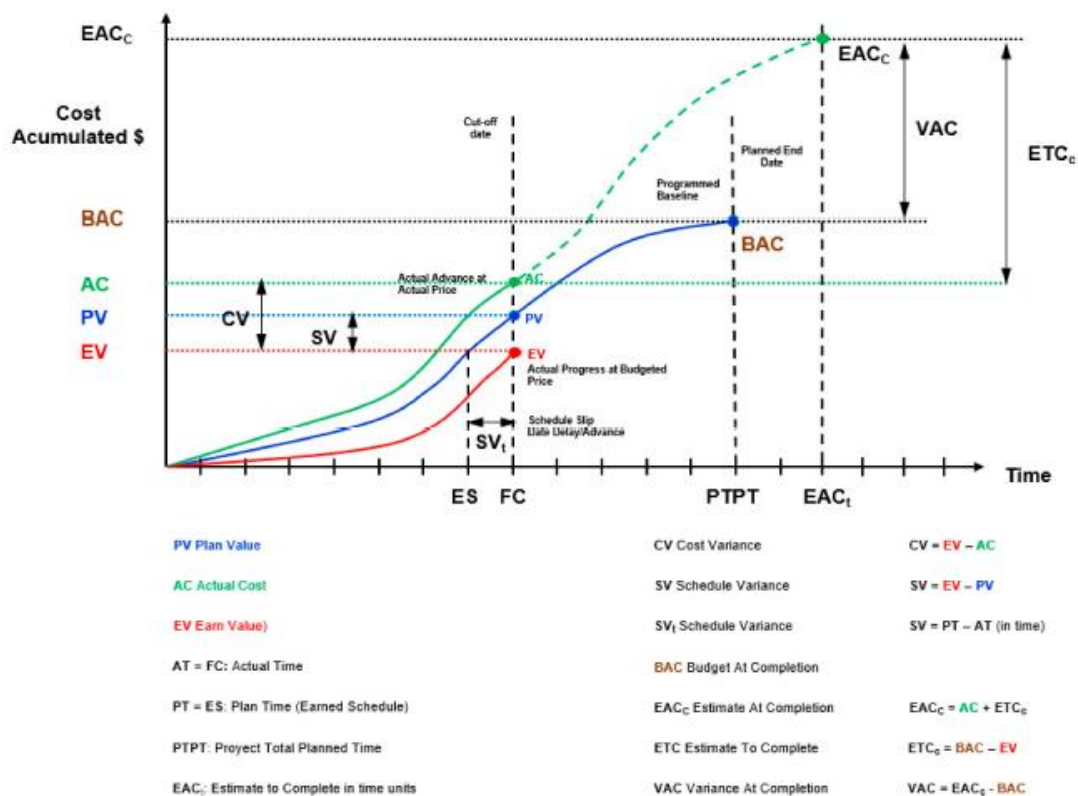


Figure 3: PV, EV, and AC curves, and cost and schedule variations [43]

[44] created a summary for EVA formulas as follows:

Cost performance Index (CPI)

$CPI = \frac{BCWP}{ACWP}$	cost performance index (CPI)
$BCWP = CPI \times ACWP$	budgeted cost of work performed (BCWP)
$ACWP = \frac{BCWP}{CPI}$	actual cost of work performed (ACWP)

Schedule performance Index (SPI)

$SPI = \frac{BCWP}{BCWS}$	schedule performance index (SPI)
$BCWP = SPI \times BCWS$	budgeted cost of work performed (BCWP)
$BCWS = \frac{BCWP}{SPI}$	budgeted cost of work scheduled (BCWS)

Cost Variance (CV)

$CV = BCWP - ACWP$	cost variance (CV)
$BCWP = CV + ACWP$	budgeted cost of work performed (BCWP)
$ACWP = BCWP - CV$	actual cost of work performed (ACWP)

Schedule Variance (SV)

$SV = BCWP - BCWS$	schedule variance (SV)
$BCWP = SV + BCWS$	budgeted cost of work performed (BCWP)
$BCWS = BCWP - SV$	budgeted cost of work scheduled (BCWS)

$VAC = BAC - EAC$	variance at completion (VAC)
$BAC = VAC + EAC$	budget at completion (BAC)
$EAC = BAC - VAC$	estimate at completion (EAC)

Authors in [45], in the new car dealership with an area of 40,000 square feet, proposed the development of an integrated system for cost and schedule control (ITCMS), where an Earned Value Management platform has been used within a virtual environment in the stages of planning and construction. The project was modelled using "Autodesk Revit 2013" software due to the integration process it provides for structural, architectural, electrical, and MEP models in a single central 3D model, leading to an improved coordination between team members during planning and construction stages. The model then was exported to "Autodesk Quantity Takeoff" software to establish cost and

time estimates, and then “Microsoft Project” software was used to track project progress, in addition to the use of “Microsoft Excel” software to obtain Earned Value Indicators. The project results were promising, where this system enables sharing information at the early stages of the project, in addition to the total management of time and cost. this system also is beneficial in the design stage, where the model can be integrated with time and cost, in addition to detecting clashes that might occur. The elements in the project after applying the workflow were decreased from 826 to 824 elements, where two steel elements were deleted due to the clashes between different specializations. Therefore, the project period was less, but not significantly, where it became 121.67 days instead of 121.75 days. This update led to a reduction in cost from \$2,592,346.88 to \$2,591,212.80. Figure 4 shows the Planned Value (PV) retrieved from “Microsoft Project” software to show the financial level of accomplishment (Axis Y, \$) that the project would fulfill based on the planned values at any time, where a measurement was done twice a month to conduct the precise earned value management. After getting the PV curve, updated EMV curves were obtained and shown in Figure 5, where Figure 5(a), the progress is behind expectations. The EV (red) and the AC (green) curves are almost the same. Figure 5(b) demonstrates that the performance of Performance Index of the schedule (SPI-blue) and the Performance Index of the cost (CPI-red) vary during the project, where the SPI illustrates that schedule performance isn’t constant, the thing that needs to be taken more into consideration by the construction project manager.

