APPLICATION OF PROJECT PLANNING TECHINQUES:
XYZ BUILDING PROJECT

Executive Summary

Planning is a vital part of project management. Project planning starts with defining the scope of the project, creating a work breakdown structure, and defining the activities and their expected durations. The resources required to accomplish the activities also need to be estimated. The durations of the activities are depicted using a bar chart or a Gantt chart, and the interdependencies are exhibited more clearly through the project network diagram. For scheduling, the critical path method is used to estimate the minimum duration of the project, and estimate the scheduling flexibility on the network paths. The accuracy of activity duration estimates can be improved by techniques such as PERT (Program Evaluation and Review Technique) which factor uncertainty and risks in estimations. To reduce the duration of the project, crashing techniques are used. In crashing, resources are added to reduce the duration of specific activities on the critical path. For smooth running of the project, it is important to have a cash flow which meets the project requirements. Hence, it is vital that a detailed cash flow is prepared to understand the inflows and outflows expected from time to time. In this report, these planning tools are applied to a hypothetical project for construction of a single-storey commercial building. As evident from the exercise, the tools and techniques discussed above are crucial for proper project planning. Knowing the deliverables, the activities and their costs, the durations and interdependencies can help improve project management. The outputs of this exercise form the basis for other project management activities like monitoring and control.

Contents

Executive Summary 3

Introduction 5

Project & its Scope 5

Work Breakdown Structure (WBS) 5

Activity Definitions & Relationships 6

Bar Chart 7

Project Network & Critical Path Method (CPM) 8

Program Evaluation and Review Technique (PERT) 10

Crashing 11

Cash flow management 11

Conclusion 12

References 13

Introduction

According to PMI (2013), a project is a temporary endeavor, with a defined start and an end point. A project is taken up to create a unique product, service, or a result (p. 3). Project management refers to application of knowledge, skills, tools, and techniques to the various project activities in order to achieve its objectives. Project management is done through 5 process groups, namely, initiation, planning, executing, monitoring and controlling, and closing (p. 5). This report focuses on the planning process group. The planning group comprises of the processes required to establish the scope of the project, refine its objectives, and decide the actions to be taken to achieve the project objectives (p. 55). The following sections of the report focus on the project planning of a hypothetical project for construction of a single-storey commercial building. The project is called XYZ Building Project (or XYZ). The scope of the project has been defined. The Work Breakdown Structure (WBS) has been shown, the activities have been defined along with their interrelationships. Bar chart, project network, CPM and PERT methods have been applied. Crashing methods to reduce project duration have been illustrated. Cash flow management of the project has also been depicted. The project planning group forms the basis of subsequent project management activities mentioned in PMI (2013, p. 5), namely, execution and monitoring and control.

