



Managing Engineering Projects ACEA7009

Applying Project Management Techniques

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List of Contents

List of Tables & Figures	I
List of Abbreviations	II
1. Introduction	1
1.1 Background	1
2. Construction of Network Diagram	2
3. Role of Communication	5
3.1 Communications Management Plan	6
3.2 Manage Communications	7
4. Application of PERT Analysis & Risk Management Techniques	8
4.1 Risk Management	10
5. Cost Analysis	12
5.1 Executive Summary of Cost	13
6. Application of CRASH Costing Techniques	13
6.1 Crash Costing Activities	15
7. Handover Issues	18
8. Conclusion	19
9. References	20
10. Bibliography	21

List of Tables & Figures

Tables

Table 1:	CT Scanner PERT Value Table.....	9
Table 2:	CT Scanner Cost Activity Table.....	12
Table 3:	Crash Costing Activity Table.....	15
Table 4:	CT Scanner Anticipated Full Cost Activity Table.....	16
Table 5:	CT Scanner Anticipated Full Crash Cost Activity Table.....	17

Figures

Figure 1:	Network Diagram.....	3
Figure 2:	Gantt Chart.....	4
Figure 3:	Activity on Node / Network Diagram.....	8

List of Abbreviations

- GC - Gantt Chart
- POW - Programme of Works
- LADs - Ligated Ascertain Damages
- PM - Project Manager
- PMBOK - Project Management Book of Knowledge
- OOH - Out of Hours
- HTMs - Health Technical Memorandums
- HBNs - Health Building Notes
- HB - Health Board
- RPA - Radiation Protection Advisor
- AHU - Air Handling Unit
- PERT - Project Evaluation Review Technique
- COW - Clerk of Works
- O&M - Operation & Maintenance (Manuals)
- H&S - Health & Safety (File)
- MC - Main Contractor

1. Introduction

The author has based this assessment on a project that is currently being undertaken in Singleton Hospital. The author is a project manager for a local Public Health Board. The project is to refurbish the Radiology Department and install a brand-new CT Scanner.

Government funding has been received as part of the of the National Imaging Replacement Programme to provide a replacement CT Scanner at Singleton Hospital. A Canon Aquilion One Prism CT Scanner has already been purchased.

Throughout this assessment the author will be reviewing several project management techniques and tools to assist the progression of the project, to minimise delays and costs and maximise growth.

The author has chosen this project because it is current and has a specific purpose that will benefit patients and staff. The service that the project aims to deliver will be of a very high standard, the Radiology Dept will have a state-of-the-art CT Scanner that will help reduce the very extensive current waiting lists. The project has many technicalities and complex procedures to overcome, it does provide a good opportunity to highlight the level of work and design required to deliver such a project.

1.1 Background

As CT Scanner technology has evolved, the detectors size has increased to allow patients to be imaged faster. However, these scanners require a larger footprint. The existing CT scanner room at Singleton is too small for the CT scanner required to deliver the service efficiently and effectively.

Desing implications of this change are to be assessed with a view to providing a CT Scanner Suite which is compliant with the relevant HTM's and HBN's as well as any statutory guidance. The Project Manager (PM) will need to seek advice from the Health Board's Radiation Protection Advisor (RPA) to gain understanding of the lead-lined requirements of the proposed suite to house the new CT scanner.

The new suite will be served by a new air handling unit (AHU) to provide a compliant number of air changes applicable to the procedures being carried out, as well as providing cooling to the specialist equipment.

2. Construction of a Network Diagram

In order to move forward with the project and achieve the objective of installing a brand-new CT Scanner in Singleton Hospital then a Gantt Chart (GC) / Programme of Works (POW) needs to be created by the Main Contractor (MC). A GC or POW allows the project team members to have a specific breakdown of what works are required, what date they are set for and the duration of each task. The POW is issued at the beginning of the project, and it lays out every single task from the start, such as enabling works, site set up, surveys etc. The POW highlights key milestones in the project to provide the PM with focal points that require assertive attention. The POW / GC allows the PM to visualise each step of the project, highlighting the principal areas and addressing potential long lead times on deliveries and installation on specialise equipment.

Over the following pages the author has included a Network Diagram and a GC which provides the targeted audience with a visualisation of the scheduled works. The network diagram indicates each activity / task which is required for the project, for this project there is forty individual tasks. The network diagram also highlights the duration for each activity and whether they link up with other activities, this is common as most construction tasks links up with other tasks. The network diagrams show or provides the PM with an understanding that shows completed tasks, ongoing activities, and upcoming milestones. There are two types of network diagrams used in project management, the arrow diagram, and the precedence diagram, for this project an arrow diagram will be used. By completing the network diagram correctly then it will provide the PM with the critical path. As “Adobe Experience Cloud” states “Arrow Diagram Method aims to visualize the critical path, identify project constraints, and facilitate project scheduling and resource allocation. It provides a straightforward representation of project activities and their interdependencies”. (Adobe Experience Cloud, 2024)