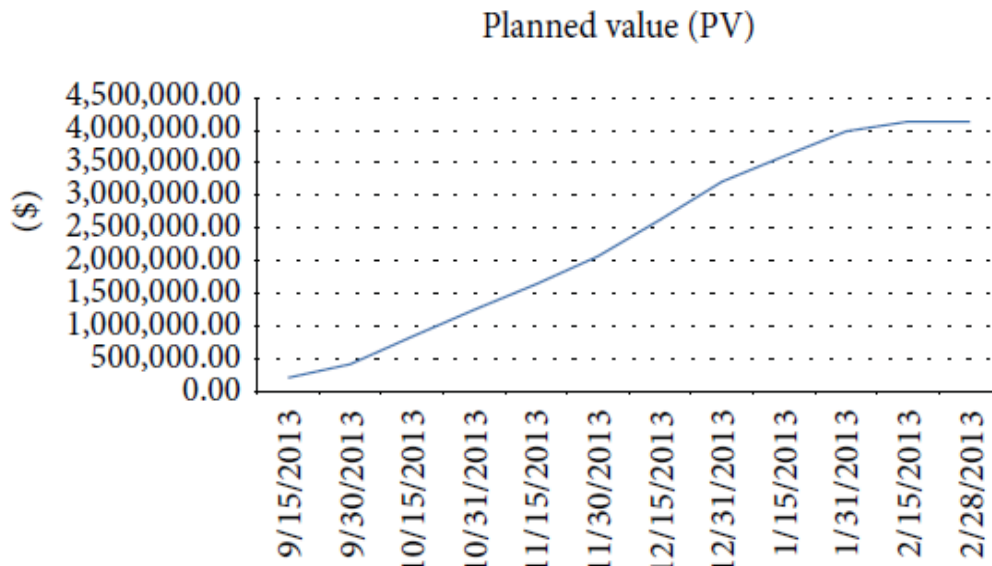


Figure 4: Planned value curve [45]

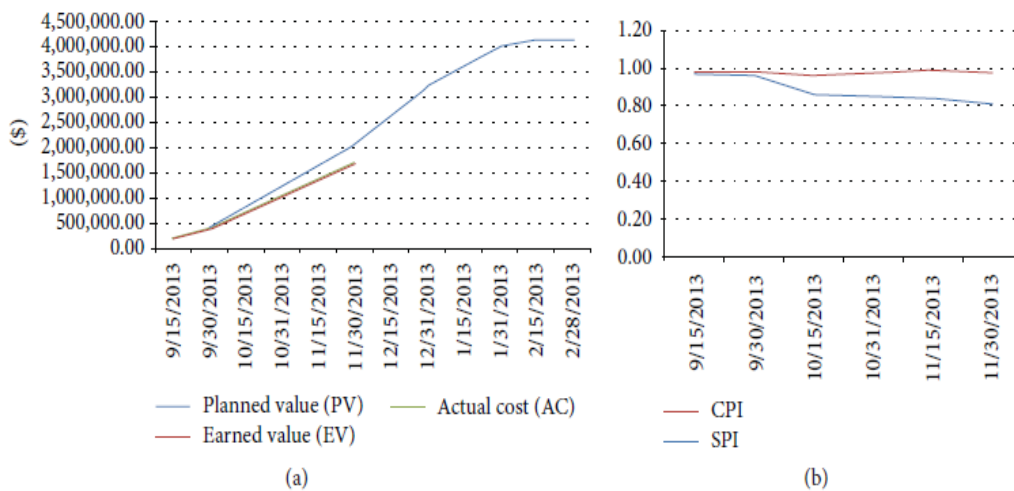


Figure 5: Updated EMV Curves [45]

[46] provided an OpenBIM software programme “COST-BIM” that integrates BIM and EVM. The software programme was designed using “Java” language of programming and “NetBeans 8.0.1” development environment. “Autodesk Revit” and “Autodesk Navisworks,” which are considered BIM software applications, were also used in this study. The programme manages the schedule and budget of the project during the phases of design and construction in one interface that contains 4 modules and 15 processes. Results were validated and checked by using a real project for social interest housing “Vivienda de Interés Social VIS.” The project has 18 towers, 6 floors each with 4 apartments in each floor, thus, a total of 432 units of an area of “23456 m^2 ”. The schedule and budget of two towers has been analysed from the foundations to the roof for the sole purpose of validation simplicity. Budget, schedule, and earned value indicators that were obtained from “Microsoft Excel” software were compared to the ones obtained from the COST-BIM software. Budget through using “COST-BIM” reduced from \$1,458,464.933 to \$1,446,108.083 due to the reduction in steel reinforcement. Also, project duration dropped from 349 days to 334 days with a percentage of 4.3%, where the “COST-BIM” software didn’t take into consideration scheduling off days according to the Colombian schedule, the thing that should be improved in the versions to be issued in the future. The software helped reduce negative scenarios through defining the activities that might cause deviations in project budget and schedule. Moreover, the “COST-BIM” is useful for construction managers during design, planning and construction phases, significantly more useful in the construction, monitoring, and decision-making process.

[47] introduced BIM as a promising technology for the construction sector combined with Earned Value Analysis (EVA) to obtain an early warning model for cost and schedule risks (BIM-CPCREWM) to effectively manage construction project risks. The model consists of 3 processes: input, data process, and output as illustrated in figure 6. The 3D model and Bill of Materials (BOM) were exported to “Autodesk Revit 2014” to be compared with the primary design of the early warning model, in addition to using C++ programming language and “SQL Server 2018” as a database. To check and validate the model, a famous hospital in China was used as a case study of a planned cost of \$550 million, where the civil works construction was estimated at \$283 million. The project is 4 floors underground, and 22 floors above the ground, in a total area under construction of 62 million m^2 . The resulted model gave detailed information about construction works delays and going over the budget, thus it helps in considering risk-response strategies that might mitigate such effects. The research concluded that BIM can play a vital role in providing detailed data about the cost and schedule of the project for the early warning model, and in dynamically showing the results of construction site risks.