Project & its Scope

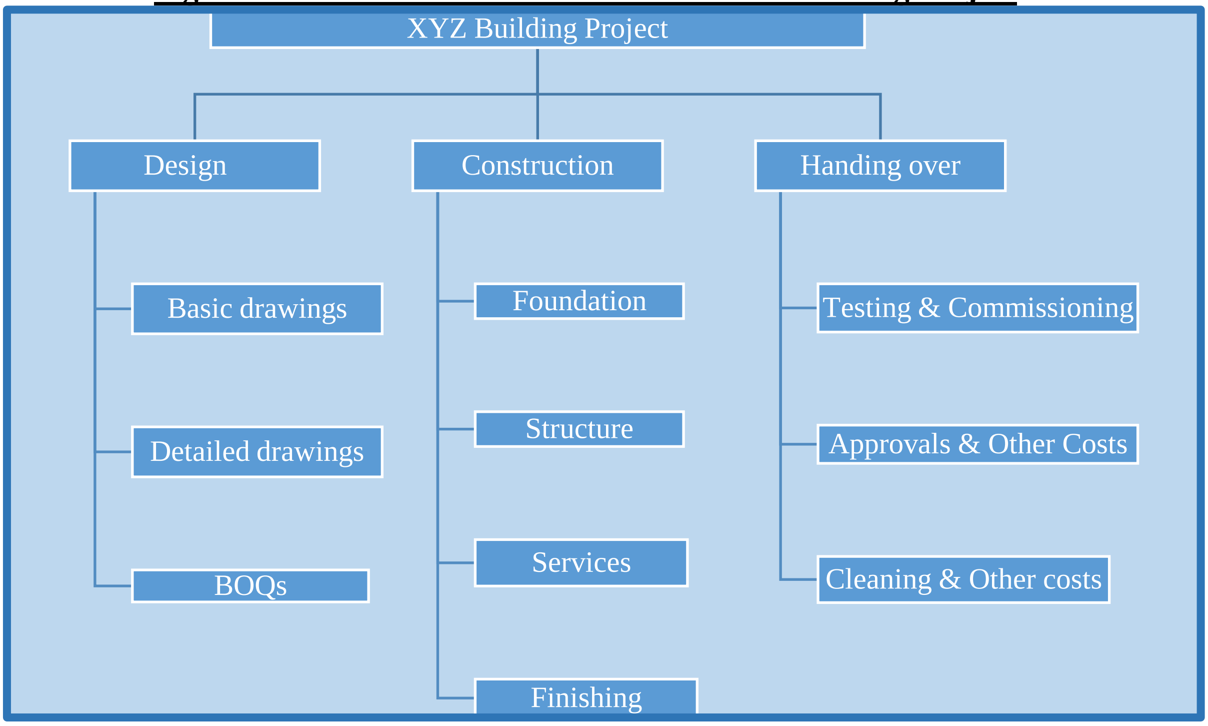
Scope of a project is defined as the work done to deliver the product, service, or result. These deliverables are the objectives of the project, and have specified features and functions (PMI 2013, p. 105). The hypothetical project under consideration is the construction of a single-storey commercial building with an internal area of 5,000 square meter. All the offices are to be on the ground floor itself. Since it is a relatively small project, the project has not been divided in construction blocks (e.g Building Block I, II etc). Broadly, the project involves design, construction and handing over of the building. The housing project example mentioned Brotherton, Fried & Norman (2008, pp. 5-12), and the commercial building project examples in Martland (2011), Marco (2011) and Taylor (2009) have been taken as a basis for understanding the main steps in which construction projects are executed. The sequence followed in construction of buildings in these examples has been largely followed. The WBS and activities defined in subsequent sections are put together based on these examples. However, the examples have been used only as a basis, and changes have been made based on common knowledge and personal experience of the group. Details of works and activities are discussed in the following sections.

Work Breakdown Structure (WBS)

According to PMI (2013), the work breakdown structure or WBS is created by subdividing project deliverables and project work into smaller, more manageable components. WBS helps create an organized vision for the project. It organizes and defines the entire project scope, and depicts the work specified in the approved scope statement. The work planned is specified in the work packages, which is the bottommost level of WBS (pp. 125-126). Lower levels of WBS are more detailed as compared to the higher levels work (p. 132). Brotherton, Fried & Norman (2008) emphasize that WBS does not describe the processes followed to execute the project. It does not elaborate the schedule either, but focuses on depicting the project outcomes or scope (p. 2).

The WBS for ZYZ is shown in figure 1. For the sake of simplicity (because 20-30 activities have to be considered), tendering process and regulatory approvals to start construction have not been considered in the WBS. Major deliverables are shown in the lowest level. For designing the project, basic drawings, detailed drawings and bill of quantities are required to be progressively created. For construction, which is the next phase, foundation is the first step. This is followed by building the structure, building services (e.g. plumbing, firefighting and heating, ventilation and Air-conditioning), and finally the testing and commissioning, approvals and cleaning to hand over the building.