CT Scanner Network Diagram

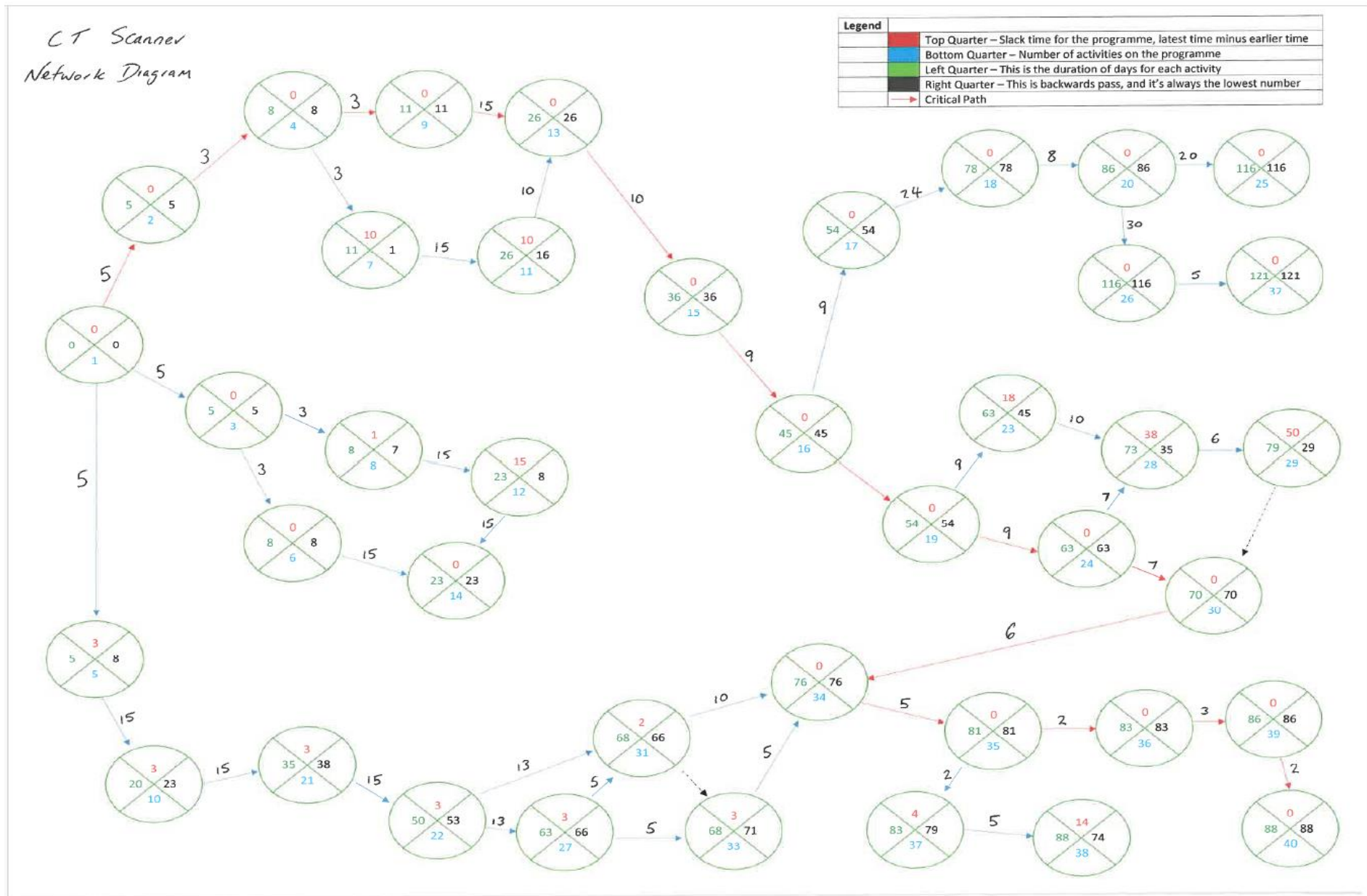


Figure 1: Network Diagram (previously known as Activity Arrow Diagram), 2024

CT Scanner Gantt Chart

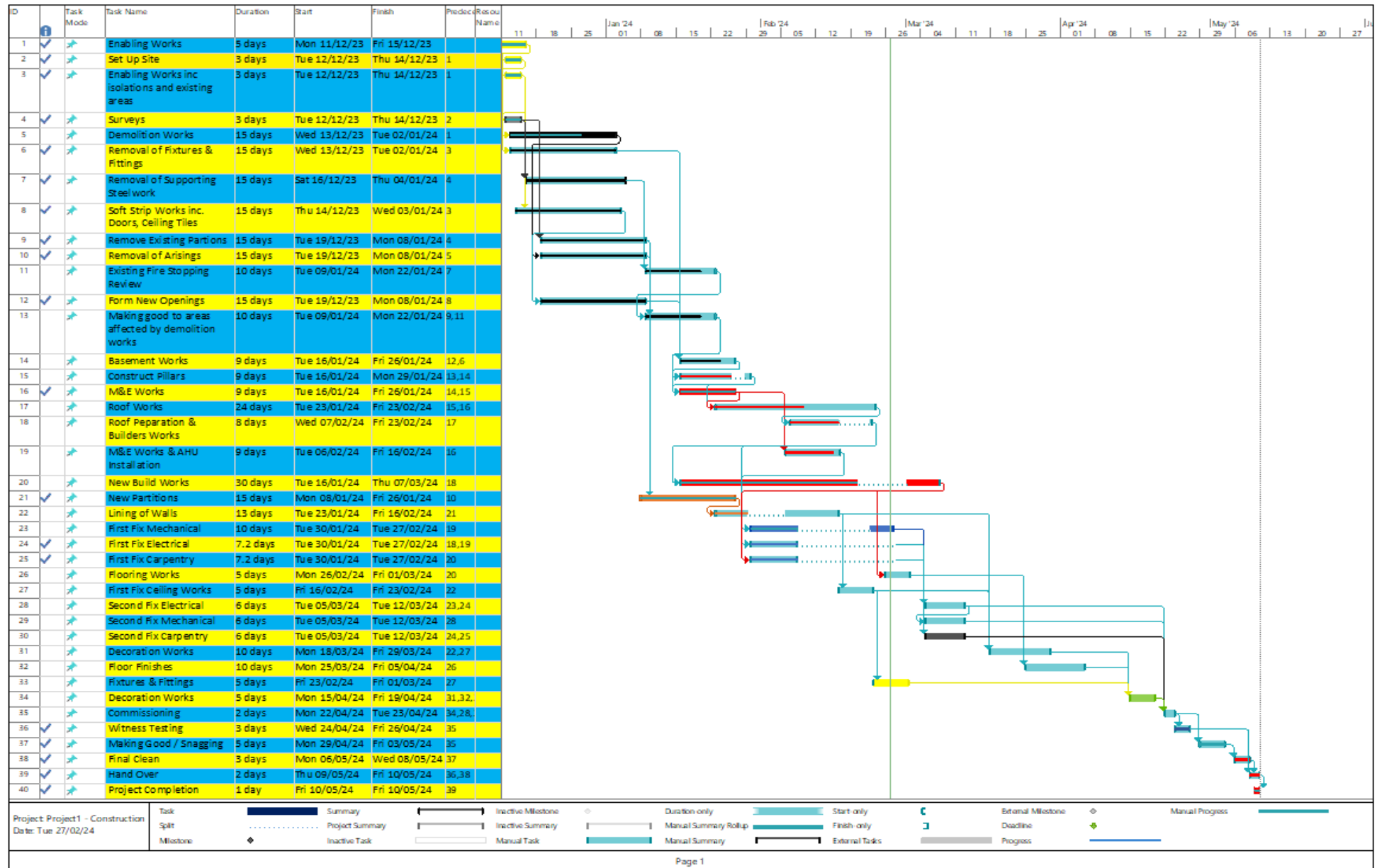


Figure 2: Gantt Chart / Programme of Works, 2024

3. Role of Communication Management

The role of communication in any project is vital to the success of the scheme, it is essential for the PM to be completely open, transparent, and direct with the members of the project team. To communicate effectively, then the PM must have a good understanding of the communications process, poor breakdown in communication can lead to poor management and result in project failure.

APM states that *“having open communication is essential and should be available to all project stakeholders, including workers and contractors. Whether in person or through virtual means, regular communication guarantees workplace morale and business success”*.

There are three main communication techniques we can use for effective project management:

- Interactive communication for immediacy.
- Push communication for substantial amounts of information
- Pull communication for accessibility.

(Communication Techniques for effective project management, 2024)

The project manager is responsible to mediate between the end / service users and the design team consultants to inform them of any changes that are required in the design stages prior to the tender package being issued. If any detail is missed or not discussed, then it could have a heavy consequence later in the scheme. All design aspects will be discussed, reviewed and either approved or removed, items that are not required will be derogated against. This provides the design team with reassurance that if there is a dispute in the design at a later stage. This has proven to be the case on previous schemes if the correct audit trail has not been executed.

These critical issues all come down to communication, and it demonstrates the power that communication can contribute to the success of the project. With the author being a PM then it will be down to him assemble the project team, lead design stages, and then deliver the project.

The CT Scanner scheme will take place in a live environment which is occupied by staff, patients, and visitors. Planning coordination with Hospital Management is key, they need to be advised

and involved from the outset. This is important as the hospital management team can inform all direct and indirect departments that the work might have an impact on.