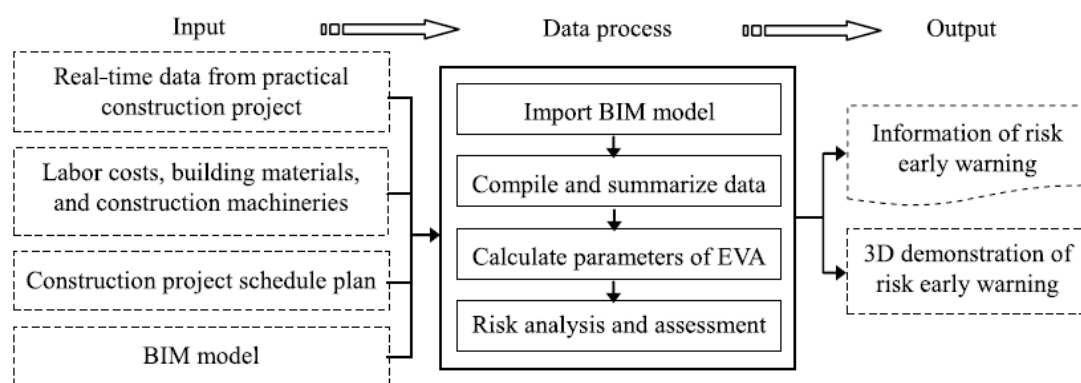


Figure 6: BIM-CPCREWM Framework [47]

3. Research Methodology

The research will build upon the literature about the integration between BIM and EVM to conduct a study on a residential building project in Hims city in Syria, which is a 6-storey building with a floor area of 187 m^2 and floor height of 3.2 metres. The inputs for the project will be Work Breakdown Structure, the Revit model, and changes in executed works. After creating the 3D model, a schedule will be done with adding costs. The main outputs will be a model for time and cost, Earned Value Management model, and 5D model. Where EVM indicators for cost and time will be established, in addition to an updated model for schedule and budget, and updated 4D and 5D models. The project

data was collected for the study and design company, where a meeting was arranged with the company's project manager to get detailed information about the project and the difficulties they have faced. At first, the model was created using "Revit 2020." The schedule was done using "Primavera P6," and the quantities obtained from "Revit" were used in "Primavera" to help set the planned prices. Finally, Earned Value Management was used to track performance of the project. Figure 7 demonstrates the workflow in this study. The authors focused on the scheduling and performance monitoring stages, where the design stage's most important part was the final 3D Revit model that is a basis for precise cost estimates because of the precise quantity estimation and the clash-free model.

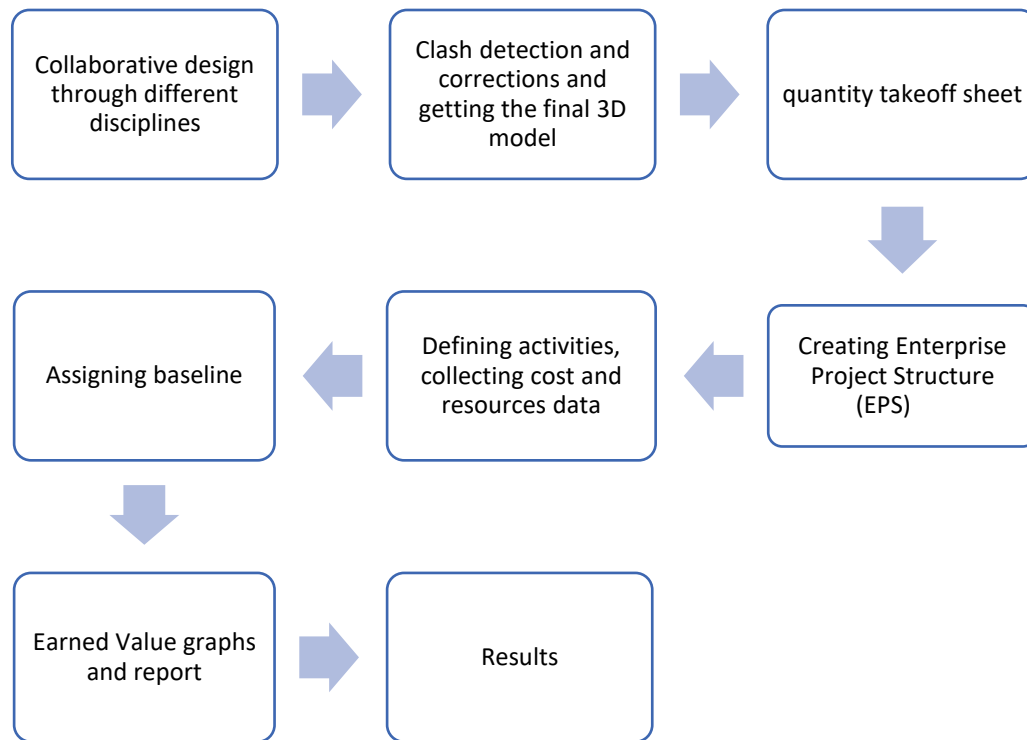


Figure 7: Methodology Workflow

4. Case study

The project is a 6-storey building with a floor area of 187 m^2 and floor height of 3.2 metres. Each floor has two apartments. The structural bearing is a 25 cm hardy slab, 20*50 cm columns, and shear walls of a thickness of 10 cm. The foundations are isolated foundations, and foundation level is at -2.35 m. the level of the ground floor is at +0.75 m.