Figure 1: Work Breakdown Structure of XYZ Building Project



Activity Definitions & Relationships

Defining the activities of a project involves the process of identifying and documenting the various actions required to produce the project deliverables. Sequencing of these activities helps identify and document the inter-relationships between various activities. It is important to estimate the resources and the time required for each activity (PMI 2013, p. 141). For the sake of simplicity, major activities have been considered, though it may be possible to break down the activities further. Furthermore, the resources required to accomplish the project have been denoted only in terms of the funds required to execute the activities. Manpower and equipment / infrastructure requirements have not been discussed. For estimating the cost, report of Turner & Townsend on construction costs in 2013 has been studied. According to Turner & Townsend (2014), the cost for building an office in Australia with 5,000 square meter area was $1,860 per square meter in 2013, and expected escalation for 2014 is 2%. So the total cost for 2013 was $9,300,000 and that in 2014 / 2015 can be taken as $9,486,000 in 2014 and $9,675,720 in 2015 (again taking 2% inflation). However, in Australia 12% of the cost goes on preliminaries, such as scaffolding, approvals, insurances, power and water, cleaning and handover and work supervision. Contractor margins are 4% (pp. 11-12). BMT (2014) also mentions similar estimates for construction of commercial buildings in Australia. A cost of $10,000,000 has been taken (as a round figure) for XYZ, and the breakup of the cost taken is 3% for design, 92% for construction (Foundation 10%, Structure 50%, 25% Services and finishing 7%) and 5% for handing over. The stage-wise percent breakup of the costs has been decided by studying the proportions mentioned in NAHB (2011) and Turner & Townsend (2014, p. 13). Australia is the 6th most expensive construction location in the world (ECH 2013), so costs may appear high. The activities have been defined based on the WBS for XYZ shown in Table 1.

Table 1: Activity definition - XYZ Building Project

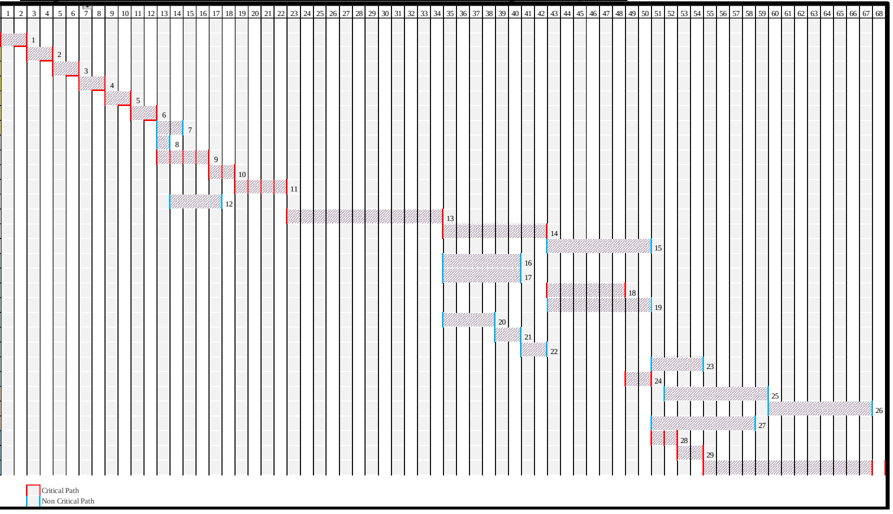
Activity ID	Activity Name	Duration (weeks)	Cost ($)	Predecessor	Relationship
0	**START**	0	-	-	-
1	Layout drawing	2	$ 30,000	Start	FS
2	Civil Drawings	2	$ 30,000	1	FS
3	Plumbing Drawings	2	$ 40,000	2	FS
4	Firefighting drawings	2	$ 50,000	3	FS
5	Electrical drawings	2	$ 50,000	3,4	FS
6	HVAC drawings	2	$ 50,000	3,4,5	FS
7	Bill of Quantities	2	$ 50,000	1,2,3,4,5,6	FS
8	Survey	1	$ 50,000	6	FS
9	Excavation	4	$ 300,000	6	FS
10	Backfilling	2	$ 150,000	9	FS
11	Foundation	4	$ 500,000	10	FS
12	Sewerage	4	$ 500,000	8	FS
13	Walls	12	$ 2,000,000	11	FS
14	Roof	8	$ 1,500,000	13	FS
15	Slab	8	$ 1,000,000	14	FS
16	Plumbing Piping	6	$ 200,000	13	FS
17	Electrical conduiting	6	$ 200,000	13	FS
18	HVAC Piping	6	$ 250,000	14	FS
19	Firefighting Piping	8	$ 200,000	14	FS
20	Electrical wiring	4	$ 200,000	13	FS
21	Electrical fittings	2	$ 250,000	20	FS
22	Plumbing fittings	2	$ 200,000	16	FS
23	Firefighting equipment	4	$ 500,000	19	FS
24	HVAC Equipment	2	$ 500,000	18	FS
25	False Ceiling	8	$ 200,000	24	FS
26	Tiling	8	$ 300,000	25	FS
27	Painting	8	$ 200,000	19	FS
28	Testing & Commissioning	2	$ 100,000	24	FS
29	Approvals & Other formalities	2	$ 300,000	28	FS
30	Cleaning & handing over	13	$ 100,000	29	FS
		TOTAL	**$ 10,000,000**		