The delivery of the Scanner equipment needs to be planned methodically and meticulously, informing, and communicating with all effected parties such as the scanner suppliers, the design team, the user groups, and hospital management. The delivery of the equipment will take place during downtime of Radiology / Out of Hours working will be necessary so that it guarantees minimal disruption to the service and department.

As part of the CT scanner works, a new Air Handling Unit (AHU) is required, this is a large piece of technical equipment that provides cool air (air changes) to the scanner room and also extracts used air.

As a PM it is vital that regular, effective communication at all levels with and across the project team is achieved. The author will ensure processes are in place to enable full engagement from the clinical team and public representatives who will be working in and / or may be affected by the project. Throughout the project the PM will arrange regular project meetings with the project team, briefings and reports and other communication correspondents whether they be internally and externally need to be issued.

A useful guide to consider would be the communications management plan from “The PMBOK Guide 2013”.

3.1 Communications Management Plan

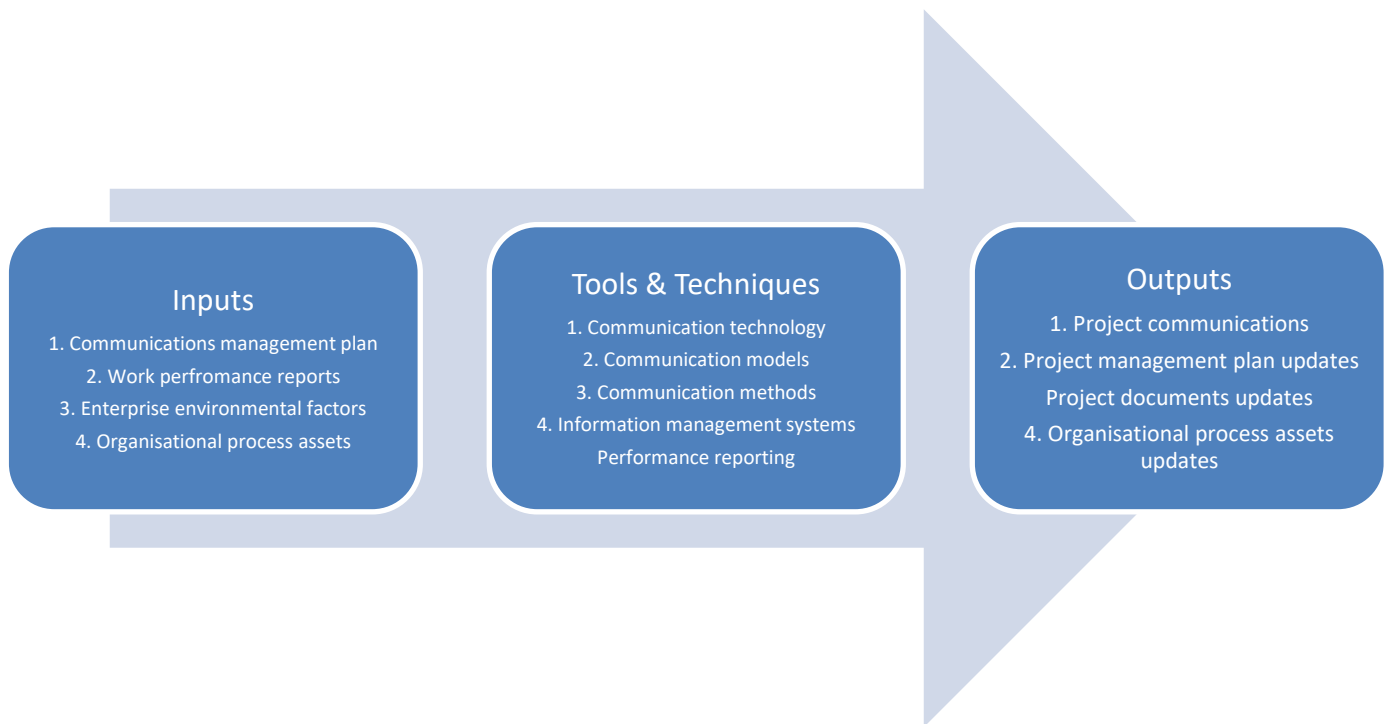
The communications management plan is a component of the project management plan that describe how project communications will be planned, structured, monitored, and controlled. The plan contains the following information:

- Stakeholder communication requirements
- Information to be communicated, including language, format, content, and level of detail.
- Reason for the distribution of that information.
- Time frame and frequency for the distribution of required information and receipt of acknowledgement or response.
- Person responsible for communicating the information.

- Person responsible for authorising release of confidential information
- Person or groups who will receive the information.
- Resources allocated for communication activities, including time and budget.
- Flow charts of the information flow in the project, workflows with possible sequence of authorisation, list of reports, and meetings plans etc.
- Communication constraints usually derived from a specific legislation or regulation, technology, and organisational policies etc. (PMBOK Guide, 2013)

3.2 Manage Communications

Manage communications is the process of creating, collecting, distributing, storing, retrieving, and the ultimate disposition of project information in accordance with the communications management plan. The key benefit of this process is that it enables an efficient and effective communications flow between project stakeholders.