Figure 8: the 3D model using Revit 2020

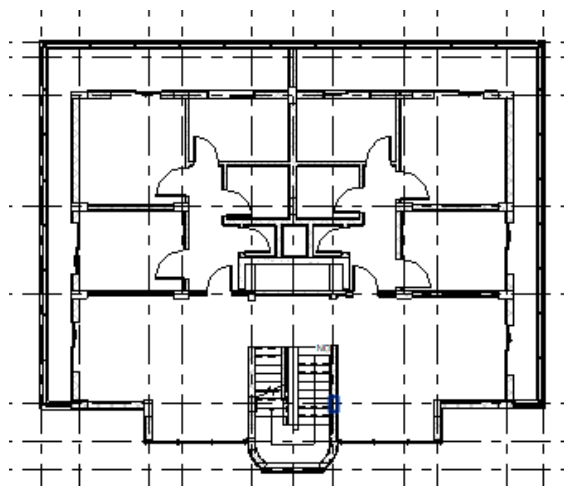


Figure 9: Plan of ground floor

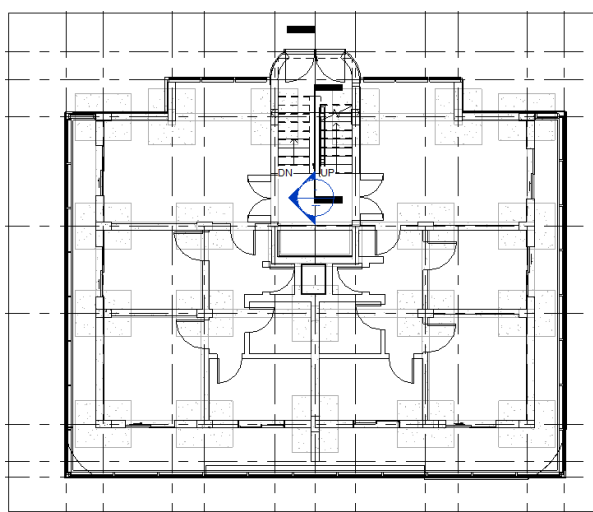


Figure 10: Plan of typical floors

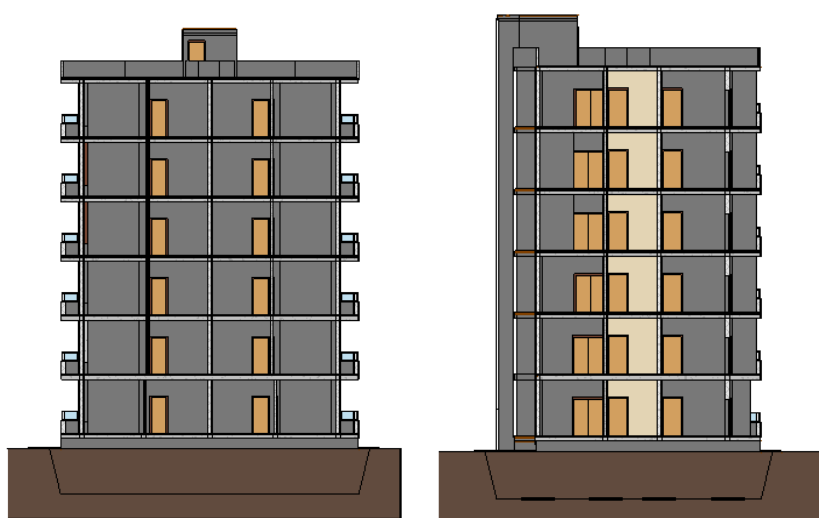


Figure 11: Vertical Sections

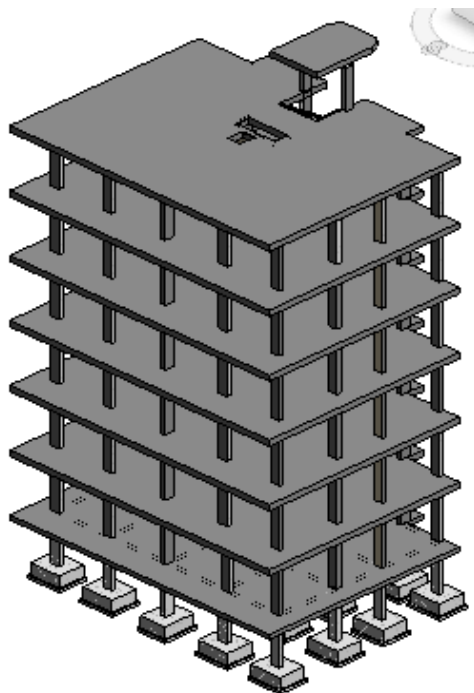


Figure 12: Structural Model

<Floor Material Takeoff>			
A	B	C	D
Level	Area	Material Name	Material Area
entry	11 m ²	Concrete, Cast-in-Place gray	11 m ²
Concrete, Cast-in-Place gray: 1			11 m ²
entry	11 m ²	Plaster	22 m ²
Plaster: 1			22 m ²
entry	106 m ²	Rubber, Silicone	106 m ²
Rubber, Silicone: 1			106 m ²
entry	187 m ²	Rubble	187 m ²
Rubble: 1			187 m ²
entry	11 m ²	Steel, Paint Finish, Ivory, Matte	11 m ²
Steel, Paint Finish, Ivory, Matte: 1			11 m ²
entry	187 m ²	Stone	218 m ²
Stone: 1			218 m ²
entry	11 m ²	Travertine	11 m ²
Travertine: 1			11 m ²
entry: 7			566 m ²
G.F	187 m ²	Concrete, Cast-in-Place gray	187 m ²
Concrete, Cast-in-Place gray: 1			187 m ²
G.F	187 m ²	Plaster	187 m ²
Plaster: 1			187 m ²
G.F	187 m ²	Stone	201 m ²
Stone: 1			201 m ²
G.F	187 m ²	Travertine	187 m ²
Travertine: 1			187 m ²
G.F: 4			763 m ²
1	187 m ²	Concrete, Cast-in-Place gray	187 m ²
Concrete, Cast-in-Place gray: 1			187 m ²

Figure 13: Quantity Takeoff using Revit

<Structural Foundation Schedule>		
A	B	C
Type	Count	Volume
150mm Foundation Slab	21	10.67 m ³
150mm Foundation Slab: 2	21	10.67 m ³
Bearing Footing - 900 x 30	3	1.18 m ³
Bearing Footing - 900 x 30	3	1.18 m ³
F 150*180*60	20	32.40 m ³
F 150*180*60: 20	20	32.40 m ³
Grand total: 44	44	44.25 m ³

<Door Schedule>		
A	B	C
Level	Type	Count
top of found	M_Door-Curtain-Wall-Double-Glass	1
M_Door-Curtain-Wall-Double-Glass: 1		1
top of found: 1		1
G.F	d 200*80	8
d 200*80: 8		8
G.F	d 200*90	4
d 200*90: 4		4
G.F	d 200*150	2
d 200*150: 2		2
G.F	double sliding 160*200	6
double sliding 160*200: 6		6
G.F: 20		20
1	d 200*80	8
d 200*80: 8		8
1	d 200*90	4
d 200*90: 4		4
1	d 200*150	2
d 200*150: 2		2
1	double sliding 160*200	6
double sliding 160*200: 6		6
1: 20		20
2	d 200*80	8
d 200*80: 8		8
2	d 200*90	5
d 200*90: 5		5

Figure 13: Quantity Takeoff using Revit (cont.)

<Window Schedule>		
A	B	C
Level	Type	Count
G.F	0915 x 1220mm	1
G.F	0915 x 1220mm	1
0915 x 1220mm: 2		2
G.F: 2		2
1	0915 x 1220mm	1
1	0915 x 1220mm	1
0915 x 1220mm: 2		2
1: 2		2
2	0915 x 1220mm	1
2	0915 x 1220mm	1
0915 x 1220mm: 2		2
2: 2		2
3	0915 x 1220mm	1
3	0915 x 1220mm	1
0915 x 1220mm: 2		2
3: 2		2
4	0915 x 1220mm	1
4	0915 x 1220mm	1
0915 x 1220mm: 2		2
4: 2		2
5	0915 x 1220mm	1
5	0915 x 1220mm	1
0915 x 1220mm: 2		2
5: 2		2

<Structural Column Schedule>		
A	B	C
Base Level	Type	Count
top of found	C 25*50	20
top of found: 20		
G.F	C 25*50	21
G.F: 21		
1	C 25*50	21
1: 21		
2	C 25*50	21
2: 21		
3	C 25*50	21
3: 21		
4	C 25*50	21
4: 21		
5	C 25*50	21
5: 21		
6	C 25*50	2
6: 2		
Grand total: 148		

Figure 13: Quantity Takeoff using Revit (cont.)