Bar Chart

Schedule management of a project, inter-alia, requires creating a precedence diagram to show the sequence of the activities and also the inter-dependencies between various activities (PMI 2013, pp. 156-159). For XYZ, Bar chart is depicted in Figure 2.

Figure 2: Bar Chart – XYZ Building Project

ID	Activity	Start	Duration	Finish	Predecessor
0	Start	0	0	0	0
1	Layout Drawings	1	2	3	Start
2	Civil Drawings	3	2	5	1
3	Plumbing Drawings	5	2	7	2
4	Firefighting drawings	7	2	9	3
5	Electrical drawings	9	2	11	3,4
6	HVAC drawings	11	2	13	3,4,5
7	Bill of Quantities	13	2	15	1,2,3,4,5,6
8	Survey	13	1	14	6
9	Excavation	13	4	17	6
10	Backfilling	17	2	19	9
11	Foundation	19	4	23	10
12	Sewerage	14	4	18	8
13	Walls	23	12	35	11
14	Roof	35	8	43	13
15	Slab	43	8	51	14
16	Plumbing Piping	35	6	41	13
17	Electrical conduiting	35	6	41	13
18	HVAC Piping	43	6	49	14
19	Firefighting Piping	43	8	51	14
20	Electrical wiring	35	4	39	13
21	Electrical fittings	39	2	41	20
22	Plumbing fittings	41	2	43	16
23	Firefighting equipment	51	4	55	19
24	HVAC Equipment	49	2	51	18
25	False Ceiling	52	8	60	24
26	Tiling	60	8	68	25
27	Painting	51	8	59	19
28	Testing & Commissioning	51	2	53	24
29	Approvals & Other formalities	53	2	55	28
30	Cleaning & handing over	55	13	68	29



The interdependencies have been decided based on the logical sequence of activities performed during construction projects. For this, the examples given in Brotherton, Fried & Norman (2008), Martland (2011), Marco (2011) and Taylor (2009) have been studied. For example, during designing, basic layout drawings are required for creating more detailed civil drawings. Electrical drawings can be created after plumbing and firefighting drawings have been completed so that there is better alignment. Bill of quantities can be best started after all drawings have been finalized. However, revisions will surely be required after all drawings have been completed to iron out differences. Similarly, backfilling cannot be done before excavation. Walls, roofs and slabs are broadly done in this order. Electrical conduits and other piping cannot be laid before the walls have been built. Fittings can be done after conduits and pipes have been laid, and fittings and equipment (e.g. plumbing electrical, firefighting and HVAC) can be installed only after the wiring / piping work is completed. Similarly, painting can be started after the piping work is completed. Total duration of the project is 67 weeks.