(PMBOK Guide, 2013)

4. Application of PERT Analysis & Risk Management Techniques

The application of Project Evaluation and Review Techniques (PERT) is a three-point estimating technique for the accuracy of single point activity duration estimates may be improved by considering estimation uncertainty and risk. PERT uses three estimates to define an approximate range for an activity's duration.

- Most likely (tM). This estimate is based on the duration on the activity, given the resources likely to be assigned, their productivity, realistic expectations of availability for the activity, dependencies on other participants, and interruptions.
- Optimistic (tO). The activity duration based on analysis of the best-case scenario for the activity.
- Pessimistic (tP). The activity duration based on analysis of the worst-case scenario for the activity.

Activity network diagrams. Previously known as arrow diagrams. They include both the AOA (Activity on Arrow) and, most used, AON (Activity on Node) formats of a network diagram. Activity network diagrams are used with project scheduling methodologies such as PERT, critical path method and precedence diagramming method.

(PMBOK Guide, 2013)

The network diagram below is based on the CT Scanner scheme. This network diagram was created using Microsoft Project.

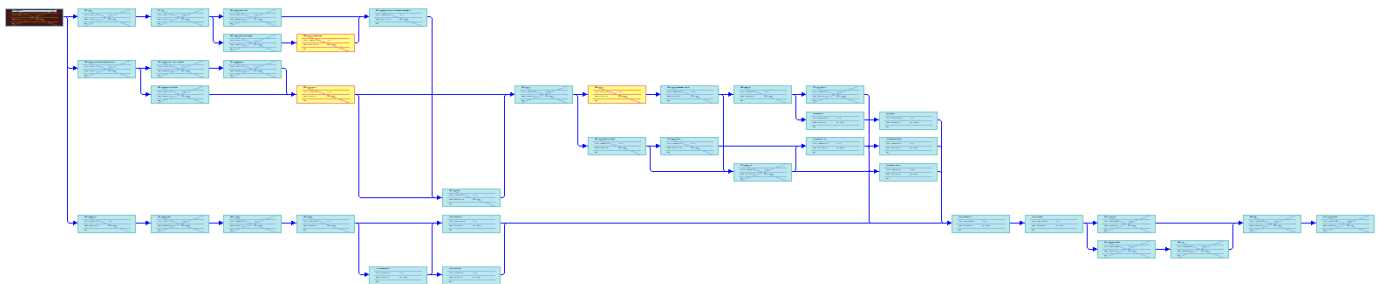


Figure 3: Activity on Node / Network Diagram, 2024

The author carried out PERT on the CT Scanner scheme. It is highlighted on the table below what the PERT values are and for which activity. It is noted that the PERT values are only on the critical path.

PERT Value Table

Activity	Optimistic (tO)	Most Likely (tM)	Pessimistic (tP)	PERT Value (Critical Path)
1-2	3	5	8	5.2
1-3	3	5	8	
1-5	3	5	8	
2-4	2	3	5	3.2
4-9	2	3	5	3.2
4-7	2	3	5	
7-11	10	15	18	
9-13	10	15	18	14.6
11-13	8	10	15	10.5
13-15	8	10	15	
3-6	2	3	4	
3-8	2	3	4	
8-12	10	15	18	
6-14	10	15	18	
12-14	10	15	18	
5-10	10	15	18	
10-21	10	15	18	
21-22	10	15	18	
22-27	9	13	16	
22-31	9	13	16	
27-31	3	5	8	
27-33	3	5	8	
31-34	8	10	15	
33-34	3	5	8	
15-16	6	9	14	9.3
16-17	6	9	14	
17-18	18	24	30	
18-20	6	8	12	
20-25	25	30	35	
20-26	25	30	35	
26-32	3	5	8	
16-19	6	9	14	9.3
19-23	6	9	14	
23-28	8	10	15	
28-29	4	6	10	
19-24	6	9	14	9.3
24-28	5	7	11	
24-30	5	7	11	7.3
30-34	4	6	10	6.3
34-35	3	5	8	5.2
35-37	1	2	4	
37-38	3	5	8	
35-36	1	2	4	2.2
36-39	1	2	4	2.2
39-40	1	1	2	1.2

Table 1: CT Scanner PERT Value Table, 2024

As the table above highlights, if the PERT value is less than the Most Likely (tM) then there is less risk, however if the PERT value is higher than the Most Likely (tM) then there is more risk involved.

The table suggests that there is high risk on 13 out of 14 activities, PERT analysis is only done on those activities that are on the critical path. The PERT value for each available is calculated using the following formula:

$$\text{PERT Time} = \frac{O + 4ML + P}{6}$$

O (tO) = Optimistic

4 x ML (tM) = Most Likely

P (tP) = Pessimistic

The figures are exacted from the PERT Table 1, this allows the author to calculate the PERT value.