<Wall Material Takeoff>		
A	B	C
Base Constraint	Material: Name	Material: Area
top of found	Concrete, Cast-in-	12 m ²
Concrete, Cast-in-Place gray: 3		12 m ²
top of found: 3		12 m ²
entry	Concrete Masonry	62 m ²
Concrete Masonry Units: 4		62 m ²
entry	Plaster	115 m ²
Plaster: 4		115 m ²
entry	Steel, Paint Finish,	57 m ²
Steel, Paint Finish, Ivory, Matte: 4		57 m ²
entry	Stone	58 m ²
Stone: 2		58 m ²
entry: 14		292 m ²
G.F	Ceramic Tile	99 m ²
Ceramic Tile: 14		99 m ²
G.F	Concrete Masonry	290 m ²
Concrete Masonry Units: 40		290 m ²
G.F	Concrete, Cast-in-	15 m ²
Concrete, Cast-in-Place gray: 3		15 m ²
G.F	Plaster	588 m ²
Plaster: 41		588 m ²
G.F	Steel, Paint Finish,	373 m ²
Steel, Paint Finish, Ivory, Matte: 42		373 m ²
G.F	Stone	146 m ²
Stone: 19		146 m ²

Figure 13: Quantity Takeoff using Revit (cont.)

Primavera schedule

Work Breakdown Structure was fully detailed to insert as many as detailed activities to have a monitoring process of a high number of units to make sure that the results are precise.