Project Network & Critical Path Method (CPM)

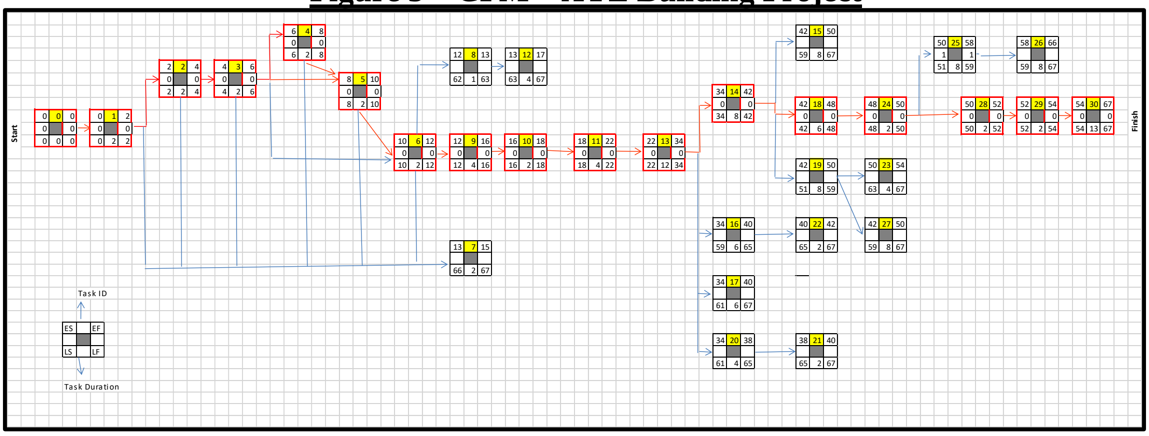
A project network diagram graphically represents of the logical relationships or dependencies between the project activities (PMI 2013, p. 159). It depicts the flow of the project. Activities are represented by boxes and the activity id is written in the box. Table 2 shows the early start (ES), early finish (EF), Late Start (LS) and Late finish dates and the critical activities. As apparent, the floats for the critical path activities is zero.

Table 2 – Calculations – Activity durations - XYZ Building Project

Activity ID	Activity Name	Duration (weeks)	Predecessor	ES	EF	LS	LF	Ctitical
0	**START**	0	-	0	0	0	0	
1	Layout drawing	2	Start	0	2	0	2	Critical
2	Civil Drawings	2	1	2	4	2	4	Critical
3	Plumbing Drawings	2	2	4	6	4	6	Critical
4	Firefighting drawings	2	3	6	8	6	8	Critical
5	Electrical drawings	2	3,4	8	10	8	10	Critical
6	HVAC drawings	2	3,4,5	10	12	10	12	Critical
7	Bill of Quantities	2	1,2,3,4,5,6	12	14	65	67	
8	Survey	1	6	12	13	62	63	
9	Excavation	4	6	12	16	12	16	Critical
10	Backfilling	2	9	16	18	16	18	Critical
11	Foundation	4	10	18	22	18	22	Critical
12	Sewerage	4	8	13	17	63	67	
13	Walls	12	11	22	34	22	34	Critical
14	Roof	8	13	34	42	34	42	Critical
15	Slab	8	14	42	50	59	67	
16	Plumbing Piping	6	13	34	40	59	65	
17	Electrical conduiting	6	13	34	40	61	67	
18	HVAC Piping	6	14	42	48	42	48	Critical
19	Firefighting Piping	8	14	42	50	51	59	
20	Electrical wiring	4	13	34	38	61	65	
21	Electrical fittings	2	20	38	40	65	67	
22	Plumbing fittings	2	16	40	42	65	67	
23	Firefighting equipment	4	19	50	54	63	67	
24	HVAC Equipment	2	18	48	50	48	50	Critical
25	False Ceiling	8	24	50	58	51	59	
26	Tiling	8	25	58	66	59	67	
27	Painting	8	19	50	58	59	67	
28	Testing & Commissioning	2	24	50	52	50	52	Critical
29	Approvals & Other formalities	2	28	52	54	52	54	Critical
30	Cleaning & handing over	13	29	54	67	54	67	Critical