By the author carrying out these exercises then it is evident to see that the activities on the critical path are at high risk, to counteract these risks then the author would need to re-value the duration of activities and assessed whether the pessimistic days could be reduced, by doing this then the Most Likely days would be more realistic. The critical path is worked out from the Network Diagram, the critical path has zero slack for each activity, this highlighted on the diagram in red arrows.

4.1 Risk Management

It is imperative that risks at thought of in advance, the author will need to anticipate any risks associated with the scheme, risks relating to the duration of the programme, risks to the value and cost of individual activities and the scheme. It is advisable to think of the risk as an iterative process in which new and existing risks must be continuously detected, analysed, managed, and monitored.

Risk Management Strategies highlights the importance of breaking down the risks into four sections:

- Risk Acceptance – This approach talks about accepting risks without taking any action to prevent them from happening. It works well as sometimes the cost of eliminating risks goes higher than the original cost of risk.
- Risk Transference – With this approach, the responsibility of managing risk is given to another party. This does not imply that the risk is eliminated, but now it will be handed by another organisation.
- Risk Avoidance – It means avoiding the risk altogether or eliminating the possibility of risk. This approach is suggested when the impact of the risk is significant for the CT Scanner.
- Risk Reduction – This approach refers to mitigating risks through proper actions to prevent them or minimise their impact. This is a standard method of treating risk. With this approach, the author can adopt measures and tactics to help manage risks more effectively.

(Risk Management Strategies in Project Management, 2024)

5. Cost Analysis

The table below indicates the estimation costs of each activity and the total cost of the project.

Activity	Resources	Duration (Days)	Activity Cost
1-2	1M, 2C, 1L	5	£3,725
1-3	2L	5	£950
1-5	2L	5	£950
2-4	1C	3	£750
4-9	1M, 1C	3	£1,200
4-7	1M, 1C	3	£1,200
7-11	1C	15	£3,750
9-13	1M, 1L	15	£3,675
11-13	1C, 1L	10	£3,450
13-15	1L	10	£950
3-6	2L	3	£570
3-8	2C, 2L	3	£2,070
8-12	2C, 2L	15	£10,350
6-14	1L	15	£1,425
12-14	1L	15	£1,425
5-10	1M, 2L	15	£5,100
10-21	2C	15	£7,500
21-22	1L	15	£1,425
22-27	1L	13	£1,235
22-31	2C	13	£6,500
27-31	2C, 2L	5	£3,450
27-33	1M	5	£750
31-34	1M, 2C, 1L	10	£7,450
33-34	2L	5	£950
15-16	2L	9	£1,710
16-17	1C	9	£2,250
17-18	1M, 2C, 2L	24	£20,160
18-20	1M, 1C	8	£3,200
20-25	1C	30	£7,500
20-26	1C, 1L	30	10,350
26-32	1L	5	£475
16-19	2L	9	£1,710
19-23	2C, 2L	9	£6,210
23-28	2C, 2L	10	£6,900
28-29	1L	6	£570
19-24	1L	9	£855
24-28	1M	7	£1,050
24-30	2C	7	£3,500
30-34	1L	6	£570
34-35	1L	5	£475
35-37	2C	2	£1,000
37-38	2C, 2L	5	£3,450
35-36	1M	2	£300
36-39	1M	2	£300
39-40	1M	1	£150
			Total: £143,485

Table 2: CT Scanner Cost Activity Table, 2024

5.1 Executive Summary of Cost

The cost for each activity is worked out as the following:

1M (1 Site Manager) = £150 per day.

1C (1 Craftsperson) = £250 per day.

1L (1 Labourer) = £95 per day.

The site manager will be required to attend site during certain activities, normally only one site manager is required. Craftsperson is deemed as trade professionals they could be carpenters, plasterers, bricklayers, mechanics and electricians, specialist contractors. Labourers are deemed as the workforce who are not professionally qualified to conduct craft works.

The way the activity cost is calculated by is i.e. Activity 1-2: 1M (£150) + 2C (£500) + 1L (£95) x duration (5 days) = £3,725 for 5 days, break that down to £745 a day to conduct this activity.

The current approved total budget for the construction works is £143,485 ex VAT and the forecasted works which includes Crash Costing is £160,150 exc. VAT.

6. Application of CRASH Costing Techniques

Crashing is time related to cost and the object is to develop an optimum time-costing relationship. The overall project duration can be reduced by reducing the duration of only the critical activities in the project network. The durations of such activities may be reduced in two ways:

- (a) By deploying more resources for the early completion of such activities.
- (b) By relaxing the technical specifications for such activities.

Total project cost is the sum of two separate costs:

- (a) The direct cost for accomplishing the work, and
- (b) The indirect cost related to the control or direction of that work, financial overhead, lost production.