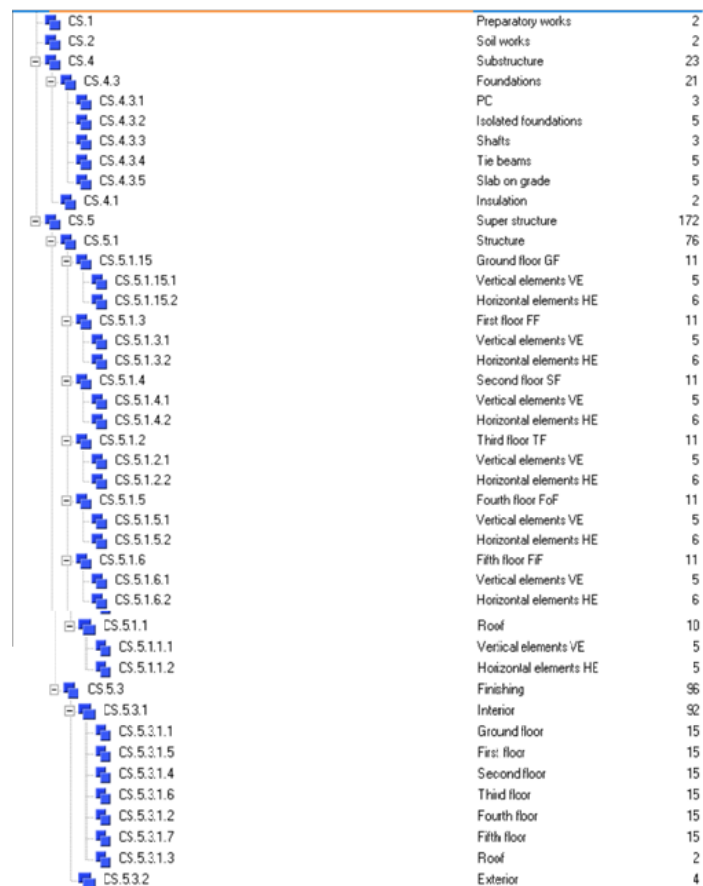


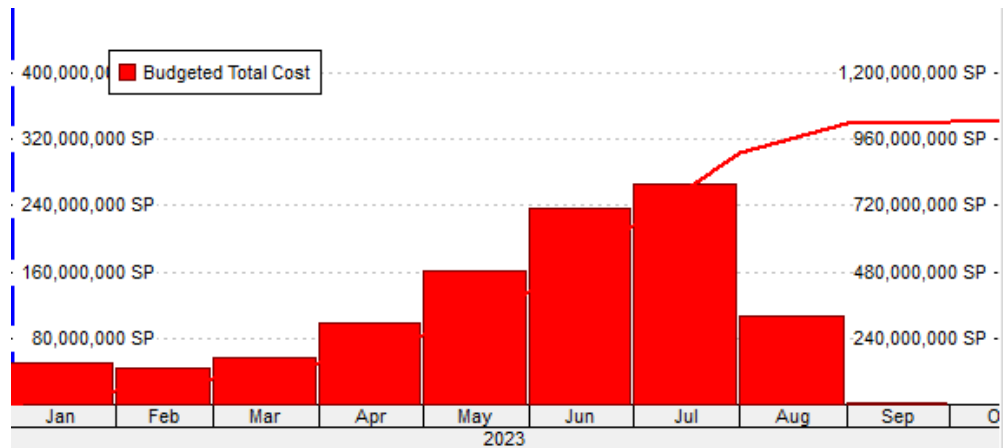
Figure 14: WBS by Primavera P6

Activity ID	Activity Name	Original Duration	Start	Finish
Total		212d	2-Jan-2023	5-Sep-2023
Residential Building		212d	2-Jan-2023	5-Sep-2023
A14120	Indirect costs	212d	2-Jan-2023	5-Sep-2023
Preparatory works		10d	2-Jan-2023	13-Jan-2023
A6000	Site preparation	10d	2-Jan-2023	13-Jan-2023
A1390	surveying	2d	5-Jan-2023	7-Jan-2023
Soil works		31d	8-Jan-2023	12-Feb-2023
A1000	Excavation	5d	8-Jan-2023	12-Jan-2023
A6010	Backfilling	4d	8-Feb-2023	12-Feb-2023
Substructure		90d	2-Jan-2023	28-Feb-2023
Foundations		50d	2-Jan-2023	28-Feb-2023
PC		3d	14-Jan-2023	16-Jan-2023
A6020	PC formwork	1d	14-Jan-2023	14-Jan-2023
A1020	Pouring PC	1d	15-Jan-2023	15-Jan-2023
A6030	deshuttering foundation PC formwork	1d	16-Jan-2023	16-Jan-2023
Isolated foundations		24d	2-Jan-2023	29-Jan-2023
E10	Detailing reinforcement of foundations	7d	2-Jan-2023	9-Jan-2023
A6040	Steel fixing for foundations	7d	16-Jan-2023	24-Jan-2023
A6050	Formwork of foundations	3d	24-Jan-2023	26-Jan-2023
A1030	Pouring concrete for foundations	1d	28-Jan-2023	28-Jan-2023
A1390	Deshuttering formworks of foundations	1d	29-Jan-2023	29-Jan-2023
Shafts		5d	30-Jan-2023	4-Feb-2023
A6060	Formwork of shafts	3d	30-Jan-2023	1-Feb-2023
A6070	Pouring concrete for shafts	1d	2-Feb-2023	2-Feb-2023
A6080	Deshuttering shafts formwork	1d	4-Feb-2023	4-Feb-2023
Tie beams		22d	24-Jan-2023	18-Feb-2023
A6090	Detailing steel reinforcement for tie beams	1d	24-Jan-2023	25-Jan-2023
A6100	Sttel fixing for tie beams	1d	13-Feb-2023	13-Feb-2023
A6110	Formworks	2d	14-Feb-2023	15-Feb-2023
A6120	Pouring concrete for tie beams	1d	16-Feb-2023	16-Feb-2023
A6130	Deshuttering tie beams formwork	1d	18-Feb-2023	18-Feb-2023
Activity ID	Activity Name	Original Duration	Start	Finish
Slab on grade		13d	14-Feb-2023	28-Feb-2023
A6140	Detailing reinforcement of SoG	6d	14-Feb-2023	20-Feb-2023
A6150	Steel fixing for SoG	6d	19-Feb-2023	25-Feb-2023
A6160	Formwork of SoG	1d	26-Feb-2023	26-Feb-2023
A6170	Pouring concrete for SoG	1d	27-Feb-2023	27-Feb-2023
A1620	Deshuttering SoG formwork	1d	28-Feb-2023	28-Feb-2023
Insulation		3d	5-Feb-2023	7-Feb-2023
A1050	Isolation of foundations	2d	5-Feb-2023	6-Feb-2023
A1060	Isolation of shafts	1d	7-Feb-2023	7-Feb-2023
Super structure		165d	26-Feb-2023	5-Sep-2023
Structure		99d	26-Feb-2023	20-Jun-2023
Ground floor GF		39d	26-Feb-2023	11-Apr-2023
Vertical elements VE		9d	26-Feb-2023	7-Mar-2023
S10	Detailing steel reinforcement for VE for GF	2d	26-Feb-2023	27-Feb-2023
S20	Steel fixing for VE for GF	2d	27-Feb-2023	1-Mar-2023
A11720	Formwork of VE for GF	3d	1-Mar-2023	5-Mar-2023
A11680	Pouring concrete for VE for GF	1d	5-Mar-2023	5-Mar-2023
A11730	Deshuttering VE of GF formwork	1d	7-Mar-2023	7-Mar-2023
Horizontal elements HE		36d	1-Mar-2023	11-Apr-2023
A11690	Detailing steel reinforcement for HE for GF	6d	1-Mar-2023	8-Mar-2023
A11710	Formwork of HE for GF	4d	8-Mar-2023	12-Mar-2023
A11700	Hardy block distribution for HE for GF	2d	13-Mar-2023	14-Mar-2023
A11660	Steel fixing for HE for GF	6d	15-Mar-2023	21-Mar-2023
A11670	Pouring concrete for HE for GF	1d	22-Mar-2023	22-Mar-2023
A11650	Deshuttering HE for GF formwork	2d	10-Apr-2023	11-Apr-2023
First floor FF		38d	22-Mar-2023	4-May-2023
Vertical elements VE		8d	22-Mar-2023	30-Mar-2023
S60	Detailing steel reinforcement for VE for FF	2d	22-Mar-2023	23-Mar-2023
S50	Steel fixing for VE for FF	2d	23-Mar-2023	25-Mar-2023
A11890	Formwork of VE for FF	3d	26-Mar-2023	28-Mar-2023
A11860	Pouring concrete for VE for FF	1d	29-Mar-2023	29-Mar-2023
A11900	Deshuttering VE of FF formwork	1d	30-Mar-2023	30-Mar-2023