The critical path method or CPM is a method which helps estimate the minimum duration of the project. It helps determine the flexibility available in the scheduling based on the paths on the networks. The critical path is that sequence of activities which represents the longest path through a project. This is the shortest project duration possible. The flexibility or the 'total float' is the amount of time that the activity can be delayed from its early start without delaying the finish date of the project or violating schedule constraints. The critical path has zero float (PMI 2013, pp. 176-177). For XYZ, the CPM network showing the critical path is shown in figure 3. The project duration is 67 weeks, which is based on the length of the critical path.

Figure 3 – CPM – XYZ Building Project



Program Evaluation and Review Technique (PERT)

Program Evaluation and Review Technique (PERT) technique helps improve the accuracy of single-point duration estimates by factoring uncertainty and risk in estimation. In PERT, the estimated time T_e is calculated as: $(T_o + 4T_m + T_p) \div 6$. T_o is the optimistic time, $+ T_m$ is the most likely time and T_p is pessimistic estimate (PMI 2013, pp. 170-171). Table 3 depicts the times for XYZ building project.

Table 3 – PERT - Duration Estimates

ID	Task	Scheduled Time	*To*:Optimistic	*Tm*:Most likely	*Tp*:Pessimistic	Activity Expected Time (Te)	Standard Deviation	Avtivities Variance
0	**START**		0	0	0	-		
1	Layout drawing	2	1	2	4	2.2	0.5	0.3
2	Civil Drawings	2	1	2	3	2.0	0.3	0.1
3	Plumbing Drawings	2	1	2	4	2.2	0.5	0.3
4	Firefighting drawings	2	1	2	4	2.2	0.5	0.3
5	Electrical drawings	2	1	2	3	2.0	0.3	0.1
6	HVAC drawings	2	1	3	5	3.0	0.7	0.4
9	Excavation	4	3	5	6	4.8	0.5	0.3
10	Backfilling	2	1	2	4	2.2	0.5	0.3
11	Foundation	4	2	4	5	3.8	0.5	0.3
13	Walls	12	9	11	13	11.0	0.7	0.4
14	Roof	8	6	9	11	8.8	0.8	0.7
18	HVAC Piping	6	4	5	9	5.5	0.8	0.7
24	HVAC Equipment	2	1	2	4	2.2	0.5	0.3
28	Testing & Commissioning	2	1	2	5	2.3	0.7	0.4
29	Approvals & Other formalities	2	1	2	4	2.2	0.5	0.3
30	Cleaning & handing over	13	10	13	15	12.8	0.8	0.7
		67			**Sum**	**69.2**	**9.2**	**5.6**
			50	**Probability of completion**		**0.00**		
			Project Standard Devitiation		***σ***	**2.37**		

The project duration by 85% and 99% confidence levels have been calculated. Also, the probabilities of finishing the project 5% of the duration earlier, and 10% of the duration later have been have been calculated (table 4).

Table 4 – Probability Calculations

Project Standard Devitiation		***σ***	**2.37**	
Project duration by 85% confidence				
z = 1.04				
Ts (Schedule Time)=	69	Weeks		
Project duration by 99% confidence				
z = 2.33				
Ts (Schedule Time)=	73	Weeks		
The Probability of finishing by 5% of CPM duration earlier (66 weeks)				65.74
Expected Duration				
z =				
Ts =	66			
TE =	69			
	-1.263352331			
Probability = 0.8577	0.8962			
Probability=	**0.1038**	**10%**		

The Probability of finishing by 10% of CPM duration later (76 weeks)				76.12
Expected Duration				
z =				
Ts =	66			
TE =	69			
	-0.771208226			
Probability = 0.8577	0.7794			
Probability=	**0.2206**	**22%**		

As evident from teh calculations, project duration by 85% confidence is 69 weeks and that by 99% confidence is 73 weeks. The probability of finishing 5% early is 10% while the probability of getting 10% late is 22%.