(Construction Management, 2024)

In order for the project to be completed at an earlier date than the programme states then a crash costing exercise is required. The aim is to reduce the duration of the project by 7 days, the project manager has a clear understanding of what activities can be reduced.

- **Activity 9 - 13 (Remove existing partition works)** – the partition works is scheduled for 15 days which is based on a 7am-3pm working day. The contractor will be instructed via a variation request / PMI to carry additional works out of hours on two weekends. This will reduce the programme by 4 days.
- Currently, Activity 9 - 13 is based on one manager @ £150 per day and one labourer @£95 per day. The PM has now instructed the contractor to crash the programme and to provide one manager @ £150 per day and six labourers @ £95 per day each.
- This activity has been chosen since there is less technical work involved and it is an easier approach to reduce due to the programme. If we increase the labour, then there is a higher chance of gaining the objective.
- **Activity 15 -16 (Pillar Construction)** – the structural pillar works is scheduled for 9 days which is based on a 7am – 3pm working day. The contractor will be instructed via a variation request / PMI to conduct additional works out of hours on two weekends. This will reduce the programme by a further 3 days.
- Currently, Activity 15-16 is based on two labourers @£95 per day. The PM has now instructed the contractor to crash the programme and to provide one manager @ £150 per day and five labourers @ £95 per day.
- Like activity 9-13, This activity has been chosen since there is less technical work involved and it is an easier approach to reduce the programme. If we increase the labour, then there is a higher chance of gaining the objective.

Crash Costing of Activities 9-13 & 15-16.

Activity	Normal Duration (Days)	Crash Duration (Days)	Normal Cost £	Crash Cost £
9 – 13	15	11	3,675	7,920
15 – 16	9	6	1,710	3,750

Activity	Normal Duration (Days)	Crash Duration (Days)	Normal Cost £	Crash Cost £	Crash Increase	Crash cost per day
9 – 13	15	11	3,675	7,920	4,245	1,061
15 – 16	9	6	1,710	3,750	2,040	680

Crash Cost Sequence

Activity	Crash Cost per day £	Normal Duration (Days)	Crash Duration (Days)	Time saved (Days)	Cumulative Project Cost Increase
9 – 13	1,061	15	11	4	+4,245
15 - 16	680	9	6	3	+2,040

Table 3: Crash Costing Activity Table

Crash Sequence is 9 – 13 and 15 – 16.

The project manager has undertaken a full breakdown of activities which indicates individual task costs and the full cost. Please see tables below for breakdown prior and post to the crash costing exercise. The tables below illustrate anticipated costs prior and post-Crash Costing.

Activities 9-13 & 15-16 original costs are highlighted in **Blue** in the table below.

Activities 9-13 & 15-16 crashed costs are highlighted in **Green** in the table below.

Anticipated full breakdown cost prior to Crash Costing.

Activity	Resources	Duration (Days)	Activity Cost
1-2	1M, 2C, 1L	5	£3,725
1-3	2L	5	£950
1-5	2L	5	£950
2-4	1C	3	£750
4-9	1M, 1C	3	£1,200
4-7	1M, 1C	3	£1,200
7-11	1C	15	£3,750
9-13	1M, 1L	15	£3,675
11-13	1C, 1L	10	£3,450
13-15	1L	10	£950
3-6	2L	3	£570
3-8	2C, 2L	3	£2,070
8-12	2C, 2L	15	£10,350
6-14	1L	15	£1,425
12-14	1L	15	£1,425
5-10	1M, 2L	15	£5,100
10-21	2C	15	£7,500
21-22	1L	15	£1,425
22-27	1L	13	£1,235
22-31	2C	13	£6,500
27-31	2C, 2L	5	£3,450
27-33	1M	5	£750
31-34	1M, 2C, 1L	10	£7,450
33-34	2L	5	£950
15-16	2L	9	£1,710
16-17	1C	9	£2,250
17-18	1M, 2C, 2L	24	£20,160
18-20	1M, 1C	8	£3,200
20-25	1C	30	£7,500
20-26	1C, 1L	30	10,350
26-32	1L	5	£475
16-19	2L	9	£1,710
19-23	2C, 2L	9	£6,210
23-28	2C, 2L	10	£6,900
28-29	1L	6	£570
19-24	1L	9	£855
24-28	1M	7	£1,050
24-30	2C	7	£3,500
30-34	1L	6	£570
34-35	1L	5	£475
35-37	2C	2	£1,000
37-38	2C, 2L	5	£3,450
35-36	1M	2	£300
36-39	1M	2	£300
39-40	1M	1	£150
			Total: £143,485

Table 4: CT Scanner Anticipated Full Cost Activity Table, 2024

Anticipated full breakdown cost from Crash Costing.