Figure 15: Project activities using Primavera P6

Activity ID	Activity Name	Original Duration	Start	Finish
Horizontal elements HE				
A11870	Detailing steel reinforcement for HE for FF	6d	26-Mar-2023	1-Apr-2023
A11880	Formwork of HE for FF	4d	1-Apr-2023	4-Apr-2023
A11910	Hardy block distribution for HE for FF	2d	5-Apr-2023	6-Apr-2023
A11840	Steel fixing for HE for FF	6d	8-Apr-2023	13-Apr-2023
A11850	Pouring concrete for HE for FF	1d	15-Apr-2023	15-Apr-2023
A11830	Desluttering HE for FF formwork	2d	3-May-2023	4-May-2023
Second floor SF				
Third floor TF				
Fourth floor FoF				
Fifth floor FiF				
Roof				
Finishing				
Interior				
Ground floor				
A11540	Block works for GF	12d	12-Apr-2023	25-Apr-2023
A11550	Primary level of plumbing for GF	5d	26-Apr-2023	1-May-2023
A11560	Primary level of electricity for GF	8d	26-Apr-2023	4-May-2023
A11570	Wood works for GF	2d	26-Apr-2023	27-Apr-2023
A11580	Plastering for GF	15d	6-May-2023	22-May-2023
A11590	Tile works for GF	5d	23-May-2023	28-May-2023
A12690	Ceramics works for GF	7d	23-May-2023	30-May-2023
A11600	Aluminum works for GF	4d	29-May-2023	1-Jun-2023
A11630	finishing of electrivyt works for GF	5d	29-May-2023	3-Jun-2023
A11640	Finishing of mangour works for GF	3d	29-May-2023	31-May-2023
A12700	Skirts for GF walls	2d	29-May-2023	30-May-2023
A11620	Finishing of plumbing works for GF	4d	31-May-2023	4-Jun-2023
A11610	Painting works for GF	17d	4-Jun-2023	22-Jun-2023
A12720	Electricity Accessories for GF	2d	24-Jun-2023	25-Jun-2023
A12710	Finishing of painting works for GF	6d	26-Jun-2023	2-Jul-2023
First floor				
A13250	Block works for FF	12d	6-May-2023	18-May-2023
Activity ID				
Activity Name				
Original Duration				
Start				
Finish				
Fifth floor FiF				
Roof				
Finishing				
Interior				
Ground floor				
A11540	Block works for GF	12d	12-Apr-2023	25-Apr-2023
A11550	Primary level of plumbing for GF	5d	26-Apr-2023	1-May-2023
A11560	Primary level of electricity for GF	8d	26-Apr-2023	4-May-2023
A11570	Wood works for GF	2d	26-Apr-2023	27-Apr-2023
A11580	Plastering for GF	15d	6-May-2023	22-May-2023
A11590	Tile works for GF	5d	23-May-2023	28-May-2023
A12690	Ceramics works for GF	7d	23-May-2023	30-May-2023
A11600	Aluminum works for GF	4d	29-May-2023	1-Jun-2023
A11630	finishing of electrivyt works for GF	5d	29-May-2023	3-Jun-2023
A11640	Finishing of mangour works for GF	3d	29-May-2023	31-May-2023
A12700	Skirts for GF walls	2d	29-May-2023	30-May-2023
A11620	Finishing of plumbing works for GF	4d	31-May-2023	4-Jun-2023
A11610	Painting works for GF	17d	4-Jun-2023	22-Jun-2023
A12720	Electricity Accessories for GF	2d	24-Jun-2023	25-Jun-2023
A12710	Finishing of painting works for GF	6d	26-Jun-2023	2-Jul-2023
First floor				
Second floor				
Third floor				
Fourth floor				
Fifth floor				
Roof				
A12600	Block works of roof	4d	29-Jun-2023	4-Jul-2023
A14030	Roof insulation	6d	4-Jul-2023	11-Jul-2023
Exterior				
A14040	Stone cladding of Northern Elevation	20d	18-Jun-2023	11-Jul-2023
A14050	Stone cladding of Western Elevation	25d	18-Jun-2023	17-Jul-2023
A14060	Stone cladding of Southern Elevation	15d	18-Jun-2023	5-Jul-2023
A14070	Stone cladding of Eastern Elevation	25d	18-Jun-2023	17-Jul-2023

Figure 15: Project activities using Primavera P6 (cont.)



Project Total COST	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23
02-Jan-23-5-Sep-23									
Total Cost	50,225,330	44,728,213	56,213,730	97,969,647	160,514,102	237,228,483	266,375,565	107,229,898	3,121,156
Cumulative	50,225,330	94,953,543	151,167,273	249,136,920	409,651,022	646,879,505	913,255,070	1,020,484,968	1,023,606,124