Crashing

Project crashing is a technique used to shorten the scheduled duration by adding resources with minimum incremental cost. Crashing works only for the activities which are on the critical path where additional resources can reduce the activity's duration (PMI 2013, p. 181). For XYZ, crashing time (for 5 weeks) and cost of each activity has been calculated. Normal and crash cost of the projects have also been shown (table 5).

Table 5 - Crashing

ID	Task	Normal		After Crashing		
		Cost	Time	Cost	Time	Crash Ratio
1	Layout drawing	$ 30,000	2	$45,000	1	15,000
2	Civil Drawings	$ 30,000	2	$ 30,000	2	(15,000)
3	Plumbing Drawings	$ 40,000	2	$ 40,000	2	(20,000)
4	Firefighting drawings	$ 50,000	2	$ 50,000	2	(25,000)
5	Electrical drawings	$ 50,000	2	$ 50,000	2	(25,000)
6	HVAC drawings	$ 50,000	2	$ 50,000	2	(25,000)
9	Excavation	$ 300,000	4	$450,000	3	150,000
10	Backfilling	$ 150,000	2	$ 150,000	2	(75,000)
11	Foundation	$ 500,000	4	$ 500,000	4	(125,000)
13	Walls	$ 2,000,000	12	$2,166,667	10	83,334
14	Roof	$ 1,500,000	8	$1,687,500	7	187,500
18	HVAC Piping	$ 250,000	6	$ 250,000	6	(41,667)
24	HVAC Equipment	$ 500,000	2	$ 500,000	2	(250,000)
28	Testing & Commissioning	$ 200,000	2	$ 200,000	2	(50,000)
29	Approvals & Other formalities	$ 100,000	2	$ 100,000	2	(150,000)
30	Cleaning & handing over	$ 300,000	13	$ 300,000	13	(7,692)
		$ 6,050,000	67	$6,569,167	62	
		Normal Cost		Crash Cost	Crash time	
	Crashing cost of critical activities	**$519,167**				
	Project Origninal Cost	**$ 10,000,000**				
	After Crashing for 5 weeks	**$ 10,519,167**				

Cash flow management

Cash flow management is an important part of the project. It involves estimating the timing of cash inflows and outflows. Cash flow diagram for XYZ is depicted below in table 6.