Activity	Resources	Duration (Days)	Activity Cost
1-2	1M, 2C, 1L	5	£3,725
1-3	2L	5	£950
1-5	2L	5	£950
2-4	1C	3	£750
4-9	1M, 1C	3	£1,200
4-7	1M, 1C	3	£1,200
7-11	1C	15	£3,750
9-13	1M, 6L	11	£7,920
11-13	1C, 1L	10	£3,450
13-15	1L	10	£950
3-6	2L	3	£570
3-8	2C, 2L	3	£2,070
8-12	2C, 2L	15	£10,350
6-14	1L	15	£1,425
12-14	1L	15	£1,425
5-10	1M, 5L, 4C	11	£7,600
10-21	2C	15	£7,500
21-22	1L	15	£1,425
22-27	1L	13	£1,235
22-31	2C	13	£6,500
27-31	2C, 2L	5	£3,450
27-33	1M	5	£750
31-34	1M, 2C, 1L	10	£7,450
33-34	2L	5	£950
15-16	1M, 5L	6	£3,750
16-17	1C	9	£2,250
17-18	1M, 5C, 6L	20	£28,040
18-20	1M, 1C	8	£3,200
20-25	1C	30	£7,500
20-26	1C, 1L	30	10,350
26-32	1L	5	£475
16-19	2L	9	£1,710
19-23	2C, 2L	9	£6,210
23-28	2C, 2L	10	£6,900
28-29	1L	6	£570
19-24	1L	9	£855
24-28	1M	7	£1,050
24-30	2C	7	£3,500
30-34	1L	6	£570
34-35	1L	5	£475
35-37	2C	2	£1,000
37-38	2C, 2L	5	£3,450
35-36	1M	2	£300
36-39	1M	2	£300
39-40	1M	1	£150
			Total: £160,150

Table 5: CT Scanner Anticipated Full Crash Cost Activity Table, 2024

Activities 9-13 & 15-16 have been reduced because they are on the critical path. Prior to the crash costing exercise of reducing the programme to 7 days then the full contract cost was £143,485, however since conducting the exercise and asserting the crash cost from the critical path of the network project, then the anticipated full contract cost will £160,150. This results in being an additional £16,665 to the contract, although the project has now been reduced by 7 days which could prevent any LADs being applied.

7. Handover Issues

There are several items to consider during the handover stage of the project. The handover date has been set, it will be down to the main contractor to determine that the project is completed and ready to handover to the client. In this instance, the author acts on the client's behalf, as the client is the service users. The author / PM will determine whether the project is acceptable and that all activities are completed to a high standard.

Prior to the handover stage, the PM will instruct a Clerk of Works to conduct a final snagging list. The snagging list will be passed over to the MC to make sure that all items are fully completed.

The PM will request confirmation of the full record drawings, Operation & Maintenance (O&M) manuals and Health and Safety (H&S) file from the MC. If the O&M manuals are not available, then handover should not be accepted. The O&Ms are essential as these contain specific and technical information about specialist equipment, if there needs to be any repairs or parts required at a future date then the Estates Department can refer to the O&M.

Another piece of key information would be if any asbestos were detected during the works and if it was removed under licenced conditions, this information should be recorded on the asbestos register and again, passed over to the Estates Department.

The PM will assess and gather all this essential information and then confirm the acceptance of the project from the MC, a completion certificate will be issued along with the final account cost to the MC. As part of the handover stage, then the client will issue a 'Defects Liability Certificate' which contractually the MC will have 12 months to cover any defects on the scheme, once the 12 months is complete then the client will release the retention (normally 2.5% of the contract cost) to the MC.

A good exercise to exert at the handover meeting is to discuss 'Lessons Learned' of the project, this provides the project team a chance to discuss what lessons can be learned from the project, what things went well and what things can be improved on in the next project. This is good practice as it is exceedingly rare that a project will go exactly to the plan, there will always be issues carrying out a construction project in a live working environment.

8. Conclusion

This assessment of applying project management techniques to a project has highlighted the importance and benefits of breaking down the individual stages to a project. The project manager is required to possess and deliver clear and precise communication skills to allow the project to flow correctly. For each activity to be completed on time and within the programme then effective communication is necessary. The communication between Main Contractor, Project Manager, Client, and all stakeholders must be transparent from the start. The PM will lead the way and be the focal point in all correspondence.

The use of PERT in projects provides benefits to the PM and the team, it highlights any risks involved in the project activities. The three estimates that come from PERT allows the PM to visualise the most likely duration of each activity, the optimistic duration based on the best-case scenario for each activity and lastly, the worse-case scenario on each activity which is called pessimistic.

The network diagram illustrates the many different routes that a project can go, it showcases the critical path and how the activities can link together. This helps the PM to identify what risks there are to the project and how would be they need to be addressed. By identifying the critical path then this allows the PM to conduct a crash costing exercise to see if the project duration can be reduced but at what cost would it take. The answer would be that to reduce the duration then the cost would increase, it would be down to the PM and Client to decide whether this is warranted or not.

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