Figure 16: Budgeted monthly and cumulative costs of the project

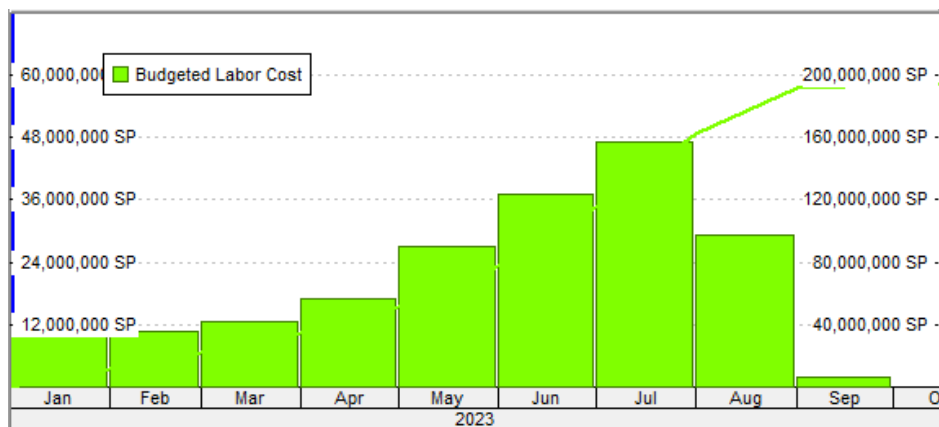


Figure 17: Budgeted monthly and cumulative costs of labour

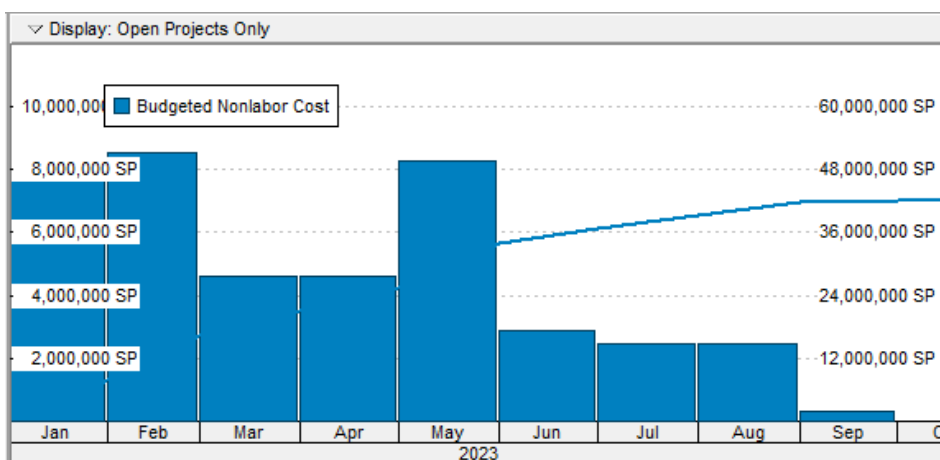


Figure 18: Budgeted monthly and cumulative costs of non-labour

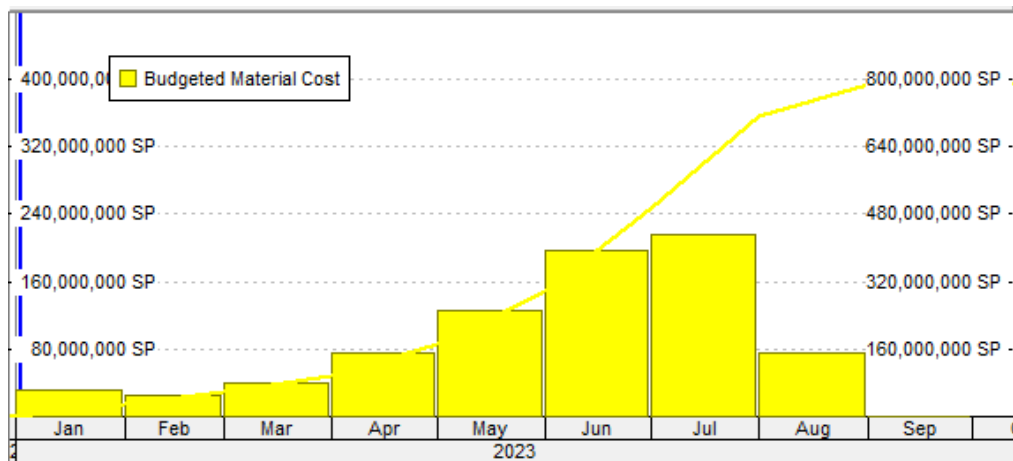


Figure 19: Budgeted monthly and cumulative costs of materials

Project performance tracking using Earned Value Management:

Project progress tracking after 4 months from the actual start, where works implemented were planned to reach hardy blocks distribution for the second floor according to the planned schedule. This planned cost was:

$$BCWS = 185,797,100 \text{ SP.}$$

The actual costs until the distribution of the hardy blocks for the second floor was:

$$ACWP = 143,803,600 \text{ SP}$$

Work executed according to the planned budget (earned value)

$$BCWP = 123,841,600 \text{ SP}$$

Cost Variance (CV):

$$CV = 123,841,600 - 143,803,600 = -199,620,000 \text{ SP}$$

Schedule Variance (SV):

$$SV = 123,841,600 - 185,797,100 = -61,955,500 \text{ SP}$$

Cost Performance Index (CPI):

$$CPI = 123,841,600 / 143,803,600 = 0.86 < 1 \text{ (OVER BUDGET)}$$

Schedule Performance Index (SPI):

$$SPI = 123,841,600 / 185,797,100 = 0.66 < 1 \text{ (BEHIND SCHEDULE)}$$

After obtaining the earned value indicators, it became possible to expect the final project cost and the remaining cost of implementation, as follows:

Estimate At Complete (EAC):

$$EAC = 1,023,606,125 / 0.86 = 1,190,239,680 \text{ SP}$$

The remaining cost and expected completion of the project (ETC):

$$ETC = 1,190,239,680 - 143,803,600 = 1,046,436,080 \text{ SP}$$

Variance At Completion (VAC) =

$$VAC = 1,023,606,125 - 1,190,239,680 = -166,633,555 \text{ SP}$$

The earned value indicators expressed a defect in the implementation process in terms of schedule and cost, but to know the exact position of the defect, the earned value indicators were analysed for each task. Some of the points at which the malfunction occurred are shown in the table (1):

Task	Planned duration days	Actual duration days	Change Percentage %	Planned cost SP	Actual cost SP	Change Percentage %
Site Preparation	10	12	20%	10000000	15000000	50%
Backfill	4	6	50%	3264000	4896000	50%
Foundation insulation	2	4	100%	612000	1368000	123.53%
Rebar detailing for the horizontal elements on the ground floor	6	12	100%	13134000	16104000	22.6%
Concrete molding for the horizontal elements on the ground floor	1	1	0	6987600	8637600	23.61%

5. Results discussion

It can be seen from table 1 that there is an obvious deviation in cost and duration, especially for the rebar detailing and foundation isolation, where the duration increased by 100% from 6 days to 12 days, and foundations isolation's cost increased by 123.53%. Such increases can be due to the inaccurate quantity takeoff and cost estimation. Also, the experience and performance of the work team is poor, in addition to the construction technology. Poor coordination and inaccurate schedule estimates are also important parts of the problem. Also, the relationship with the local authorities was a reason for such problems, where the consultant engineer refused the steel rebars submission for the ground floor slab because of the non-approval of the construction and re-work plans at first. This problem could be avoided if Revit was used from the beginning to detect and remove clashes and for quantity takeoff to obtain accurate quantities, thus leading to a precise cost estimation and accurate planning. This process would've saved a lot, especially at the implementation phase, where the waste and the misuse of resources wouldn't be present the way it is with the conventional method. Also, earned value management was important to discover where exactly the problem is. This is important for future research because it can enhance the AEC sector in Syria if committed to correctly alongside the sound engineering practices regarding work qualifications, coordination, construction technology, sound construction project management practices, because there isn't an obvious influence of project managers in the AEC sector on the decisions made during the project lifecycle.

6. Recommendations

While the construction sector in Syria needs thorough improvement in all aspects, but this research will shed the light on specific parts as follows:

- 1- Mandating the use of BIM in Syrian AEC projects, especially with the establishment and start of the Master's Programme in Building Information Modelling and Management in March 2021, and there are 37 graduates now (graduated in January 2023). This process starts with mandating 3D Revit models, where Revit proved to be effective regarding sound design and accurate quantity estimates. The BIMM Master Programme graduates should be the pioneers in this transition, where they have both the academic and professional experience to participate in the process of BIM application and adoption.

- 2- Adopting sound project management practices, starting with contractual procedures, and not ending with project delivery. These practices aren't well-presented in the Syrian AEC industry, it is rather unavailable in many cases in many companies. The use of BIM and EVM would increase the efficiency of current practices, for they enhance project total performance throughout the entire project lifecycle.
- 3- Providing solid training on EVM for project management engineers to help them monitor project's progress more effectively. This is accompanied with the need of companies to activate the role of project management engineers more in the process of making decisions in all project phases, where such practices can't be seen in construction projects in Syria due to randomization and the dominance of project funder on the whole process.

7. Conclusion

The Earned Value Management is key in enhancing project performance, this was evident in the case study in this research. The major contribution of EVM is present in improving project planning of works through reports that demonstrates exactly how task are processing throughout the project phases, each with detailed information about cost and schedule with their variations. Companies, therefore, are in need of applying EVM because of the significant record of project monetary and time overruns in Syrian construction projects. The integration of BIM during the project phases is also of a significant necessity, where some AEC companies in Syria started to adopt 3D models as the focus of the project works. The question remains "When shall the Syrian Order of Engineers set and mandate binding criteria for sound engineering practices?"

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