Table 6 - Cash flows – XYZ Limited

								Cumulative Inflow		Net Cashflow	
Month	Monthly Cost	Cumulative Outflow	Overhead + Profit (5% + 10 %)	Amount Due	Retention	Amount Due Less retention	Monthly Inflow	Before Payment	After Payment	Before Payment	After Payment
1	$ 60,000	$ 60,000	$ 9,000	$ 69,000	$ 3,450	$ 65,550	0	0	0	$ (60,000)	$ (60,000)
2	$ 90,000	$ 150,000	$ 13,500	$ 103,500	$ 5,175	$ 98,325	$ 65,550	$ -	$ 65,550	$ (150,000)	$ (84,450)
3	$ 100,000	$ 250,000	$ 15,000	$ 115,000	$ 5,750	$ 109,250	$ 98,325	$ 65,550	$ 98,325	$ (184,450)	$ (151,675)
4	$ 775,000	$ 1,025,000	$ 116,250	$ 891,250	$ 44,563	$ 846,688	$ 109,250	$ 98,325	$ 109,250	$ (926,675)	$ (915,750)
5	$ 525,000	$ 1,550,000	$ 78,750	$ 603,750	$ 30,188	$ 573,563	$ 846,688	$ 174,800	$ 846,688	$(1,375,200)	$ (703,313)
6	$ 583,333	$ 2,133,333	$ 87,500	$ 670,833	$ 33,542	$ 637,291	$ 573,563	$ 945,013	$ 573,563	$(1,188,321)	$ (1,559,771)
7	$ 666,667	$ 2,800,000	$ 100,000	$ 766,667	$ 38,333	$ 728,334	$ 637,291	$ 748,363	$ 637,291	$(2,051,638)	$ (2,162,709)
8	$ 666,667	$ 3,466,667	$ 100,000	$ 766,667	$ 38,333	$ 728,334	$ 728,334	$1,582,304	$ 728,334	$(1,884,363)	$ (2,738,333)
9	$ 941,667	$ 4,408,334	$ 141,250	$1,082,917	$ 54,146	$1,028,771	$ 728,334	$1,476,696	$ 728,334	$(2,931,638)	$ (3,680,000)
10	$ 1,366,667	$ 5,775,001	$ 205,000	$1,571,667	$ 78,583	$1,493,084	$1,028,771	$2,310,638	$1,028,771	$(3,464,364)	$ (4,746,230)
11	$ 958,333	$ 6,733,334	$ 143,750	$1,102,083	$ 55,104	$1,046,979	$1,493,084	$2,505,467	$1,493,084	$(4,227,867)	$ (5,240,250)
12	$ 766,667	$ 7,500,001	$ 115,000	$ 881,667	$ 44,083	$ 837,584	$1,046,979	$3,803,721	$1,046,979	$(3,696,280)	$ (6,453,022)
13	$ 1,225,000	$ 8,725,001	$ 183,750	$1,408,750	$ 70,438	$1,338,313	$ 837,584	$3,552,446	$ 837,584	$(5,172,555)	$ (7,887,417)
14	$ 765,385	$ 9,490,386	$ 114,808	$ 880,193	$ 44,010	$ 836,183	$1,338,313	$4,641,305	$1,338,313	$(4,849,081)	$ (8,152,074)
15	$ 193,269	$ 9,683,655	$ 28,990	$ 222,259	$ 11,113	$ 211,146	$ 836,183	$4,890,759	$ 836,183	$(4,792,896)	$ (8,847,472)
16	$ 180,769	$ 9,864,424	$ 27,115	$ 207,884	$ 10,394	$ 197,490	$ 211,146	$5,477,488	$ 211,146	$(4,386,936)	$ (9,653,278)
17	$ 135,577	$ 10,000,001	$ 20,337	$ 155,914	$ 7,796	$ 148,118	$ 197,490	$5,101,905	$ 197,490	$(4,898,096)	$ (9,802,511)
		$ 10,000,001					$ 148,118	$5,674,978	$ 148,118	$(4,325,023)	$ (9,851,883)
		$ 10,000,001					$ -	$5,250,023	$ -	$(4,749,978)	$ (10,000,001)

It shows the retention, profits and the inflows before and after payment. This shows that one needs to keep a suitable buffer to ensure smooth execution of the project.

Conclusion

The planning tools and techniques of project management were applied to a hypothetical single-storey commercial building construction project named as XYZ Building Project. The project scope was defined, a work breakdown structure was created, activities required to accomplish the project objectives were identified, and durations and costs of these activities were also estimated. The durations were represented through a bar chart. For scheduling, the interdependencies were analyzed through a network diagram and the critical path was determined. Program Evaluation and Review Technique (PERT) was used to improve the accuracy of the duration estimates by factoring uncertainty and risks. Crashing was used to reduce the duration of activities on the critical path. Finally, cash flow tables were created to understand the inflows and outflows based on the project cost. As evident from the exercise, the tools and techniques discussed above are crucial for proper project planning. It is concluded that by applying these techniques, one can understand the scope, the deliverables, and the activities required to complete the deliverables. The interdependencies between the deliverables and the time durations help understand the critical path and the total duration of the project. Crashing techniques can then be applied to the right activities to shorten the duration of the project at minimum cost. It is also critical to understand the cost of the activities and the timing of the cash inflows and outflows to ensure that the work does not suffer due to want of cash.

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